16. DEEP-SEA CRETACEOUS MACROFOSSILS: HOLE 317A, MANIHIKI PLATEAU

Erle G. Kauffman, Department of Paleobiology, U.S. National Museum, Smithsonian Institution, Washington, D.C.

INTRODUCTION

Previous deep-sea cores penetrating Mesozoic strata have failed to yield significant numbers of benthonic macrofossils, especially molluscs, other than fragments of calcitic outer prismatic shell layers presumed, on the basis of internal structure, to belong to the ubiquitous bivalve Family Inoceramidae. In part this paucity of material has been attributed to unfavorable environments of deep benthonic sediments. In part it has been blamed on dissolution of shell material below the carbonate compensation depth, and especially of unstable aragonite which is an important component of many mollusc shells. Aragonite compensation depth is about 3500 meters today; the major zone of dissolution lies shallower, at a few hundred meters, where the rate of aragonite solution is highest (Kennedy, 1969, p. 462-465).

In addition, the search for macrofossils of all types has been seriously hindered by DSDP policy prohibiting systematic splitting and examination of core material along closely spaced bedding planes except in narrow intervals where macrofossils are obvious (usually from shell material exposed on the core margin or in natural bedding plane breaks). A wealth of fossil material, especially molluscan remains largely preserved as small thin shells, molds, and casts, may lie hidden in existing DSDP cores.

The paucity of macrofossil material in these cores, to date, has been a great disappointment because of the potentially important role Mollusca, in particular, could play in biostratigraphic, paleoenvironmental, and biogeographic interpretation of the deep ocean environment through time. Contrary to still widespread belief, the present bathyal and abyssal life zones contain diverse benthonic assemblages of molluscs, dominantly bivalves, with normally low, but locally high population densities. This is clearly pointed out in the works of Allen (1971), Clarke (1962), Filatova (1961), Hessler and Sanders (1967), Knudsen (1967, 1970), Sanders and Allen (1973), and many others. Further, many of these bivalves are partially or wholly composed of aragonitic layers and commonly collected as unetched dead shells. This suggests that the commonly held view that aragonitic molluscs should be rare or absent in benthonic sediments below the carbonate compensation depth limits must be reevaluated to take into account protection of aragonite from rapid solution by thick organic sheaths of conchiolin (periostracum and crystal membranes), dense shell structure, and the possibility of more solution-resistant forms of calcium carbonate in molluscs that commonly or exclusively live below the compensation depth. Bivalves should therefore be a relatively common element of deep-sea sediments, and thus should be critical to geological and paleobiological interpretation.

Bivalves and other benthos are highly sensitive indicators of modern marine bottom environments, and thus of ancient sedimentary environments and their interpretation in deep-sea cores. In addition, molluscs are today (Hall, 1964), and in the past (e.g., Kauffman, 1973a, b), primary organisms in the determination of biogeographic units (realms, regions, provinces, subprovinces) and the study of their evolution.

Equally important is the biostratigraphic potential of molluscs that might be obtained from deep-sea cores; ammonites and bivalves are the most common Mesozoic molluscan elements in these samples and both are of primary importance to refined zonation and regional correlation. The mobile, widespread, and rapidly evolving ammonites are among the best biostratigraphic indicators known. Kauffman (1970, 1972, 1973a, b, 1975, in press) has demonstrated that many lineages of Bivalvia are equally widespread, and evolve nearly as rapidly as ammonites, at considerably faster rates than are known for planktonic microbiota of the same age. This is even true for bivalve groups which are common today in deep-sea environments, such as the Thyasiridae (Kauffman, 1967). Intensive study of molluscs preserved in deep-sea cores should therefore yield at least some taxa with the potential for refined regional zonation and correlation not now available with the microbiota. The fact that most deep-water bivalves and gastropods are relatively small as adults (less than 1 cm in length), and some are minute, enhances the probability that they will be preserved commonly in core material. Obviously, it would be advantageous to develop some mechanism whereby small molluscs could be regularly sought in DSDP core samples.

The discovery of moderately abundant and taxonomically diverse Cretaceous bivalves associated with sparse echinoid and worm fossils in volcaniclastic sands and coccolith-foraminiferal chalks of Hole 317A is therefore of considerable importance. Their study provides insight into the research problems and ultimate use of mollusca in the interpretation of deep-sea samples. This paper treats the systematics, age, correlation, and paleoenvironmental implications of this biota. The taxa and sampling intervals of fossils obtained from Cores 10-16 are listed in Table 1 with their age implications.

Unfortunately, nearly all of the taxa are undescribed or indeterminate at the species level so that precise dating and correlation are difficult. Neocomian-Albian dates are indicated by many taxa, however. Slightly to highly recrystallized shell material is present in most specimens, and though commonly crushed, the shells preserve even delicate morphological characters necessary for taxonomic analysis. Many of the taxa represent deep water groups which characteristically have aragonitic shell layers; in some specimens, the cross-lamellar and cross-foliated structure of original aragonite layers is preserved in delicate calcite pseudo-

TABLE 1
Macroinvertebrate Taxa; DSDP Leg 33, Hole 317A, Drilled 2 December 1973

Core 10, Section 1, Interval 145 cm
Aucellina reticulata, n. sp.
fragment of *Maccoyella* sp.
Inoceramus? prisms
small ribbed echinoid spines
Age implications: Barremian-early Late Albian; mainly early-middle Albian

Core 11, Section 3, Interval 64-73 cm
Pseudavicula, n. sp. (erect form)
indeterminate bivalve shell fragments
Age implications: Lower Cretaceous

Core 11, Section 3, Interval 134-137 cm
Arctotis filisculptus, n. sp.
Pseudavicula pacifica, n. sp.
Verticordia?, sp. indet.
translucent shell fragments, cf. *Amusium* sp.
indeterminate, cross-lamellar, bivalve shell fragments
Age implications: Valanginian-lower Albian

Core 11, Section 4, Interval 50-56 cm
Neithea?, sp. indet.
Verticordia?, sp. indet.
smooth bivalve shell fragments, indet.
Age implications: Neocomian-Senonian

Core 11, Section 5, Interval 6-12 cm
Arctotis sp. A (simple, weakly ornamented form)
Age implications: Valanginian, possibly younger

Core 11, Section 5, Interval 83-85 cm
Nucula sp. A
Not age diagnostic

Core 11, Section 5, Interval 89-96 cm
Limopsis (*Petunculina*?) *undulorugosus*, n. sp.
Aucellina sp., cf. *A. gryphaeoides* (Sowerby)
large, thin-shelled, smooth bivalve (fragments), indet.
Age implications: Albian

Core 12, Section 1, Interval 88-92 cm
Limopsis (*Petunculina*?) *undulorugosus*, n. sp.
Here? (*Herella*?) *subpacifica*, n. sp.
Arctotis sp. B, cf. *A. intermedia* Bodylevsky
Age implications: Volgian-Early Cretaceous

Core 12, Section 1, Interval 121-128 cm
Manihikia erecta, n. gen., n. sp.
Cardium (sensu lato), sp. juv.
Maccoyella?, sp. indet. (fragment)
Acesta (*Costellacesta*?), sp. juv.
cross-lamellar bivalve shell fragments, indet.
Age implications: Early Cretaceous

Core 12, Section 1, Interval 129-131 cm
Tindaria?, sp. indet.
cf. *Maccoyella* or *Pseudavicula*, sp. indet., large fragment
Age implications: Early Cretaceous

Core 12, Section 2, Interval 26-31 cm
Aucellina, n. sp., ex. gr. *A. gryphaeoides* (Sowerby)
bivalve shell fragments, indet.
Age implications: Albian

Core 12, Section 5, Interval 31-35 cm
Maccoyella breviauriculata, n. sp. (juvenile)
Limopsis (*Petunculina*?) *undulorugosus*, n. sp.
Arctotis?, sp. indet.
smooth subcircular pectinid bivalve, gen. indet.
indeterminate bivalve shell fragments
Chondrites, small simple species
Age implications: Early Cretaceous

Core 12, Section 6, Interval 36-43 cm
Limopsis (*Petunculina*?) *delicatulus*, n. sp.
bivalve shell fragments, indet.
Age implications: Cretaceous or younger

Core 12, Section 6, Interval 43-47 cm
Pseudavicula pacifica, n. sp.
Buchia, n. sp.

TABLE 1 – *Continued*

Oxytoma, sp. indet. (juvenile)
Chondrites sp. (small simply branching species)
Age implications: Early Cretaceous

Core 12, Section 6, Interval 56-58 cm
Inoperna?, sp. indet.
cross-lamellae bivalve shell fragments, indet.
Age implications: Late? Albian

Core 12, Section 6, Interval 58-64 cm
Inoceramus, large sp. indet. (fragments)
smooth, cross-lamellar, bivalve shell fragments, indet.
Age implications: Cretaceous

Core 12, Section 6, Interval 85-93 cm
Posterodonta manihikiensis, n. gen., n. sp.
Pseudavicula pacifica, n. sp.
Age implications: Early Cretaceous, possibly Albian

Core 12, Section 6, Interval 114-116 cm
Posterodonta manihikiensis, n. gen., n. sp.
bivalve shell fragments, indet.
Age implications: Aptian or Albian?

Core 13, Section 1, Interval 108-114 cm
Limopsis (*Petunculina*?) *delicatulus*, n. sp.
cf. *Electroma*, sp. indet.
Inoceramus, sp. indet., prismatic shell fragments
indeterminate bivalve fragments
echinoid spine, finely ribbed
Age implications: Cretaceous

Core 13, Section 2, Interval 0-5 cm
Nucula sp. B
Arctotis?, sp. indet. (fragment)
echinoid spine, finely ribbed
Age implications: Late Jurassic-Early Cretaceous

Core 13, Section 2, Interval 51-56 cm
In overlying chalk
Maccoyella breviauriculata, n. sp.
cf. *Amusium* spp., translucent shell fragments
cf. Lucinidae, gen. et sp., indet., fragments
Age implications: Early Cretaceous
In underlying dark volcanic mud
Planolites?, sp. indet., tube cross-section
Not age diagnostic

Core 13, Section 2, Interval 78-83 cm
Arctotis filisculptus, n. sp.
Aucellina sp., cf. *A. gryphaeoides* (Sowerby) of Day (1968, pl. 50, fig. 19)
Maccoyella?, sp. indet., fragments
Poromya, sp. indet., fragments
Palliolum (*Delectopecten*) or *Camptonectes* (*Camptochlamys*) fragment, sp. indet.
Limaria?, sp. indet.
cf. *Amusium*, translucent shell fragment
cf. Lucinidae spp., fragment
indeterminate cross-lamellar, bivalve shell fragments
Age implications: Valanginian-Albian

Core 13, Section 3, Interval 90-93 cm
Maccoyella n. sp. A, cf. *M. barklyi* (Moore)
cf. *Parvicorbis*, gen. et sp. indet.
cf. *Liopistha*, sp. indet.
Pseudavicula? sp. aff. *P. anomala* (Moore)
cf. Lucinidae, gen. et sp. indet.
cf. *Amusium* sp., thin transparent shell fragments
bivalve shell fragments, indet.
Age implications: Late Aptian-Albian

Core 16, Section 2, Interval 85 cm
Veniella?, sp. indet. (internal mold)
bivalve fragments, indet.
Age implications: Cretaceous, possibly Albian-Maestrichtian

Core 16, Section 2, Interval 97-100 cm
small gastropod fragment, indet.
cf. *Amusium* spp., thin-shelled, transparent fragment, indet.
Serpula sp. cf. *S. cretacea* (Conrad)
Age implications: Cretaceous

morphs. Preservational characteristics of the shells suggest that recrystallization took place early in diagenesis, though in some cases it appears to have taken place after partial consolidation and cementation of the sediment.

The ecological and paleoenvironmental significance of the Leg 33 bivalve assemblages is considerable; five faunal associations dominated by bivalves can be tentatively defined. Based on comparisons with modern counterpart communities, the bivalves of the carbonate sequence (four distinct associations) clearly represent a deep-water assemblage of probable outer shelf to bathyal origin; a fifth association in older, dark greenish-gray volcaniclastics indicates a relatively shallow-water platform environment. This implies deepening of the Manihiki Plateau during the middle Early Cretaceous transition from volcaniclastic to carbonate sedimentary environments at the site.

It is of additional importance that this probably represents the oldest known deep-ocean bivalve assemblage with modern affinities, and thus provides an important early record for the study of evolution in bathyal benthonic communities of the Pacific. The diversity of this assemblage is only slighly less than that of modern counterpart assemblages from the deep Pacific, and similar taxa are present, recording conservatism in deep ocean evolution. These aspects of the problem are more thoroughly discussed, and the taxa described to the extent warrented by the material, in succeeding chapters.

PRESERVATION: SHELL STRUCTURE AND COMPOSITION

Virtually all molluscs examined from Hole 317A have shell material, or its replacement, well preserved for each taxon. None show partial dissolution features or obvious surface etching. Thus, there is no direct evidence of preburial dissolution, or of diagenetic dissolution without replacement. Several taxa which normally have aragonitic shell layers are present. In many cases these layers are equally as well preserved as co-occurring calcitic shell layers; in other cases, aragonitic layers show coarser recrystallization, destroying original structure, than do adjacent calcitic layers. Commonly, shell material adheres to the external mold when the core is split; the internal mold counterpart normally retains some adhering shell, however, and in some cases, selectively the inner shell layer. Virtually all internal molds for which no external counterpart is known have some adhering shell material, including those in dark greenish-gray volcanic sand underlying the chalk (Hole 317A, Sample 16-2, 85 cm, and 97-100 cm). Most originally inflated shells have been moderately crushed during early diagenetic compaction. Crushing seems to have preceded recrystallization. External and internal surface features (e.g., ornament, muscle insertion areas) are preserved in detail on most specimens, even when they have coarsely recrystallized internal shell structure.

Examination of thin-sections from most core pieces showed a predominance of coarse calcite recrystallization of shell material, without pseudomorphic replacement of original structure; this mainly occurs in normally aragonitic shell layers. This type of replacement may suggest a diagenetic history involving total dissolution of shell layers followed by void filling through later calcite emplacement, and thus possibly a high degree of consolidation and partial cementation of the matrix prior to replacement of the shell. Totally recrystallized shells do not seem to be any thinner than those of the same taxa preserving original shell structure, this may also indicate some cementation of the host matrix before replacement and little compaction between times of dissolution and replacement of shell material. Though of secondary importance, imperfect to nearly perfect replacement of original aragonitic shell structure, and preservation of original calcite structure, are common in many sections.

Observation of bivalve shell structure in thin-sections (transmitted light) and scanning electron microscope photographs (Plate 3, Figures 1, 12, 14, 17) revealed four types of original shell structure preserved to varying degrees.

1) Prismatonacreous bivalves of two sizes: (a) Small, thin (0.5 mm or less) shells of short, blocky, vertically growing calcite crystals, and a dense, dark brown, structureless inner layer (as now preserved) which is much thinner and may have originally been aragonitic nacre. This type of bivalve is rarely seen in section; the shells could represent any of a number of Pteriidae, small Inoceramidae, or Mytilidae known to exist at this time. No specimens complete enough for identification were recovered. The largest fragment seen was about 1.0 mm in length. (b) Thick shell fragments of the prismatic layer only (nacre apparently dissolved) comprised of straight, slender prisms up to 5.5 mm long, from large flat Inoceramidae shells.

2) Cross-lamellar layers, originally composed of aragonite sheets, are the most commonly preserved shell structure and are seemingly associated mainly with large valves of *Limopsis* (Family Limopsidae). In cross-section these appear to intersect at angles normal for simple bivalve cross-lamellar structure (Taylor et al., 1969, pl. 17; pl. 18, fig. 1, 3).

3) Aggregations of thin, irregular and lenticular lenses, each composed of gently inclined, parallel foliations or laminae. The lenses and laminae intersect at low and variable angles; in some cases the internal foliations dip in opposing directions from one lens to the next, forming a broadly obtuse angle of intersection (Plate 3, Figure 1). This angle is much broader than found in true (normally aragonitic) cross-lamellar structure. The term, cross-foliated structure, is thus applied. In most cases the foliations within the lenses or plates of calcite are poorly preserved or destroyed through recrystallization, whereas the lens boundaries are preserved; in a few specimens all structure is well preserved. Small borings, presumably those of fungi, are common in this but no other type of shell in the samples. The original mineralogy of this layer was probably aragonite; the taxonomic affinities of this type of structure are not clearly known. It may represent the common bivalves *Arctotis, Maccoyella,* or *Pseudavicula* (Oxytomidae).

4) In the inner shell layer of small *Maccoyella* (Oxytomidae), rows of small, shallowly inclined needles or narrow laths that look similar to aragonite needles, are

slightly recrystallized and occur in concentric rows subparallel to the growing edge. Alternate rows dip in different directions (Plate 3, Figures 12, 14, 17), as in cross-lamellar structure, but at very low angles to the shell surface and thus with a broad angle of intersection. This angle is generally greater than normal for aragonitic cross-lamellar structure in Bivalvia, but is within the known range (e.g., see Taylor et al., 1969, pl. 18, fig. 2; *Ensis*). The composition of the needles seems to be calcite as presently preserved. This type of arrangement is also best termed cross-foliated structure. This layer was probably aragonite originally.

In addition to these original structures observed in thin-section and by scanning electron microscopy, two other types of original shell structure were observed with a binocular microscope.

5) Very thin, transparent to translucent shells with small, closely and evenly spaced nodes, possibly marking the termination of punctae through the shell, which are thought to belong to *Poromya*, a common deep-water bivalve characterized by thin nacreous shells with surficial granulations. No specimens complete enough for definite identification were recovered.

6) Very thin, transparent to translucent shell fragments with radially arranged "zones" of internal structure giving the appearance of different densities and/or light reflection qualities, viewed microscopically. These are thought to reflect cross-lamellar structure and/or development of internal ribs in the very thin, aragonitic, inner layer of some "paper pecten," probably belonging to the *Amusium* group of the Family Pectinidae.

It is significant that several of the shell structures preserved in the matrix indicate that original aragonite shell layers were developed in benthonic taxa living at or near the site of preservation. All are presently altered to calcite according to limited X-ray analysis. Recrystallization preserving such detail in shell structure seems to have been early in diagenesis; but coarse calcite recrystallization dominates all samples and probably represents post-cementation diagenetic changes. These bivalves, originally possessing aragonitic shell layers, lived with a fauna indicating probably outer shelf to bathyal habitats (see Ecology section), based on modern counterpart ecology; in some cases this may have been below the compensation depth (about 3500 m today), or at least below the zone of maximum dissolution rates (a few hundred m today). This suggests that widespread and indiscriminate application of the simple rule of thumb—sediments rich in aragonitic fossils indicate shallower waters, and those lacking aragonitic fossils point to deeper and presumably cooler waters (e.g., Kennedy, 1969, p. 462-465)—must be used cautiously. Certain aragonitic-shelled taxa today, and presumably in the past, live well below the compensation depth, and certainly below the depth where the rate of aragonite dissolution is highest in modern oceans, without surface dissolution of even dead shells. These obviously have protective organic membranes, a more stable form of aragonite, and/or denser shell structure than many shallow-water aragonitic molluscs. The relationship between taxonomic position, structure and composition of the aragonite layers, and oceanic conditions favoring aragonite dissolution and establishment of compensation depth needs to be thoroughly studied, a dissolution gradient set for each major taxonomic division, and diagenetic dissolution more thoroughly understood before depth interpretations can be made on the presence or absence of aragonite in ancient or living mollusc shells.

AGE OF THE BIOTA

Several factors prohibit precise age determination and regional correlations based on the macroinvertebrates from Hole 317A. Most are not well enough preserved to allow specific determination, and the age ranges of genera, where determinate, are commonly too long to be useful in precise dating. The ranges of some genera, previously recorded only from Upper Cretaceous or younger rocks, are extended into the Lower Cretaceous on the basis of material contained in these samples, further detracting from the use of genera as age indicators. In addition, many of the species present are undescribed, and for these only a few can be referred to known species groups, and thus to somewhat restricted age ranges. Most correlations are with Australia. A paucity of pre-Aptian systematic study on southern Pacific Cretaceous biotas also detracts from our ability to identify, date, and correlate these fossils.

By combining the age ranges of genera and species groups present at each level, and by choosing as an age for each level the range of overlap of these data (or the most reliable data if there are major preservational differences between taxa), a general age has been assigned to each collection (Table 1). The majority of data indicates that all samples are of Lower Cretaceous age, and some data are no more specific than this. The best dates are obtained from comparison of Hole 317A bivalves with known species groups of the genera *Aucellina, Maccoyella,* and *Pseudavicula*. These data are summarized below.

Sample 10-1, 145 cm may be as old as Barremian and as young as lower upper Albian; closest relations seem to be with lower to middle Albian *Aucellina*. Other fossils in Core 10 only indicate a Lower Cretaceous age.

Core 11 contains molluscs suggesting a Valanginian to lower Albian age at the top of the fossiliferous interval (Sample 11-3, 134-137 cm), a probably Neocomian (Valanginian) age in the middle of this interval (11-4, 50-56 cm, Neocomian-Senonian; 11-5, 6-12 cm, Valanginian), and strangely, a probably Albian age based on *Aucellina* cf. *A. gryphaeoides* near the base (11-5, 89-96 cm).

Core 12 is dated as Lower Cretaceous, probably Albian (based on *Aucellina* sp. cf. *A. gryphaeoides*) in the upper part (Section 1 through Section 6, interval 43-47 cm), and upper Aptian or lower Albian below this.

Core 13 has only a few taxa suggesting a Lower Cretaceous age above Section 2, 78 cm level. Section 2, interval 78-83 cm, indicates Valanginian through Albian age (probably pre-Albian), and Section 3, interval 90-93 cm suggests an upper Aptian through upper Albian age.

Core 16 contains no diagnostic fossils other than to suggest a Cretaceous age.

The above summary must be applied with caution for reasons previously stated. It is suggested that good microfossil dating from these sediments would be more

reliable at the present time than dating based on Mollusca. It should be noted, however, that early indications of Barremian through Aptian nannofossils in these sediments (S. Schlanger, personal communication, 1974) are generally compatible with molluscan dating, except where Albian dates are obtained by comparisons of *Aucellina* sp. cf. *A. gryphaeoides* occurrences with those of Queensland, Australia, cited for identical forms by Day (1968).

PALEOECOLOGY AND PALEOENVIRONMENTS

Besides their biostratigraphic significance, the principal value of the Hole 317A macroinvertebrates is their use in reconstructing the ecology, community structure, and environment of deposition of these older Cretaceous deposits. The interpretation is naturally limited by the small sample size, but nevertheless numerous important points can be made.

Lower Cretaceous fossils from Hole 317A occur in two facies: dark greenish-gray volcaniclastic sand and silt of probable Neocomian age (Barremian and older) found in Core 16, Section 2, is the initial facies and contains moderately sparse macrofossils; it is overlain by Neocomian-Albian chalks and calcareous oozes, comprised dominantly of foraminifers and nannofossils, which contain moderate numbers of small, thin-shelled Bivalvia, sparse echinoid spines, and sparse marine worm burrows restricted to narrow intervals.

Jenkyns (this volume) notes that the volcaniclastic sands are the initial deposits of depositional basins on the newly formed Manihiki lava Plateau, and represent sediments initially derived from violent interaction between basaltic lavas and sea water during emplacement in shallow water (photic; depth determined from sedimentary structures). Colonization of these deposits by benthonic organisms took place after a period of relative volcanic quiescence and current reworking; macrofossils are restricted to the upper part of the volcaniclastic sequence, where Jenkyns (this volume) reports bryozoa, small thin-shelled bivalves, and echinoid fragments from thin-section analysis. The volcanic sands and silts also contain a small assemblage of larger molluscs and serpulid worms, which is completely distinct from the fauna of overlying calcareous sediments. Thick-shelled bivalves of moderate size (Arcticidae; *Veniella*? sp.), smaller thin-shelled bivalves, small gastropods (with shells), and a thick-shelled, straight serpulid worm tube occur in this facies. The presence of gastropods, whose aragonite shells are especially susceptible to dissolution below the aragonite compensation depth, and which are absent in the chalks and oozes, suggests shallow shelf-depth waters (<200 m) above the aragonite compensation depth (about 3500 m today). *Veniella*? sp. also suggests shelf or upper slope depths. Its size and shell thickness are typical of bivalves found in shallow to middle shelf environments today, and atypical of bathyal, abyssal, or hadal bivalves. *Veniella* of similar nature are characteristic faunal elements of inner and middle shelf, Tropical to Warm Temperate Cretaceous paleocommunities in many parts of the world (e.g., Atlantic and Gulf Coast of North America, Caribbean island platforms), and are atypical of more offshore, deeper water deposits. Heavy shelled serpulids, especially those of this size and straight growth habit, are similarly found mainly in shallow water to mid-shelf depth Cretaceous paleoenvironments where firm surfaces for attachment of the tube are available.

Thus, the depositional environments of the initial volcaniclastic deposits on the Manihiki Plateau would seem to have been those associated with a relatively shallow (shelf-depth), current-swept, raised oceanic platform. Sedimentologic evidence (Jenkyns, this volume) includes the presence of hyaloclastites and graded beds, probably from suspension clouds produced during volcanic eruptions, in the lower part of the section associated with vesicular basalts; cross-lamination, indicating some current reworking, is associated with an increase in "fucoidal" trace fossils (burrowing worms and arthropods) and fragments of echinoderms, bryozoans, and bivalves in the upper part of the sequence. The preservation of shelled gastropods, and the occurrence and ecology of thick-shelled *Veniella*? and *Serpula* support Jenkyns' conclusions of a shallow-water origin. As noted by Jenkyns (this volume), lack of any evidence for reef-forming organisms in this Cretaceous Tropical platform may indicate either water depths greater than those conducive to reef growth (more than 100 m) and/or intermittent volcanic activity creating difficult marine benthonic environments for reef-forming organisms. The increase in benthonic diversity and numbers of individuals upward through the volcaniclastic sequence and the deep-water aspect of overlying carbonates, would seem to favor the former explanation.

Volcaniclastic sediments grade upward into light colored chalks and marls (calcareous oozes) by gradual addition of carbonate through the section (mainly increase in coccolith content) and decrease in grain size (Jenkyns, this volume). But there is no gradation in the macrofauna. The initial carbonate-associated macrofauna obtained from Hole 317A cores is completely distinct from that of the volcaniclastics and clearly indicative of deeper, quieter water environments, suggesting probable subsidence of the Manihiki Plateau during middle Neocomian through Albian time.

Macroinvertebrates of the overlying Lower Cretaceous chalks and calcareous oozes indicate quiet water environments of the outer shelf and upper bathyal zones (200 m to 2000 m, or deeper). Hessler and Sanders (1967), Sanders and Hessler (1969), and others have characterized modern deep-water biotas as having high diversity with low population densities for most species. Bivalvia strongly dominate calcium-carbonate-shelled macroorganisms; gastropods are less common, or absent. Most taxa are small and thin shelled. Much of the species diversity among bivalves seems to be among specialized deep-water genera belonging to a few families, such as the Nuculidae, Nuculanidae, Pectinidae, Propeamusiidae, Poromyidae, Lucinidae, Thyasiridae, Arcidae, Cuspidariidae, and a few others. Knudsen (1967, 1970) and others have illustrated the characteristics of deep-water bivalve assemblages through careful systematic and ecological studies.

Chalk and calcareous ooze macrofaunas of the Hole 317A samples are strikingly similar to bathyal and abyssal assemblages living today (see Knudsen, 1967,

1970). Small, thin-shelled bivalves dominate and are relatively complete; fragments are not current-worked. Diversity is remarkably high considering the small sample sizes. Forty-two macroinvertebrate taxa are recognized in Cores 10-13; all but three are Bivalvia. One to eight macroinvertebrates, mostly bivalves, were noted in single samples, with an average diversity of three taxa. Each taxon is represented by only one or a few specimens, possibly indicating low population densities. Actual macrofauna diversity was obviously higher, as no soft-bodied forms are preserved, and the figures do not take into account the numerous shell fragments in each sample which, though indeterminate, probably represent at least a few additional bivalve taxa. No gastropods were noted in the calcareous Lower Cretaceous facies. Diversity decreases up-section (Figure 1), possibly indicating increasingly more difficult benthonic environmental conditions with deepening. The principal bivalve groups, however, occur sporadically throughout the sampled interval.

The composition of the Cretaceous carbonate bivalve assemblages also suggest bathyal-abyssal habitats. Many Cretaceous genera are identical or related to modern deep-water bivalve genera which are less commonly or rarely found in shelf depth environments. These include *Poromya*, small transparent to translucent *Amusium, Delectopecten, Acesta, Limopsis,* and the nuculanid *Tindaria*. Knudsen (1967, 1970) provides abundant ecological data for modern representatives of these groups in bathyal and abyssal environments throughout the world; Keen and Coan (1974) summarize eastern Pacific data. Pertinent data from these and other sources are abstracted below.

Poromya: Knudsen's (1967, 1970) data from four common species show average depth occurrences of 740, 2471, 1917, and 3646 meters, with a total depth range of

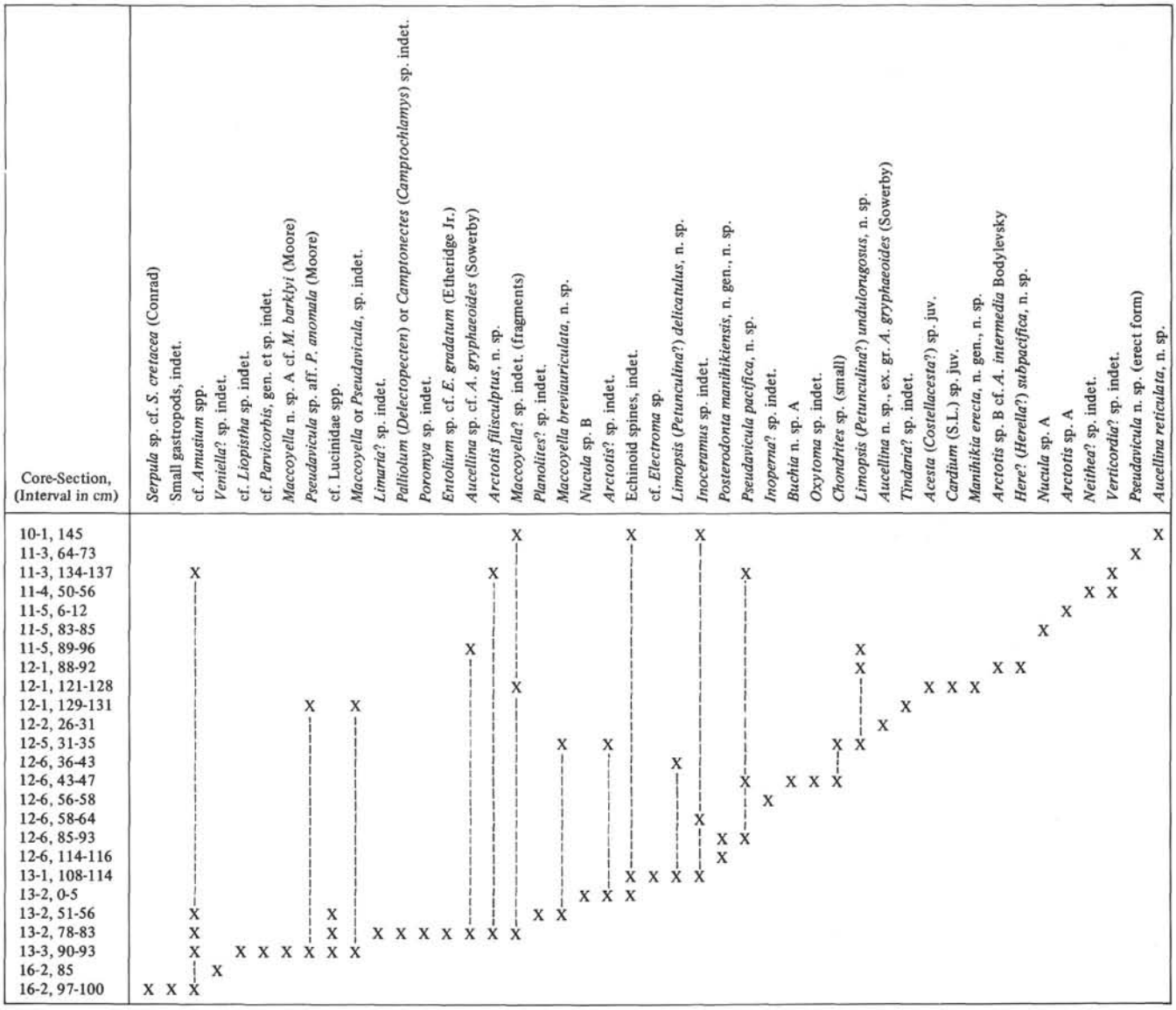


Figure 1. *Biostratigraphic distribution of all identifiable Lower Cretaceous macroinvertebrate fossils from DSDP Leg 33, Hole 317A; see Table 1 for more detailed age interpretation of each sample. Highly questionable occurrences of fragments not included.*

694-5300 meters, and an overall average depth occurrence of 3289 meters. Average bottom temperatures preferred are around 2.4°C, and preferred substrates range from globigerinid ooze to dark organic mud and silty mud. Keen and Coan (1974) report a depth range of 75-2930 meters for seven species. Most are deep-water inhabitants. Many *Poromya* are carnivorous on microorganisms (e.g., ostracodes, foraminifers) in deep, food-poor habitats they prefer.

Amusiidae: this group is represented mainly as thin fragments, and the specific genera occurring in Cretaceous deposits are not known. *Amusium*, the principal modern representative and a common fossil, ranges from 190 to 3297 meters depth according to Knudsen (1967, 1970) though somewhat shallower and deeper ranges are known. Average depth occurrences for 13 common species are: 1586, 1405, 396, 3297, 1789, 2745, 882, 1614, 869, 464, 664, 543, 712 meters; that is, primarily bathyal. Average recorded water temperatures are 1.7°C to 11.6°C for these species. Soft green and gray mud, and globigerinid ooze are principal associated substrates of *Amusium*. Most species are filter-feeding carnivores, feeding on small crustaceans and foraminifers.

Limopsis: an extremely common deep-water bivalve with average depth occurrences of 12 "species" (some conspecific) listed by Knudsen (1967, 1970) of: 5011, 4939, 3009, 4787, 3065, 3094, 2517, 1920, 460, 1478, 3011, 694, meters, with a total range for all species analyzed of 180-4990 meters (lower shelf, bathyal, upper abyssal). Temperature averages are between 2.0°C and 2.6°C, ranging up to 8.9°C. Preferred substrates are soft gray, green, and brown mud and globigerinid ooze; the latter is compatible with Cretaceous occurrences. *Limopsis* is a suspension feeder on diverse materials.

Delectopecten: one deep-water species recorded by Knudsen (1967, 1970) ranges between 906 and 1936 meters (bathyal) in bottom temperatures averaging 2.5°C on soft mud. The genus also occurs at shelf depths, as indicated by the total range for four eastern Pacific species of 20-2010 meters (Keen and Coan, 1974).

Tindaria: this globose, detritus-feeding protobranch bivalve is represented by 10 common to rare deep-water species (Knudsen, 1967, 1970) ranging between 1846 and 7300 meters (bathyal, abyssal), with individual species yielding average depth readings at 4202, 2820, 2862, 5133, 3291, 5202, 2312, 2018, 2780, and 6733 meters, at bottom temperatures ranging from -0.5°C to 2.7°C. Soft to hard dark clay and globigerinid oozes are preferred substrates.

Lucinidae: species of *Lucina* and the many related genera and subgenera range from littoral to abyssal depths. Knudsen reports deep-water species between 217 and 1415 meters depth (average for three species: 897, 511, 503 m) at water temperatures between 1.8°C and 10.8°C (averages 6.38, 10.5, 10.8°C), primarily on green and brown clay-rich muds. Lucinidae are represented in Hole 317A cores by fragments of small, thin-shelled species with regular concentric raised growth lines, resembling several extant and fossil genera. Members of the Lucinidae are in general more typical of shelf depths, but small thin-shelled forms are most common in bathyal and outer shelf zones.

Nuculidae: *Nucula* is a ubiquitous genus ranging from shallow sublittoral to hadal depths and feeding on organic detritus in gray, green, and brown muds rich in organic material. Average depths of occurrence for nine typical deep-water species today are (Knudsen, 1967, 1970): 777, 120, 589, 241, 819, 775, 4020, 2519, and 2660 meters, with a total range for these species of 265 to 4020 meters. Average bottom temperature ranges from 2.3°C to 9.2°C. Keen and Coan (1974) list 10 east Pacific species with a total depth range of 10-2000 meters. *Nucula* and other protobranchs are an important component of ancient and modern deep-water communities; their relative abundance in communities generally increases with depth.

Verticordia: a common upper bathyal genus, but with species more abundant in outer shelf environments. Knudsen (1967, 1970) does not record it, but depth ranges in the U.S. National Museum collection indicate species from 2 to 2718 meters, with most forms occurring between 100 and 400 meters. The average depth for all species is 942 meters, but for all species occurrences sampled is 121 meters. Keen and Coan (1974) record living east Pacific species between 35 and 1200 meters.

Thus many of the important bivalve components of the Cretaceous macrofauna with living counterparts are characteristic of, or common in, outer shelf, bathyal and abyssal ocean depths today. The combination of these taxa in Cretaceous carbonate pelagic sediments of Core 317A is strong evidence for water depths somewhere between 200 and 4000 meters (bathyal zone). A survey of level bottom community studies ranging from shelf to abyssal depths supports this. Parker (1964), for example, did not encounter a similar suite of taxa in his study of the Gulf of California and continental slope of Mexico until depths of 1800 to 4122 meters (his "abyssal southern borderland and lower slope basin"), where he found *Nucula* and other protobranchs, *Tindaria, Limopsis,* and *Poromya* in association with taxa not represented in the Hole 317A cores (e.g., *Arca, Abra, Cuspidaria, Myondera,* and six genera of small gastropods). Thorson's (1957) study of level bottom communities, mainly on continental shelf areas, did not turn up equivalent ecological associations. The Cretaceous bivalves *Liopistha* (Poromyidae), *Neithea* (Pectinidae), and *Acesta* (*Costellacesta*?) probably also belong to this predominantly deep-water assemblage. Modern representatives of *Liopistha* and *Costellacesta* are common outer shelf, bathyal and upper abyssal organisms, and *Neithea* is most commonly found with outer-shelf depth, quiet water, Cretaceous deposits, predominantly associated with chalks and glauconitic sands.

Other common elements of the Hole 317A carbonate facies assemblage do not detract from these environmental interpretations. *Inoceramus, Buchia,* and *Aucellina* are important, widespread, environmentally ubiquitous Mesozoic bivalves not uncommonly found associated with deep, cool-water deposits. The various Oxytomidae (*Oxytoma, Pseudavicula, Maccoyella,* and *Arctotis*) are typical of fine-grained outer-shelf and deep-water deposits of the Pacific Mesozoic ecosystem, with heavier shelled, larger forms ranging into coarse shallow-water deposits. The Hole 317A forms are all small, thin-shelled taxa.

The absence of diverse, infaunal, phytoplankton suspension feeding bivalves, of any gastropods, of thick-shelled forms, and the dominance of suspension feeding carnivores, epifaunal omniverous suspension feeders, and deposit feeding bivalves and worms all suggest water depths below the photic zone (about 50 m) and mainly below outer shelf depths (200 m). Absence of ammonites and gastropods with relatively unstable aragonite shells, and presence of aragonitic bivalves which today survive in deep-water environments due to thick organic sheaths (enlarged periostacum) covering the shell, and possibly unique shell structure, also suggest that chalks and oozes of Hole 317A were deposited below the normal aragonite compensation depth, and are probably bathyal in origin.

The small number of samples does not allow statistical analysis of community structure among the carbonate-associated macrofossils of Hole 317A. Subjective evaluation, however, suggests four recurrent associations of taxa which may represent deep, level-bottom communities during the Cretaceous, as follows:

1) A Buchiidae (*Buchia* or *Aucellina*) dominated association of very low diversity (1-4 taxa), in which buchiids occur alone or commonly with some oxytomid bivalve (*Oxytoma, Maccoyella*), and rarely have associated *Inoceramus* shell fragments, *Chondrites* burrows, and echinoid spines (small, delicate, ribbed forms). Such a low-diversity association is typical of many occurrences of Buchiidae throughout the Jurassic and Cretaceous. It may suggest that Buchiidae are opportunistic and thus strongly dominate their community, and/or that they can occupy marginally habitable benthonic environments which exclude many other types of benthos. Significantly, infaunal organisms other than sparse chondritid burrows (detritus-feeding worms) are absent; substrates supporting these associations dominated by byssate epifaunal bivalves may have been somewhat toxic internally.

2) Oxytomidae-dominated association (*Oxytoma, Maccoyella, Pseudavicula,* and *Arctotis*) characterized by two or more oxytomid genera (byssate epifauna) commonly in association with paper pectens (*Amusium* Group, Pectinidae) and infaunal suspension feeders like *Verticordia* and Lucinidae. A diverse group of epifaunal and infaunal bivalves is occasionally associated with this group of taxa, including mobile epibenthonic *Acesta* (Limidae), and *Palliolum* (*Delectopecten*) (Pectinidae), byssate epibenthonic *Aucellina*, infaunal *Liopistha, Poromya,* and a small *Cardium.* This is the most diverse association in Hole 317A cores (1-8 taxa, average 4), and encompasses the broadest variety of habitats and feeding strategies. This assemblage certainly represents the best benthonic environment for habitation, without severe environmental restrictions within or above the sediment-water interface, and in the presence of firm substrates for attachment of diverse byssate bivalves. This may be the shallowest phase of carbonate deposition during the Lower Cretaceous history of the Manihiki Plateau; this association is best developed in the lower part of the section (Cores 12, 13) above the transitional sediments between the chalks and the shallow-water volcaniclastics of Core 16.

3) Protobranch-dominated association (*Nucula, Tindaria*). These deposit-feeding infaunal genera are sparsely represented, but in some cases are the only large and complete shells in samples otherwise containing small shell fragments and an occasional echinoid spine or oxytomid bivalve (*Maccoyella, Arctotis*—basally attached, epifaunal suspension feeders). No other infaunal element is associated with the protobranchs, and they are not found with association 2 and its diverse infauna. This may represent a relatively poor, benthonic environmental phase with highly organic and somewhat deleterious chemical conditions within the substrate (high H_2S, decreased O_2)—conditions favoring protobranchs but not most other infauna. A general alternation of associations with diverse suspension-feeding infaunal bivalves, and those with only deposit feeding bivalves may represent periodic community and environmental succession such as described for the Cretaceous by Rhoads et al. (1972) and Kauffman (1974).

4) *Limopsis*-dominated association, with commonly associated oxytomid bivalves (*Arctotis, Maccoyella*) and thin-shelled smooth pectinids (*Amusium* Group). Byssate epifaunal bivalves represent the most diverse group in this association (*Arctotis, Maccoyella, Pseudavicula, Electroma, Aucellina,* and *Inoceramus* are all found in one or more samples of this association), suggesting diverse hard substrates for attachment and possibly early diagenetic cementation of the carbonates into "softgrounds." Echinoid spines are also known to be associated, but only one suspension feeding infaunal bivalve shell, *Here*? (*Herella*?), is recorded, perhaps also attesting to the compact (or, alternatively, chemically deleterious) nature of the substrate.

Whereas these associations seem to alternate up through the section (Figure 2), they show no consistent trends indicating broad environmental changes other than a gradual loss in diversity of the more diverse units (2, 4).

An important point that needs to be developed in future research is the remarkable resemblance, in taxonomic composition and diversity, of these—the oldest Mesozoic bathyal molluscan associations yet recorded in detail—and equivalent living communities. Comparison with the modern data of Knudsen (1967, 1970), Parker (1964), and others shows only slightly decreased Cretaceous deep-sea diversity and only one-third to one-half nonoverlapping genera or morphotypes. This remarkable conservativeness in community evolution has been predicted, and noted for individual organisms, but not yet recorded at the community level for mollusc-dominated associations. This alone is a strong recommendation for greater opportunity to study macroinvertebrate assemblages in JOIDES cores in the future.

Biogeographic Relationships

The only close biogeographic affinities shown by the Hole 317A Lower Cretaceous species, species groups, and genera are to the Lower Cretaceous of Australia, and especially to the faunas of the Great Artesian Basin from Queensland described in the unpublished work of Day (1968). The presence of *Buchia* and *Arctotis* suggests secondary and distant biogeographic relationships

Core-Section, (Interval in cm)	*Serpula*	Small gastropods	cf. *Amusium*	*Veniella*?	cf. *Liopistha*	*Verticordia*?	*Maccoyella*	*Pseudavicula*	Lucinidae, gen. indet.	*Limaria*?	*Palliolum (Delectopecten)* or *Camptonectes (Camptochlamys)*	*Entolium*	*Poromya*	*Arctotis*	*Aucellina*	*Planolites*?	*Nucula*	Echinoid spines	*Inoceramus*	cf. *Electroma* sp.	*Limopsis (Petunculina*?)	*Posterodonta*	*Inoperna*?	*Buchia*	*Oxytoma*	*Chondrites*	*Tindaria*?	*Acesta (Costellocesta*?)	*Cardium* (S.L.)	*Manihikia*	*Neithea*?	*Here*? *(Herella*?)	
10-1, 145							X								X			X	X													Buchiidae Association
11-3, 64-73								X																								
11-3, 134-137			X			X		X						X																		Oxytomidae Association
11-4, 50-56						X																									X		
11-5, 6-12														X																			
11-5, 83-85																	X															Protobranch Association
11-5, 89-96															X						X											*Limopsis* Association
12-1, 88-92														X							X										X	
12-1, 121-128							X																					X	X	X		Oxytomidae Association
12-1, 129-131							X	X																			X					Protobranch Association
12-2, 26-31															X																	Buchiidae Association
12-5, 31-35							X							X							X					X						*Limopsis* Association
12-6, 36-43																					X											
12-6, 43-47								X																X	X	X						Buchiidae Association
12-6, 56-58																				X			X									?
12-6, 58-64																			X													?
12-6, 85-93								X														X										Oxytomidae Association
12-6, 114-116																						X										?
13-1, 108-114																		X	X	X	X											*Limopsis* Association
13-2, 0-5														X			X	X														Protobranch Association
13-2, 51-56			X				X		X							X																
13-2, 78-83			X				X		X	X	X		X	X	X																	Oxytomidae Association
13-3, 90-93			X		X		X	X	X																							
16-2, 85				X																												Shelf Mollusc Association
16-2, 97-100	X	X	X																													

Figure 2. *Biostratigraphic distribution of macroinvertebrate subgenera, genera, or suprageneric groups from DSDP Leg 33, Hole 317A and assignment of assemblages from each level to ecological associations defined in text (right column). Question mark indicates data insufficient for ecological assignment.*

to Russia and Siberia. These data strongly suggest that the Manihiki Plateau, during the Lower Cretaceous, belonged to the Australian Subprovince of the Austral Province, which was shown by Kauffman (1970) to be strongly differentiated by Lower Cretaceous time, diminishing in biotic uniqueness during the Late Cretaceous. Kauffman placed this province in the warmer part (Subtropical to Warm Temperate) of the South Temperate Realm (= antiboreal of various authors), and lacking data, did not extend the province boundaries as far east as the Manihiki Plateau; such an extension is now possible.

It is probable that the taxa of Russian affinities made their way southward through the cool, deep portions of the Tropical-Subtropical Pacific to the Manihiki Plateau. Possibly pelagic larvas of these groups were carried on deep countercurrents. North-south, deep-water migration of typically cool-water North Temperate bivalves has also been recently observed by the author in regard to Jurassic Inoceramidae and Buchiidae of the Lassiter Coast, Antarctica, where several Russian, Siberian, and Alaskan species and species groups are reported south of the equator for the first time (R.W. Imlay and E.G. Kauffman, in preparation).

CONCLUSIONS

Lower Cretaceous macroinvertebrates record deepening of waters over the Manihiki Plateau from the time of its formation by early Neocomian shallow-water basaltic extrusions, to Aptian-Albian time when pelagic coccolith-foraminifer chalks and oozes accumulated on the plateau at outer shelf and bathyal depths. Five macroinvertebrate associations, strongly dominated by Bivalvia and characterized by relatively high diversity and low population densities, considering the small sample size, can be subjectively defined. A probable lower Neocomian association marking the first appearance of macrofossils in the upper part of dark greenish-gray volcaniclastic sands is characterized by thick-shelled *Veniella*?, gastropods retaining shell material, smaller thin-shelled bivalves, thick-shelled serpulid worm tubes, echinoderm fragments, and sparse bryozoans. This assemblage and associated current-formed sedimentary structures, coupled with the lack of evidence for coral reef growth on this Subtropical (?) platform, suggest mid-shelf depths of about 100 meters and somewhat mobile substrates.

The macrofauna and its environmental implications change markedly in younger Neocomian to Albian

chalks and foraminifer-coccolith oozes (micrites) which gradationally replace basal volcaniclastic sands upsection. The four associations that characterize these carbonates all contain suites of taxa which, based on their diversity, small size, delicate thin shells, ecology of modern counterpart genera, and fossil occurrence elsewhere, indicate outer shelf to (dominantly) bathyal depths (200-4000 m) and probably record subsidence of the Manihiki Plateau, significant rise in global sea level, or both.

The four Lower Cretaceous carbonate assemblages represent different phases of community or ecosystem succession and environmental fluctuations in deep portions of the Manihiki Plateau. A low-diversity association dominated by Buchiidae (*Aucellina, Buchia*) associated with other byssate epifaunal bivalves, but with sparse infauna, possibly represents a colonization surface of opportunistic species on marginally habitable substrates (especially within the sediment). A second low-diversity association characterized by the protobranch, deposit-feeding bivalves *Nucula* or *Tindaria*, with or without sparse byssate epifaunal oxytomid bivalves, probably suggests soft, water-saturated substrates rich in organic material with abundant hydrogen sulfide, and somewhat depleted in oxygen. Two other carbonate associations are more diverse in taxa and habitat types and represent more normal marine benthonic environments in quiet but well-circulated waters. One association is dominated by the shallow infaunal bivalve *Limopsis* associated with a diverse epifaunal suite of bivalves such as *Arctotis, Maccoyella, Pseudavicula,* Pectinidae, *Electroma, Aucellina,* and *Inoceramus*. Firm, perhaps partially cemented carbonate sufaces are implied. A second association equally mixes infaunal and epifaunal bivalve elements and is dominated by the byssate epifaunal oxytomid bivalves *Maccoyella, Arctotis,* and *Pseudavicula*. This is the most diverse association and occurs predominantly in the lower (shallower?) part of the Lower Cretaceous carbonate sequence. Carbonate associations all show decreasing diversity up-section, possibly reflecting deepening of the plateau and/or onset of more difficult benthonic environments, but there is apparently no consistent succession of associations or "paleocommunities" within the carbonate sequence.

These are possibly the oldest bathyal associations of "modern" bivalves known, and yet they are clearly composed of taxa which are closely comparable in diversity, morphotypes, habitat, and in many cases systematic position with those characterizing living Pacific and Atlantic communities of the bathyal zone. This suggests highly conservative evolution for taxa and communities in the deep ocean, and is thus compatible with existing evolutionary theory (e.g., the Time-Stability hypothesis of Sanders, 1969). Many of the Hole 317A Cretaceous bivalve species are new, and at least two new genera are present. The supraspecific taxa are interesting in that many of them combine characteristics of two or more genera and subgenera better known from the Cenozoic and Recent, suggesting that they lie at the rootstocks of deep-water bivalve evolution.

SYSTEMATIC PALEONTOLOGY

Phylum ANNELIDA

Family SERPULIDAE

Genus SERPULA

Serpula sp. cf. S. cretacea (Conrad)
(Plate 3, Figure 7)

Reference—Stephenson, 1941, p. 56, 57, pl. 4, fig. 1-3.

Material: A single long tube fragment with the shell intact, external ornamentation preserved; figured specimen, USNM 218015, from Sample 16-2, 97-100 cm.

Description: Tube slender, with straight to slightly sinuous marginal outline; flanks slightly tapering toward point of origin; measurements of preserved fragment; length 16 mm, width 3 mm, wall thickness 0.6 mm. Interior of tube hollow, without obvious septa or dissepiments. Surface of tube marked by small, rounded, closely and irregularly spaced, irregularly developed, slightly raised concentric undulations or "wrinkles"; no longitudinal ornamentation.

Remarks: Whereas most Cretaceous serpulid worms are coiled and cemented over much of their length to hard substrata, some species, and particularly those of softer substrata, grow upward in small to large, intertwining clusters, or as isolated individuals attached only by the base of the tube, so that large segments of the tube are nearly straight and without attachment scars. *Serpula cretacea* is one of the most common of these, and this species group is widely distributed around the globe in Cretaceous deposits. The specimen from the Manihiki Plateau resembles *S. cretacea* in size, taper, wall thickness, and surface markings, but the fragment is too incomplete for definite identification.

TRACE FOSSILS

Trace Fossil Genus CHONDRITES Sternberg, 1833

Chondrites sp. (small)
(Plate 2, Figure 10)

Material: Moderately abundant, small, simply branching burrow fillings of lighter colored carbonate in light gray coccolith-rich chalk and marl at two intervals. Figured specimen, USNM 218049, from Sample 12-5, 31-35 cm. Additional specimens from Sample 12-6, 43-47 cm. (USNM 218045a, b, with *Buchia*, n. sp. A).

Description: Preserved tubes small; maximum observed length 17.5 mm, width 1.3 mm. Central tube relatively straight, or slightly sinuous and curved, terminating in rounded end, not changing thickness significantly over observed interval. One to four short branches, of same size as central tube, arise at relatively high angles to axis of central tube; side branches short, terminally rounded, 4-5 per 25 mm tube length. Some central tubes without branches. Burrows normally inclined to bedding plane at shallow to moderate angles, in some cases nearly parallel to bedding.

Remarks: The tubes are not extensively developed enough on the limited core surfaces for assignment to known form-species of *Chondrites*, largely differentiated on the tube size and overall burrowing pattern. *Chondrites* is common only at the levels cited above (which otherwise lack a diverse infauna); it is otherwise absent, or very rare, even in the presence of diverse infaunal bivalves; their occurrence seems to be that of an infaunal opportunistic species and perhaps indicates periods when the sediment interior became chemically only marginally habitable. Well-defined burrowing boundaries indicate low levels of sediment-water saturation and possibly a slowdown in sedimentation rate during *Chondrites* habitation.

Trace Fossil Genus PLANOLITES Nicholson, 1873

Planolites? sp. indet.

Remarks: A single cross-section of a tube (USNM 218042), similar in size and shape to that made by presumed worms in the burrow-fossil *Planolites*, was observed from Sample 13-2, 51-56 cm, in a thin bed of volcaniclastic? silt interbedded in the lower part of the car-

bonate sequence. The tube is 9 mm wide and 6 mm high in cross-section and subparallel to the bedding planes. The basal part and center of the tube are filled with materials similar to the surrounding matrix; the dorsolateral and dorsal portions of the tube contain a very fine, dark olive-brown mud. The burrow boundaries are sharp, indicating low levels of water saturation in the sediment.

Phylum MOLLUSCA

Class BIVALVIA

Family NUCULIDAE Gray, 1824

Genus NUCULA Lamarck, 1799

Remarks: This genus is characterized by its ovate to trigonal valve outline, moderately to strongly opisthocline shells, opisthogyrous beaks and umbos, taxodont hinge with central resilifer, musculature (especially dorsal accessory muscles), normally crenulated commissural margin, entire pallial line lacking a posterior sinus, and by its surface ornament of radiating costellae and finer raised threads, and fine to moderately prominent concentric growth lines. Subgenera are determined on the relative strength and pattern of ornamental elements, and presence or absence of marginal crenulations. The specimens from Hole 317A assigned to this genus are both incomplete, but similar in shape, size, and ornamentation to *Nucula* s.l. The genus is common in shelf depth to abyssal deposits, becoming smaller, with greater species diversity, and forming a relatively higher percentage of the molluscan component in level bottom communities, with increasing depth. Among subgenera differentiated in Cox et al. (1969), *Nucula* sp. B seems to share characters of *Nucula (Nucula)*, which has dominant radial sculpture and strong marginal crenulations, but is not yet known before the Upper Cretaceous, and *N. (Lamellinucula)* with its concentric sculpture strongly developed and radial sculpture weakly developed (Eocene-Recent). *Nucula* sp. B has relatively faint marginal crenulations and stronger concentric than radial sculpture, but the concentric elements are not as strongly developed as is typical of *Lamellinucula*, and slightly more so than is typical of most *N. (Nucula)*. This form is possibly transitional between the two subgenera, and occurs at a point in time where *Nucula* was first diversifying in form. *Nucula* sp. A seems to lack marginal crenulations and has no trace of radial ornamentation on the internal mold, but is nuculid in shape, size, and convexity. This species may belong to the subgenus *Leionucula* Quenstedt (Cretaceous-Recent; cosmopolitan), which is strongly opisthocline and opisthogyrous dorsally, lacks marginal commissural crenulations, and has a smooth shell exterior. Unfortunately, the material available for study from Hole 317A is too poorly or incompletely preserved to attempt definite assignment to subgenera, or specific determination. The two species are thus left in open nomenclature and assigned to *Nucula s.l.*

Nucula sp. A
(Plate 2, Figure 7)

Material: A single, nearly complete, internal mold of a small left valve with the tip of the beak and edge of the anterodorsal margin broken; figured specimen, USNM 218020, from Sample 11-5, 83-85 cm.

Description: Small; height 9 mm, length 10.5 mm, width 2 mm; moderately convex, with maximum inflation central on disc. Outline ovate, anteriorly posteriorly somewhat elongated (Plate 2, Figure 17); dorsoanterior margin slightly curved; ventroanterior, ventral, and ventroposterior margins moderately and subevenly rounded; dorsoposterior margin moderately concave below recurved beak, umbo. Valve slightly opisthocline, strongly opisthogyrous, with blunt, rounded beak and swollen, prominent umbo strongly projecting dorsoposteriorly. Shell surface, to the extent it is reflected on internal mold, smooth, with only very faint traces of fine growth lines (Plate 2, Figure 17). Commissural margin smooth. Posterodorsal margin of internal mold with faint impressions suggesting presence of small taxodont teeth. No other features preserved; right valve unknown.

Remarks: Assignment to *Nucula s.l.* is based on the valve outline, strongly opisthogyrous nature of the beaks and umbos, and on the comparable convexity of the shell. The size is compatible with smaller species of *Nucula*. This form differs from *Nucula* sp. B in being higher, more ovate, less opisthocline, in lacking apparent radial ornamentation and marginal crenulations, in having weaker, less regular growth lines, and in having more projecting, more strongly opisthogyrous beaks and umbos. Because of the poor preservation of this specimen, subgeneric assignment is not attempted and the species is left in open nomenclature.

Nucula sp. B
(Plate 3, Figure 1)

Material: Internal mold of a single small adult shell with valves cojoined, pieces of shell adhering, valves slightly displaced and crushed, dorsoposterior one-third of shell missing at core margin; figured specimen, USNM 218031, from Sample 13-2, 0-5 cm.

Description: Moderately small; height approximately 12 mm, length 14.5 mm, width 1.6 mm; equivalve, moderately convex, maximum inflation dorsocentral. Outline ovate, anteriorly posteriorly elongated; moderately opisthocline; ventral and anterior margins moderately and subequally rounded; anterodorsal margin nearly straight; other margins unknown. Ornamentation consisting of fine, raised, equally developed, closely and evenly spaced growth lines, becoming weaker and less regular ventrally. Very fine, faint, closely and evenly spaced, raised radiating lines and threads transgress stronger growth lines; ornament most prominent centrally, where a faint reticulate pattern is formed. Shell moderately thin. No other features known.

Remarks: The shape, convexity, shell inclination with the beaks apparently placed well behind the midline, and the ornamentation dominated by fine concentric lines with faint radial threads crossing them at closely spaced intervals, all suggest affinites to *Nucula* more than to other infaunal bivalves. Many surficially similar Cretaceous species exist, but not enough is known about the Hole 317A specimen to make specific comparisons. *Nucula* sp. A from the same hole is smaller, more rounded, more opisthocline, and has a concave postodorsal margin, features which make it easily distinguishable from *Nucula* sp. B.

Family MALLETIIDAE Adams and Adams, 1858

Genus TINDARIA Bellardi, 1875

Remarks: *Tindaria* is a typical protobranch of deep-water communities (see Knudsen, 1967, 1970) which is characterized by small but relatively thick, ovate to rounded shells with markedly inflated, prosogyrous beaks and umbos, and well-developed concentric surface sculpture with or without weak radial elements. Taxodont dentition is well developed and involves numerous small teeth, their axes converging toward mid-shell; a weak pallial sinus is present. The genus is previously known from Tertiary to Recent sediments, and is cosmopolitan in distribution. The specimen from Hole 317A is questionably assigned to *Tindaria* purely on the basis of its shape and size, and characteristically inflated prosogyrous umbo and beak, which are identical to living species such as *T. antarctica* Thiele (Knudsen, 1970, pl. 6, fig. 24).

Tindaria? sp. indet.
(Plate 3, Figure 10)

Material: A single, complete but poorly preserved, internal mold of a moderately small right valve; shell fragments preserved along dorsoanterior margin; hinge and interior shell morphology not well preserved. Figured specimen, USNm 218012, from Sample 12-1, 129-131 cm.

Description: Moderately small; height 12 mm, length 15 mm, width 3 mm. Moderately convex, with maximum inflation dorsally on umbo; flanks flattening ventrally and ventrolaterally. Outline elongate-ovate along length axis, moderately prosocline, with flattened ventral and dorsolateral margins, moderately and evenly rounded anterior and posterior margins. Hinge line moderately long, straight, equalling approximately one-half shell length. Beak bluntly pointed, situated just anterior to midline, slightly projecting above dorsal margin; beak-umbo inflated, moderately prosogyrous, strongly curved inward; change in convexity between umbo and main part of disc obvious but not strongly marked. Worn surface of internal mold smooth except for very fine, sinuous radiating striae near margin which may mark tracks of pallial muscles; pallial line not preserved. Surface of small anterior shell fragment bearing weakly incised growth lines, moderately and somewhat evenly spaced. No other features preserved.

Remarks: The poor preservation of the internal mold, and lack of original shell features, prohibit confident assignment of this form to

any species, or even definitely to the genus *Tindaria*, which it closely resembles in size, shape and umbonal characters (e.g., *T. antarctica* Thiele, *in* Knudsen, 1970). The elongate-ovate form of the shell is not normal for this genus, but is precisely that of certain described deep-sea species such as that cited above. If this is a *Tindaria*, and no other genus seems to quite have this shape and characteristically swollen umbo, then the range of the genus would be extended back from the lower Tertiary to the Lower Cretaceous. Inasmuch as deep-water bivalves are very conservative in their evolution, and the general nature of the associated benthonic biota in the carbonates from Hole 317A is that of a bathyal assemblage, it is not surprising to find possible ancient representatives of more modern deep-water taxa for the first time in this, the oldest known deep-water molluscan fauna with modern affinities.

Family LIMOPSIDAE Dall, 1895

Genus LIMOPSIS Sassi, 1827

Subgenus PETUNCULINA d'Orbigny, 1843

Diagnosis: Small to moderately small; subround, ovate, or orbicular in outline and slightly prosocline; equivalve, moderately biconvex; surface with radial costae, costellae, commonly bifurcating and slightly curved to sinuous, in some species absent from beak area; concentric growth lines small, raised and sharp to low and faint, weaker than radial elements of ornament. Inner margin of commissure crenulated to striated in position of external costae. Pallial line entire, well incised, commonly with radial striae on shell surface medial to it. Adductors moderately large, slightly unequal, anterior adductor smaller; adductor insertion areas depressed. Hinge plate moderately thickened, with taxodont teeth radiating from hypothetical point near mid-shell. Shallow triangular resilifer on cardinal area below beaks contains bulk of short ligament. Cretaceous to Recent.

Remarks: No specimens assigned to *Limopsis* (*Petunculina*) from DSDP Leg 33 cores preserve the complete hinge area and to this degree the subgeneric assignments are tentative. Taxodont teeth were noted at the posterior termination of the hinge in the holotype of *L.* (*P.*?) *delicatulus*, n. sp. In addition, most specimens are somewhat crushed. But in shape, size, nature of the radial ornament, and as preserved on rare specimens, the nature of adductor and pallial muscle insertion areas strongly indicate assignment to this genus. Small sinuous marginal or pallial striations similar to those on many living *Limopsis* were noted in specimens from Samples 11-5, 89-96 cm, and 12-1, 88-92 cm. A probable posterior adductor insertion area occurs in a specimen from Sample 11-3, 64-73 cm.

Limopsis (Petunculina?) delicatulus, n. sp.
(Plate 2, Figures 12, 13)

Material: A crushed, bivalved adult specimen, valves co-attached and left valve excavated, shell mostly intact and a small portion of the hinge line showing; anterior margin incomplete (Holotype, USNM 218024) from Sample 12-6, 36-43 cm. A crushed internal mold of a left valve with shell adhering in places, posterior margin missing, from Sample 13-1, 108-114 cm (Paratype, USNM 218026). Possible additional fragments.

Description: Largest specimen attaining height of about 26 mm, length 28 mm, width 6.7 mm. Outline broadly ovate; shell suberect, slightly prosocline, with moderately and evenly rounded anterior and posterior margins, broadly and evenly rounded ventral margin; posterodorsal margin straight, short, bounding inconspicuous subtriangular posterior auricle with rounded dorsoposterior corner. Anterior auricle incompletely known, apparently short or absent, poorly defined, with short, straight dorsal margin. Auricular sulci shallow, indistinct, incomplete. Moderately biconvex and apparently equivalve or nearly so; maximum inflation near valve center. Beak deformed but apparently bluntly rounded, subcentral (slightly anterior to midline); beak-umbo moderately inflated, slightly prosogyrous and incurved, as now crushed, projecting moderately above dorsal margin. Surface ornament consisting of numerous, fine, slightly raised radial lines and costellae, straight and subequally developed on umbo, without extensive bifurcation; slightly sinuous and posteriorly curved, unequally developed, with common intercalated fine costellae over main body of shell. Radial elements extending from beak to commissure, well defined on both interior and exterior shell surfaces in well-preserved specimens. Concentric ornament of fine, rounded, slightly raised, growth lines, subequally developed on dorsal half of shell, faint and unequally developed ventrally. Radial ornament stronger than concentric. Anterior end of hinge plate visible on posterior end of right valve (specimen USNM 218024); hinge plate moderately thickened, with four small, short taxodont teeth visible, inclined toward center of shell; a small flattened and slightly flared area of hinge plate, without teeth, lies posterior to last taxodont tooth. Commissure edge largely broken away; no internal crenulations seen. Other interior shell features poorly known. Specimen USNM 218026 shows faint, fine, slightly sinuous grooves on inner shell margin just within pallial line, and a subcircular, moderately depressed mid-anterior adductor insertion area just within shell margin, with a small medial buttress (interpreted from internal mold). Preserved shell white, dense calcite with cross-foliated or shallow cross-lamellar structure.

Remarks: This shell would seem to equate in shape to living limopsids with reduced auricles and slightly thickened hinge plate bearing small taxodont teeth, such as *Limopsis marionensis* Smith (see Knudsen, 1970, pl. 12, fig. 1-4). The preserved hinge structures, and the general shape and ornament of this species strongly suggest affinities to *Petunculina*; but the lack of crenulations on the commissural margin, where rarely preserved, does not fit this subgenus. The value of this as a generic or subgeneric character is not yet fully known; modern populations of *Limopsis* (*Petunculina*) have specimens which seemingly lack crenulations or have them only partially developed. Absence of crenulations on poorly preserved limopsids from this collection is not considered important to their classification, therefore.

Limopsis (*Petunculina*?) *undulorugosus*, n. sp. is more elongate and rectangular, with a flattened ventral margin, coarse concentric rugae, and fainter radial elements.

Limopsis (Petunculina?) undulorugosus, n. sp.
(Plate 2, Figure 16)

Material: Two moderately complete left valves, internal molds and external counterparts with shell adhering, both moderately crushed and with anterior margin and beak incomplete; additional shell fragments. The largest left valve (Holotype, internal mold and counterpart, USNM 218008a) is from Sample 12-1, 88-92 cm; a smaller, more quadrate left valve and possible conspecific fragments come from Sample 11-5, 88-96 cm (Paratype, USNM 218928, internal mold; counterpart is USNM 218027c). A probable conspecific fragment, Paratype, USNM 218665, Sample 12-5, 31-35 cm.

Description: Moderately small, attaining length of about 25 mm and height of 21 mm; moderately convex with maximum inflation dorsocentral on shell. Outline elongate-ovate to subrectangular, with flattened to slightly curved ventral margin, moderately and asymmetrically curved posterior margin, moderately short, straight dorsoposterior (hinge) margin; anterior edge unknown. Shell moderately prosocline. Beak anterior to midline and blunt, rounded as preserved. Beak, umbo slightly prosogyrous, projecting moderately above dorsal margin. Surface covered with faint, slightly sinuous, posteriorly curved, irregularly developed, fine rounded costae with intercalated costellae on ventral part of shell. Radial ornament originates on umbo, with significant intercalation beginning near midshell. Radial ornament faintly marked on commissural edge of shell interior. Concentric ornament of coarse, asymmetrical, irregularly developed rugae and faint irregular growth lines. Margin, as preserved, faintly and irregularly crenulated at intersection with costae. A fragment possibly belonging to, and co-occurring with this species (Sample 11-5, 89-96 cm) shows fine sinuous striae on shell interior, just inside pallial line. Possible subcircular, anterior adductor muscle insertion area slightly impressed with a faint medial buttress. Hinge and other shell features unknown. No specimens complete enough for accurate measurements. Shell layer preserved is white and comprised of cross-laminated or shallow cross-lamellar crystal structure, now totally calcite.

Remarks: This type of shell is unusual for *Limopsis* in respect to the coarse rugae and the elongate-ovate, prosocline valve outline. But these features are known from modern limopsids, for example, the coarsely rugate *Limopsis guineensis* Thiele and Jaeckel (see Knudsen, 1970, pl. 9, fig. 12) and elongate variants of *L. pelagica pelagica* Smith (Knudsen, 1970, pl. 10, fig. 8, 9) and *L. pelagica dalli* Lamy (ibid., pl. 11, fig. 7, 8). The specimen from Sample 12-1, 88-92 cm is larger and decidedly more elongate than specimens of *Limopsis* (*Petunculina*?) *undulorugosus*, n. sp. from Sample 11-5, 89-96 cm, but in view of the range of variation known in the valve outline of modern species of *Limopsis* (see *L. pelagica pelagica* Smith, *in* Knudsen, 1970, compare pl. 10, fig. 2 with fig. 8, 9), and the deformed nature of many shells in

this core, these differences are not regarded as being significant at the species level.

The species differs from *Limopsis* (*Petunculina*?) *delicatulus*, n. sp. in being more elongate, in having a straight ventral margin, an anterior beak, more prosocline shell, and fainter, less regular radial ornamentation.

Family MANZANELLIDAE ? Chronic, 1952

Genus POSTERODONTA Kauffman, n. gen.

Description: Moderate size, known specimens reaching height of 30-35 mm. Moderately low convexity; maximum inflation dorsocentral. Outline erect-ovate to elongate-ovate, with height greater than length. Posterior margin slightly rounded to subtruncated, other margins moderately rounded; dorsal margin short, straight, elevated to level of beaks and bearing hinge platform posterior to beaks; anterodorsal margin straight, very short, depressed below beaks. Small, triangular, flattened posterior auricle separated from disc by shallow, indistinct auricular sulcus. Anterior auricle absent, though margin may be slightly flared at anterodorsal corner. Beaks bluntly pointed, situated anterior to midline; beaks, umbos inflated, strongly prosogyrous, strongly curved forward and inward over anterodorsal margin, but only slightly projecting above posterodorsal margin. Ornamentation of numerous, fine, closely spaced, subregularly developed costellae and raised radiating threads, weakly developed dorsally, becoming stronger and more numerous ventrally. Concentric ornamentation comprised of very fine, close-set growth lines with or without scattered raised, coarse, growth lines or small concentric folds. Hinge plate moderately thickened posterior to beaks, slightly thickened anteriorly, bearing a central, broad, rounded cardinal swelling below beaks, and a few moderately large, somewhat irregular taxodont teeth posteriorly; taxodont teeth moderately inclined toward midpoint of shell. Pallial line entire, with very fine, radially arranged, close-set sinuous grooves along inner margin of pallial line, marking mantle muscle tracks. Shell very thin. Other characters unknown.

Remarks: Familial placement of this genus presents an enigma. The hinge structure, restricted to a few taxodont teeth situated behind the beaks, is strongly suggestive of placement in the Manzanellidae, the only taxodont family with asymmetrical development of the hinge structures of this magnitude. A swollen tooth-like structure beneath the beaks occurs in *Posterodonta* and also in Manzanellidae like *Huxleyia*, further suggesting a relationship. The anterior end of the hinge plate is broken off in *Posterodonta manihikiensis*, so that no familial assignment is certain based on dentition, but it is obvious from what remains of the hinge that the anterior part is not greatly thickened like the posterior section, and that no prominent teeth were situated on the anterior hinge plate; there are no tooth impressions left in the internal mold in this area. One genus of Manzanellidae, *Nucinella*, has an erect prosocline shell somewhat similar to *Posterodonta manihikiensis*, but has a different dentition (see Cox et al., 1969, fig. C14).

Despite these similarities to the Manzanellidae, *Posterodonta* shows structures which seem to contradict such an assignment. The shell is larger than most known Manzanellidae, more erect, and the beaks and umbos are more coiled than typical for that family. In addition, the ornamentation, dominated by sinuous radiating costellae and raised threads, is atypical of Manzanellidae, which usually lack radial ornamentation. The ornamentation is in many ways more similar to members of the *Limopsidae* (subgenera *Petunculina, Nipponolimopsis*), which also have reduced taxodont dentition, but on both sides of the beak.

One structure seems to suggest that this is an unusual genus of the Manzanellidae rather than the Limopsidae or other taxodont families. There is no cardinal area above the row of irregular taxodont teeth for ligament attachment as in Limopsidae, Glycymeridae, and Arcidae. Rather, a narrow sinuous groove extends from the posterior part of the central cardinal swelling along the top of the dental plate, opening at the posterodorsal margin and facing outward. Presumably this poorly preserved structure is the ligamental groove, in which rested an external ligament, opisthodetic in orientation. These are the ligamental characters of the Manzanellidae.

Posterodonta manihikiensis, n. gen., n. sp.
(Plate 2, Figures 15, 18, 19, 20, 21)

Material: A nearly complete, moderately small, internal mold of a right valve, ventral margin broken, posterior flank partially broken, shell adhering in beak and hinge area; Holotype, USNM 218035a, Sample 12-6, 85-93 cm. Shell interior of Holotype, USNM 218035b. Paratype, incomplete internal mold, central portion of a left valve with shell preserved on beak, and in counterpart exposing interior of shell; anterior, ventroposterior, ventral flanks broken and hinge structures missing, USNM 218029a (internal mold), 218029b (counterpart shell interior), from Sample 12-6, 114-116 cm, questionably conspecific with Holotype.

Description: Moderately small shell; height approximately 30 mm, length 27 mm, width 4.2 mm, length on hinge line 10 mm on largest specimen, the Holotype. Convexity moderately low; maximum inflation dorsocentral just below base of umbo; flanks becoming flattened. Outline erect, elongate-ovate, slightly prosocline. Anterior and posterior margins gently curved; ventral margin moderately rounded. Dorsal margin short on both sides of umbo, the anterior segment depressed lower than the posterior, slightly longer segment; margin straight. Beaks bluntly pointed, situated anterior to midline, approximately one-third the length from the anterior margin. Beak, umbo moderately inflated, moderately prosogyrous, strongly incurved over anterodorsal margin, projecting only slightly above level of posterodorsal margin. Posterior auricle small, somewhat flattened, triangular with obtuse apex, separated from disk by very shallow auricular sulcus. No anterior auricle; dorsoanterior margin slightly flared outward on holotype. Ornamentation consisting of numerous, sinuous, small, rounded costellae and raised radiating lines or threads, subequally developed and subevenly spaced over much of shell, becoming fainter toward beak area, increasing to some degree ventrally through bifurcation. Concentric ornament over most of valve consisting of faint, flat growth lines and low, rounded, commonly incomplete folds; concentric ornamentation of umbo stronger, consisting of closely and regularly spaced, equally developed, small, sharp, raised growth lines without radiating elements. Hinge plate moderately thickened posterior to beaks, slightly thickened anteriorly, containing at least four irregular, sinuous, subregularly spaced taxodont-like teeth inclined toward the midpoint of the shell, situated posterior to beak. A large rounded swelling, possibly a crude cardinal tooth, lies below the beak, its anterior termination unknown. Sockets between teeth moderately deep, very narrow (Plate 2, Figure 15). Narrow, curved, externally facing ligamental groove (?) extending, subparallel to posterodorsal margin, from just above first posterior socket on hinge, along top of taxodont teeth, to posterodorsal corner, where it opens and becomes indistinct. Only pallial musculature known, consisting of a partially preserved, entire pallial line, within which are numerous, small, closely and irregularly spaced, sinuous grooves marking tracks of pallial muscles. Shell very thin.

Remarks: Although the anterior hinge plate is partially missing and its features unknown, it is obvious from the preserved portion and the internal mold of the hinge area that it is not greatly thickened, and bears no prominent teeth. The hinge area is partly corroded and recrystallized, so that the dentition and ligamental features are only coarsely preserved; the preservation is sufficient, however, to determine the principal elements of the dentition, and to compare it with known genera of taxodont bivalves. All features of the dentition indicate close affinities to the Manzanellidae, and the fact that this represents a new genus of bivalves with a posterior, taxodont-like dental pattern. The bulbous cardinal swelling below the beak of *Posterodonta* may be the base for an extended anterior lateral tooth common to the Manzanellidae, but the tooth itself is not preserved. This form seems to be transitional in characters between some Limopsidae and members of the Manzanellidae, with greater affinities to the latter. No known Cretaceous species are comparable. Genera of the Manzanellidae are known from the Permian to the Recent, and the group is nearly cosmopolitan in distribution.

Family MYTILIDAE Rafinesque, 1815

Genus INOPERNA Conrad, 1875

Inoperna? sp. indet.
(Plate 3, Figure 2)

Material: A single fragment, anterodorsal quadrant, of an adult right valve, internal mold with shell fragments in beak area, somewhat crushed; figured specimen, USNM 218017, Sample 12-6, 56-58 cm.

Description: Shell moderate size, probably reaching about 25-30 mm in length; convexity low, maximum inflation dorsal along low umbonal fold. Beak broken, nearly terminal-anterior, apparently blunt; umbo slightly inflated. Outline of shell very elongate ovate, strongly

prosocline and prosogyrous. Growth lines indicate slightly curved doroposterior, ventral and ventro-anterior margins, strongly curved ventroposterior corner and dorsoanterior margin, forming a small lobe anterior to beak area; long straight posterodorsal margin (hinge line). Posterior auricle poorly defined, very broadly triangular with low, highly obtuse apex; no auricular sulcus. Ornament consisting of very low, rounded, moderately and subevenly spaced, subequally developed concentric folds or low rugae (on internal mold), strongly curved over umbonal fold, most prominent dorsoanteriorly on shell; faint traces of very fine, flat, growth lines also present. Hinge plate moderately thickened posterior to beaks; ligamental groove apparently a simple, shallow, narrow trough or groove on in-facing portion of hinge plate. Shell very thin. No other features preserved.

Remarks: The specimen has characteristics which are very close to those of *Falcimytilus*? *rugocostatus* (Moore) illustrated from Australia by Day (1968, pl. 44, fig. 2, 3), and originally assigned by Moore to *Mytilus*. It differs in having closer, weaker rugae, a flatter shell, and a poorly defined posterior auricle. This species, and the specimen from the Manihiki Plateau, do not belong to either genus however; they are too elongated and prosocline, and too coarsely rugate to be placed in *Mytilus*, and in addition have a small anterior lobe, without terminal anterior beaks. On the other hand, neither possess the principal characters of *Falcimytilus*, the hook-shaped shell with the prominent angular umbonal ridge along the mid-shell. The elongated shape, small posterior auricle, and regularly developed though weakly defined concentric rugae suggest strong affinities to *Inoperna*, typical specimens of which are somewhat more coarsely rugate, more curved, and elongated. The specimen from the Manihiki Plateau is too fragmental for definite generic identification. Perhaps these specimens represent an evolutionary transition between *Inoperna* and *Modiolus*, the latter genus having a shorter, more triangular or broadly ovate shell, without coarse concentric ornament such as rugae, but with a small anterior lobe and indistinct posterior auricle. *Inoperna* is known from the Early Jurassic to the Late Cretaceous and is cosmopolitan.

Family PTERIIDAE Gray, 1847

Genus ELECTROMA Stolicza, 1871

cf. Electroma sp.
(Plate 2, Figure 9)

Material: A single internal mold, left valve, incomplete, with dorsal margin and entire posterior auricle broken off, shell crushed, very small thin pieces of shell material adhering; figured specimen, USNM 218040a; counterpart of mold with shell adhering, exposing interior surface, USNM 218040b; from Sample 108-114 cm.

Description: Moderately small; approximate measurements are: height 16mm, length 17mm, width 1 mm (compressed shell). Slightly convex, with maximum inflation just dorsal to mid-shell. Outline inclined-ovate, moderately prosocline; anterior margin nearly straight; ventral and ventroposterior margins moderately and asymmetrically curved; dorsoposterior margin poorly known, appears slightly concave in curvature. Dorsal margin presumed straight, moderately long, Fragments of posterior auricle remaining indicate it to have been flat, moderately large, triangular, separated from disc by very shallow and indistinct auricular sulcus, its apex obtusely angular and possibly very slightly extended posteriorly at tip. Surface ornament only of very fine, moderately and irregularly spaced, flat growth lamellae and scattered, very low, incomplete concentric folds. No radial ornament. Shell very thin. All other features, and right valve, unknown.

Remarks: This specimen, insofar as it is preserved, resembles living and fossil species of *Electroma* very closely, and especially in regard to the shape and inclination of the valve, with its truncated anterior margin, the weak ornamentation, thin flat shell, and apparent lack of a posteriorly projecting apex on the posterior auricle. *Electroma* was previously recorded from the southwest Pacific and Europe in Upper Cretaceous to Recent deposits; the age is here tentatively extended into the Lower Cretaceous. The generic assignment is questioned because of the incomplete nature of the single available specimen, especially lack of hinge characters and the posterior auricle. Inasmuch as subgenera of *Electroma* are principally defined on the basis of the posterior auricle and its development, no subgeneric assignment is possible.

Family INOCERAMIDAE Giebel, 1852

Genus INOCERAMUS Sowerby, 1814, sensu lato

Inoceramus sp. indet.

Material: Large thick fragments of the prismatic layer from a large shell; described specimen, USNM 218016, from Sample 12-6, 58-64 cm. Small fragments of thin-shelled forms, prismatic layer only, Sample 10-1, 145 cm (on fragment with type specimen of *Aucellina reticulata* n. sp.; USNM 218038), and also on a fragment from Sample 13-1, 108-114 cm.

Description: Prismatic layer only preserved; largest fragment 15.7 mm long and 5.3 mm thick; white, to orange-brown near shell surface. Prisms straight, very long and slender, slightly tapering in some case, perpendicular to shell surface, lacking numerous dark growth lines which are more typical of shallow-water specimens of Inoceramiidae; abrupt color change in cross-section probably marks yearly growth band. Thin and thick shell fragments probably denoting two distinct species. Nacreous layer absent in all specimens.

Remarks: *Inoceramus* prisms and fragments have been, to date, the most common macrofossils in DSDP Mesozoic cores, attesting to their resistance to destruction with depth (and dissolution), and also to the wide environmental tolerance and dispersal potential among the Inoceramidae (Kauffman, 1975, in press). In addition to levels cited above, inoceramid prisms were observed as scattered elements in thin-sections from several levels.

Family OXYTOMIDAE Ichikawa, 1958

Genus OXYTOMA Meek, 1864

Diagnosis: Moderate size, outline suborbicular, subovate, or broadly lunate, acline to strongly prosocline, inequivalve, right valve somewhat smaller than left valve, flat to slightly convex, with small beak, umbo, only slightly projecting above dorsal margin. Left valve slightly to moderately convex, more so than right valve, with moderately inflated umbo and projecting, somewhat prosogyrous, bluntly pointed beak and umbo. Posterior auricle prominent, elongated, pointed at posterior extremity, with strongly concave notch in posterior margin situated below auricle. Posterior auricle commonly flattened, smooth, and separated from disc by subtle to moderately prominent auricular sulcus. Anterior auricle of left valve small, triangular, flattened, commonly without strong ornament, separated from disc by indistinct sulcus. Anterior auricle of right valve small, triangular, with prominent subauricular byssal notch, deep, its outline an acute triangle; ctenolium present; inner side of byssal notch with angular inward projection of shell margin. Ornament of left valve strongly developed, consisting of radial costae and costellae of 1 to 3 orders of strength, with primary costae well separated, normally sharp, raised, equally developed, and evenly spaced over valve except on auricles; secondary costellae subequally developed, weak to moderately prominent. Right valve nearly smooth or with weak radial elements, much finer than those of left valve, commonly incompletely developed. Ligamental area subparallel to commissural plane in left valve, nearly perpendicular to commissural plane in right valve; edentulous. Adductor insertion area in posteroventral quadrant of shell. Upper Triassic through Lower Cretaceous, ? Upper Cretaceous. Cosmopolitan.

Oxytoma sp. indet.
(Plate 3, Figure 13)

Material: One small, probably juvenile, right valve; internal mold with small portions of shell adhering. Posterior extremity of auricle missing, beak broken. Figured specimen (USNM 218002) from Sample 12-6, 43-47 cm.

Description: Only juvenile right valve known; small, height 1.8 mm, length 2.1 mm; slightly convex, maximum inflation subcentral. Outline ovate; moderately prosocline; dorsal margin (hinge line) moderately long and straight; mid-posterior and ventral margin moderately and evenly rounded, ventroanterior margin slightly rounded, midanterior margin narrowly rounded and somewhat projecting; byssal notch below anterior auricle moderately shallow, triangular, opening anteriorly. Dorsoposterior margin forming acutely triangular recess below posteriorly extended, very narrow, flattened posterior auricle

(incompletely known; posterior extremity broken). Length of posterior auricle at least one-quarter length of shell; auricle flat, appears to have been very acutely pointed posteriorly, without auricular sulcus. Anterior auricle small, triangular, appears slightly folded, separated from disc by narrow auricular sulcus; poorly preserved on available specimen. Beak, umbo situated just anterior to midline of shell, moderately prosogyrous, slightly inflated; tip of beak unknown. Surface of shell appear smooth except for very faint, incomplete, concentric rugae or low folds. Very faint radial impressions on shell interior (mantle muscle tracks of pallial line?). Shell moderately thin. Hinge line posterior to beak slightly thickened. No other shell features observed.

Remarks: The pointed, narrow, posteriorly extended auricle, shell outline, smooth shell surface, and shallow triangular byssal notch all suggest affinities to *Oxytoma* more than to other genera. *Pteria* is an alternative possibility for the generic assignment, but most *Pteria* are more inclined, more elongate-ovate, and have a more prominent anterior auricle than this specimen. The age range of *Oxytoma*, upper Triassic to Upper Cretaceous, is compatible with the stratigraphic occurrence of this shell. The species clearly belongs to the subgenus *Oxytoma* rather than *Hypoxytoma*, which does not have a greatly extended posterior auricle and is more erect and subcircular in form.

Genus MACCOYELLA Etheridge, Jr., 1892

Diagnosis: Attaining large size; outline ovate to suborbicular, acline to somewhat prosocline or opisthocline; midanterior, ventral, and posterior margins moderately rounded; dorsoanterior margin flattened with very small triangular byssal notch near its dorsal extremity on right valve of some species; dorsal margin (hinge line) moderately long and straight, extending unequally on both sides of beak, more so posteriorly. Inequivalve, with right valve flat to very slightly convex and smaller dorsally than left valve; left valve moderately to strongly convex (maximum inflation dorsocentral), with a bluntly pointed anterocentral beak, and an inflated, orthogyrous to slightly prosogyrous, incurved umbo; beak-umbo projecting moderately above dorsal margin. Beak of right valve small, pointed, slightly projecting above dorsal margin, or even with it. Posterior auricles moderately large, flattened, ornamented as on disc, broadly and asymmetrically triangular in outline, not clearly set off from disc by auricular sulci in most species, with shallow sulci in others; dorsoposterior corner obtuse. Left anterior auricle moderately small to very small, triangular, flattened, ornamented as on disc or lacking radial elements, separated from disc by shallow but prominent auricular sulcus. Right anterior auricle smaller, thickened, projecting inward and slightly upward in many species; subauricular byssal notch narrow, triangular to slit-like, small, best seen from shell interior, its axis oblique to hinge axis and dorsoanteriorly directed. Notch possibly absent on some species. Surface ornament of both valves consisting of moderately to strongly raised, rounded, slightly curved or sinuous, subregularly alternating, radiating costae and costellae, in many species of two or more orders of strength, and showing high levels of intercalation ventrally; fine to moderate size, crowded, irregular to subregularly developed, raised concentric growth lines may produce small squamae on radial ribs at their intersection. Ornament of right valve may be less prominent and less regular than that of left. Ligamental area of left valve broad, massive to moderately thick, concave, striated, with broad, triangular, slightly inclined to erect, shallow resilifer, ventroanterior and/or anterior to which lies a large irregular tooth in some species. Pallial line discontinuous; pitted, not clearly defined posterior to adductor. Posterior adductor insertion area rounded, moderately impressed, in posteroventral quadrant of shell. Upper Jurassic?, Lower Cretaceous of the South Pacific region.

Maccoyella n. sp. A cf. M. barklyi (Moore)
(Plate 1, Figures 4, 8; Plate 3, Figures 12, 14, 17)

Reference—Cox et al., 1969, fig. C70, 4a, b; Day, 1968, pl. 51, fig. 1-8; pl. 52, fig. 1, 2.

Material: A single immature right valve, complete internal mold with shell preserved on the dorsoanterior flank, retaining byssal slit, anterior auricle, and hinge plate beneath and anterior to beak; figured specimen, USNM 218011, from Sample 13-3, 90-93 cm.

Description: Small; height 4.5 mm, length 4.4 mm, width 1.5 mm; moderately convex with maximum inflation dorsocentral at base of umbo. Outline circular, acline to very slightly prosocline; posterior, ventral, ventroanterior margins moderately and evenly rounded; dorsoanterior margin slightly rounded. Dorsal margin long, straight, equalling three-fourths the length. Posterior auricle very small, subtriangular, indistinct, slightly flared and separated from disc by broad shallow auricular sulcus. Anterior auricle prominent, greatly thickened, strongly folded (concave inward), narrow, moderately long, anteriorly projecting, slightly curved, weakly noded along folded crest, separated from umbonal area by small narrow sulcus. Byssal slit very narrow, slightly curved (dorsally concave), long, extending nearly to beak, bounded by prominent ctenolium on shell margins consisting of 5-6 small, prominent, rounded denticles with tips touching or nearly so across narrow slit; denticles directly opposed on opposite sides of byssal slit. Ornament (from anterior shell fragment) consisting of fine, raised, equally developed and evenly spaced radial costellae of two sizes, regularly alternating, with one smaller costellae intercalated between each pair of slightly larger ones. Hinge plate moderately thick, with shallow triangular resilifer below beaks and what appears to be a small knob-like tooth anterior to resilifer. Pallial line discontinuous, comprised of elongate shallow mantle muscle insertion areas marked medially by fine, sinuous, shallow, muscle tracks (Plate 1, Figure 8).

Remarks: This specimen is too immature, and too poorly preserved for formal description, but represents a new species of the late Aptian *Maccoyella barklyi* (Moore) species group. The Hole 317A specimen resembles *M. barklyi* in its rounded form, ornament pattern (see especially Day, 1968, pl. 52, fig. 2), anteriorly projecting, elongate anterior auricle, narrow byssal slit, and erect shell. It differs from *M. barklyi* in being slightly higher, with more prominent concentric and weaker radial ornamentation, and especially in having a relatively longer, noded anterior auricle with the prominent beaded ctenolium in the byssal slit below the auricle.

Maccoyella breviauriculata, n. sp.
(Plate 1, Figures 1, 5, 6, 10)

Material: Two medium-size right valves with nearly all shell preserved (interior exposed) and their counterpart internal molds; one nearly complete valve with only portions of beak area and ventral margin broken (Holotype, USNM 218009a), the second preserving only the posterior one-third of a slightly larger valve, with shell (Paratype, USNM 218009b), both on a single surface from Sample 13-2, 51-56 cm. A small right valve, dorsal one-half with shell (interior exposed), ventral margin broken, only mold of anterior auricle preserved (Paratype, USNM 218010), from Sample 12-5, 31-35 cm.

Description: Moderate size, attaining height of 22 mm, length 24.5 mm, width 1.5 mm. Slightly convex; maximum inflation dorsocentral at base or middle of umbo. Outline suborbicular to broadly ovate; dorsal margin (hinge line) short, straight; dorsoposterior margin slightly concave on flank of posterior auricle; ventroposterior, ventral, anterior margins moderately and evenly curved. Byssal notch in right valve deep, narrow, channel-shaped, arcuate, opening dorsoanteriorly and extending inward almost to beak; subauricular in position. Posterior auricle unusually small for genus, triangular with angular obtuse posterodorsal corner, flattened, lacking well-defined ornament, separated from disk by shallow, narrow auricular sulcus. Anterior auricle (Plate 1, Figure 5) small, tongue-shaped in outline, thickened, slightly folded and twisted outwards, separated from umbo by moderately deep, narrow, auricular sulcus, Beak unknown, situated slightly anterior to midline. Umbo slightly inflated, prosogyrous, with much weaker ornamentation than found on main body of disc. Surface ornamentation (Plate 1, Figures 6, 10) consisting primarily of small but moderately prominent, raised, rounded, crowded and subevenly spaced, radiating costellae of varying size, in some areas roughly alternating, with 3 to 6 smaller costellae between slightly larger ones. Ornamentation becoming faint on umbo, dorsoanterior flank, and posterior auricle. Trace of costellae slightly sinuous, anteriorly curved; moderate numbers of smaller costellae added by intercalation on ventral portion of shell. Concentric ornamentation consisting of fine, slightly raised, crowded, subevenly spaced and subequally developed growth lines which form subtle reticulate surface pattern at intersection with costellae, where strongly developed. Hinge plate moderately thickened; resilifer deep, triangular; musculature unknown. Shell very thin. Left valve not found.

Remarks: This species is unusual for *Maccoyella* in having such reduced posterior auricles, and in the tongue-like shape of the anterior auricle; but in regard to coarse radial ornament on the right valve, the folded and thickened nature of the anterior auricle, its small size, the extensive, narrow byssal slit, and the slightly opisthocline inclination of the right valve, the species seems closest to this genus among the Oxytomidae. Small *M. barklyi* (Moore) from the Australian Lower

Cretaceous are similar to *M. breviauriculata*, n. sp. in having a projecting tongue-shaped anterior auricle of similar dimensions, but have a rounded shell, larger posterior auricle, and less dense, more regularly alternating costellae. *Maccoyella barklyi* (Moore) illustrated by Cox et al. (1969) have similar though coarser ornamentation without regular alternation of large and small costellae on the right valve, but this is atypical of the species. No other species are closely comparable. Perhaps this type of shell will eventually be determined to represent a new subgenus of *Maccoyella*, with features such as the reduced posterior auricle and projecting anterior auricle, which are transitional to the northern genus *Arctotis*. *Maccoyella barklyi*, the most closely comparable form, is late Aptian in age.

Genus ARCTOTIS Bodylevsky, 1960

Diagnosis: Moderate size; outline subrounded to broadly ovate, acline to subacline; dorsal margin (hinge line) moderately long, straight, Beaks situated just posterior to midshell on most species, bluntly pointed, orthogyrous, very slightly projecting above dorsal margin of right valve, moderately projecting in left valve and incurved; left umbo swollen. Inequivalve; right valve nearly flat to flat and smaller than left valve dorsally; left valve moderately inflated; maximum inflation dorsocentral. Posterior auricle of moderate size, triangular, flattened, forming obtuse angle at posterodorsal corner, separated from disc by weak and shallow to prominent and moderately deep auricular sulcus. Some species with an additional sulcus on posterior flank, mediad from posterior auricular sulcus and separated from it by a low fold. Left anterior auricle triangular, somewhat flattened, moderately small, indistinct, in many species slightly projecting anteriorly with a shallow concave recess in outline of anterior auricular margin. Right anterior auricle elongate, tongue-shaped, one-half to three-quarters the length of the posterior auricle, strongly projecting anteriorly, flattened, separated from disc by small, moderately incised auricular sulcus. Byssal notch below right anterior auricle anteriorly directed, deep to moderately deep, slightly curved, narrow and elongate, ranging in form to triangular and moderately incised. Ctenolium not reported. Ornament of left valve composed of moderately but unequally developed, irregularly spaced (locally subregular), incomplete, slightly sinuous, crowded costellae and fine raised radial lines which are commonly absent from the dorsal part of the shell; radial ornament showing high levels of intercalation ventrally. Ornament of right valve similar but weaker, with fewer, less prominent, less continuous costellae; some right valves lack radial ornament. Concentric ornament consisting of very fine growth lines and/or fine raised lines, in some cases regularly developed and subequally spaced, forming crude reticulate surface pattern over parts of left valve. Ligament area broad, with deep, wide, triangular resilifer situated subcentrally. Pallial line discontinuous, a series of closely spaced mantle muscle insertion areas which leave sinuous elongate tracks near pallial line; pallial line pitted. Lower Jurassic (Lias) to Lower Cretaceous (Valanginian), extended here to the Albian. Dominantly North-Temperate, but ranging into cool, deep waters of warmer latitudes.

Remarks: The genus is primarily known from Siberia, with scattered reports elsewhere in the North Temperate Realm of the Jurassic and Cretaceous. It is regarded as a cool water temperate species (northern Mid-Temperate according to Kauffman, 1973) and has not previously been reported above the Valanginian. The apparent occurrence of *Arctotis* in younger Lower Cretaceous deposits of the Manihiki Plateau DSDP cores was thus unexpected. The specimens from Hole 317A assigned here to *Arctotis* are all small right valves with characteristics typical of the genus; they are round to ovate, with weak, irregular radial threads and costellae, subregular fine concentric ornamentation in the early growth stages, and typical auricles and byssal notch. In basic morphology they closely compare with arctotids like *A. intermedia* Bodylevsky from the Volgian of the USSR, illustrated in the Treatise of Invertebrate Paleontology (Cox et al., 1969) as typical of the genus. The radial ornamentation of these small shells is too weak and irregular for assignment to *Maccoyella* Etheridge, Jr., and the nature of the auricles is clearly distinct from that in *Maccoyella*, *Pseudavicula*, or *Oxytoma*, all of which are more typical Oxytomidae of the Lower Cretaceous in the southern Pacific region.

The occurrence of *Arctotis* in cores from the Manihiki Plateau supports an interpretation of cool water temperatures, and thus probably bathyal depths, for the Lower Cretaceous carbonate sequence in Hole 317A. This interpretation is further supported by the southern occurrence of this normally North Temperate Russian genus; migration of the genus to the South Pacific area would be expected to have taken place through deep ocean, cool water pathways below the Pacific Tropical marine belt, as it typical of modern deep water Circumpacific molluscs. The Manihiki Plateau occurrences of *Arctotis* extend the biostratigraphic range of the genus upwards at least into the lower Albian.

Arctotis filisculptus, n. sp.
(Plate 1, Figures 9, 11, 12, 16)

Material: Two nearly complete, small right valves; shell intact and external surface buried in matrix, margins chipped, hinge features partially preserved, with internal mold counterparts; Holotype, the larger shell of the two (Plate 1, Figure 11), USNM 218004a (internal mold is USNM 218033c); Paratype (Plate 1, Figures 9, 12), USNM 218005. Internal mold of a small right valve, probably belonging to this species, with part of the posterior auricle and the entire anterior auricle missing; parts of shell adhering; Paratype from Sample 11-3, 134-137 cm., USNM 218006a. USNM 218004 and 218005 are from Sample 13-2, 78-83 cm.

Description: Small, attaining a size of 9 mm height, 10.5 mm length, 1 mm width (only right valve known); outline suborbicular to broadly ovate with length slightly greater than height; anterior, ventral, and ventroposterior margins moderately and evenly rounded (Plate 1, Figures 11, 16), dorsoposterior margins flat to slightly convex (at edge of posterior auricle); dorsal margin (hinge line) straight, moderately long (two-thirds of length). Byssal notch situated dorsoanteriorly below anterior auricle; notch narrow, arcuate, deeply incised, narrowing toward umbo, opening anteriorly. No ctenolium preserved. Anterior auricle of right valve moderately small, tongue-shaped, subparallel to hinge axis, slightly curved dorsoanteriorly, slightly folded; incompletely known from holotype. Posterior auricle of moderate size, triangular with obtuse apex, flattened, separated from disc by a shallow to very shallow and indistinct auricular sulcus. Auricles seemingly lack radial ornamentation. Beak of right valve anterocentral, small, bluntly pointed, projecting only to dorsal margin; beak, umbo slightly prosogyrous, slightly inflated. Convexity of right valve low, maximum inflation dorsocentral. Concentric ornamentation dominates, consisting of low, rounded, commonly incomplete, irregularly spaced rugae or folds, and fine crowded growth lines, raised and subequally developed over part of shell. Radial ornamentation consisting of very fine, faint, raised lines crowded on umbo, becoming larger (costellae), lower, and less numerous toward ventral margin, presumably disappearing on larger shells. Edentulous; hinge plate slightly thickened under beaks; resilifer not preserved. Musculature unknown. Shell thin.

Remarks: This species can be differentiated from other *Arctotis* in the Hole 317A samples by its shell outline, inclination, and ornamentation. It is more elongate-ovate, more prosocline, and more symmetrical than *Arctotis* sp. A (Plate 1, Figures 2, 3), has the beak placed anterior rather than posterior to the midline, stronger radial ornamentation, and more regular fine concentric ornamentation than that species. Compared with *A* sp. B cf. *A. intermedia* Bodylevsky (Plate 1, Figure 18), *A. filisculptus* is shorter and rounder, with more anteriorly situated beaks, more prosocline inclination, and less regular concentric ornamentation. The radial lines of *A. filisculptus* are coarser and less regular below the umbonal area than are those on *Arctotis* sp. B. The shape, faint and irregular nature of the radial sculpture, size and shape of the anterior auricle and auricular sulcus, and tendency toward subregular fine concentric ornamentation are all characters which suggest affinities to *Arctotis* as opposed to other genera.

Arctotis sp. A
(Plate 1, Figures 2, 3)

Material: A single internal mold of a small right valve with pieces of shell adhering, anterior auricle broken off, posterior auricle partially broken at extremity; Figured specimens, internal mold, USNM 218007a, external mold, USNM 218007b, from Sample 11-5, 6-12 cm.

Description: Small shell; only right valve known; height 17.5 mm, length 17.7 mm, width 1.5 mm. Low convexity; maximum inflation at base of umbo. Outline subcircular; suberect to slightly opisthocline. Dorsal margin straight, of moderate length; dorsoposterior margin slightly curved; ventroposterior, ventral, anterior margins moderately and evenly curved. Byssal notch elongated, curved, narrow, opening anteriorly below anterior auricle (missing here), without preserved ctenolium. Anterior auricle apparently narrow, tongue-shaped, projecting anteriorly; full extent unknown. Posterior auricle small, triangular, somewhat flattened, indistinctly separated from disc by

shallow auricular sulcus. Beak pointed, situated posterior to midline, very slightly projecting above dorsal margin; beak, umbo slightly prosogyrous, inflated. Ornamentation consisting of fine, flat, irregularly crowded concentric growth lines and scattered, discontinuous, low, rounded rugae mainly expressed on anterior flank; radial ornamentation very faint and secondary to concentric features, consisting of about 12 small, low, rounded, curved and sinuous costellae originating on umbo and extending without intercalation nearly to the ventral margin, becoming fainter and disappearing just above margin. Shell moderately thin. Hinge plate moderately thickened but no detail preserved. Musculature incomplete; suggestion of discontinuous pallial line preserved.

Remarks: This species, possibly new, cannot be further described and named without better preserved material. It differs from *A. filisculptus*, n. sp. in being rounder, slightly opisthocline, with posterocentrally situated beaks, and fewer, weaker radiating ornamental elements. *Arctotis* sp. B. cf. *A. intermedia* Bodylevsky is a higher, more erect shell with finer and more numerous radial costellae, and more regular concentric ornamentation of raised growth lines. The presence of the anterior auricle is suggested by its broken base, and assignment to *Arctotis* in preference to other Oxytomidae is made on the basis of weak radial ornament, shape of the shell, and implied nature of the anterior auricle and byssal notch.

Arctotis sp. B cf. A. intermedia Bodylevsky
(Plate 1, Figure 18)

Reference—*Arctotis intermedia* Bodylevsky *in* Cox et al., 1969, fig. C69, 3d.

Material: A single, posterior one-half of an internal mold and its counterpart with the shell interior showing, right valve, lacking everything anterior to mid-shell; figured specimen, USNM 218008b, from Sample 12-1, 88-92 cm.

Description: Small, attaining 18 mm height; convexity low, with maximum inflation dorsocentral at base of umbone; outline erect-ovate, height greater than length, slightly prosocline; dorsoposterior margin flat; ventroposterior and ventral margins moderately and evenly rounded; other margins unknown. Posterior auricle small, flattened, broadly triangular, separated from disc by shallow, indistinct auricular sulcus; posterodorsal auricular angle obtuse. Ornamentation consisting of moderately raised, rounded, equally developed and evenly spaced, concentric lines of two sizes, regularly alternating over part of shell surface, with 3 to 4 small lines between slightly larger ones; radial ornamentation consisting of fainter, slightly raised lines and costellae, crowded centrally but sparse on lateral flanks, irregularly spaced, unequally developed, intercalating and increasing in number ventrally, sinuous and slightly curved in posterior direction. Shell thin, becoming moderately thickened along hinge plate. No other features preserved.

Remarks: The erect posture of the shell, subregular concentric ornamentation, weak radial costellae with their irregular development, intercalation, and sinuous course, and the low valve convexity all suggest affinities to *Arctotis* and are remarkably similar in character to the Volgian species, *A. intermedia* Bodylevsky (see Cox et al., 1969, fig. C69, 3d). The Russian species differs primarily in having stronger and more widely spaced concentric growth lines and larger but more weakly developed radiating costellae. The specimen from the Manihiki Plateau probably represents a new species, but the material is too incomplete for formal description. Other species of *Arctotis* described from this core are easily differentiated by their shorter, more rounded shells and less regular concentric ornamentation.

Genus PSEUDAVICULA Hudleston, 1890

Diagnosis: Attaining moderate size, suborbicular to ovate, slightly to moderately prosocline, with moderately and subevenly rounded anterior, ventral, and ventroposterior margins, straight to slightly concave dorsoposterior margin at edge of posterior auricle. Dorsal margin (hinge line) straight, equalling one-half or more of total length, with beak at anterior termination. Posterior auricle broad, triangular, somewhat flattened, normally with obtuse dorsoposterior angle, ranging to slightly acute on rare species with slightly pointed, projecting posterior tip of auricle. Posterior auricle separated from disc by very shallow, broad, indistinct auricular sulcus; a shallow postumbonal sulcus occurs in some species, separated from auricular sulcus by a broad low posterior fold, and from central disc by broad low umbonal fold. No left anterior auricle; right anterior auricle very small, anteriorly projecting, acutely triangular to tongue-shaped, folded, with subauricular byssal notch below it; notch narrow, moderately deep, bounded in some species by finely beaded ctenolium. Shell biconvex with inflation slight; left valve more convex than right; maximum inflation dorsocentral below inflated umbonal area. Beak blunt, situated about one-third of total length from anterior margin. Beak, umbo orthogyrous to slightly prosogyrous, somewhat incurved, slightly projecting above dorsal margin. Ornament normally consisting of numerous weakly defined, closely and subevenly spaced, subequally to unequally developed, fine raised costellae and radiating threads, increasing significantly in number through bifurcation toward ventral margin of adults; costellae may be of variable size, but rarely size-classed; trace of costellae and threads slightly curved posteriorly and slightly sinuous; radial ornament covers valve of many species, with maximum development centrally; ornament fading anteriorly and posteriorly, and on auricle of a few species; rare species lack obvious radial elements (e.g., *P. papyracea* Etheridge). Concentric ornament of fine, closely set, flat growth lines or microlamellae, in some cases regularly spaced and very slightly raised, and low distant rugae or concentric folds. Edentulous; ligamental plate faces outward, triangular, broadening below beak where broad triangular resilifer situated. Pallial line discontinuous, pitted. South Pacific; Lower Cretaceous.

Remarks: This genus is only known previously from Australia, yet is a relatively common element of the Manihiki Plateau Lower Cretaceous carbonate biota. The generic emendation is designed to be less restrictive on shape and ornament characteristics than the brief diagnosis in Cox et al. (1969, p. N356); it is based on a literature study of the Australian species, and the specimens in hand. The shape, small anterior auricle, broad nature of the posterior auricle, valve inclination, and valve convexity all strongly suggest affinities to *Pseudavicula* rather than to other Oxytomidae for the Manihiki Plateau specimens. The ornamentation of these species, however, is more commonly dominated by concentric elements than radial elements (with the exception of *P.* sp. cf. *P. anomala*, which has coarse costellae), and this is unusual but not unknown for the genus (e.g., *P. papyracea* Etheridge).

Pseudavicula sp. aff. P. anomala (Moore)
(Plate 1, Figure 7; Plate 2, Figures 2, 3)

Material: A small, nearly complete left valve, internal mold with about 30% of shell material adhering; beak crushed and dorsal edge poorly preserved; USNM 218019a, figured specimen: Partial counterpart, incomplete external mold with pieces of shell adhering; figured specimen (Plate 2, Figure 3), USNM 218019b, both from Sample 13-3, 90-93 cm. Possible conspecific fragment, external mold, left valve, with ornament, shell fragments, USNM 218008d, Sample 12-1, 88-92 cm.

Description: Shell moderately small; height 13 mm, length 13.8 mm, width 2.5 mm; slightly convex, with maximum inflation dorsocentral above midpoint of shell. Outline inclined-ovate, moderately prosocline; anterior, ventral margins moderately and evenly rounded; posterior margin straight to slightly concave; anterodorsal margin straight, moderately inclined downward from hinge axis; posterodorsal margin straight, moderately short, equalling about one-third the total length. Posterior auricle subtly defined, triangular with subangular obtuse apex, slightly flared, separated from disc by very shallow but distinct auricular sulcus. Beak rounded, situated one-third the length from the anterior margin; beak, umbo somewhat inflated, orthogyrous, moderately projecting above dorsal margin. Ornament consisting of numerous, well defined, slightly curved, raised, rounded costellae extending from umbo to ventral margin, subevenly spaced and subequally developed, increasing slightly in numbers ventrally through intercalation of smaller costellae (Plate 2, Figures 2, 3), not distinctly size-classed. Concentric ornamentation secondary to radial features, consisting of very fine, crowded, flat growth lines over entire valve, and moderately spaced, very low, rounded, incomplete concentric folds. Shell very thin. Features of hinge area and musculature not preserved.

Remarks: This species is referred to *Pseudavicula* on the basis of its rounded outline, erect beaks and umbos, well-developed posterior aruicle, shallow posterior auricular sulcus, and moderately fine, subequal radiating costellae without extensive bifurcation; it also lacks an anterior auricle and has relatively low convexity on both valves, as in *Pseudavicula*. Among described species, the Manihiki Plateau specimen is most closely related to *P. anomala* (Moore) from the Lower Cretaceous (late Aptian-Albian) of Australia. *Pseudavicula anomala* can be distinguished by its more rounded shape, less projecting beak

and umbo, slightly larger and more rounded posterior auricle, and slightly more regular spacing and straighter trend of the costellae, which tend in some specimens toward distinct size-classing, with one smaller costellae intercalated between larger ones from midshell to the ventral margin. The two forms are probably linearly related; *P. anomala* appears to be the oldest, being found only in the Aptian of Western Australia, New South Wales, and Queensland.

Pseudavicula pacifica, n. sp.
(Plate 2, Figures 4, 7, 8, 11)

Material: Holotype, a small, nearly complete internal mold of a right valve, part of posterior margin broken, and shell adhering to anterodorsal flank, preserving anterior auricle; USNM 218037a; counterpart showing shell interior, USNM 218037b; from Sample 12-6, 85-93 cm; Paratype, internal mold (USNM 218013) and its shelled counterpart (USNM 218006b), a small right valve with posteroventral margin broken, anterior auricle missing, fragments of shell adhering dorsally and ventrally, from Sample 11-3, 134-137 cm. Paratype, incomplete small right valve, ventral and posterior margin broken, internal mold with adhering shell fragments (USNM 218048a), and shelled counterpart, interior exposed (USNM 218048b); Sample 12-6, 43-47 cm.

Description: Small; attaining height of 6.5 mm, length 6.7 mm, width 0.8 mm. Slightly convex (Plate 2, Figures 4, 7), moderately prosocline, with evenly and moderately curved anterior, ventral, and presumably ventroposterior margins; dorsoposterior margin straight to very slightly concave at edge of posterior auricle. Dorsal margin (hinge line) straight, moderately long. Posterior auricle of moderate size, broadly triangular, with obtuse apex; auricle separated from disc by very shallow auricular sulcus. Anterior auricle small, narrow, very acutely subtriangular, anteriorly projecting and slightly curved upward, moderately folded, laterally twisted toward its end, separated from disc by narrow, shallow auricular sulcus terminating in a subauricular byssal notch. Byssal notch (Plate 2, Figure 7) small, narrow, acutely triangular with axis curved concave upward, its margins bounded by a ctenolium comprised of very small, close-set, bead-like denticles. Beak bluntly pointed, slightly projecting above dorsal margin, situated just anterior to midline; beak, umbo slightly inflated, somewhat prosogyrous. Ornamentation dominated by small, closely and equally spaced, subequally developed, slightly raised concentric growth lines, and by rare low concentric folds. Radiating ornamentation very weakly defined, consisting of small, slightly raised, closely and subregularly spaced costellae or raised threads, many incomplete, some arising through bifurcation; radial lines best developed on anterior and central portions of shell. Ligamental plate moderately thickened; interior details not preserved. Musculature, other shell features, and left valve not known. Shell thin.

Remarks: The inclined, broadly ovate shape of the valves, low convexity, depressed beaks, large, subtly defined posterior auricle, very small anterior auricle, and narrow byssal notch all suggest assignment to *Pseudavicula,* and especially to the species group of *P. papyracea* Etheridge, Jr. The very weak radiating ornament, and the somewhat elongated, twisted nature of the anterior auricle are not typical of *Pseudavicula*, but are nevertheless characteristics known from certain species previously assigned to this genus on the basis of well preserved material. The most closely comparable species is *P. papyracea* Etheridge (early to early late Albian; Australia), which also lacks well-defined radial ornamentation, is somewhat prosocline, has an early ornamentation of regular, slightly raised small growth lines like that of *P. pacifica,* n. sp., and has a very small, anteriorly projecting, right anterior auricle with a narrow byssal notch below it. *Pseudavicula papyracea* differs from *P. pacifica* in being rounder and somewhat less prosocline, in having a longer, more projecting posterior auricle with a slightly acute apex, a smaller and less twisted right anterior auricle with a more broadly triangular byssal notch below it, and in having no radial ornament, or only locally developed fine discontinuous threads (depending on the specimen observed). The anterior margin of *P. papyracea* is also more rounded and projecting, and the beaks more depressed than in *P. pacifica.* Among other species of *Pseudavicula* occurring in the Hole 317A material, *Pseudavicula* sp. aff. *P. anomala* (Moore) is easily differentiated by its coarse radiating costellae and smaller posterior auricle, and *Pseudavicula*, n. sp. (erect form) is a higher, more erect shell with finer and less regular concentric growth lines, and better defined radial ornamentation in the dorsal region.

Pseudavicula, n. sp. (erect form)
(Plate 2, Figure 1)

Material: A single, medium size, internal mold of a left valve and its less complete external counterpart; one-half of shell preserved on mold; beak missing; dorsal edge crushed; figured specimen, USNM 218025, from Sample 11-3, 64-73 cm.

Description: Moderately small; attaining height of 20 mm, length 16.6 mm, width 2.5 mm. Slightly convex (left valve); maximum inflation dorsocentral; flanks flattened. Outline erect-subrectangular, with straight posterodorsal margin (hinge line) equalling about one-half total length, slightly curved anterior and posterior margins, moderately curved ventral margin with more narrowly rounded ventrolateral corners. No anterior auricle. Posterior auricle triangular, flattened, slightly flared, with obtuse apex, seemingly separated from disk by shallow auricular sulcus, but this area deformed on only specimen. Beak unknown, anterior on hinge line. Beak-umbo slightly inflated, orthogyrous, only slightly projecting above dorsal margin. Hinge plate poorly preserved, slightly thickened. Ornamentation over entire valve consisting of fine, closely and subevenly spaced, subequally developed, flat concentric lamellae with finely scalloped edges where they intersect radial ornament on dorsal half of shell. Rare, small, faint, low, rounded, incomplete concentric folds developed. Radial ornamentation consisting of very fine, crowded, unequally developed, slightly curved (posteriorly) and sinuous, raised radial lines and threads, locally becoming small costellae; radial elements becoming finer and fainter with growth, increasing significantly in numbers through intercalation, largely disappearing just above ventral margin. Shell very thin. No other features observed.

Remarks: The lack of an anterior auricle, the large posterior auricle, low left valve convexity, and nature of the ornamentation suggest affinities to *Pseudavicula* rather than to other Oxytomidae, or less related genera. The shell is, however, higher and more erect than most *Pseudavicula*. It probably belongs to the species group of *P. papyracea* Etheridge, Jr., with its erect, faintly ornamented shells. *Pseudavicula*, n. sp. (erect form) is easily distinguished from *P. papyracea*, and all other Pacific species, by its relatively higher shell and very fine, irregular, radial ornamentation on the dorsal half of the valve. Formal description must await better material showing the beak, dorsal margin, and hinge features.

Family PECTINIDAE Rafinesque, 1815

Genus AMUSIUM Röding, 1798

Translucent shell fragments, cf. Amusium spp.

Remarks: A common element of the carbonate facies of Hole 317A samples are small, very thin, translucent shell fragments with cross-lamellar or cross-foliated shell structure belonging to some type of "paper pecten." Presumably these are related to the common deep-water *Amusium* group (Pectinidae). Unfortunately, no specimens are complete enough to show the beak and hinge area, or entire shell outline. The shells appear to have been nearly flat and subcircular; some bear only very fine, flat, and in some cases equally developed concentric growth lines over most of the shell, but with indications of a few very large, low ribs (internal?) radiating for a short distance from the beak area. A few fragments also show very small, faint, moderately spaced, radiating raised lines. If the larger radiating elements are truly internal ribs, assignment to *Amusium* seems justified. The largest shell size indicated by the fragments is less than 10 mm height. Fragments have been noted in the following samples: 11-3, 134-137 cm (USNM 218006c); 13-2, 51-56 cm (USNM 218009c); 13-2, 78-83 cm (USNM 218004b); 13-3, 90-93 cm (USNM 218018b); 16-2, 97-100 cm (USNM 218635).

Genus ENTOLIUM Meek, 1865

Entolium sp. cf. E. gradatum (Etheridge, Jr.)
(Plate 3, Figure 4)

Material: A single large fragment of a moderately small, flat valve, external mold only, ventral and medial portions of disc; figured specimen, USNM 218042, from Sample 13-2, 78-83 cm.

Description: Shell moderately small, probably reaching 20-25 mm in height (fragment 9.5 mm high, 10.5 mm long). Very low convexity

with flattened flanks. Outline rounded; shell erect; margins preserved are moderately and evenly rounded. Ornamentation of small, moderately prominent, closely and evenly spaced, equally developed, flat concentric lamellae becoming slightly more crowded near ventral margin. Two subparallel pairs of very faint, sinuous, radiating lines transgress center of shell, vaguely visible on right and left sides of Plate 3, Figure 4. Very faint, incomplete, radiating striae lie between and lateral to radiating lines on fragment. Shell thin.

Remarks: The size, shape, and ornamentation of this fragment are that of *Entolium*; the two pairs of stronger radial lines are not thought to represent internal ribs, which might suggest instead affinities to the amusiid bivalves. Most *Entolium* have smoother shells, with well-developed concentric lamellae, and little or no radial ornamentation. But the early late Albian group of *E. gradatum* (Etheridge, Jr.) is characterized by coarser than normal concentric lamellae, even more so than found in this fragment at approximately equivalent growth stages. Radial lines are faint to obsolete on *E. gradatum*. The fragment from the Manihiki Plateau is too poorly preserved for specific identification but appears to belong to the species group of *E. gradatum*, and may even represent a variant of this species. *Entolium* is a cosmopolitan pectinid known from middle Triassic through Late Cretaceous time. It is a common element of offshore, deeper water deposits in the Cretaceous, and especially of fine carbonates comprised of planktonic foraminifers and coccoliths for the most part. It is thus sedimentologically and ecologically compatible with the Manihiki Plateau occurrence.

Genus PALLIOLUM Monterosato, 1884

Subgenus P. (DELECTOPECTEN) Stewart, 1930

or

Genus CAMPTONECTES Agassiz, 1864

Subgenus (CAMPTOCHLAMYS) Arkell, 1930

Palliolum (Delectopecten) or Camptonectes (Camptochlamys), sp. indet.

Remarks: A single small shell fragment of the ventral one-half of a rounded, flat, pectinoid valve characterized by a finely cancellate ornamentation pattern of small, sharp, equally spaced and evenly developed, raised concentric growth lines, and radiating lines of equal strength and spacing, occurs in Sample 13-2, 78-83 cm. The fragment is 2.5 mm high and indicates a valve no higher than 7-8 mm. There is nothing preserved of the dorsal part of the shell, prohibiting confident taxonomic placement. The ornament pattern is not widespread among pectinid bivalves, however, and is nearly identical to that on two subgenera: *Palliolum* (*Delectopecten*), known from upper Eocene to Recent localities in western North America, Japan, Australia, and northern Europe; and *Camptonectes* (*Camptochlamys*) from the Bajocian-Portlandian, Jurassic, of England. The former is the more likely generic assignment for this fragment. USNM 218033b, on opposite side of fragment with *Limaria*? sp. indet.

Genus NEITHEA Drouet, 1825

Neithea? sp. indet.
(Plate 2, Figure 5)

Material: A single, partial internal mold of a small left valve lacking the beak area, ventral, and anterior margins; rare shell fragments adhering; figured specimen USNM 218022, from Sample 11-4, 50-56 cm.

Description: Valve small, approximate height 3.2 mm, length 2.6 mm, width 0.8 mm. Moderately convex (left valve), maximum inflation just dorsal to midpoint of valve. Outline subtriangular, acline; anterior and posterior margins slightly concave; ventral margin moderately and evenly curved, convex. Dorsal margin unknown. Ornament of strong, raised, narrowly rounded, radiating costae, 5-6 on central portion of disc, between which are intercalated smaller costellae ventrally, 1 per interspace. Costae, costellae evenly spaced and equally developed within size class. Costellae not extending onto umbo; costae extending to beak. Shell moderately thin. No other features known.

Remarks: The symmetrical acline shell, moderate convexity, and general strength and distribution of the ornamentation all suggest affinities to the common Cretaceous pectinoid, *Neithea*. Among the known subgenera of *Neithea* (see Cox et al., 1969, p. N371), the subgenus *Neitheops* Stewart, 1930, seems most closely, but not exactly, comparable. This subgenus is distinguished from the others by the presence of costellae intercalated between the major costae, usually 3 to 5 per interspace. Whereas the valve outline and development of the costae on the Manihiki Plateau specimen are identical to development of the same characters on most *Neitheops*, this specimen only has one costellae intercalated between each pair of prominent costae. Although it has not yet been quantified, a survey of Cretaceous *Neitheops* seems to suggest that the older and more primitive forms commonly have fewer intercalated costellae than those of the Late Cretaceous. The Manihiki Plateau specimen, possibly as old as Neocomian based on associated taxa, would seem to fit this trend and justify tentative placement in the genus *Neithea* and subgenus *Neitheops*. The specimen is too small and incomplete for meaningful species comparison, but I am not aware of previously described species with only a single intercalated costellae between each pair of costae. This may represent a new species.

Family BUCHIIDAE Cox, 1953

Genus BUCHIA Rouillier, 1845

Diagnosis: Small to moderate size, highly inequivalve, with left valve strongly inflated, right valve flat to slightly convex and smaller in size. Moderately to strongly prosocline; outline elongate-ovate, with somewhat flattened posterior slope. Beak of left valve pointed; beak, umbo inflated, strongly projecting above hinge line, incurved toward right valve. Beak of right valve blunt, slightly projecting above dorsal margin or, commonly, recessed below hinge line; right umbo slightly inflated. Posterior auricle small, subtriangular, weakly defined in many species, commonly separated from disc by moderately deep, asymmetrical auricular sulcus. Anterior auricle present only on right valve, small but prominent, folded, concave medially, tongue-like in shape, *not* in alignment with hinge line, but projecting dorsoanteriorly to intersect crude socket on hinge of left valve, just anterior to beak. Surface ornament of strong to weakly defined, regular to subregularly developed, raised concentric ridges, small rugae, and/or growth lines; radial threads and costellae irregularly developed on a few species, primarily confined to dorsal part of valve where present. Ornament of right valve slightly to moderately weaker than that of left; a few species nearly smooth. Cardinal plate of both valves moderately large, shaped like an inequilateral triangle, with an asymmetrically triangular, shallow, broad resilifer originating subcentrally below beak, and extending posteroventrally, with its axis inclined to hinge axis. Byssal gape below anterior auricle open, subtriangular, small, extending halfway or less to umbo; ctenolium may be present. Musculature and shell structure not yet described in detail. Middle Jurassic (Aalenian) to Lower Cretaceous (Albian), cosmopolitan, dominantly North Temperate ("Boreal") in distribution, but ranging worldwide in cool waters.

Remarks: *Buchia* is uncommonly reported in the South Pacific, and in rocks of late Lower Cretaceous age, but the specimen in hand clearly belongs to this genus rather than to the more common Southern Hemisphere Cretaceous genus *Aucellina*. The right valve from Sample 12-6, 43-47 cm resembles *Buchia* in being strongly prosocline, somewhat convex, with a prominent anterior auricle which is thickened and folded, and projects dorsoanteriorly out of line with the hinge axis. The ornament consists of weak concentric folds and growth lines, with very fine radial lines restricted to the early part of the umbo. The cardinal plate is moderately large, subtriangular, and has a broad, shallow, posteriorly inclined resilifer. In addition, the byssal notch extends only about halfway to the beak. Characters suggesting affinities to *Aucellina* are the radial costellae on the umbo, and the ctenolium, previously thought to be restricted to that genus. To this degree the Hole 317A specimen is transitional between the two genera; but the morphology is dominantly that of *Buchia*. *Buchia* and *Aucellina* are generally regarded as cool-water Temperate forms and their common occurrence in this Cretaceous Tropical site supports the idea of a deep-water origin of the faunas.

Buchia, n. sp. A
(Plate 1, Figures 13, 17)

Material: A single, nearly complete, small adult right valve (USNM 218045a, b) internal mold with shell preserved only on the dorsal half,

and counterpart external mold with shell ventrally; hinge plate, resilifer, anterior auricle and ornament well preserved, from Sample 12-6, 43-47 cm.

Description: Small size; height 13.5 mm, axial length 15.4 mm, width 2.9 mm. Outline elongate-ovate; strongly prosocline, with flattened dorsoposterior margin, moderately rounded posteroventral margin, and gently and evenly rounded anterior margin having a small triangular byssal notch just below the anterior auricle (Plate 1, Figure 17). Hinge line moderately short, straight, almost entirely posterior to beak; dorsal margin moderately projecting upward above and anterior to beak along edge of anterior auricle, with concave depression in center of this projecting edge; auricle small, somewhat folded, but with flattened medial area, subtriangular, separated from cardinal plate by a narrow curved groove (Plate 1, Figure 17), and separated from disc by a narrow, moderately deep, triangular auricular sulcus terminating in a small but prominent triangular byssal notch anteriorly; ctenolium of 5-6 small bead-like denticulations along shell margins of notch. Posterior auricle broadly triangular, flattened, separated from disc by a shallow auricular sulcus. Right valve slightly convex, with maximum inflation dorsocentral on umbo. Beak bluntly pointed, anterior on hinge line, projecting only slightly above inner edge of cardinal plate. Umbo and beak moderately prosogyrous. Ornament consisting predominantly of subequal, very faint, rounded concentric folds and very fine growth lines (Plate 1, Figure 13), decreasing in prominence ventrally; adult portions of shell nearly smooth; very fine, closely and subregularly spaced, radiating raised threads of two sizes developed on umbone only; 1-3 smaller threads lie between slightly stronger ones.

Hinge (cardinal) plate of moderate thickness, broadly and asymmetrically triangular, bearing medially a broad, shallow, triangular resilifer occupying nearly three-quarters of area of plate, with its mid-axis posteriorly inclined. Fine, sinuous, radial grooves around shell margin probably reflect mantle muscle tracks of pallial line. Shell moderately thin. Left valve unknown.

Remarks: The slightly convex valve, strong prosogyrous inclination, dominance of concentric ornamentation, posteroventrally inclined resilifer, and dorsoanteriorly projecting anterior auricle which is out of line with the hinge axis all suggest placement of this species with *Buchia* instead of *Aucellina*, the more common buchiid of the Southern Hemisphere, and of Late Cretaceous Tropical to Warm Temperate deposits. No described forms closely resemble this valve, and it probably represents a new species. But since the left valve is not known, and most species of *Buchia* are characterized by the morphology of this valve, formal description is not yet warranted. Right valves of distinct species of *Buchia* are commonly very similar and provide few criteria for the differentiation of closely related species. Assignment to *Buchia* assumes that inclination and nature of the anterior auricle, the resilifer, and the nature of the ornamentation are all valid generic characters within the family.

Some valves assigned to *Aucellina* sp. cf. *A. gryphaeoides* (J. Sowerby) by Day (1968, pl. 50, fig. 24), though decidedly more ovate and less inclined, have a somewhat similar anterior auricle and weak radial ornamentation primarily developed on the umbo, and are thus seemingly transitional between this species and *Aucellina*. A few characteristics of *Buchia*, n. sp. A are similar to *Aucellina*: the radial umbonal ornament, ctenolium, and only subtle folding and projection of the anterior auricle. *Buchia*, n. sp. A seems to be transitional between *Aucellina* and *Buchia* in these respects, as might be expected of the Lower Cretaceous, during which time these genera split.

Genus AUCELLINA Pompeckj, 1901

Diagnosis: Small to moderately small, highly inequivalve, with right valve flat to very slightly convex, left valve larger and moderately to highly convex, having pointed, strongly projecting, prosogyrous, incurved beak and umbo. Beak of right valve blunt, only slightly projecting above dorsal margin, or recessed below it; right umbo only slightly inflated. Outline ovate to subrounded, suberect to moderately prosocline, markedly less than in most *Buchia*. Posterior auricle commonly well defined on left valve; subtriangular, small, flattened, separated by weak to moderately prominent auricular sulcus; posterior auricle poorly defined on right valve. Anterior auricle well defined on right valve only; small, tongue-shaped, anteriorly projecting and slightly curved, its dorsal margin in line with hinge axis. Byssal notch below anterior auricle deep, narrow, curved, bordered by well-defined ctenolium consisting of bead-like projections along shell margins of notch; notch extending commonly almost to beak, separating anterior auricle from disc. Cardinal plate moderately broad, triangular, extending along almost entire length of hinge line and anteriorly onto dorsal margin of auricle in right valve. Resilium triangular, shallow, only slightly inclined posteroventrally behind beaks, not as inclined as in *Buchia*. Ornament commonly of small, raised to flat, concentric growth lines, in some cases subregular on umbonal and midshell areas, and in many species prominent radial threads, costellae, or costae which commonly extend over most of shell, producing reticulated pattern at intersection with concentric growth lines. Some species nearly smooth. Ornament of right valve commonly weaker than that of left valve.

Remarks: The two species of *Aucellina* recovered from Hole 317A belong to a species-group centered around Barremian-Albian forms such as *A. gryphaeoides* (Sowerby), *A. hughendenensis* (Etheridge), *A. caucasica* (Abich), and *A. aptiensis* (d'Orbigny), and are closest to forms illustrated as *A.* cf. *gryphaeoides* by Day (1968) from the early late Albian of the Great Artesian Basin, Queensland, Australia.

Aucellina reticulata, n. sp.
(Plate 1, Figures 15, 19)

Material: A single, complete left valve with the shell intact and ornament well preserved, but with the beak and hinge features embedded in chert. From Sample 10-1, 145 cm; Holotype USNM 218038.

Description: Small size; height 19.1 mm, length 14.1 mm, axial length 20 mm, width 7.6 mm. Shell suberect to moderately prosocline depending on orientation of hinge axis (buried in matrix); outline elongate-ovate, with moderately rounded ventral and anterior margins, slightly rounded posterior margin (Plate 1, Figure 15). Highly convex, maximum inflation subcentral. Posterior flank steep, somewhat flattened, separated from main part of disc by subtle umbonal fold. Posterior auricle, if developed, small (buried in chert). No anterior auricle preserved. Beak probably bluntly pointed; beak and umbo somewhat prosogyrous, strongly projecting above hinge axis and incurved, highly inflated, with ornament identical to that over rest of shell. Surface covered with equally developed and evenly spaced, sharp raised concentric growth lines at close intervals, and equal size radial raised lines or costellae of approximately the same spacing; concentric and radial lines producing a finely reticulated surface pattern. Radial lines expanding slightly at junctions with raised concentric lines, forming small raised nodes or microsquamae at intersections. Radial lines may be disjunct across concentric lines, producing slight offsets (Plate 1, Figure 19). A few coarser concentric lamellae developed near ventral margin. Shell thin; internal structure unknown. No other shell features observed.

Remarks: The generic assignment is questioned only because the hinge features, which are necessary for definite identification, are buried in chert matrix and cannot be extracted. In all other respects this species resembles members of an *Aucellina* species group which includes such Lower Cretaceous forms as *A. gryphaeoides* (Sowerby), *A.* sp. cf. *A. gryphaeoides* of Day (1968), *A. aptiensis* (d'Orbigny), *A. caucasica* (Abich), *A. hughendenensis* (Etheridge), and *A. dowlingi* McLearn. *Aucellina dowlingi* has variants which develop an ornamentation most closely similar to *A. reticulata*, n. sp. (see Imlay, 1961, pl. 8, fig. 20). Such reticulate ornament is not typical of *A. dowlingi*, however (Imlay, 1961, pl. 8, fig. 16-19, 24, 25), and in addition this species has a narrower, more curved, more prosocline left valve than *A. reticulata*. *Aucellina* sp. cf. *A. gryphaeoides* (Sowerby) illustrated by Day (1968, especially pl. 50, fig. 19, 23) are most closely comparable to *A. reticulata* in shape, size, and ornamentation and are possibly conspecific. But even these early late Albian forms show significant differences from the new species, having weaker radial costellae, clearly of two sizes, which subregularly alternate (1-3 fine costellae between coarser ones) and lacking squamose projections of the radial costellae at their intersection with concentric lines. *Aucellina reticulata* may be ancestral to *A.* sp. cf. *A. gryphaeoides* of Day (1968). *Aucellina hughendenensis* (Etheridge) also has reticulate ornament, but it is coarser, more irregular, and unevenly developed over the shell. The valve outline of *A. hughendenensis* is broader and the axis of growth more curved than in *A. reticulata*.

Aucellina sp. cf. A. gryphaeoides (Sowerby)
(Plate 1, Figures 14, 20)

Aucellina cf. *gryphaeoides* (J. Sowerby); Day, 1968, p. 457-462, pl. 49, fig. 1, 2; pl. 50, fig. 8-25 (unpublished thesis).

Material: A large fragment of the posterior half and beak area of a small left valve with the auricle and shell material preserved, illustrated specimen (USNM 218003), from Sample 13-2, 78-83 cm. A

partial internal mold of a small left valve, dorsal one-third missing, small shell fragments adhering, figured specimen (USNM 218027a) from Sample 11-5, 89-96 cm.

Description: Small; maximum observed height approximately 13 mm, length 9 mm. Left valve suberect to moderately prosocline; outline elongate-ovate; anterior flank slightly rounded, ventral margin moderately and evenly rounded, posterior margin slightly rounded to flattened on edge of posterior auricle. Posterodorsal margin (auricular edge) short, straight, with rounded dorsoposterior corner. Posterior auricle small, triangular, flattened, poorly defined, separated from disc by a shallow, indistinct auricular sulcus. Left valve highly convex, with maximum inflation dorsocentral. Beak unknown. Umbo inflated, strongly projecting beyond hinge axis, prosogyrous, strongly incurved, bearing ornament similar to that of main shell surface. Ornamentation dominantly consisting of equally and closely spaced, evenly developed, sharp, raised growth lines and (ventrally) somewhat raised growth lamellae with slightly irregular ventral margins (Plate 1, Figure 20). Very faint, fine, slightly raised radial threads and costellae, many of which are discontinous and unevenly spaced, cross stronger concentric lines to form a weak reticulation in places. Radial elements of ornament strongest on posterior flank of left valve. Shell thin. Other shell features, and right valve, unknown from Hole 317A material.

Remarks: These specimens appear to be identical to variants of *Aucellina* sp. cf. *A. gryphaeoides* (Sowerby) illustrated in the unpublished thesis of Day (1968) from the early late Albian of the Great Artesian Basin, Queensland, Australia (Day, 1968, pl. 50, fig. 19 especially). These forms constitute a new species, and as noted by Day and others, are not conspecific with *A. gryphaeoides*, which appears to be a rounder, more curved species generally lacking regular concentric ornament and any development of radial ornament (see Woods, 1905, pl. 10, fig. 6-13). The species should probably be described from Day's excellent material when his work is published.

Aucellina reticulata n. sp. differs in having regularly reticulated surface ornament with equally developed concentric and radial elements, in having raised growth lines over the entire shell instead of lamellae, in having a steeper, more abruptly terminated posterior flank separated from the main body of the disc by an umbonal fold, and in the more rounded nature of the anterior margin.

Aucellina n. sp. ex. gr. A. gryphaeoides (Sowerby)
(Plate 1, Figures 21-23)

Material: A single dorsal half of an adult right valve, internal mold, but showing all of the hinge structures, with shell adhering over most of dorsal area; figured specimen (USNM 218001a) from Sample 12-2, 26-31 cm. Partial counterpart, external mold with shell fragments adhering, USNM 218001b.

Description: Moderately small; estimated height 24 mm, length 23.5 mm, width 5 mm. Slightly convex; maximum inflation on umbo. Outline subcircular, with moderately rounded anterior and posterior margins, straight dorsal margin of moderate length. Byssal notch (Plate 1, Figures 21, 22) deep, moderately narrow, slightly curved, subtriangular in outline, extending from below anterior auricle almost to beak. Shell margins of byssal notch with well-developed ctenolium consisting of closely spaced, subequally developed, moderately elongate, slightly sinuous, raised denticulations, slightly inclined toward apex of notch and continuous for a short distance on anterior auricle and flank as coarse raised growth lines. Anterior auricle small, prominent, strongly twisted and inclined at high angle to commissural plane; narrow, projecting anterodorsally from beak to level of dorsal margin of cardinal plate, but not beyond as in *Buchia*. Cardinal plate of moderate size, poorly preserved, extending onto dorsal surface of anterior auricle, bearing centrally a shallow, triangular resilifer of moderate size; resilifer axis slightly inclined to hinge axis in posteroventral direction; lateral cardinal plates with moderately coarse growth striae. Shell surface covered with very fine, slightly raised, crowded, irregularly to (on the umbo) subregularly spaced growth lines. Fine, equally developed, evenly spaced, raised radiating threads and small costellae crowded on umbo, disappearing ventrally, forming microreticulated umbonal ornament (Plate 1, Figure 22). Very faint, small, concentric undulations or microrugae characterize more mature parts of shell. Ornament accentuated near byssal notch. Beaks located posterior to midline, bluntly pointed, extending to just below dorsal margin. Beak, umbo moderately prosogyrous, slightly inflated; valve appears somewhat opisthocline relative to beak and umbo. Shell very thin. Other structures, and left valve, unknown.

Remarks: This species belongs to the species group of *Aucellina gryphaeoides* (Sowerby), but it is unusual in its rounded shape, generally opisthocline shell inclination, posteriorly situated beaks, narrow twisted anterior auricle, and the ornate ctenolium below it in the byssal notch. *Aucellina gryphaeoides* (see Woods, 1905, pl. 10, fig. 6-13) has a prosocline to suberect shell with similar concentric ornamentation but lacks radial umbonal costellae. In contrast to the new species from Hole 317A, *A. gryphaeoides* also has a flattened, anteriorly directed, more elongate, and tongue-shaped anterior auricle, and a ctenolium composed of rounded bead-like denticles. The byssal slit is narrower than in *A.* n. sp. ex. gr. *gryphaeoides*, and opens anteriorly rather than dorsoanteriorly.

Aucellina sp. cf. *A. gryphaeoides* (Sowerby) illustrated by Day (1968, pl. 49, fig. 1, 2; pl. 50, fig. 8-25) is even more similar in that it has fine radial umbonal ornamentation and a more erect anterior auricle, which is folded and somewhat twisted. But this species differs from that in the Hole 317A sample in having, on the right valve, a much larger and somewhat flared posterior auricle with a shallow auricular sulcus, a larger and broader anterior auricle, and a narrower and more curved byssal notch.

This species, though probably new, must be left in open nomenclature until the left valve, upon which Buchiidae are principally defined, is found and described.

Family LIMIDAE Rafinesque, 1815

Genus ACESTA Adams and Adams, 1858

Subgenus COSTELLACESTA Kauffman, 1964

Acesta (Costellacesta?) sp. juv.
(Plate 2, Figure 6)

Material: A single, small, juvenile, internal mold of a complete right valve with the ventral margin chipped and shell preserved in the beak and auricle areas; figured specimen, USNM 218034, from Sample 12-1, 121-128 cm.

Description: Right valve very small; height 4.8 mm, length 4.0 mm, width 1.1 mm, length of hinge line 0.9 mm. Moderately convex, with maximum inflation just dorsal to midpoint of shell. Outline subtriangular; dorsal margin short and straight posterior to beak along dorsal edge of posterior auricle; anterior margin very slightly concave; ventral and ventroposterior margins moderately and evenly rounded; dorsoposterior margin straight, with moderately concave notch at dorsal end below auricle. Beak bluntly pointed, situated just anterior to midline. Beak, umbo slightly inflated, orthogyrous, slightly projecting above hinge line. Posterior auricle small, subtriangular with slightly obtuse apex, slightly folded and thickened, separated from disc by narrow, moderately deep, prominent posterior auricular sulcus. Ornamentation dominated by radial elements, consisting of small, raised, angular costellae, equally developed and evenly spaced, extending from base of umbo to ventral margin, with 3 to 4 smaller angular raised lines of equal extent intercalated between each pair of costellae; concentric ornament, as preserved on internal mold, consisting of scattered, very fine, faint, flat growth lines. No other shell features preserved.

Remarks: The erect, triangular form of the shell, lack of an anterior auricle, and slightly concave anterior margin all suggest close affinities to *Acesta*. Kauffman differentiated the subgenus *Costellacesta* (1964) from other subgenera on the basis of its two stage radial ornamentation, with one or more intercalated costellae between costae. This small shell seems to fit this subgenus more closely than any other, but definite determination of the subgenus, and description of the probably new species, must await more mature and better preserved shells showing the adult ornamentation and hinge features. The subgenus *Costellacesta* is previously known only from the Maestrichtian, and its range is here tentatively extended into the Lower Cretaceous. The living *Acesta* and its subgenera, and presumably the fossil representatives, are characteristic deep-water limids (Kauffman, 1964). This is compatible with the associated biota in the Manihiki Plateau samples, which indicate upper bathyal depths.

Genus LIMARIA Link, 1807

Limaria? sp., indet.
(Plate 3, Figure 11)

Material: A very small shell with interior exposed, right valve, shell nearly complete except that posterior, dorsal and dorsoanterior margins, including the beak, are broken off; figured specimen, USNM

218033a. Counterpart, partial internal mold, on slab with type of *Arctotis filisculptus*, n. sp., USNM 218004; from Sample 13-2, 78-83 cm.

Description: Right valve very small; approximate height 2.4 mm, length 2 mm, width 0.5 mm. Slightly convex, with maximum inflation dorsocentral; ventral flank flattened. Outline ovate (Plate 3, Figure 11), vertically elongated, slightly prosocline; ventral and ventrolateral margins moderately and evenly rounded; dorsoanterior and dorsoposterior margins, insofar as preserved, slightly curved to straight. Other margins unknown. Posterior auricle poorly defined, a small, flattened, triangular area not clearly separated from disc by auricular sulcus; apex angular, obtuse. Ornamentation consisting of 17 or 18 small, raised, rounded, equally developed and evenly spaced costellae, extending from umbo to ventral margin with straight trace; on the ventral portion of the shell, single smaller costellae or raised threads are intercalated between each pair of costellae. Concentric ornament of small, closely and evenly spaced, subequally developed, slightly raised, rounded growth lines, on ventral part of shell forming nodes on costellae where they intersect, producing a crude reticulated pattern (Plate 3, Figure 11). Shell thin, slightly thickening toward dorsal margin. No other features known.

Remarks: The size, valve shape, regularly alternating, two-stage radial ornamentation, and weak development of the small posterior auricle are all features which suggest assignment to the cosmopolitan genus *Limaria*, previously known only from the Eocene to the Recent; its range is here tentatively extended into the Lower Cretaceous. The specimen is atypical of *Limaria* in development of semireticulated ventral ornamentation and its reduced convexity (possibly due to compression) but these features are within the known range of variation. *Pseudolimea* Arkell, also considered a possibility for the generic assignment, is less similar to this shell than *Limaria* despite its similar ornament pattern. The principal radial elements of *Pseudolimea* are strong angular costae, and the shell is broader and markedly more inflated than the specimen from the Manihiki Plateau. The specimen is too small and incomplete for subgeneric or specific identification, detailed description, or meaningful comparison with known species; the species is probably new.

Family LUCINIDAE Fleming, 1828

cf. Lucinidae spp.

Remarks: Specimens listed under this heading are all similar, small, fragments of the dorsal half of small shells obviously belonging within the Lucinidae. On various fragments the following features were seen: small, moderately prosogyrous beaks only slightly projecting above a dorsal margin, which is elongated anteriorly and posteriorly into rounded, flattened, subtly defined auricles; the dorsal ornamentation consists of very small, equally developed, evenly spaced, sharp raised growth lines or microridges with fine concentric striae between them; there is a prominent concave notch, possibly forming a small lunule, below the beaks.

Any number of lucinid genera have these same characters, and no certain generic assignment is possible from this material. The occurrence of small, thin-shelled Lucinidae in carbonates containing deep-water mollusc associations is compatible with modern ecological occurrences of the family.

The above description is primarily based on fragments from Sample 13-3, 90-93 cm, which preserve most of the dorsal features of the shell and the surface ornament; described specimen, USNM 218018a. Other fragments were observed on core fragments containing other described bivalve taxa from Samples 13-2, 78-83 cm and 13-2, 51-56 cm.

Genus HERE Gabb, 1866

Subgenus H. (HERELLA) Chavan, 1942

Here? (Herella?) subpacifica, n. sp.
(Plate 3, Figure 5)

Material: A single small right valve, complete, somewhat worn, with shell intact, interior exposed, hinge features mostly preserved; Holotype, USNM 218008c from Sample 12-1, 88-92 cm.

Description: Shell small; height 8.6 mm, length 8.5 mm, width 1.1 mm, length of hinge line 3.7 mm. Slightly convex, with maximum inflation on lower part of umbonal area. Outline circular; anterior, ventral, posterior margins moderately and evenly rounded; posterodorsal margin slightly rounded; anterodorsal margin moderately concave, forming prominent notch below beak; shell slightly prosocline. Beak bluntly rounded, situated just anterior to midline; beak, umbo inflated slightly, moderately prosogyrous, projecting moderately above and over anterodorsal margin. No auricles differentiated. Ornamentation consisting of weakly and irregularly developed, subequally (posterior) to sparsely and unequally spaced (anterior) radiating costellae and low raised rounded lines, their trace moderately curved, concave anteriorly; costellae and radiating lines best developed on center and posterior flank of shell (Plate 3, Figure 5), sparse to absent anteriorly. Concentric ornamentation consisting of moderately and subequally spaced, subregularly developed, low, rounded folds and slightly raised growth lines, best defined posteriorly and ventrally on disc. Intersection of radial and concentric elements forming weakly defined and somewhat uneven cancellated ornament pattern, especially on posterior one-half of shell. Hinge short, sinuously curved, slightly thickened, partially worn on specimen available. Dentition consisting of a single, very small, ovate cardinal tooth below beak, directed somewhat anteriorly, and a low swelling on the middle part of the anterodorsal commissure, possibly representing a very poorly defined anterior lateral tooth. No posterior dentition. Lunule appears to be well defined, short, moderately deep, and impinging onto hinge plate below beak. No musculature preserved. Fine commissural denticulations preserved on dorsoposterior shell margin; rest of margin smooth. Shell moderately thin; preserved layer cross-lamellar in structure.

Remarks: Assignment to the genus *Here* (*Herella*) among the Lucinidae is based on the weakly cancellated surface ornament, strongest posteriorly on the shell, on the valve size and shape, prominent development of a concave notch below the beaks, probably bearing a short, moderately excavated lunule, preservation of a single, exposed, small cardinal tooth below the beak, suggestion of a very weak anterior lateral tooth, and development of fine marginal crenulations. The assignment must be questioned, however, due to differences in the dentition and lunule. In younger *Here* (*Herella*) there are more cardinals, 2-3 (?), but only the posterior one (or none) is exposed, the others being covered by deep inflection of the lunule. This does not exactly seem to be the case in the specimen from the Manihiki Plateau, which has only a single obvious cardinal, and does not have the lunule so deeply incised, to the point where it is covering additional cardinal teeth. The anterior margin in front of the single cardinal is swollen and somewhat folded, but no evidence of underlying teeth was observed. Since the cardinals are very weak and variable in this group, and since other characteristics of the shell are so similar between modern *Herella* and the Lower Cretaceous specimen from the Manihiki Plateau, these dental differences may not be of great significance. If this is truly a primitive *Here* (*Herella*), or a closely related new subgenus, it is the first report of the group in the Indo-Pacific, and extends the age range of the genus from the Paleocene to the Lower Cretaceous (Neocomian).

Family FIMBRIIDAE Nicol, 1950

Genus PARVICORBIS Cossmann, 1892

cf. Parvicorbis, gen. et. sp. indet.

Material: A single small incomplete external mold of a right valve, dorsal margin broken, with thin shell fragments adhering; too poorly preserved for photography; Described specimen, USNM 218634, from Sample 13-3, 90-93 cm.

Description: Small; reconstructed height approximately 4.7 mm, length 5.0 mm; slightly convex, maximum inflation dorsocentral below umbo. Outline broadly elliptical to subrectangular, with length slightly greater than height; slightly prosocline (?). Anterior, ventroposterior margins moderately and subevenly rounded. Ventral, dorsoposterior margins slightly rounded, subtruncated. Dorsal margin of moderate length, approximately one-half the total length, probably straight, with segment posterior to beaks longest. Posterodorsal flank extended into flat triangular auricle, not clearly differentiated from disc by auricular sulcus. Beak situated anterior to midline, about one-third the total length from the anterior margin; umbo slightly inflated, prosogyrous, probably slightly projecting above dorsal margin. Ornamentation of anterior flank dominated by subevenly to unevenly developed, subequally spaced, low, rounded, raised costellae, 16-18 over anterior half of shell, their trace moderately curved, concave anteriorly. Some costellae arise by intercalation on ventral half of

shell. Costellae disappearing posteriorly. Growth lines cover entire valve; lines raised, sharp, small, equally spaced and evenly developed. Shell thin. No other features known.

Remarks: The shell is too small and poorly preserved for definite taxonomic assignment or formal description. The subrectangular to elliptical outline, and ornamentation pattern of sharp, raised growth lines and unequal radiating costellae which are concentrated on the anterior flank, all suggest that the species belongs within the Family Fimbriidae. Among genera of this family, the outline of the shell is closest to *Parvicorbis* Cossmann from the Eocene of Europe, a rather small and delicate fimbriid with concentric to semireticulated surface sculpture. Some members of the Genus *Fimbria* Megerle von Mühlfeld, 1811, are also similar in shape, but normally have coarser ornamentation and thicker shells. *Fimbria* is known from the Middle Jurassic to Recent, and has been reported widely in Europe, North America, around the Indo-Pacific margins, and in Australia. Better material will be necessary to confirm assignment to the Fimbriidae, and for description of this apparently new species.

Family CARDIIDAE Lamarck, 1809

Subfamily CARDIINAE? Lamarck, 1809

Genus CARDIUM Linné, 1758

Cardium (sensu lato) sp. juv.
(Plate 3, Figure 16)

Material: A single juvenile right? valve, complete internal mold with shell adhering along margins; figured specimen, USNM 218032, from Sample 12-1, 121-128 cm.

Description: Shell very small; height 2 mm, length 1.7 mm, width 0.8 mm; moderately high convexity, maximum inflation central on disc. Outline subquadrate, slightly prosocline (Plate 3, Figure 16), with moderately long, straight posterodorsal margin, slightly curved anterior and posterior margins, moderately curved ventral margin with narrowly rounded to subangular ventrolateral corners. Anterior face steep, flat, separated from main body of disc by low fold; anterior margin slightly projecting beyond beak. Posterior "auricle" small, triangular, indistinct, without auricular sulcus. Beak bluntly pointed, projecting slightly above dorsal margin, incurved, anteriorly situated on hinge line; beak, umbo moderately prosogyrous, highly inflated. Ornament consisting of about 15 radiating costae, prominent, raised, rounded, subequally developed and evenly spaced, narrow and faint on umbo, becoming stronger and broader ventrally on internal mold; costae nonbifurcating, best developed in mid-shell region, weakening on anterior and posterior flanks. Hinge thickened; detail unknown; shell otherwise moderately thin. No other features preserved.

Remarks: The specimen is too small and incompletely preserved for definite generic or specific identification, and probably retains juvenile features not characteristic of the adult growth phase. The quadrate outline and strong expression of the costae on the shell interior, and thus on the internal mold, suggest a genus within the Subfamily Cardiinae, or less probably, the Fraginae. Small shells of *Ethmocardium, Granocardium,* and *Vepricardium* (especially the Subgenus *Perucardia* with its truncated anterior face) are known to have these characteristics, but without the evidence necessary to choose among these, the specimen is here assigned to "*Cardium*" as used in the older, broader sense. The description is based on the assumption that this is a right valve, seemingly indicated by the strong curvature of the beaks and broad "posterior" dorsal margin; but the hinge characters necessary to prove this are destroyed or buried in matrix without the possibility of extraction due to the recrystallized nature of the shell. Various small Cardiidae are known from deep-water deposits today (e.g., Knudsen, 1967, 1970).

Family ARCTICIDAE Newton, 1891

Genus VENIELLA Stoliczka, 1870

Veniella ? sp. indet.
(Plate 3, Figure 6)

Material: A single, moderate size, internal mold of an adult right valve, nearly complete, portions of ventral edge broken, thick fragments of shell adhering around beak; figured specimen, USNM 218014, from Sample 16-2, 8 cm.

Description: Moderate size; height 27 mm, length 26.8 mm, width 7.6 mm; moderately convex, maximum inflation just dorsal to mid-shell point; outline subtriangular to subovate, moderately prosocline; dorsoposterior margin straight to very slightly curved; ventroposterior and ventroanterior margins narrowly rounded, ventral margin moderately and evenly rounded, dorsoanterior margin below umbo moderately concave. Umbonal fold strong, moderately to (dorsally) narrowly rounded (probably sharper on shell exterior), extending from beak to posteroventral corner of shell. Posterior flank moderately steep and flattened. No auricles. Beak pointed, situated about one-quarter of total length from anterior margin; beak, umbo inflated, strongly prosogyrous, strongly curved forward and inward over dorsoanterior margin, highly projecting above dorsal margin. Ornamentation, as indicated by internal mold, restricted to scattered, very low, rounded, concentric folds or rugae, and fine growth lines. Hinge plate greatly thickened, with moderately deep subumbonal cavity; dentition unknown except for portion of at least one massive anterior cardinal tooth; ligamental groove unknown. Musculature well defined on internal mold, consisting of equal sized, strongly incised (raised areas on internal mold) anterior and posterior adductor impressions bordered by low buttresses dorsally and medially; adductor insertion areas of moderate size, subrounded, the anterior impression more deeply excavated than the posterior one. Pallial line well impressed as moderately deep, narrow, groove; entire, without pallial sinus for siphons. Pallial line set back about 5 mm from commissural margin, which is not crenulated on this specimen.

Remarks: The shell shape, thickness, nature of the musculature (especially the adductor insertion areas), entire, nonsinused pallial line, and strong umbonal fold are all characters which suggest assignment of this shell to *Veniella* rather than to other Arcticidae. The assignment is here questioned only because the dentition is not preserved for confirmation, and the umbonal fold is not as angular as in most *Veniella*; it is within the known range of variation, however. Many *Veniella* have a more angular, projecting ventroposterior corner than this specimen appears to have, but the illustration is deceiving in this respect since this corner is broken and gives the appearance of a more rounded margin than existed on the original shell (as determined from growth line traces). Thick-shelled bivalves like *Veniella*, and this genus at this size in particular, are typical of Cretaceous shelf environments and not yet found as a common element of deeper deposits. The occurrence of *Veniella*? sp. in volcanoclastic sands near the base of the Hole 317A cores suggests a shallow-water paleoenvironment (200 m or less), as the sedimentology also indicates. *Veniella* is nearly cosmopolitan as a genus, and reported commonly from circum-Pacific, Caribbean, and circum-Atlantic localities. The genus is previously reported from the Upper Cretaceous, and this occurrence tentatively extends the range downward into the Lower Cretaceous at least to the Barremian, and probably lower in the Neocomian.

Family POROMYIDAE Dall, 1886

Genus POROMYA Forbes, 1844

Poromya sp. indet.
(Plate 3, Figure 15)

Material: Rare irregular fragments showing characteristic thin translucent shell with subregularly distributed and closely set small pustules found in living representatives of genus. Largest fragment; figured specimen, USNM 218039, from Sample 13-2, 78-83 cm.

Description: Shell small; complete valves unknown; convexity apparently slight to moderate; valves very thin, translucent, with surface of disc (probably posterior half) covered with very small, round, raised, closely and subregularly spaced, white-colored beads or pustules; no direct evidence for pores through shell below them. Approximately 160 beads per square mm.

Remarks: No specimens are complete enough for definite subgeneric and specific determination. The fragments strongly suggest *Poromya* as the genus; no other bivalve has the same beaded structure. The specimens from the Manihiki Plateau compare very favorably with the living *Poromya microdonta* Dall (posterior flank) in respect to the size and spacing of the pustules; the living form is more convex than indicated by meager fragments from the Cretaceous, which are, however, compressed as a result of sediment compaction. The genus *Poromya* is previously known from the Cretaceous to the Recent.

Genus LIOPISTHA Meek, 1864

cf. Liopistha sp. indet.

Remarks: A fragment of the central and posterior portions of the disc from a small, very thin-shelled bivalve resembling the Upper Cretaceous genus *Liopistha* in general form and ornamentation was observed in Sample 13-3, 90-93 cm (USNM 218021) on the Manihiki Plateau. The shell is very thin and semitranslucent; fragments indicate individuals of small size, not exceeding 10 mm in length, with ovate, slightly prosocline shells and opisthogyrate, moderately projecting beaks and umbos. The posterior flank is somewhat projecting and without ornament; the central disc bears faint, moderately and evenly spaced, gently curved, radiating costellae. These are all characters of *Liopistha* (*Liopistha*), a common Late Cretaceous genus of offshore shelf and slope facies in North America, Japan, and continental Asia. These occurrences suggest extension of the age range into the Lower Cretaceous at least to the late Aptian, as determined from associated bivalves in the sample. The material is too fragmental for illustration or definite taxonomic determination.

Family VERTICORDIIDAE Stoliczka, 1871

Genus VERTICORDIA Sowerby, 1844

Verticordia? sp. indet.
(Plate 2, Figure 14)

Material: Figured specimen, USNM 218023b, a small interior shell surface of a right valve, and counterpart internal mold (USNM 218023a) with thin shell adhering over part of surface, beak area and dorsoanterior flank missing at core edge; from Sample 11-4, 50-56 cm. A partial internal mold of a very small right valve with ornamentation better defined than on figured specimen, USNM 218030, from Sample 11-3, 134-137 cm.

Description: Small shell; measurements of largest specimen; approximate height 8.0 mm, length 8.1 mm, width 1.4 mm. Slightly convex; maximum inflation dorsocentral; distal flanks tapering evenly. Outline ovate, with length greater than height; ventral and ventrolateral margins moderately rounded, maximum curvature at ventrolateral corners; dorsoanterior margin slightly concave in notch below beaks; dorsoposterior margin slightly curved, convex outward. Beak bluntly pointed, situated anterior to midline; beak, umbo slightly inflated, strongly prosogyrous, moderately projecting above curved dorsal margin; shell moderately prosocline. No auricles. Ornamentation consisting of 4 to 5 moderately strong, raised, narrowly rounded, equally developed and evenly spaced costae on posterior flank of shell; costae with slightly curved trace, concave anteriorly (Plate 2, Figure 14). Central and anterior portions of disc with very faint, crowded, subequally spaced, raised radial threads, their trace similar to that of costae. Concentric ornamentation of fine flat growth lines or lamellae, crowded and unevenly spaced, and distant, subequally spaced, very low rounded concentric folds. Shell moderately thin. No other features observed.

Remarks: This species, which is probably new, possesses morphological features which are closest to the Verticordiidae, and among these to *Verticordia s.l.*, among possible bivalve genera. Generic assignment must remain tentative until the hinge characters are known, however, and because the species does not fit precisely into described subgenera of *Verticordia*. Subgenera like *Verticordia* and *Spinosipella* have coarse, angular costae, like those on the posterior flank of the specimen from Hole 317A, but coarser, over the entire disc; these subgenera lack fine raised threads. The subgenus *Vertambitus*, which appears to be closest in shape to the Hole 317A specimen, has even coarser plicae and is smaller; it is similar, however, in having the plicae more strongly developed on the posterior flank than elsewhere on the shell. The subgenus *Vertisphaera* is more lucinoid in shape but has very similar, weakly developed, radial ornamentation of close-set raised threads, without coarser posterior costae. The probable new species from the Manihiki Plateau therefore seems to represent a morphological transition between *Vertambitus* and *Vertisphaera*; these both are Recent South Pacific subgenera, and the genus *Verticordia* is known from the Paleocene to the Recent in deep Tropical waters from the Pacific, the Caribbean, North and Central America, all the way to formerly Tropical-Subtropical parts of Europe.

Family VERTICORDIIDAE? Stoliczka, 1871

Genus MANIHIKIA, n. gen.

Description: Moderately small; height greater than length. Moderately convex, maximum inflation near midshell. Outline erect-ovate; valves slightly prosocline to suberect. No anterior auricle; posterior auricle small, obtusely triangular with rounded apex, poorly defined, with or without shallow, indistinct auricular sulcus separating it from disc. Beaks blunt, situated centrally or just anterior to midline, moderately projecting above short, curved dorsal margin. Umbo inflated; beak-umbo slightly prosogyrous, strongly incurved. Ornament consisting of fine, subequally developed and evenly spaced, slightly raised and rounded concentric growth lines transgressed by very fine, sinuous, closely and subregularly spaced, unequally developed radiating lines and threads; radiating elements increase in number ventrally through bifurcation. Hinge plate short, moderately thickened, slightly curved, bearing two massive, knob-like, moderately projecting "cardinal" teeth below and just posterior to beak, with a small, triangular, moderately deep socket between them. Surfaces of teeth prominently and vertically grooved (one deep groove on anterior cardinal tooth; three on posterior cardinal tooth of specimen on hand). Subumbonal cavity moderately deep. Shell moderately thin, with cross-lamellar (originally)nacreous?) structure. No other features known.

Remarks: This new genus is unusual in its massive dentition and grooved cardinal teeth, but otherwise possesses features typical of septibranch bivalves, and especially of members of the Verticordiidae, which have small radially ribbed shells, with thin valves possessing a nacreous inner layer, and with one to two, normally weak knob-like cardinal teeth below the beak, most commonly on the right valve; the teeth become massive in a few genera, such as *Kurinuia* and *Pecchiolia* (see illustrations in Cox et al., 1969, fig. F30, F31). *Manihikia*, named for the Manihiki Plateau, south-central Pacific Ocean, where the type was collected, is identical in shell form and ornament to *Policordia* Cox et al., 1969, fig. F31, 1b); *Policordia* is edentulous, however, and thus distinct.

Manihikia erecta Kauffman, n. sp.
(Plate 3, Figures 3, 8)

Material: A single moderately small right valve, nearly complete with ventroanterior flank partially missing at core edge; shell intact, including hinge structures; shell interior exposed; Holotype, USNM 218036, from DSDP Sample 12-1, 121-128 cm.

Description: Shell moderately small; height 22.9 mm, length approximately 22.5 mm, width 6 mm; length of hinge line 10 mm including thickened shell edges. Moderately convex (right valve) with maximum inflation dorsocentral just above midshell. Outline erect-ovate (Plate 3, Figure 3); hinge line slightly curved; all other margins moderately and evenly curved. Beak blunt, situated just anterior to midline; beak-umbo inflated, slightly prosogyrous, strongly incurved, moderately projecting above the dorsal margin. No posterior auricle developed; anterior auricle small, subtriangular, somewhat flattened, slightly flared, separated from disc by very shallow, incomplete auricular sulcus; auricle partially destroyed on Holotype. Ornamentation consisting of fine, closely and subequally spaced, unevenly developed, slightly raised, rounded costellae and radiating threads; trace of radial elements slightly curved (concave anteriorly) and slightly sinuous; radial ornament not distinctly size-classed, becoming weaker ventrally. Concentric ornamentation of fine, closely and subequally spaced, subevenly to unevenly developed, slightly raised and rounded growth lines of about the same magnitude as the radial ornamentation (Plate 3, Figure 3). Hinge plate somewhat thickened and slightly curved, concave ventrally, with moderately deep subumbonal cavity. Dentition (Plate 3, Figure 8) consisting of two massive, knob-like, downward projecting cardinal teeth, one below and one just posterior to beak, between which lies a moderately deep, subtriangular socket; posterior cardinal tooth slightly larger than anterior tooth, its inner surface marked by three sinuous grooves; anterior cardinal tooth split, with a single wedge-shaped groove medially. Ligamental groove? external, a shallow narrow depression extending from the top of the cardinal socket, posteriorly beneath the beak and parallel to the shell margin, to the posterior termination of the hinge line (Plate 3, Figure 8). Musculature not preserved. Shell thin, layer cross-lamellar.

Remarks: No described species of Cretaceous to Recent bivalve is closely comparable to this form. In all but the dentition it resembles the living Hawaiian species *Policordia diomedea*, which has similar size, shell form and ornamentation (although the radial costellae are stronger than on *M. erecta*). This species, like all *Policordia*, is edentulous, however. Possibly, *Manihikia* represents an ancestral member of the Verticordiidae which gave rise to erect, finely ribbed, edentulous forms such as *Policordia*.

Phylum ECHINODERMATA

Class ECHINOIDEA

Echinoid spines, indet.

Remarks: Individual echinoid spines occur at sporadic levels in the cores of Leg 33, Hole 317A. All appear to be the same type. They are long (longest spine estimated at 25 mm, with a maximum basal width of 1 mm), slender, very gradually and evenly tapering except for a subtle swelling near the attachment base; the spines lack a hollow interior, and are surficially ornamented by about 50 fine, crowded, raised rounded riblets with faintly beaded crests; riblets, or raised lines, equally developed and evenly spaced, each individual wider than the interspeces bounding it. This is probably the spine of some surface dwelling regular echinoid, but the material is insufficient to allow familial or generic assignment. Specimens were noted in Sample 13-2, 0-5 cm (USNM 218031b; part of the type collection of *Nucula* sp. B); in Sample 13-1, 108-114 cm (USNM 218043); and from Sample 10-1, 145 cm (USNM 218038 on type specimen of *Aucellina reticulata*, n. sp.).

ACKNOWLEDGMENTS

I am deeply indebted to numerous individuals and organizations for their support of this research. The material was initially collected by scientists onboard *Glomar Challenger* during Leg 33 fof the Deep Sea Drilling Project, supported by funds from the National Science Foundation. The Lower Cretaceous macrofauna was first brought to my attention by Dr. S. Schlanger of the University of California, Riverside, and was made available to me for study by the staff of the Scripps Institution for Oceanography, La Jolla, California. Dr. Hugh Jenkyns of the University of Durham, England, unselfishly made his manuscript and sedimentological data on the Cretaceous of the Manihiki Plateau available to me during the study of the biota, and reviewed all but the systematic part of the manuscript. Dr. Thomas Waller, Department of Paleobiology, Smithsonian Institution, was of considerable assistance in studies of shell microstructure and the taxonomic placement of the deep-water bivalves. Other members of the Department of Paleobiology staff providing assistance were: my laboratory assistants Ms. Barbara Duffy Heffernan, who collected much of the ecological data and helped considerably with the mechanics of the manuscript; Mr. David Govoni, who prepared most of the specimens; and Mr. Lorenzo Ford, who prepared the thin-sections. Mr. Vic Krantz, photographer of the Museum of Natural History, showed incredible patience with the difficult job of photographing the minute and poorly preserved molluscs.

REFERENCES

Allen, J.A., 1971. Evolution and functional morphology of the deep water protobranch bivalves of the Atlantic: Joint Oceanogr. Assem. Proc., Tokyo, 1970, p. 251-253.

Clarke, A.H., 1962. Annotated list and bibliography of the abyssal marine mollusks of the world: Nat. Mus. Canada Bull., v. 181, p. 1-114.

Cox, L.R. et al., 1969. Part N, Volumes 1, 2 (of 3), Mollusca 6, Bivalvia. *In* Moore, R.C. (Ed.), Treatise on invertebrate paleontology: Geol. Soc. Am. (Univ. Kansas Press).

Day, R.W., 1968. Biostratigraphy and taxonomy of Lower Cretaceous Molluscan faunas from the Queensland portion of the Great Artesian Basin: Unpublished Ph.D. Thesis, Dept. Geol., Australian National University, Canberra, v. 1-3, p. 1-585.

Filatova, Z.A., 1961. Some new data on the bivalve molluscs from the Java Trench: Okeanologiya, v. I, p. 133-135 (in Russian).

Hall, C.A., 1964. Shallow water marine climates and molluscan provinces: Ecology, v. 45, p. 226-234.

Hessler, R.R. and Sanders, H.L., 1967. Faunal diversity in the deep sea. Deep-Sea Res., v. 14, p. 65-78.

Imlay, R.W., 1961. Characteristic Lower Cretaceous megafossils from northern Alaska: U.S. Geol. Surv., Prof. Paper 335, p. 1-74.

Kauffman, E.G., 1964. *Costellacesta*, a new subgenus of *Lima* from the Cretaceous of the Gulf and Atlantic Coast Province: Tulane Stud. Geol., v. 2, p. 89-101.

_____, 1967. Cretaceous *Thyasira* from the Western Interior of North America: Smithsonian Misc. Coll., v. 152, p. 1-159.

_____, 1969. Form, function and evolution. *In* Moore, R.C. (Ed.), Treatise on invertebrate paleontology, Part N, v. 1, p. N129-N205.

_____, 1970. Population systematics, radiometrics, and zonation—a new biostratigraphy: N. Am. Paleontol. Conv. Proc., Part F, p. 612-666.

_____, 1972. Evolutionary rates and patterns of North American Cretaceous Mollusca: Int. Geol. Congr. Proc., 1972, p. 174-189.

_____, 1973a. Cretaceous bivalvia. *In* Hallam, A. (Ed.), Atlas of paleobiogeography: Amsterdam (Elsevier Pub. Co.), p. 353-383.

_____, 1973b. Evolutionary rates and biostratigraphy: Geol. Soc. Am., Ann. Mtng., p. 688 (abstract).

_____, 1974. Cretaceous assemblages, communities and associations, Western Interior United States and Caribbean Islands. *In* Ziegler, A.M. et al., (Eds.), Principles of benthic community analysis: Sedimenta IV, Comp. Sed. Lab., Univ. Miami, p. 12.1-12.27.

_____, in press. Dispersal and biostratigraphic utility of benthonic Bivalvia in the Cretaceous of the Western Interior: *In* Caldwell, W.G.E. (Ed.), Proc. Collog. Cret. Sys. in West. Int. N. Amer., 1973, Saskatoon, Sask., Spec. Pap., Geol. Soc. Canada.

Keen, A.M. and Coan, E., 1974. Marine molluscan genera of western North America: An illustrated key: Stanford (Stanford Univ. Press), 2nd ed., p. 1-208.

Kennedy, W.J., 1969. The correlation of the lower chalk of south-east England: Geol. Assoc. Proc., v. 80, p. 459-560.

Knudsen, J., 1967. The deep-sea Bivalvia: British Mus. (Nat. Hist.) Pub. 657, John Murray Exped., 1933-34, Sci. Rept., v. 11, p. 237-343.

_____, 1970. The systematics and biology of abyssal and hadal Bivalvia: Galathea Rept., v. 11, Copenhagen (Danish Sci. Press, Ltd.), p. 1-241.

Parker, R.H., 1964. Zoogeography and ecology of some macroinvertebrates, particularly Mollusks, in the Gulf of California and the Continental Slope off Mexico: Vidensk. Medd. fra Dansk naturh. Foren., v. 126, p. 1-178.

Rhoads, D.C., Speden, I.G., and Waage, K.M., 1972. Trophic group analysis of Upper Cretaceous (Maestrichtian) bivalve assemblages from South Dakota: Am. Assoc. Petrol. Geol. Bull., v. 56, p. 1100-1113.

Sanders, H.L., 1969. Benthic marine diversity and the stability-time hypothesis. *In* Woodwell, G.M. and Smith, H.H. (Eds.), Diversity and stability in ecological systems: Brookhaven Symp. in Biol., v. 22, p. 71-81.

Sanders, H.L. and Allen, J.A., 1973. Studies on deep-sea Protobranchia (Bivalvia); Prologue and the

Pristiglomidae: Mus. Comp. Zool. Bull., Harvard Univ., v. 145, p. 237-262.
Sanders, H.L. and Hessler, R.R., 1969. Ecology of the deep sea benthos: Science, v. 163, p. 1419-1424.
Stephenson, L.W., 1941. The larger invertebrate fossils of the Navarro Group of Texas: Univ. Texas Pub. No. 4101, p. 1-641.
Taylor, J.D., Kennedy, W.J., and Hall, A., 1969. The shell structure and mineralogy of the Bivalvia. Introduction. Nuculacea-Trigonacea. British Mus. (Nat. Hist.), Zool. Bull., Suppl. 3, p. 1-125.
Thorson, G., 1957. Bottom communities (sublittoral or shallow shelf). *In* Hedgpeth, J.W. (ed.), Treatise on marine ecology and paleoecology, Ecology: v. 1, Geol. Soc. Am. Mem. 67, p. 461-534.
Woods, H., 1905. A monograph of the Cretaceous Lamellibranchia of England: Palaeontograph. Soc., Mono., v. 2, p. 72-73.

PLATE 1

Lower Cretaceous Bivalvia from DSDP Leg 33, Hole 317A

Figures 1, 5, 6, 10 — *Maccoyella breviauriculata* Kauffman, n. sp.
1. Interior view (×2), incomplete right valve with abnormally coarse rugae; Sample 13-2, 51-56 cm; Paratype, USNM 218009b.
5. Interior view (×20), immature right valve with well-defined anterior auricle, partial resilifer, early umbonal ornament; Sample 12-5, 31-35 cm; Paratype, USNM 218010.
6. Internal mold, right valve (×2), with typical ornament, form, auricles (tip of anterior auricle broken); Sample 13-2, 51-56 cm; Holotype, USNM 218009a.
10. Interior view, right valve (×2); Holotype, USNM 218009a; counterpart of Figure 6; data the same.

Figures 2, 3 — *Arctotis* sp. A; both figures ×4, from Sample 11-5, 6-12 cm.
2. Internal mold, right valve, anterior auricle broken, showing early radial ornament disappearing on later growth stages; figured specimen, USNM 218007a.
3. Interior view, external mold of same specimen as Figure 2, piece of anterior auricle adhering; figured specimen, USNM 218007b.

Figures 4, 8 — *Maccoyella* sp. cf. *M. barklyi* (Moore), internal mold, right valve, with shell adhering dorsoanteriorly; figured specimen, USNM 218011, from Sample 13-3, 90-93 cm.
4. After preparation, showing narrow byssal notch and ctenolium, radial ornament on shell fragment, radial mantle muscle tracks on internal mold indicating discontinuous pallial line (×5).
8. Before preparation; outline well preserved (×10).

Figure 7 — *Pseudavicula*? sp. aff. *P. anomala*?, external mold, left valve, with shell adhering ventrally, showing ornament on mold; figured specimen (×6), USNM 218008d, Sample 12-1, 88-92 cm.

Figures 9, 11, 12, 16 — *Arctotis filisculptus* Kauffman, n. sp.
9. Slightly oblique interior view (×8), right valve, with ornamentation well preserved; Paratype, USNM 218005, from Sample 13-2, 78-83 cm.
11. Interior view, right valve (×8) with auricles, byssal notch, and ornament typically developed; Holotype, USNM 218004, from Sample 13-2, 78-83 cm.
12. Internal mold of Figure 9, data the same.
16. Internal mold (×6), right valve, anterior auricle missing, ornamentation typically defined; Paratype, USNM 218006, Sample 11-3, 134-137 cm.

Figures 13, 17 — *Buchia* n. sp. A, right valve; figured specimen, USNM 218045a, from Sample 12-6, 43-47 cm.
13. Right-lateral view of entire specimen (×3) showing outline and projecting anterior auricle.
17. Partial right-lateral view (×5), slightly oblique dorsally, showing characters of hinge plate, resilifer, auricle, byssal notch with ctenolium, and fine radiating umbonal ornament.

Figures 14, 20 — *Aucellina* sp. cf. *A. gryphaeoides* (Sowerby).
14. Lateral view (×3), internal mold, left valve, with beak broken, fine radial surface ornament preserved; figured specimen, USNM 218027a, from Sample 11-5, 78-83 cm.
20. Oblique posterior view (×8), incomplete left valve with shell, showing typical surface ornamentation; figured specimen, USNM 218003, from Sample 13-2, 78-83 cm.

Figures 15, 19 — *Aucellina reticulata* Kauffman, n. sp.; left valve with shell, showing typical form, surface ornamentation; Holotype, USNM 218038, from Sample 10-1, 145 cm.
15. Lateral view, entire left valve (×3).
19. Typical reticulated surface ornamentation at mid-shell, same view (×6).

Figure 18 — *Arctotis* sp. B cf. *A. intermedia* Bodylevsky; incomplete internal mold, right valve, lateral view (×3), showing regular concentric ornament, very fine radial lines; figured specimen, USNM 218008b, Sample 12-1, 88-92 cm.

Figures 21-23 — *Aucellina* n. sp., ex. gr. *A. gryphaeoides* (Sowerby); internal mold, right valve, shell preserved dorsally; figured specimen, USNM 218001, from Sample 12-2, 26-31 cm.
21. Partial right lateral view (×4), anterior auricle and byssal notch, showing ctenolium.
22. Right lateral view (×4), dorsal one-half, showing auricle, byssal notch, umbonal ornament.
23. Right lateral view (×2), entire specimen before preparation of byssal notch, showing adult concentric ornament.

PLATE 1

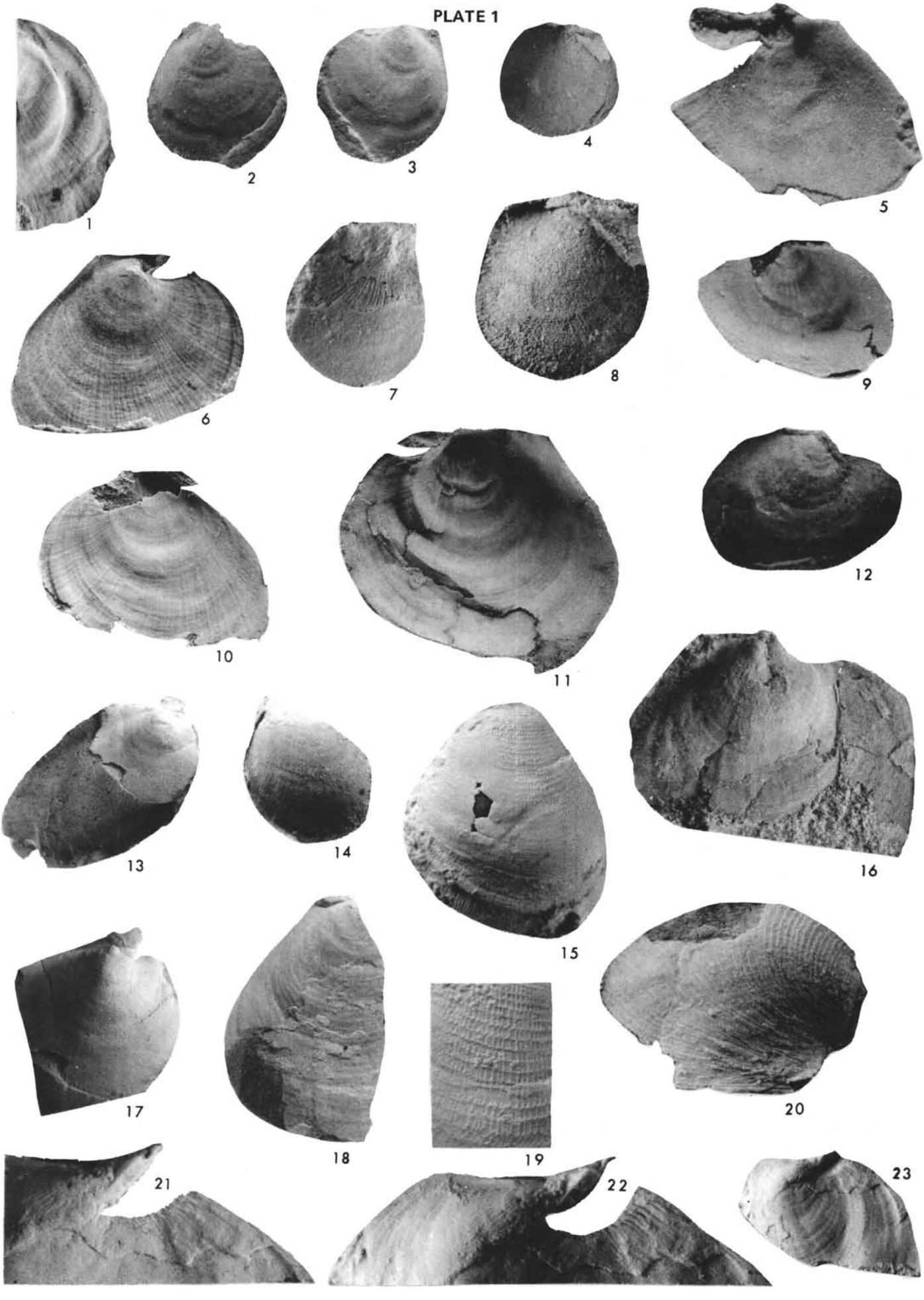


PLATE 2

Lower Cretaceous Bivalvia and Trace Fossils from Leg 33, Hole 317A

Figure 1 — *Pseudavicula* n. sp. (erect form); left lateral view (×2), left valve, internal mold with shell adhering dorsally; figured specimen, USNM 218025, from Sample 11-3, 64-73 cm.

Figures 2, 3 — *Pseudavicula* sp. aff. *P. anomala* (Moore); left valve showing typical form, ornament; from Sample 13-3, 90-93 cm.
2. Internal mold, left lateral view (×3), some shell adhering; figured specimen, USNM 218019a.
3. Partial external mold with shell, interior view, (×3); figured specimen, USNM 218019b.

Figures 4, 7, 8, 11 — *Pseudavicula pacifica* Kauffman, n. sp.
External mold, right valve, interior view (×5) showing posterior auricle, radial ornament; anterior auricle broken; counterpart of Holotype, USNM 218037b, from Sample 12-6, 85-93.
7. Right lateral view (×4), internal mold, right valve, with shell of anterior auricle preserved; Holotype, USNM 218037a; occurrence same as Figure 4.
8. Interior view (×5), external mold, right valve, showing even concentric ornament; beak and auricles broken; Paratype, USNM 218006b, Sample 11-3, 134-137 cm.
11. Right lateral view (×5), internal mold of Figure 8 with shell adhering ventrally, anterior auricle broken; Paratype, USNM 218013; occurrence same as Figure 8.

Figure 5 — *Neithea*? sp. indet., incomplete left valve, lateral view (×4), with typical ornament; figured specimen, USNM 218022, Sample 11-4, 50-56 cm.

Figure 6 — *Acesta* (*Costellacesta*?) sp. juv.; lateral view (×5), right valve, with typical ornament; figured specimen, USNM 218034, Sample 12-1, 121-128 cm.

Figure 9 — cf. *Electroma* sp.; lateral view (×2), crushed left valve, beak and posterior auricle missing; figured specimen, USNM 218040a, Sample 13-1, 108-114 cm.

Figure 10 — *Chondrites* sp.; partial slab with simply branching burrows filled with white chalk; figured specimen (×2), USNM 218049, Sample 12-5, 31-35 cm.

Figures 12, 13 — *Limopsis* (*Petunculina*) *delicatulus* Kauffman, n. sp.
12. Left lateral view (×3), incomplete left valve with small auricles, fine radial ornament; Paratype, USNM 218026, Sample 13-1, 108-114 cm.
13. Right lateral view (×2), incomplete coattached valves with shell intact, typical fine radiating costellae; Holotype, USNM 218024, Sample 12-6, 36-43 cm.

Figure 14 — *Verticordia*? sp. indet.; interior view (×8), incomplete right valve showing faint posterior costellae; beak, umbo broken off; figured specimen, USNM 218023b, Sample 11-4, 50-56 cm.

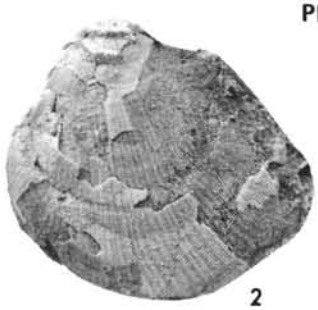
Figures 15, 18-21 — *Posterodonta manihikiensis* Kauffman, n. gen., n. sp., from Core 12, Section 6.
15. Interior view (×4), hinge area of figure 20, showing massive cardinal swelling, four inclined taxodont teeth, part of external ligamental groove; Holotype, USNM 218035a; interval 85-93 cm.
18. Internal mold, incomplete left valve, lateral view (×2), showing fine radial sculpture; Paratype, USNM 218029a; interval 114-116 cm.
19. Interior view (×2), counterpart shell of Holotype (Figure 20), showing radiating pallial muscle tracks along inner edge of pallial line, USNM 218035b; interval 85-93 cm.
20. Internal mold, right valve, lateral view (×4), shell outline typical; Holotype, USNM 218035a; interval 85-93 cm.
21. Partial internal mold, same as Figure 20 (×4), showing detail of radiating mantle muscle tracks inside pallial line; Holotype, USNM 218035a.

Figure 16 — *Limopsis* (*Petunculina*?) *undulorugosus* Kauffman, n. sp. Interior view (×2), external mold, incomplete left valve showing prominent rugae and faint radial costellae; Holotype, USNM 218008a, Sample 12-1, 88-92 cm.

Figure 17 — *Nucula* sp. A; internal mold, left valve, lateral view (×2), with opisthogyrous beaks; figured specimen, USNM 218020, Sample 11-5, 83-85 cm.

PLATE 2


1

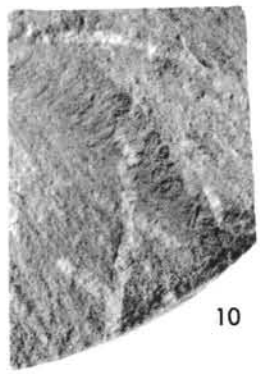

2


3


4


5


6

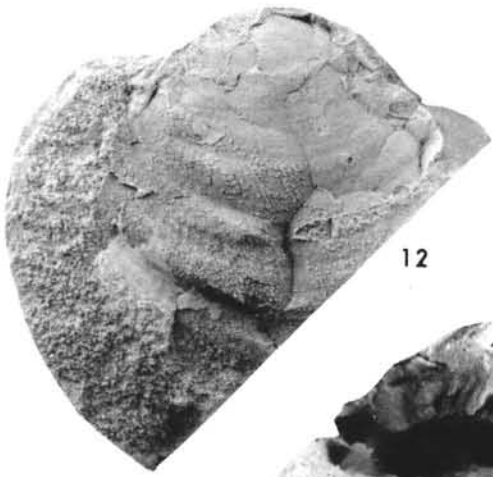

10


7

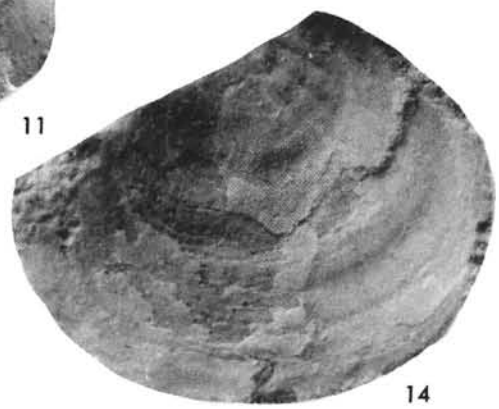

8


9


11


12


13


14


15


16


17


20


18


19


21

PLATE 3

Lower Cretaceous Bivalvia and *Serpula* from Leg 33, Hole 317A

Figure 1 — Oxytomidae? gen. indet., thin section (×80), transmitted light, through cross-foliated inner shell layer showing lenticular units of finer lamellar plates, gently dipping in opposing directions, from Sample 9-2, 114-117 cm. Photo courtesy of Dr. Hugh Jenkyns.

Figure 2 — *Inoperna*? sp. indet.; lateral view (×3), internal mold of incomplete right valve showing faint regular rugae, general elongate form, auricle; figured specimen, USNM 218017, Sample 12-6, 56-58 cm.

Figures 3, 8 — *Manihikia erecta* Kauffman, n. gen., n. sp.; interior view, right valve; Holotype, USNM 218036, Sample 12-1, 121-128 cm.
3. Complete interior of Holotype (×2), showing outline, faint radial and concentric ornament.
8. Hinge area, showing grooved massive cardinal teeth, external ligamental groove (×8).

Figure 4 — *Entolium* sp. cf. *E. gradatum* (Etheridge, Jr.), external mold of shell fragment (×8), with equal overlapping lamellae, faint radial ribs; figured specimen, USNM 218042, Sample 13-2, 78-83 cm.

Figure 5 — *Here*? (*Herella*?) *subpacifica* Kauffman, n. sp.; interior view (×6) right valve, showing weak dentition, faint radial ornamentation; Holotype, USNM 218008c, Sample 12-1, 88-92 cm.

Figure 6 — *Veniella*? sp. indet.; lateral view (×2), internal mold, right valve, showing casts of incised adductor muscles, entire pallial line, thick shell on beak; figured specimen, USNM 218014, Sample 16-2, 85 cm.

Figure 7 — *Serpula* sp. cf. *S. cretacea* (Conrad); tube fragment, lateral view (×3); figured specimen, USNM 218015, Sample 16-2, 97-100 cm.

Figure 9 — *Nucula* sp. B; internal mold, umbo and dorsoanterior flank broken, left valve (×4), showing faint concentric ornament; figured specimen, USNM 218031, Sample 13-2, 0-5 cm.

Figure 10 — *Tindaria*? sp. indet.; internal mold, lateral view (×2) right valve showing characteristic outline, swollen umbo; figured specimen, USNM 218012, Sample 12-1, 129-131 cm.

Figure 11 — *Limaria*? sp. indet.; external mold, right valve, interior view (×13), beak, umbo broken, showing typical ornament; figured specimen, USNM 218004, Sample 13-2, 78-83 cm.

Figures 12, 14, 17 — *Maccoyella* n. sp. A cf. *M. barklyi* (Moore); scanning electron micrographs of surface and fractured margin of inner shell layer showing concentric rows of cross-lamellar structure possibly originally composed of possible aragonite needles; figured specimen, USNM 218011, Sample 13-3, 90-93 cm.
12. Oblique side view of cross-lamellar structure, fractured surface (×6000).
14. Close-up (×3000) of three alternating rows of needles, from center of Figure 17.
17. General surface view (×680) of cross-lamellar structure.

Figure 13 — *Oxytoma* sp. indet.; internal mold, right valve (×15), tip of posterior auricle broken; figured specimen, USNM 218002, Sample 12-6, 43-47 cm.

Figure 15 — *Poromya* sp. indet.; shell fragment (×6), exterior view, showing regularly distributed surficial granules; figured specimen, USNM 218039, Sample 13-2, 78-83 cm.

Figure 16 — *Cardium* (S.L.) sp. juv.; internal mold, right valve, lateral view (×15), showing shape and strong costellae; figured specimen, USNM 218032, Sample 12-1, 121-128 cm.

PLATE 3