Eocene Mollusks From Eua, Tonga

GEOLOGICAL SURVEY PROFESSIONAL PAPER 640-C

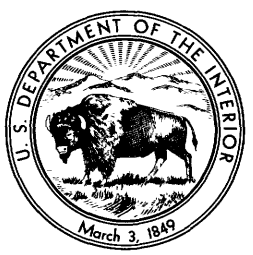
Eocene Mollusks From Eua, Tonga

By HARRY S. LADD

LATE EOCENE FOSSILS FROM EUA, TONGA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 640-C

Twenty-five mollusks are described from offreef tuffaceous limestone



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1970

UNITED STATES DEPARTMENT OF THE INTERIOR

WALTER J. HICKEL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

Library of Congress catalog-card No. 77–608174

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 55 cents (paper cover)

LATE EOCENE FOSSILS FROM EUA, TONGA—FOREWORD

One of the most widespread units of the Cenozoic section in the islands of the open Pacific is a series of limestones assigned to the upper Eocene (Tertiary *b*). Such limestones, containing diagnostic larger Foraminifera, have been reported in many parts of an area spreading 4,000 miles across the tropical Pacific (fig. 1), from Palau and the Mariana Islands on the northwest through the Marshall Islands (Eniwetok) to Fiji and Tonga on the southeast (Whipple, in Hoffmeister, 1932, p. 79–86; Asano, 1939; Cole, 1950, 1957a, 1957b, 1960). In almost all the islands the limestones are dense and crystalline. Foraminifera and algae are abundant locally, but in most places fossils cannot be extracted and must therefore be studied in random thin sections. On the little island of Eua, Tonga, a locality was recently found where the Eocene limestone is tuffaceous, considerably weathered, and richly fossiliferous. Abundant fossils that represent a dozen organic groups were found. Such abundance and diversity signaled the find as a remarkable one that would add greatly to our knowledge of life in the western Pacific during the Eocene.

The island of Eua measures only 12 by 5 miles but it rises 1,000 feet above sea level. It occupies an interesting position tectonically, as its steep eastern side faces the Tonga Trench. In addition, Eua is the oldest island in the Tonga group that has a plutonic core (Guest, 1959) and a series of associated volcanic rocks, which are partly blanketed by thick limestones of late Eocene age. Younger volcanic rocks and sediments of late Tertiary age are also present (Hoffmeister, 1932).

This series of reports is concerned with one facies of the upper Eocene limestone. After the limestone series was deposited, Eua was uplifted periodically and a sequence of six terraces was cut in the limestones on the windward (eastern) side. Hoffmeister was the first to recognize the Eocene age of the main limestone of the terraces, three of which have veneers of Pliocene reef corals. He made a planetable map of the terraced eastern ridge and recorded the average altitudes of the terraces as 100, 200, 340, 400, 550, and 760 feet. The east-facing "rocky backbone" of Eua thus looks in profile like a giant staircase facing the Tonga Trench. The Eocene limestone may once have covered all of Eua but is now largely limited to the eastern ridge (Hoffmeister, 1932; the Eocene Foraminifera were described by Whipple in this same report, p. 79–86).

The fossils described in this series of reports were obtained from an outcrop on the 400-foot terrace about a quarter of a mile north of Vaingana (fig. 2). At this locality, the limestone lies close to the underlying volcanic rock and is tuffaceous and partly weathered; almost everywhere else on Eua the limestone is pure, hard, and crystalline.

In 1943, Harold T. Stearns, then of the U.S. Geological Survey, also served as a consultant to the Armed Forces at Pacific bases and made a brief visit to Eua. He collected a sample that contained half a dozen fossil brachiopods from the 400-foot terrace on the eastern side of the island. Stearns recorded the locality as: "Tele-a-hiva at elevation of 400 feet about ½ mile north of army lookout tower, at the second stream north of Vaigana [sic]." The brachiopods were examined by G. A. Cooper of the U.S. National Museum. Some years later when I was studying other island fossils collected by Stearns, Cooper showed me the brachiopods and expressed a desire for additional specimens so that he could continue his study of their internal structures.

In 1966, I learned that Yoshio Kondo of the Bernice P. Bishop Museum in Honolulu intended to visit Eua in connection with his studies of living Pacific island land snails (under National Science Foundation grant GB–3974). I sent Stearns' locality data and marked copy of Hoffmeister's Eua map to Kondo, and I informed Stearns of the plan to collect additional material.

Late in August 1967, Kondo reached Eua and, aided by a Tongan guide, Tomiki, and an interpreter, Moʻese Vea, spent 2 days searching for the fossil locality. The lookout tower mentioned by Stearns no longer exists and Kondo found that Tele-a-hiva translates to "Nine Gulches." Traveling northward from "Vaigana" (Otu Vaingana) through heavy brush on exceedingly rugged karst topography for about 1,000 feet, he reached the first of the gulches. There he found a soft fossiliferous layer between two harder limestones and collected a

40-pound sample of the material. This gulch locality is probably not the exact spot visited by Stearns. The two collections have minor differences in nature of preservation, but they obviously came from the same formation.

The exact extent of the richly fossiliferous bed is not known but it is probably limited both horizontally and vertically. In 1926, when Hoffmeister made his map of the terraces, he did not come upon this facies, and in 1928 when I spent 2 weeks on Eua with Hoffmeister, reviewing his mapping, no exposures of this zone were seen although we visited Vaingana. Addi-

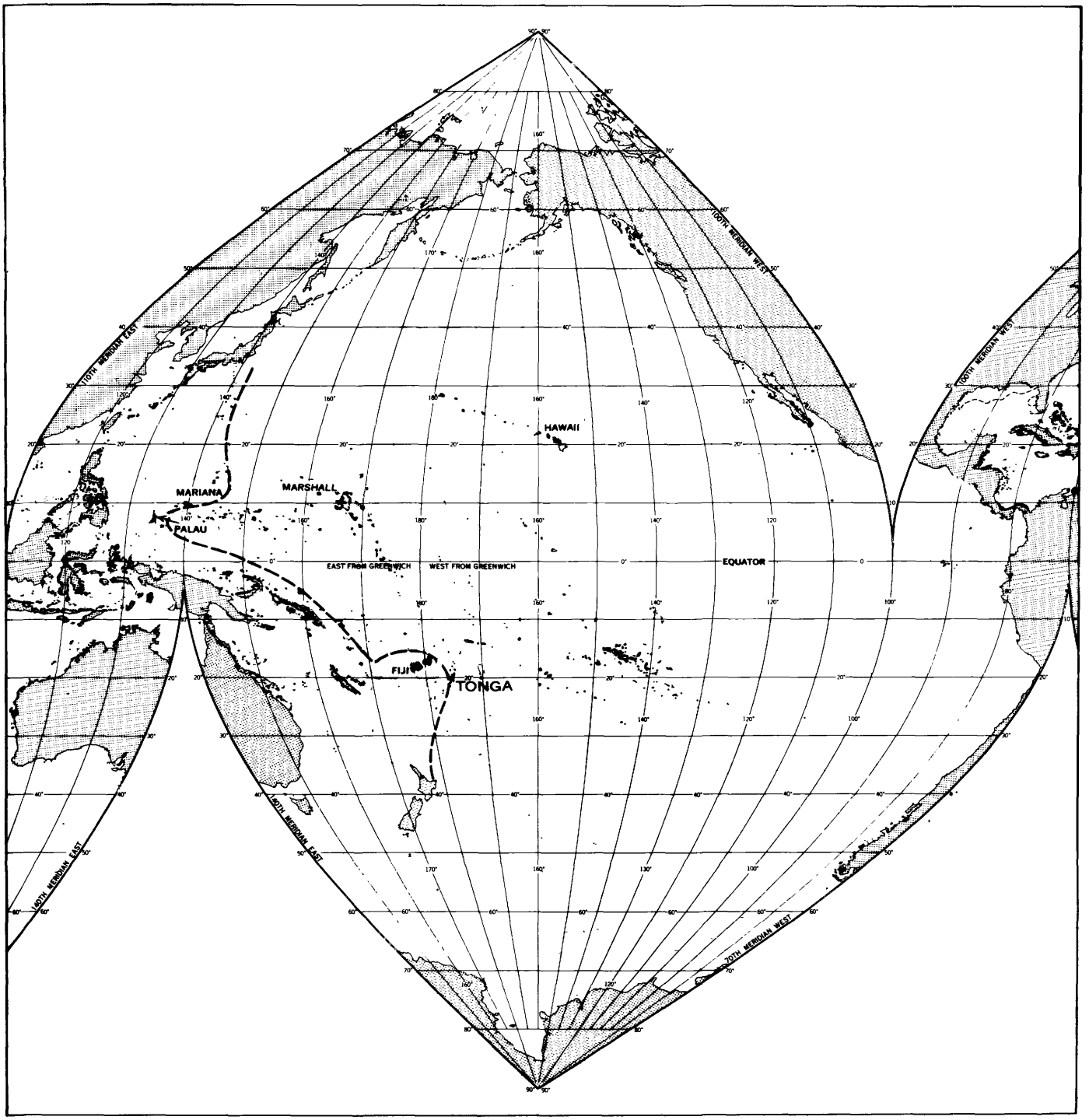


FIGURE 1.—Location of Tonga and other island groups in the southwest Pacific where upper Eocene limestone has been identified. Dashed line marks structural boundary of the Pacific Basin (andesite line). Islands shown include the surrounding reefs.

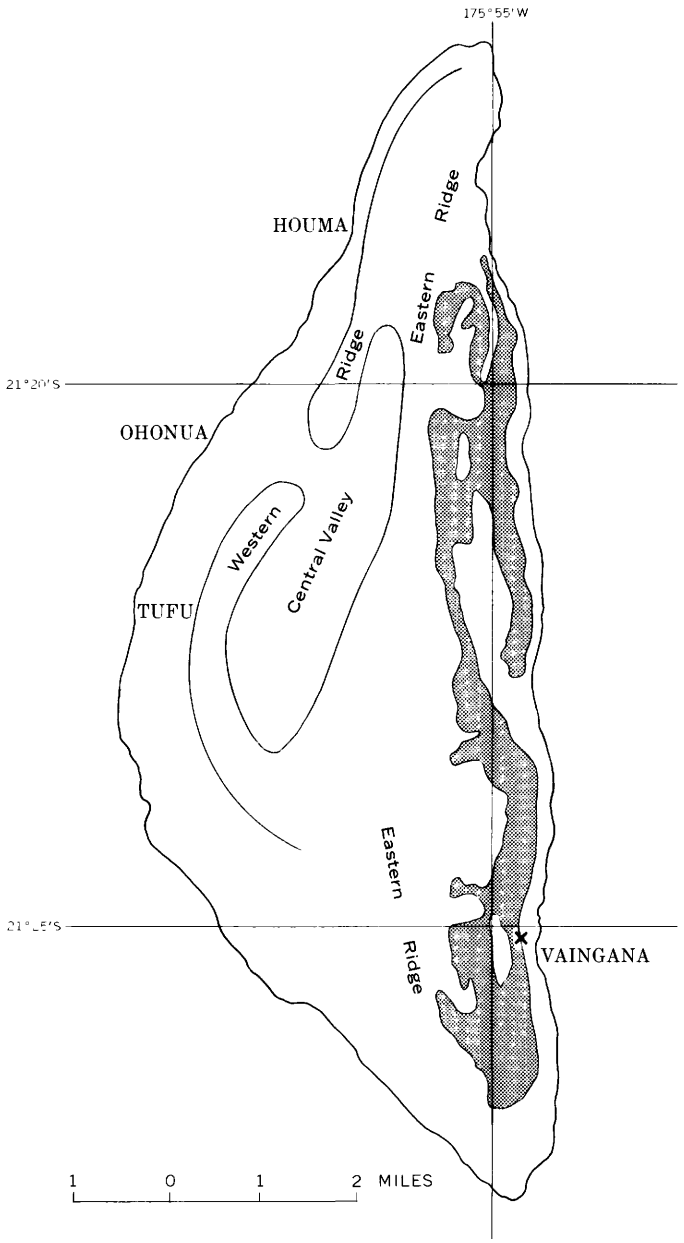


FIGURE 2.—Map of Eua, Tonga, showing the location of the recently discovered fossil outcrop (×) and the main mass of Eocene limestone (patterned area) on the east side of the island, as mapped by Hoffmeister (1932).

tional fieldwork in the area of the rugged "Nine Gulches" would be worthwhile.

William Melson of the Smithsonian Institution examined hand specimens and thin sections of the tuffaceous limestone and noted that the volcanic constituents are highly altered, making it difficult to determine their original nature. The rock is composed of 50 percent or more of volcanoclastic debris, much of which has been replaced by calcite. The predominant volcanic fragments are of porphyritic pumiceous glassy material; most of the phenocrysts are plagioclase, now largely replaced by calcite. The original groundmass of pumiceous glass is now devitrified and dark brown. Fragments of tuff are rare. There appears to be a large and varied assemblage of secondary minerals. The volcanic fragments are mainly porphyritic andesitic rocks, or possibly plagioclase-bearing dacites. The presence of abundant fossils suggests that the volcanic material has been reworked.

The soft tuffaceous limestone collected by Kondo was treated with a wetting agent and penetrant in the laboratory. The material broke down easily, revealing a variety of fossil remains: Foraminifera, discoasters, corals, hydrozoans, brachiopods, bryozoans, annelids, crinoids, echinoids, ostracodes, barnacles, decapod crustaceans, mollusks, shark teeth, otoliths, and spores and other plant microfossils.

W. Storrs Cole has described the larger Foraminifera; these fossils suggest to him a depth of deposition of about 200 feet, but other groups—notably the smaller Foraminifera, the corals, brachiopods, bryozoans, mollusks, ostracodes, and barnacles—point to a considerably greater depth of deposition.

Material representing a total of 17 organic groups was distributed to paleontologists for study and report. Seven of these collections were small or were made up of incomplete specimens leading only to summary reports, but the others, except for the larger Foraminifera, contained much new material. The brachiopod, bryozoan, ostracode, barnacle, and mollusk collections contained the first identifiable Eocene species from the islands of the open Pacific, an area extending 4,000 miles from Palau to Tonga.

HARRY S. LADD

CONTENTS

ILLUSTRATIONS

[Plates 1-5 follow index]

TABLES

EOCENE MOLLUSKS FROM EUA, TONGA

By HARRY S. LADD

ABSTRACT

Twenty-five mollusks have been recovered from tuffaceous limestones of late Eocene age; 22 are gastropods, three are pelecypods. Nine species, all gastropods, are described as new. The assemblage suggests a depth of water of about 100 fathoms. A few shells suggest shallow water, but most of these are worn and probably have been carried in.

INTRODUCTION

The geographic and stratigraphic position of the fossiliferous beds and the circumstances leading to the collection of the material are discussed under the heading "Foreword." The rock is a tuffaceous limestone containing abundant fossils that represent many organic groups (pl. 1).

Eocene mollusks are known to occur in the crystalline limestones of Palau, the Mariana Islands (Cloud and others, 1956, p. 50), and the Marshall Islands (Ladd and Schlanger, 1960, p. 894–895). Several fossil mollusks from the limestones of Makatea in the Tuamotu Archipelago are said to have an Eocene aspect but they have not been fully described (Repelin, 1919). Some of the Marshall Island shells have been identified, but descriptions have not yet been published. No closely comparable Eocene deposits have been described from Pacific islands, but water-laid tuffaceous rocks carrying well-preserved and abundant late Eocene Foraminifera have been reported from Guam (Cloud and Cole, 1953), and forereef outer slope limestone with corals, algae, and Eocene Foraminifera has been described from Eniwetok (Schlanger, 1963, p. 999–1002).

ACKNOWLEDGMENTS

I am indebted to Dr. Yoshio Kondo of the Bernice P. Bishop Museum, Honolulu, Hawaii, and his field assistants, Tomiki and Mosese Vea, for collecting the Tongan material. Warren Blow of the U.S. Geological Survey prepared most of the fossils herein described. All photographs were made by Robert H. McKinney of the Geological Survey, some being retouched by Mrs. Elinor Stromberg, also of the Geological Survey. During the preparation of the paper, helpful discussions were held with Drs. Harald Rehder and J. P. E. Morrison of the U.S. National Museum and with Norman Sohl and Druid Wilson of the Geological Survey. The paper has benefited from critical reviews by Mrs. Katherine V. W. Palmer and A. A. Olsson of the Paleontological Research Institution, Ithaca, N.Y.

AGE AND CONDITIONS OF DEPOSITION

On the basis of nonmolluscan fossils, the age of the Eua deposits is fairly well established as late Eocene (Tertiary *b*). Both smaller and larger Foraminifera support this interpretation (Todd, 1970; Cole 1970). Evidence from the calcareous nannoplankton is in general agreement with this determination, though an age of earliest Oligocene seems possible (M. N. Bramlette, in Todd, 1970, p. A18).

The molluscan fauna contains a variety of Cenozoic genera and subgenera, many of which go back at least to Eocene times (table 1). None of the mollusks can be identified with still-living species, but the assemblage does not have a characteristic "Eocene look." The Tongan mollusks are thought to have lived in deeper waters than most Eocene mollusks from other areas, which may account for their more youthful appearance.

As recorded in the descriptions to follow, a variety of mollusks, mostly small, has been recovered and identified, generically or specifically. In addition, there are numerous sculptured shell fragments, mostly gastropods, and many molds of minute mollusks, both gastropods and pelecypods. More than half of the identified mollusks are represented by a single specimen, and many of these are incomplete.

Mollusks commonly found in the shallow waters over reef flats and in lagoons are sparsely represented. The nine species described as new are listed with their living relatives in table 2. The relationship is fairly close in four species, less close in four others, and rather distant

387-857 O—70——2

TABLE 1.—*Geologic range of genera and subgenera of mollusks from Eua, Tonga*

	Cretaceous	Eocene	Oligocene	Miocene	Pliocene	Pleistocene	Holocene
Scissurella (Anatoma)					—	—	—
Sinezona					—	—	—
Basilissa (Ancistrobasis)							—
Bathybembix			—	—	—	—	—
Turcica (Perrinea)				—	—	—	—
Astele (Callistele)				—	—	—	—
Astraea (Bolma)				—	—	—	—
Pareuchelus?		—	—	—	—		
Daronia (Daronia)							—
Munditiella				—	—	—	—
Lydiphnis		—	—	—	—	—	—
Mathilda (Fimbriatella?)		—	—	—	—		
Gegania	—	—	—	—	—	—	—
Epitonium (Boreoscala?)		—	—	—	—	—	—
Xenophora	—	—	—	—	—	—	—
Pedicularia (Pedicularia)				—	—	—	—
Latirus	—	—	—	—	—	—	—
Hastula		—	—	—	—	—	—

in one species (*Gegania*). All but three of the related Holocene species are from the Indo-Pacific. Five of the new fossil species are represented in the collection by a dozen or more specimens, and living relatives of four of these species range into fairly deep waters. It is difficult to evaluate the molluscan evidence, but it seems probable that the limestone represents offreef deposition at a depth of about 100 fathoms.

TABLE 2.—*Distribution and depths of living relatives of new Eocene species from Eua, Tonga*

Eua Eocene species	Living relative	Area	Depth (fathoms)
Scissurella (Anatoma) tongaensis.	*S. proxima* Dall	Atlantic	20–434
Do	*S. regia* Mestayer	New Zealand	73–100
Sinezona kondoi	*S. brevis* (Hedley)	New Zealand	50
Basilissa (Ancistrobasis) pacifica.	*B. costulata* Watson.	Caribbean	15–640
Turcica (Perrinia) blowi	*T. (P.) morrisoni* Ladd	Marshall Islands	0–30
Astraea (Bolma) stearnsi	*A. (B.) bartschi* (Dall)	Molucca Islands	205
Daronia (Daronia) hoffmeisteri.	*D. jaffaensis* (Verco)	Australia	50–90
Munditiella euaensis	*M. qualum* (Hedley)	Funafuti	(1)
Lydiphnis vainganaensis	*L. euchilopteron* (Melvill and Standen).	Gulf of Oman	156
Gegania whipplei	*G. pinguis* Jeffrey	Atlantic	740–1425

[1] Beach.

SYSTEMATIC PALEONTOLOGY

Family SCISSURELLIDAE

Genus SCISSURELLA d'Orbigny

d'Orbigny, 1823, Soc. Hist. nat. Paris Mem., v. 1, p. 343.

Type (by subsequent designation, Gray, 1847, List of genera of Recent Mollusca, p. 146): *Scissurella laevigata* d'Orbigny. Living, Mediterranean Sea.

Scissurella s.s. is characterized by a flattened spire and a slit high on the whorl.

Subgenus ANATOMA Woodward

Woodward, 1859, Zool. Soc. London Proc., p. 204.

Type (by original designation): *Scissurella crispata* Fleming. Living, North Sea.

Anatoma has a slightly elevated spire and a slit near the middle of the whorl.

Scissurella (Anatoma) tongaensis Ladd, n. sp.

Plate 2, figures 1–4

Shell small, spire moderately high, composed of 3½ whorls, body whorl large, suture distinct. Periphery of whorl near the midpoint, bearing a strong carina, above and below which the surface of the whorl is gently convex; aperture broadly elliptical, inner lip extended below. Sculpture consisting of fine close-set slightly flexuous axial threads.

Measurements.—Holotype, USNM 650547: diameter 2.0 mm, height 1.6 mm. Paratype, USNM 650548: diameter 2.1 mm, height 1.9 mm.

The Tongan fossil closely resembles the living *Scissurella proxima* Dall (1927, p. 10) that occurs in the eastern Atlantic, but the inner lip of the fossil is more deeply extended below; the fossil bears stronger axial threads below the peripheral carina, but lacks the spiral sculpture shown by *S. proxima*. *S. tongaensis* also closely resembles *S. regia* Mestayer (1916, p. 124, pl. 12, figs. 3–3c; 1919, p. 130) but lacks the spiral lirae ascribed to the Holocene species from the New Zealand area.

Occurrence.—Represented by 50 specimens, none of which shows a complete aperture.

Genus SINEZONA Finlay

Finlay, 1926, New Zealand Inst. Trans., v. 57, p. 341.

Type (by original designation): *Schismope brevis* Hedley. Living, New Zealand.

Sinezona kondoi Ladd, n. sp.

Plate 2, figures 5–8

Shell small, spire composed of 3½ whorls, nearly flat; apex depressed, body whorl flattened above, broadly rounded below, these two parts of the whorl separated by a prominent selenizone that is perforated near the aperture by an oval foramen. Protoconch smooth, whorls of spire with sharply raised regularly spaced axial ribs that are of equal prominence above and below the selenizone; axials conspicuously beaded where crossed by fine spiral threads. Umbilicus narrow, deep, smooth within, bordered by a sharply elevated edge. Aperture elongate-oval.

Measurements.—Holotype, USNM 650549: diameter 1.7 mm, height 1.2 mm. Paratype, USNM 650550: diameter 1.6 mm, height 1.3 mm.

The Tongan fossil closely resembles the type of the genus, *S. brevis* (Hedley) (1904, p. 90, fig. 16), but is much more sharply angled at the selenizone than is the shell of the living species from New Zealand.

Occurrence.—Represented by 13 specimens. The genus has not previously been reported prior to the Pliocene. This species is named for Dr. Yoshio Kondo of the Bishop Museum through whose efforts the Tongan material was collected.

Family TROCHIDAE

Genus BASILISSA Watson

Watson, 1879, Linnean Soc. London Jour., v. 14, p. 593.
Type (by subsequent designation, Cossmann, 1888, Catatogue illustre des coquilles fossiles de l'éocène * * * de Paris, v. 3, p. 68): *Basilissa superba* Watson. Holocene, Australia.

Basilissa s.s. has a strong peripheral carina.

Subgenus ANCISTROBASIS Dall

Dall, 1889, Harvard Univ. Mus. Comp. Zoology, Bull., v. 18, p. 32, 384.
Type (by monotypy): *Basilissa costulata* Watson. Holocene, Caribbean.

Basilissa (Ancistrobasis) pacifica Ladd, n. sp.

Plate 2, figures 9–11

Shell small, broadly conical, with a flattened base. Protoconch rounded and smooth, consisting of about 1½ whorls; spire of about four gently convex whorls. Sculpture consisting of close-set, sinuous axial ribs that are slightly beaded where they cross finer and more numerous spirals. On some shells, one or two spirals near the middle of the whorl are larger than the others and are more conspicuously beaded where crossed by the axials. Suture prominent; periphery of body whorl pinched to a sharp edge; base flattened and spirally ribbed; umbilicus wide and deep; aperture subquadrate, columella smooth, gently curved.

Measurements.—Holotype, USNM 650560: height 1.6 mm, diameter 2.3 mm. Paratype, USNM 650561: height 1.3 mm, diameter 2.0 mm.

Basilissa (*Ancistrobasis*) *pacifica* resembles *B.* (*A.*) *costulata*, the Holocene type species of *Ancistrobasis*, in important features, but it is a smaller shell and the whorls of the spire are inflated, whereas the spire in *B.* (*A.*) *costulata* is slightly concave; likewise, the base of the fossil shell is more inflated than that of the living species.

I have not seen specimens of *B. cossmanni* Tate from the Eocene of Australia (Tate, 1894, p. 185, pl. 11, fig. 8) but it appears to be a larger shell with a higher and more flat-sided spire than that of the Tongan species.

Occurrence.—Represented by a dozen specimens. The related living species, *B.* (*A.*) *costulata*, has been collected from a number of stations ranging in depth from 119 to 640 fathoms and from one station at a depth of only 15 fathoms (Dall, 1881, p. 48; Watson, 1886, p. 103).

Genus BATHYBEMBIX Crosse

Crosse, 1892, Jour. Conchyliologie, v. 40, p. 288–292.
Type (by original designation): *Bembix aeola* Watson. Holocene, Japan.

Bathybembix? sp.

Plate 2, figures 12, 13

The recrystallized tips of two trochid shells bear axial sculpture suggestive of that shown by several living species of *Bathybembix*, including the type, *B. aeola* (Watson). The figured specimen shows parts of six whorls that form a flat-sided cone below the eroded protoconch; each whorl bears about 20 regularly spaced axial ribs that cross the whorl without curvature; suture marked by a spiral ridge slightly stronger than the axial ribs.

Measurements.—Figured apical fragment, USNM 650559: diameter 2.0 mm, height 1.4 mm.

Bathybembix includes large, thin-shelled forms. The genus is known from Oligocene to Holocene. Living species are widely distributed, but none have been found in water shallower than 150 feet; from such depths they range to more than 3,000 feet. The small Tongan shell probably represents a related genus.

Genus TURCICA A. Adams

Adams, A., 1854, Zool. Soc. London Proc., p. 37.
Type (by monotypy): *Turcica monilifera* A. Adams. Holocene, Morton Bay, Australia.

Subgenus PERRINIA H. and A. Adams

Adams, H. and A., 1854, Genera of Recent Mollusca, v. 1, p. 419.
Type (by subsequent designation, Pilsbry, 1889, Manual of Conchology, v. 11, p. 15): *Monodonta angulifera* A. Adams. Holocene, Philippine Islands.

Turcica (Perrinia) blowi Ladd, n. sp.

Plate 2, figures 14–17

Shell small, conic, turreted; spire consisting of about three flattened whorls each with a prominent median carina that is extended into a series of flattened, triangular, and slightly upturned spines, 18 on the body whorl; at the base of the whorl a thin smooth carina extends outward beyond the median carina; between the median carina and the overlying suture are three secondary spirals; a series of broad slightly oblique axial ribs extend across the upper part of the whorl to the turned-up extensions of the median carina and continue as weakened axials to the peripheral carina; base convex, covered by threadlike spirals that are

strongest near the periphery; suture deeply impressed; aperture subquadrate; imperforate; outer lip extended below; columella heavy with an obscure tooth near its base.

The apical whorl of the paratype shows traces of fine axial sculpture.

Measurements.—Holotype, USNM 650567: height 1.5 mm, diameter 1.7 mm. Incomplete paratype, USNM 650568: height 1.4 mm, diameter 1.0 mm.

T. blowi resembles *T. morrisoni* Ladd that lives at shallow depths in the Marshall Islands and has been recovered from Holocene and Miocene (Tertiary *f*) sediments in drill holes there (Ladd, 1966, p. 36, pl. 3, fig. 18, pl. 4, figs. 1–5). The Tongan shells are smaller than those of *T. morrisoni*, have a more prominent basal carina, weaker spirals on the base, and lack the apertural lirae that are present in *T. morrisoni*.

Two specimens were recovered, one being incomplete. The species is named for Warren C. Blow of the U.S Geological Survey, who prepared most of the material recently collected at Vaingana.

Genus ASTELE Swainson

Swainson, 1855, Royal Soc. Van Diemensland Papers, v. 3, p. 38.
Type (by monotypy): *Trochus subcarinatus* Swainson, Holocene, Tasmania.

Subgenus CALLISTELE Cotton and Godfrey

Cotton and Godfrey, 1935, South Australian Naturalist, v. 16, no. 2, p. 20.
Type (by original designation): *Astele calliston* Verco. Holocene, Australia.

Astele (Callistele) sp.

Plate 3, figures 1–3

Shell minute, trochoid spire with gently convex base; aperture subquadrate; umbilicus moderately wide and deep. Sculpture consisting of fine spiral threads, about six on the lower flat half of each whorl with additional but more obscure threads on the upper slightly concave half; coarse wavy axial threads are distantly but regularly spaced over all whorls; they override the spiral threads but are not beaded at the crossings; axial threads thicken near periphery, causing scallops in its sharp edge; base with three prominent spiral riblets, two near the periphery, the third close to a coarse beaded rib that descends into the umbilicus.

Measurements.—Figured specimen, USNM 650578: height (incomplete) 1.2 mm, diameter 1.7 mm.

The Tongan fossil resembles *Astele* (*Callistele*) *engebiensis* Ladd (1966, p. 37, pl. 4, figs. 11–13) in many important features but differs from this form and from the type species by the possession of the sinuous axial threads. The single incomplete Tongan specimen is made up of three whorls. It probably represents an undescribed form, but a name is withheld pending the discovery of better type material.

Family TURBINIDAE

Genus ASTRAEA Röding

Röding, 1798, Mus. Boltenianum, pt. 2, p. 79.
Type (by subsequent designation, Suter, 1913, Manual New Zealand Mollusca, p. 166): *Trochus imperialis* Gmelin=*T. heliotropium* Martyn. Holocene, New Zealand.

Subgenus BOLMA Risso

Risso, 1826, Hist. nat. des principales productions de l'Europe méridionale * * *: v. 4, p. 117.
Type (by monotypy): *Turbo rugosa* Linnaeus. Holocene, Mediterranean and eastern Atlantic.

Astraea (Bolma) stearnsi Ladd, n. sp.

Plate 3, figures 6, 7

Shell small, trochoid; protoconch, of about one whorl, depressed; spire turreted, consisting of about five flat-sided whorls; suture wide and deep; base gently convex, nonumbilicate; aperture subcircular, columella arcuate, smooth. The first two whorls of the spire nearly smooth but with traces of axial sculpture and an incipient peripheral cord that becomes a strong, beaded structure on later whorls; all but the earlier whorls bear four spiral lines of coarse beads in the flattened area between the periphery and the suture. Body whorl flattened below the periphery to form a wide band that carries three spiral rows of coarse beads; at the base of the band there is a beaded cord stronger than those lying above; below this cord the base is smooth.

Measurements.—Holotype, the only specimen, USNM 650566: diameter (incomplete) 9.0 mm, height 11.2 mm.

The subgenus *Bolma* has been recorded from the Miocene of Europe, but it has not previously been reported from the Eocene. The Tongan shell is the first fossil occurrence from the Pacific.

The nearest living relative of the Tongan fossil is *Bolma bartschi* Dall (1913, p. 591; 1926, p. 6, pl. 36, fig. 9) based on a single shell dredged alive from a depth of 205 fathoms in the Moluccas. The Holocene shell is much larger than the fossil, and there are differences in sculpture: the living species, for example, lacks the strong beaded spirals on the body whorl below the periphery; it has, instead, numerous wavy spiral threads.

A. (*B.*) *stearnsi* is named for Dr. Harold T. Stearns who collected the first megafossils from the rich Vaingana locality in 1943.

Genus PAREUCHELUS O. Boettger

Boettger, O. 1907, Mitt. siebenb. ver. für Nat. zu Hermannstadt Verh., v. 55, p. 187.
Type (by original designation) : *Euchelus excellens* O. Boettger. Miocene, Hungary.

Pareuchelus? sp.

Plate 3, figures 8–10

Shell minute, globose, slightly turreted, higher than wide. Protoconch not preserved; spire consisting of about four inflated whorls, separated by a deep suture. Sculpture consisting of strong spiral keels, six above the base on the body whorl, the lower four coarser than the upper two, crossed and slightly beaded by close-set, regularly spaced, sharp, oblique axial ribs; base moderately convex; sculpture the same as rest of whorl, but more subdued; nonumbilicate; aperture rounded above, its lower edge extended to below the columella to form a right-angled plate.

Measurements.—Figured specimen, USNM 650577: height (incomplete) 1.5 mm, diameter 1.5 mm.

Occurrence.—Four incomplete specimens appear to represent an undescribed species, but a name is withheld pending the recovery of satisfactory type material.

Pareuchelus has a reported range of Eocene to Pliocene and is known from Europe and Indonesia (Keen, 1960, p. I267).

Family ADEORBIDAE

Genus DARONIA A. Adams

Adams, A., 1861, Annals Mag. Nat. History, 3d ser., v. 8, p. 244.
Type (by original designation) : *Cyclostrema spirula* A. Adams. Holocene, southwest Pacific.

Subgenus DARONIA s.s.

Daronia (Daronia) hoffmeisteri Ladd, n. sp.

Plate 3, figures 11–13

Shell small, spire depressed, planorboid, diameter approximately twice the height; protoconch smooth, followed by 2½ rounded whorls; suture impressed; aperture circular, oblique, peristome continuous; umbilicus wide and deep, bounded by a distinct spiral; sculpture consisting of faint lines of growth.

Measurements.—Holotype, USNM 650554: height 0.9 mm, diameter 1.9 mm.

The type of *Daronia* is a larger shell than the species here described; it is spirally striate and its last whorl becomes disjointed.

D. hoffmeisteri appears to be closely related to *D. jaffaensis* (Verco), dredged off the coast of South Australia in 90 fathoms of water (Verco, 1909, p. 270, pl. 20, figs. 6, 7) and off Tasmania at depths of 50–80 fathoms (Cotton, 1945, p. 158); Cotton chose it as the type of *Eudaronia*. *D. jaffaensis* has a spiral cord above in addition to the one bounding the umbilicus, and it has a reniform aperture with incomplete peristome.

Occurrence.—This is the most abundant mollusk in the fauna, being represented by more than 100 specimens. It is named for Dr. J. Edward Hoffmeister who mapped the island of Eua and determined its geologic history.

Genus MUNDITIELLA Kuroda and Habe

Kuroda and Habe, 1954, Venus, v. 18, no. 2, p. 86, 90–91.
Type (by original designation) : *Cyclostrema ammonocercs* A. Adams. Holocene, Japan.

Munditiella euaensis Ladd, n. sp.

Plate 3, figures 14–16; Plate 4, figures 1–3

Shell small, diameter exceeding height, upper part of spire nearly flat, body whorl descending; suture impressed; aperture semicircular, inner lip greatly extended below; umbilicus moderately wide and deep. Sculpture consisting of erect, regularly spaced axial ribs, about 20 on body whorl, that extend entirely across the exposed parts of all whorls.

Measurements.—Holotype, USNM 650564: diameter 1.5 mm, height 1.2 mm. Paratype, USNM 650565: diameter 1.4 mm, height 1.0 mm.

M. euaensis resembles *M. parryensis* Ladd (1966, p. 78), a species known from the Holocene and late Miocene (Tertiary *g*) of the Marshall Islands, but lacks the secondary axial lines and the obscure spiral ridges of that species. *M. euaensis* is smaller than the Holocene *M. qualum* (Hedley) that has been reported from the Pleistocene of Tongatapu, Tonga, and Eniwetok, Marshall Islands (Ladd, 1966, p. 77), and there are differences in sculpture: on *M. qualum* there are spiral threads and secondary axial threads, and the body whorl is flattened and free of axial ribs immediately below the suture and around the umbilicus. *M. euaensis* also resembles a living species from Hong Kong described by Gould (1859, p. 142) as *Liotia asteriscus*, but that species has a carinated body whorl with a spiral rib that encircles the umbilicus.

Occurrence.—Represented by 15 specimens, none of which is complete. The nearest living relative, *M. qualum*, was collected by Hedley (1889, p. 406) from sands on the lagoon shore of Funafuti. The Tongatapu and Marshall Island occurrences are in shallow-water limestones.

Genus LYDIPHNIS Melvill

Melvill, 1906, Malacological Soc. London Proc., v. 7, p. 25.
Type (by monotypy) : *Cyclostrema euchilopteron* Melvill and Standen. Holocene, Gulf of Oman.

Lydiphnis vainganaensis Ladd, n. sp.

Plate 4, figures 4–6

Shell small, nummuloidal; spire strongly depressed, consisting of a small rounded protoconch and two to

three subsequent whorls; body whorl with two strong spiral keels that project from sharp peripheral angles above and below; a third but less sharply elevated keel is on the upper surface of the whorl midway between periphery and suture; upper surface of whorl marked with oblique lines of growth; aperture subquadrate, umbilicus wide and deep.

Measurements.—Holotype, USNM 650576: height 0.8 mm, diameter 2.2 mm.

L. vainganaensis is similar to the Holocene type species but lacks the strong secondary spiral sculpture of that species. It is proportionately lower (flatter) than *L. novi-castri* (Van Winkle) (1919, p. 9, pl. 1, figs. 11, 12; Palmer, 1937, p. 48, pl. 2, figs. 4, 5) from the Eocene of Virginia.

Occurrence.—Represented by four nearly complete specimens and two internal molds of calcite.

Family MATHILDIDAE

Genus MATHILDA Semper

Semper, 1865, Jour. Conchyliologie, v. 13, p. 330

Type (by subsequent designation, Cossmann, 1888, Catalogue illustré des coquilles fossiles de l'Éocène * * * de Paris, v. 3, p. 309): *Turbo quadricarinatus* Brocchi. Pliocene, Sicily.

Subgenus FIMBRIATELLA Sacco

Sacco, 1895, Molluschi * * * del Piemonte e della Liguria, pt. 19, p. 36.

Type (by original designation): *Cerithium fimbriatum* Michelloti. Late Miocene, Italy.

Mathilda (Fimbriatella?) sp.

Plate 4, figure 7

Two incomplete shells have the unusual sculpture that seems to characterize *Fimbriatella.* Each of the several whorls bears a strong beaded spiral rib that caps a broad spiral ridge one-third of the distance above the suture. In the narrow band below this major spiral is a single secondary spiral; in the broader band above, there are two secondary spirals. Surface of shell cancellated by fine regularly spaced axial threads that cross the spirals at right angles and bead them in the process.

Measurements.—Figured specimen, USNM 650551: height (incomplete) 2.5 mm, diameter 1.4 mm.

Species of *Fimbriatella* have been reported from all parts of the Tertiary—Paleocene to Pliocene (Sohl, 1960, p. 129).

Genus GEGANIA Jeffreys

Jeffreys, 1884, Zool. Soc. London Proc., p. 365, pl. 27, fig. 10.

Type (by monotypy): *Gegania pinguis* Jeffrey. Holocene, Atlantic.

Gegania whipplei Ladd, n. sp.

Plate 4, figures 8–11

Shell small and delicate; protoconch composed of four slightly inflated whorls covered by close-set slanted axial riblets and arranged in an acute, heterostrophic coil; spire short, made up of about four inflated whorls, the body whorl larger than all the others combined: suture wide and deep; aperture elliptical, outer lip thin, inner lip reflected toward deep umbilicus. Sculpture reticulate, consisting of fine close-set spiral threads that are overridden but not beaded by more widely spaced axial threads.

Measurements.—Incomplete holotype, USNM 650574: height 1.7 mm, diameter 1.2 mm. Figured paratype, USNM 650575: height (incomplete) 2.6 mm, diameter 1.9 mm.

The Tongan species with its multiwhorled, heterostrophic protoconch and its prominent umbilicus is not a typical *Gegania.* It also differs from the type species and others of the genus by having axial threads that are less numerous than those in the spiral series.

Occurrence.—Represented by a total of eight specimens. All seem smaller than the average of the genus, but they probably are mature shells. The species is named for the late G. Leslie Whipple who was the first to recognize Eocene fossils from Eua.

Family CERITHIOPSIDAE

Genus CERITHIOPSIS s.l.

Cerithiopsis sp.

Plate 4, figure 12

A single incomplete specimen of a cerithiopsid consists of four whorls of a small slender shell; each whorl has two major beaded spirals, the lower one much the larger; immediately above the suture is a weak spiral thread; base flattened, aperture subcircular.

Measurements.—USNM 650573: height (incomplete) 2.4 mm, diameter 0.9 mm.

The sculpture suggests *Orthochetus* Cossmann, a Cretaceous to Eocene genus questionably assigned to the Cerithiopsidae by Wenz (1938, p. 779).

Family EPITONIIDAE

Genus EPITONIUM Röding

Röding, 1798, Mus. Boltenianum, pt. 2, p. 91.

Type (by subsequent designation, Suter, 1913, Manual of New Zealand Mollusca, p. 319): *Turbo scalaris* Linnaeus. Holocene, western Pacific.

Subgenus BOREOSCALA Kobelt

Kobelt, 1902, Iconographie der schalentragenden europäischen Meeresconchylein, v. 3, p. 23.

Type (by monotypy): *Scala groenlandica* Chemnitz (=*Scalaria greenlandicum* Perry). Holocene, circumpolar and south to northern Japan, New York.

Epitonium (Boreoscala?) sp.

Plate 4, figure 13

Fifteen incomplete specimens of a small epitonid are

tentatively referred to *Boreoscala*. The figured specimen shows six convex whorls that form an apical angle of 22°; suture prominent, aperture subcircular; imperforate. Sculpture consisting of numerous (19 on last whorl) erect, axial lamellae that are slightly bent backward; strong spiral threads between lamellae, with traces of secondary spirals.

Measurements.—Figured specimen, USNM 650572: height (incomplete) 4.5 mm, diameter 2.1 mm.

The Tongan species seems to agree in essential features with *E.* (*B.*) *greenlandicum*, the much larger type of *Boreoscala*. Other incomplete fossil shells have a more acute spire and may represent a second species.

Family XENOPHORIDAE

Genus XENOPHORA Fischer von Waldheim

Fischer von Waldheim, 1807, Muséum Demidoff, ou catalogue systématique et raissoné des curiosites de la nature, v. 3, p. 213.

Type (by ruling Internat. Comm. Zool. Nomenclature): *Trochus conchyliophorus* Born. Holocene, West Indies.

Xenophora sp.

Plate 3, figures 4, 5

Minute, spire of moderate height, base flattened, whorls gently convex; a prominent keel lies immediately above the suture; margin of keel scalloped; upper surface of whorls have subcircular depressed areas, apparently the scars of attached objects; base concave near periphery; umbilicate. Aperture ovate; part of specimen shows fine axial lines.

Measurements.—Incomplete figured specimen, USNM 650557: diameter 5.1 mm, height 3.3 mm.

Family OVULIDAE

Genus PEDICULARIA Swainson

Swainson, 1840, Treatise on malacology, p. 245, 357.

Type (by monotypy): *Pedicularia scitula* Swainson. Holocene, Mediterranean.

Subgenus PEDICULARIONA Iredale

Iredale, 1935, Australian Zoologist, v. 8, p. 101.

Type (by original designation): *Pedicularia stylasteris* Hedley. Holocene, Australia.

Pedicularia (Pedicullariona) sp.

Plate 4, figures 14, 15

A single, apparently worn, specimen is partly filled with tightly cemented material, obscuring internal features, but external features indicate clearly that the specimen is a pedicularid. The shell is subrectangular in outline with an undulating margin whose edge is thin anteriorly but thickened posteriorly. The apex is low; sculpture consists of somewhat irregular concentric growth lines and traces of radial threads; interior surface glossy.

Measurements.—USNM 650571: length 11.0 mm, width 3.7 mm, convexity 1.9 mm.

The Tongan fossil bears a general resemblance to the variable *P. pacifica* Pease (1868, p. 96, pl. 11, figs. 17, 18), a species now living in many parts of the western Pacific, but is more delicate, less convex, and lacks the median constriction that characterizes the living species. The genus has not previously been found below the Miocene. The occurrence in the Tongan Eocene is also of interest because species of *Pedicularia* live today on octacorals and scleractinians normally found well below coral reef depths.

FAMILY NATICIDAE

Genus NEVERITA Risso

Risso 1826,. Histoire naturelle des principales productions de l'Europe méridionale, v. 4, p. 149.

Type (by monotypy): *Neverita josephinia* Risso. Holocene, Mediterranean Sea.

Neverita? sp.

Plate 4, figure 16

A worn and partly crushed shell of a low-spired naticid is the only representative of the family Naticidae found in the Tongan Eocene collection. The occurrence is of interest, as the specimen is one of the largest mollusks in the collection and represents a group commonly found in the sands of shallow water.

The fossil has the width and the partly covered umbilicus of a typical neveritid. Its suture appears depressed, but this may be due to crushing.

Measurements.—USNM 650552: height 10.0 mm, diameter 11.2 mm.

Family FASCIOLARIIDAE

Genus LATIRUS Montfort

Montfort, 1810, Conchyliologie systématique, v. 2, p. 531.

Type (by original designation): *Latirus aurantiacus* Montfort (= *Murex gibbulus* Gmelin). Holocene, Australia.

Latirus sp.

Plate 5, figure 1

An incomplete specimen showing the protoconch and about three whorls of the spire preserves sculpture that appears to be that of a *Latirus*. The protoconch consists of at least three whorls, the lower two bearing strong, close-set axial ribs that parallel the axis of coiling. The whorls of the spire bear two major and several minor spirals that are coarsely beaded as they cross prominent, regularly spaced axial ribs; surface of the whorls between the major beaded axials show traces of fine, close-set axial threads.

Measurements.—Figured specimen, USNM 650556: height (incomplete) 3.3 mm, diameter 2.2 mm.

The sculpture of the spire is similar to that of *L. sexcostatus* Johnson (1899, p. 74) from the Claibornian, middle Eocene, of the Gulf Coast of North America, but the Tongan fossil has stronger axial threads.

Family CONIDAE

Genus CONUS Linnaeus

Linnaeus, 1758, Systema Naturae, 10th ed., p. 712.
Type (by subsequent designation, Children, 1823, Lamarck's genera of shells, p. 107.): *Conus marmoreus* Linnaeus. Holocene, Indo-Pacific.

Conus sp.

Plate 5, figure 2

A single cone is small with a moderately high flat spire; the shoulder is rounded, the sides of body whorl flat; early whorls are scalloped at the suture, this feature less prominent on later whorls; anal fasciole concave; aperture narrow, widening slightly anteriorly; traces of low spirals are preserved anteriorly.

Measurements.—USNM 650553; height 15 mm, diameter 7.7 mm; it is the largest gastropod in the extensive Eocene fauna. Most cones are found in warm equatorial waters where they are particularly abundant on rocky reef flats and other shallow-water terraces. A few cones have been taken alive from depths of 30–40 fathoms, but the worn condition of the Eocene fossil suggests that it was carried to its final resting place from shallow water.

Family TEREBRIDAE

Genus HASTULA H. and A. Adams

Adams, H. and A., 1853, Genera of Recent Mollusca, v. 1, p. 225.
Type (by subsequent designation, Cossmann, 1896, Essaisde paléoconchologie comparée pt. 2, p. 53): *Buccinum strigilatum* Linnaeus. Holocene, Indo-Pacific.

Hastula sp.

Plate 5, figure 3

Small, slender, flat-sided; whorls more than 13; suture distinct, giving the whorls a slight shoulder. Sculpture consisting of low axial ribs that extend without curvature from suture to suture, six to seven showing in side view; on the youngest whorls the ribs become less prominent anteriorly.

Measurements.—USNM 650556: height (incomplete) 8.7 mm, diameter 2.2 mm.

The Tongan fossil bears a general resemblance to *H. homala* Woodring and *H. jamaicensis* Woodring (renamed *H. vautrini* by Jung, 1965, p. 594) from the Miocene of Jamaica (Woodring, 1928, p. 143, pl. 4, figs. 4, 5) but is straighter and more slender than either. It appears to be more closely related to *H. lissa* Jung from the Miocene of Venezuela (Jung, 1965, p. 593, pl. 79, fig. 16), but the ribs on the Tongan shell are stronger and more persistent. Closer comparison must await more complete examples of both species.

Family ATYIDAE

Genus ATYS Montfort

Montfort, 1810, Conchyliologie systématique, v. 2, p. 343.
Type (by monotypy): *Atys cymbulus* Montfort (= *Fulla naucum* Linnaeus). Holocene, Indo-Pacific.

Atys? sp.

Plate 5, figure 4

A single, minute, recrystallized specimen seems to represent the Atyidae. It is broadly lenticular in outline, widest slightly below the midpoint. The aperture extends full length, widening slightly anteriorly; spire concealed, columellar fold obscure; no trace of surface sculpture.

Measurements.—USNM 650558: height 1.8 mm, diameter 1.1 mm.

The generic position of this specimen is uncertain. In general configuration it resembles *Atys volvulinus* (A. Adams), a living Japanese species, type of the subgenus *Nipponatys* Kuroda and Habe (Habe, 1952, p. 141, pl. 20, fig. 5).

Family PECTINIDAE

Genus PECTEN s.l.

Pecten? sp.

Plate 5, figure 5

An incomplete, nearly flat valve, USNM 650579, measuring 14 mm in height bears about 15 low ribs that show a tendency to divide into two or three ribs near the ventral margin. The shell is the largest of the pelecypods but it has few diagnostic features. The valve was possibly carried in from shallow water.

Family OSTREIDAE

Genus CRASSOSTREA Sacco

Sacco, 1897, I molluschi dei terreni terbziarii de' Piemonte e della Liguria, v. 12, p. 99.
Type (by original designation): *Ostrea virginica* Gmelin. Holocene, eastern America.

Crassostrea sp.

Plate 5, figures 6–9

Half a dozen shells representing both left and right valves of oysters were recovered. All are small and thin, and all probably are young shells. Lateral margins are smooth, muscle scars obscure. The shells have the characteristic shape of *Crassostrea* but are not heavy as are adult shells of the genus. Shells mostly smooth but have irregular lamellar growth lines.

Measurements.—Figured specimens: Plate 5, figures 6, 7, a left (attached) valve, USNM 650569: length 4.1 mm, height 5.8 mm, convexity 1.5 mm. Plate 5, figures 8, 9, a right (upper) valve, USNM 650570: length 5.5 mm, height 7.5 mm, convexity 1.3 mm.

None of the shells shows any trace of cellular structure such as characterizes salt-water oysters, and it seems probable that these light shells were carried seaward from the brackish waters of a nearby land area.

Family CORBULIDAE

Genus CORBULA Lamarck

Lamarck, 1799, Prodrome d'une nouvelle class. des coquilles, Soc. Hist. nat. Paris Mém., v. 1, p. 89.

Type (by subsequent designation, Schmidt, 1818—fide Stewart, 1930, Acad. Nat. Sci. Philadelphia Spec. Pub. 3, p. 286–287): *Corbula sulcata* Lamarck. Holocene, west coast of Africa.

Subgenus CUNEOCORBULA Cossmann

Cossmann, 1886, Catalogue illustré. des coquilles fossiles de l'Éocène. * * * Paris, v. 1, p. 37.

Type (by subsequent designation, Dall, 1898, Wagner Free Inst. Sci. Trans., v. 3, pt. 4, p. 838): *Corbula biangulata* Deshayes. Eocene, Paris Basin.

Corbula (Cuneocorbula?) sp.

Plate 5, figure 10

A single, incomplete, right valve probably represents a species of *Cuneocorbula*. The shell is small, elongate, extend posteriorly, slightly truncated anteriorly. A strong ridge extends from the umbo to the posterior ventral margin. Sculpture consists of concentric lines that are weakly developed over most of the shell but are strong on the narrow strip dorsal to the umbonal ridge; this discrepancy in sculpture suggests that a second ridge may have been present dorsal to the one that is preserved.

Measurements.—USNM 650562: length 6.7 mm, height 3.9 mm, convexity (one valve) 1.3 mm.

REFERENCES CITED

Asano, Kiyoshi, 1939, Limestones of the South Sea Islands under the Japanese Mandate: Yabe Jubilee Pub., v. 1, p. 537–550.

Cloud, P. E., Jr., and Cole, W. S., 1953, Eocene Foraminifera from Guam, and their implications: Science, v. 117, no. 3039, p. 323–324.

Cloud, P. E., Jr., Schmidt, R. G., and Burke, H. W., 1956, General geology, Part I *of* Geology of Saipan, Mariana Islands: U.S. Geol. Survey Prof. Paper 280–A, 126 p.

Cole, W. S., 1950, Larger Foraminifera from the Palau Islands: U.S. Geol. Survey Prof. Paper 221–B, p. 21–31.

——— 1957a, Larger Foraminifera *in* Part 3, Paleontology *of* Geology of Saipan, Mariana Islands: U.S. Geol. Survey Prof. Paper 280–I, p. 321–360.

——— 1957b, Larger Foraminifera from Eniwetok Atoll drill holes: U.S. Geol. Survey Prof. Paper 260–V, p. 743–784 [1959].

——— 1960, Upper Eocene and Oligocene larger Foraminifera from Vitu Levu, Fiji: U.S. Geol. Survey Prof. Paper 374–A, 7 p. [1961].

——— 1970, Larger Foraminifera of late Eocene age from Eua, Tonga: U.S. Geol. Survey Prof. Paper 640–B, 16 p., 5 pls., 2 figs.

Cotton, B. C., 1945, Southern Australian Gastropoda, Pt. 1, Streptoneura: Royal Soc. South Australia Trans., v. 69, p. 150–171.

Dall, W. H., 1881, Reports on the results of dredging * * * in the Gulf of Mexico, and in the Caribbean Sea, 1877–79 * * * by the "Blake" * * *: Harvard Univ. Mus. Comp. Zoology Bull., v. 9, no. 2, p. 33–144.

——— 1913, Diagnoses of new shells from the Pacific Ocean: U.S. Natl. Mus. Proc., v. 45, p. 587–597.

——— 1926, Illustrations of unfigured types of shells in the collection of the United States National Museum: U.S. Natl. Mus. Proc., v. 66, art. 17, 41 p. 36 pls.

——— 1927, Diagnoses of undescribed new species of mollusks. in the collection of the United States National Museum: U.S. Natl. Mus. Proc., v. 70, art. 19, 11 p.

Gould, A. A., 1859, [Expedition shells, North Pacific Exploring Expedition]: Boston Soc. Nat. History Proc., v. 7, p. 138–142, 161–167, 323–340, 382–389, 400–409.

Guest, N. J., 1959, Geological mapping, Tonga: Fiji Geol. Survey Dept., Ann. Rept. for 1958, Council Paper 17, p. 3.

Habe, T., 1952, Atyidae in Japan, *in* Kuroda, Tokubei, ed., Illustrated catalogue of Japanese shells, no. 20, p. 137–152, 2 pls.

Hedley, Charles, 1899, The Mollusca of Funafuti: Australian Mus. Mem., v. 3, pts. 7–9, p. 397–565.

——— 1904, Additions to the marine molluscan fauna of New Zealand: Australian Mus. Recs., v. 5, pt. 2, p. 86–98.

Hoffmeister, J. E., 1932, Geology of Eua, Tonga: Bernice P. Bishop Mus. Bull. 96, 93 p., 22 pls., 6 figs.

Johnson, C. W., 1899, New and interesting species in the "Isaac Lea Collection of Eocene Mollusca": Acad. Nat. Sci. Philadelphia Proc. 1899, p. 71–82, 2 pls.

Jung, Peter, 1965, Miocene Mollusca from the Paraguana Peninsula, Venezuela: Bulls. Am. Paleontology, v. 49, no. 223, p. 389–652.

Keen, A. M., 1960, *in* Knight, J. B., and others, Systematic description [Archaeogastropoda], *in* Moore, R. C., ed., Treatise on invertebrate paleontology, Part I, Mollusca 1: New York and Lawrence, Kans., Geol. Soc. America and Univ. Kansas Press, p. I171–I310.

Ladd, H. S., 1966, Chitons and gastropods (Haliotidae through Adeorbidae) from the western Pacific islands: U.S. Geol. Survey Prof. Paper 531, 98 p.

Ladd, H. S., and Schlanger, S. O., 1960, Drilling operations on Eniwetok Atoll: U.S. Geol. Survey Prof. Paper 260–Y, p. 863–905.

Mestayer, M. K., 1916, Preliminary list of Mollusca from dredgings taken off the northern coast of New Zealand: New Zealand Inst. Trans., v. 48, p. 122–128, 1 pl.

——— 1919, New species of Mollusca, from various dredgings taken off the coast of New Zealand * * *: New Zealand Inst. Trans., v. 51, p. 130–135, 1 pl.

Palmer, K. V. W., 1937, The Claibornian Scaphopoda, Gastropoda, and dibranchiate Cephalopoda of the southern United States: Bulls. Am. Paleontology, v. 7, no. 32, 730 p., 90 pls.

Pease, W. H., 1868, Descriptions of marine gastropods inhabiting Polynesia: Am. Jour. Conchology, v. 4, p. 91–102.

Repelin, J., 1919, Sur un point de l'histoire de l'océan Pacifique: Acad. Sci., Paris, Comptes rendus, v. 168, p. 237–239.

Schlanger, S. O., 1963, Subsurface geology of Eniwetok Atoll: U.S. Geol. Survey Prof. Paper 260–BB, p. 991–1066.

Sohl, N. F., 1960, Archeogastropoda, Mesogastropoda, and stratigraphy of the Ripley, Owl Creek, and Prairie Bluff Formations: U.S. Geol. Survey Prof. Paper 331–A, 151 p. [1961].

Tate, Ralph, 1894, Unrecorded genera of the older Tertiary fauna of Australia, including diagnoses of some new genera and species: Royal Soc. New South Wales Jour., v. 27, p. 167–196, 4 pls.

Todd, Ruth, 1970, Smaller Foraminifera of late Eocene age from Eua, Tonga: U.S. Geol. Survey Prof. Paper 640–A, 21 p., 8 pls., 4 figs.

Van Winkle, Katherine, 1919, Remarks on Virginia Eocene fossils *in* Van Winkle, Katherine, and Harris, G. D., New or otherwise interesting Tertiary molluscan species from the east coast of America: Bulls. Am. Paleontology, v. 8, no. 33, p. 6–12, 1 pl.

Verco, J. C., 1909, Notes on South Australian marine Mollusca * * *: Royal Soc. South Australia Trans., v. 33, p. 270–342.

Watson, R. B., 1886, Voyage of H.M.S. Challenger * * * Scaphopoda and Gastropoda: 756 p., 53 pls.

Wenz, Wilhelm, 1938–44, Gastropoda, Teil 1, Prosobranchia, *in* Schindewolf, O. H., Handbuch der Paläozoologie: Berlin, v. 6, 1639 p., 4211 figs. (pts. 1, 2, 1938; pt. 3, 1939; pt. 4, 1940; pt. 5, 1941; pt. 6, 1943; pt. 7, 1944).

Woodring, W. P., 1928, Miocene mollusks from Bowden, Jamaica; Part II, Gastropods and discussion of results: Carnegie Inst. Washington Pub. 385, 564 p.

INDEX

[Italic page numbers indicate major references and descriptions]

PLATES 1–5

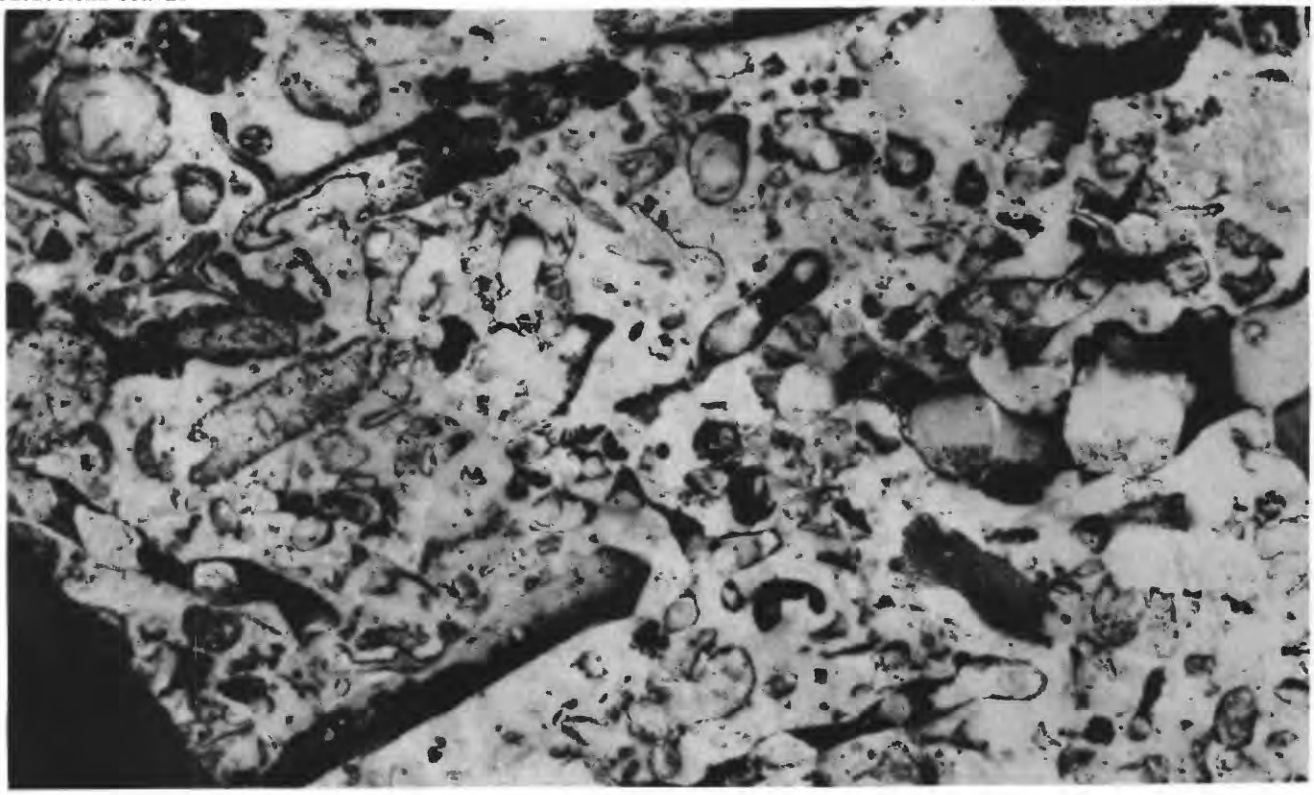
PLATE 1

[Rock samples showing abundance, diversity, and size range of fossils; × 2]

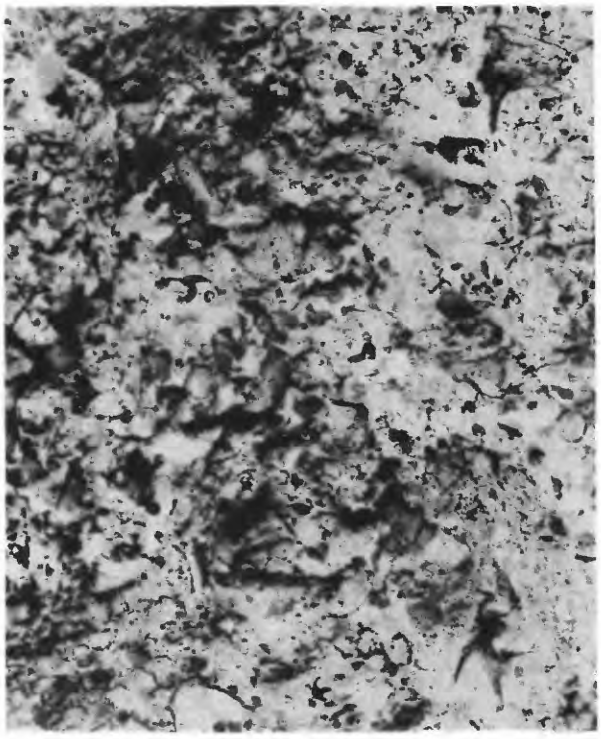
FIGURE 1. Part of hard unweathered bed. This material is not dolomitized or silicified. Some of the elongated fragments (echinoid spines and coral branches) are subparallel, suggesting current action.

2. Weathered rock containing small forms and grains of altered volcanic material.

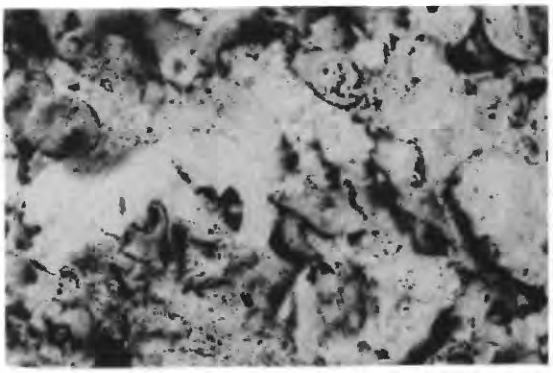
3, 4. Samples of soft rock that have been etched to bring out corals, Foraminifera, and shells (brachiopods and mollusks).



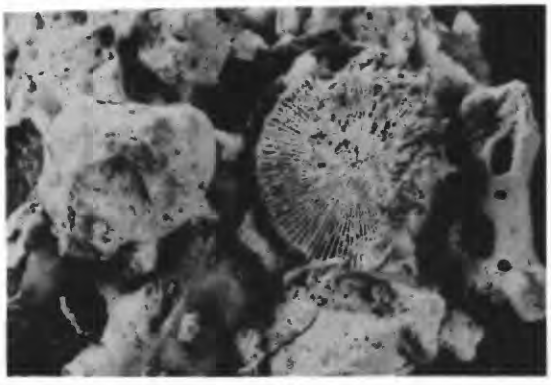
1



2



3



4

ROCK SAMPLES SHOWING ABUNDANCE, DIVERSITY, AND SIZE RANGE OF FOSSILS

PLATE 2

[All views x 20]

FIGURES 1–4. *Scissurella* (*Anatoma*) *tongaensis* Ladd, n. sp. (p. C2).
1, 2. Holotype, height 1.6 mm, USNM 650547.
3, 4. Paratype, height 1.9 mm, USNM 650548.
5–8. *Sinezona kondoi* Ladd, n. sp. (p. C2).
5, 6. Holotype, height 1.2 mm, USNM 650549.
7, 8. Paratype, height 1.3 mm, USNM 650550.
9–11. *Basilissa* (*Ancistrobasis*) *pacifica* Ladd, n. sp. (p. C3).
9, 10. Holotype, height 1.6 mm, USNM 650560.
11. Paratype, height 1.3 mm, USNM 650561.
12, 13. *Bathybembix*? sp. (p. C3).
Diameter 2.0 mm, USNM 650559.
14–17. *Turcica* (*Perrinia*) *blowi* Ladd, n. sp. (p. C3).
14–16. Holotype, height 1.5 mm, USNM 650567.
17. Paratype, height 1.5 mm, USNM 650568.

SCISSURELLIDAE AND TROCHIDAE

PLATE 3

FIGURES 1–3. *Astele* (*Callistele*) sp. (p. C4).
Diameter 1.7 mm, × 20, USNM 650578.

4, 5. *Xenophora* sp. (p. C7).
Height 3.3 mm, × 8, USNM 650557.

6, 7. *Astraea* (*Bolma*) *stearnsi* Ladd, n. sp. (p. C4).
Holotype, height 11.2 mm, × 4, USNM 650566.

8–10. *Pareuchelus*? sp. (p. C5).
Diameter 1.5 mm, × 20, USNM 650577.

11–13. *Daronia* (*Daronia*) *hoffmeisteri* Ladd, n. sp. (p. C5).
Holotype, diamater 1.9 mm, × 20, USNM 650554.

14–16. *Munditiella euaensis* Ladd, n. sp. (p. C5).
Holotype, diameter 1.5 mm, × 20, USNM 650564.

TROCHIDAE, TURBINIDAE, ADEORBIDAE, XENOPHORIDAE

PLATE 4

FIGURES 1–3. *Munditiella euaensis* Ladd, n. sp. (p. C5).
Paratype, diameter 1.4 mm, × 20, USNM 650565.

4–6. *Lydiphnis vainganaensis* Ladd, n. sp. (p. C5).
Holotype, diameter 2.2 mm, × 20, USNM 650576.

7. *Mathilda* (*Fimbriatella*?) sp. (p. C6).
Height 2.5 mm, × 20, USNM 650551.

8–11. *Gegania whipplei* Ladd, n. sp. (p. C6).
8–10. Holotype, diameter 1.2 mm, × 20, USNM 650574.
11. Paratype, diameter 1.9 mm, × 20, USNM 650575.

12. *Cerithiopsis* sp. (p. C6).
Height 2.4 mm, × 20, USNM 650573.

13. *Epitonium* (*Boreoscala*?) sp. (p. C6).
Height 4.5 mm, × 15, USNM 650572.

14, 15. *Pedicularia* (*Pediculariona*) sp. (p. C7).
Length 11.0 mm, × 5, USNM 650571.

16. *Neverita*? sp. (p. C7).
Diameter 11.2 mm, × 4, USNM 650552.

ADEORBIDAE, MATHILDIDAE, CERITHIOPSIDAE, EPITONIIDAE, OVULIDAE, NATICIDAE

PLATE 5

FIGURE 1. *Latirus* sp. (p. C7).
Height 3.3 mm, × 15, USNM 650556.

2. *Conus* sp. (p. C8).
Height 15 mm, × 3, USNM 650553.

3. *Hastula* sp. (p. C8).
Height 8.7 mm, × 10, USNM 650556.

4. *Atys*? sp. (p. C8).
Height 1.8 mm, × 20, USNM 650558.

5. *Pecten*? sp. (p. C8).
Height 14 mm, × 3, USNM 650579.

6–9. *Crassostrea* sp. (p. C8).
6, 7. Attached valve, length 4.1 mm, × 10, USNM 650569.
8, 9. Upper valve, length 5.5 mm, × 10, USNM 650570.

10. *Corbula* sp. (p. C9).
Length 6.7 mm, × 10, USNM 650562.

U.S. GOVERNMENT PRINTING OFFICE:1970 O—387-857

FASCIOLARIIDAE, CONIDAE, TEREBRIDAE, PECTINIDAE, OSTREIDAE, CORBULIDAE