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VOL. LXX



1976-77

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Ithaca, New York 14850
U. S. A.

BULLETIN

AMERICAN

PALEONTOLOGY

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BULLETINS

OF

AMERICAN

PALEONTOLOGY

(Founded 1895)

Vol. 70

No. 292

A Lewis G. Weeks Publication

BATHYAL GASTROPODS OF THE FAMILY
TURRIDAE IN THE EARLY OLIGOCENE KEASEY
FORMATION IN OREGON, WITH A REVIEW OF
SOME DEEP-WATER GENERA IN THE PALEOGENE
OF THE EASTERN PACIFIC

By

CAROLE S. HICKMAN

1976

Paleontological Research Institution
Ithaca, New York 14850 U. S. A.

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Paleontological Research Institution
Ithaca, New York 14850 U. S. A.

Library of Congress Card Number: 76-13800

Printed in the United States of America
Arnold Printing Corporation

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BATHYAL GASTROPODS OF THE FAMILY TURRIDAE
IN THE EARLY OLIGOCENE KEASEY FORMATION IN
OREGON, WITH A REVIEW OF SOME DEEP-WATER
GENERA IN THE PALEOGENE OF THE EASTERN PACIFIC

CAROLE S. HICKMAN
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ABSTRACT

Marine deep-water (bathyal) mollusk assemblages in the early Oligocene Keasey Formation in Oregon contain a diverse (rich in species) and abundant (rich in individuals) component of undescribed neogastropod species in the family Turridae (superfamily Conacea). Taxonomic analyses of these species and their congeners in the Paleogene deep-water facies of the northeastern Pacific provide a context for investigation of problems in evolution, paleoecology, historical biogeography, and biostratigraphy.

The high proportion of turrid species characteristic of Paleogene bathyal neogastropod faunas (greater than 50 percent) is comparable to turrid representation in modern bathyal faunas and constitutes an important criterion for bathyal paleobathymetric interpretation. Large (greater than 30 mm), relatively thin-shelled species in the subfamilies Turriculinae and Turrinae predominate, and the large component of borsoniine and daphnelline species in comparable modern faunas is interpreted as a consequence of late Cenozoic adaptive radiation of toxoglossate turrids and replacement of more primitive non-toxoglossate forms. Many Paleogene species occur at high relative frequency and density within the total mollusk fauna of the deep-water facies.

Morphological variability in large species populations (greater than 50 individuals) is comparable with that in related shallow-water species and fails to support the widely held assumption of homogeneity and stability of the bathyal environment (or alternatively contradicts the principle that variability is reduced in more stable and homogeneous environments). Signs of predation in the form of naticid borings and subsequently repaired shell damage suggest a higher degree of trophic complexity than is assumed for environments below 200 meters.

New approaches to generic and specific discrimination are outlined, focusing on geometry of the anal sinus and specifying standard measurements from which quantitative and non-quantitative characters are defined. These characters are utilized in diagnosis of new generic and specific taxa, in evaluation and systematic revision of previously described taxa, and in definition of groups of temporally sequential species of biostratigraphic significance.

One new subgenus and three new genera are proposed; 13 new species are described and figured; and 11 potentially new species are treated under open nomenclature. Lectotypes are designated for five of C. E. Weaver's Paleogene turrid species.

Turrids are useful in intraprovincial correlation at the zonal level throughout the provincial Oligocene of the Pacific Northwest, particularly those genera in which morphological trends are documented within a sequence of short-lived species. Biostratigraphic potential for fine subdivision of the Paleogene deep-water facies is demonstrated by turrid species in the Keasey Formation. Stratigraphic ranges are defined from occurrences at numerous horizons within a 700 meter sequence, and four successive assemblages are recognized. Prognosis for similar refinement in the Pacific Northwest Oligocene is good. Two of the species analyzed are useful in interprovincial correlation.

Available data are insufficient for detailed reconstruction of biogeographic patterns, although ties with the Japanese and Australo-Neozealandic fauna in the Oligocene and broader ties with European and Caribbean faunas during the Eocene are proposed on reevaluation of generic names that are traditionally used with geographic restriction. Five generic names (*Comitas*, *Acamptogenotia*, *Parasyrinx*, *Ptychosyrinx*, and *Pleuroloria*) are utilized for the first time for species in the Paleogene of the northeastern Pacific.

INTRODUCTION

Marine gastropods of the family Turridae occur throughout the Tertiary formations of western Washington, Oregon, and California. They are most abundant and diverse in Eocene and Oligocene rocks and particularly in the deep-water (outer shelf and bathyal) facies of the Pacific Northwest. In spite of their abundance, diversity, and good preservation, turrids have been neglected in Paleogene biostratigraphy. Stratigraphic ranges are obscured by confused species concepts and misidentifications that extend to higher levels of taxonomy, where criteria for the recognition of subfamilies and genera are lacking or at best inconsistent.

A review of deep-water turrid lineages in the Pacific Northwest Paleogene was undertaken to augment a systematic and biostratigraphic study of a particularly rich series of assemblages of undescribed turrid species in the early Oligocene Keasey Formation in northwestern Oregon. The resulting monograph offers a review of the problems of classification of fossil turrids and character weighting in the group. New approaches to taxonomy at the generic and specific levels rely heavily on the configuration of the anal sinus, specifying measurements from which quantitative and non-quantitative characters are defined. Evaluation of stratigraphic data using refined species concepts demonstrates the biostratigraphic utility and potential of the family. Consideration of temporal and spatial distributions of genera and their characters in a global context promotes understanding of the historical biogeography and evolution of deep-water turrids and constitutes one of the first detailed examinations of lineages of deep-water mollusks in the perspective of geologic time.

In spite of more than 250 available generic and subgeneric categories in the family, it has been necessary to propose one new subgeneric and three new generic names. Thirteen additional genera and subgenera are treated, five of which are reported for the first time from the northeastern Pacific. Several taxa that have been recognized only within the Australo-Neozelandic region prove much more widely distributed within the bathyal facies of the Pacific. A large proportion of the generic names that have been applied during the past century to northeastern Pacific Paleogene deep-water turrids now prove to be inappropriate. There are notable instances in

which close relationships among poorly defined or inadequately illustrated species have been overlooked or obscured in the literature because of placement in distantly related genera. Thirteen new species are described (11 from the Keasey Formation), and 11 additional forms are treated under open nomenclature.

ACKNOWLEDGMENTS

I am indebted to Harold E. Vokes, Tulane University, for permission to describe material in his collections from U.S. Geological Survey localities in the Keasey Formation in Oregon.

For access to collections and assistance locating and borrowing specimens I am grateful to J. Wyatt Durham and Joseph H. Peck, Jr., University of California, Berkeley; Peter Rodda and Jean Durham, California Academy of Sciences; Thomas R. Waller, U.S. National Museum and Druid Wilson, U.S. Geological Survey, Washington, D.C.; Warren O. Addicott, U.S. Geological Survey, Menlo Park; James H. McLean, Los Angeles County Museum of Natural History, and Virginia Orr Maes, Academy of Natural Sciences, Philadelphia. John M. Armentrout, formerly at the University of Washington, Seattle, kindly made available his collections of turrids from the Lincoln Creek Formation. Ellen J. Moore, U.S. Geological Survey, provided unpublished data on turrid species in the Pittsburg Bluff Formation. Bruce Welton donated several specimens and furnished locality data, and members of the Geological Society of the Oregon Country cooperated to make personal collections available for study.

Special thanks are due Virginia Orr Maes and James H. McLean for thought-provoking discussions of problems of turrid taxonomy.

Myra Keen, Stanford University, and Warren Addicott critically read the entire manuscript and provided valuable suggestions for improvement as well as encouragement throughout the course of the study. N. J. Silberling and W. R. Evitt, Stanford University, also read the manuscript and contributed helpful criticism.

Conversations with J. C. Ingle and W. R. Dickinson, Stanford University, have contributed to the formulation of ideas about the biological and physical characteristics of deep-water environments under consideration.

Photographs and text-figures were prepared by the writer except for the photography of type specimens from the University of California, Berkeley, and the California Academy of Sciences, which was done by Kenji Sakamoto, U. S. Geological Survey, Menlo Park.

James C. Hickman provided invaluable help in the field, ideas for the solution of specific taxonomic problems, and constant encouragement and support.

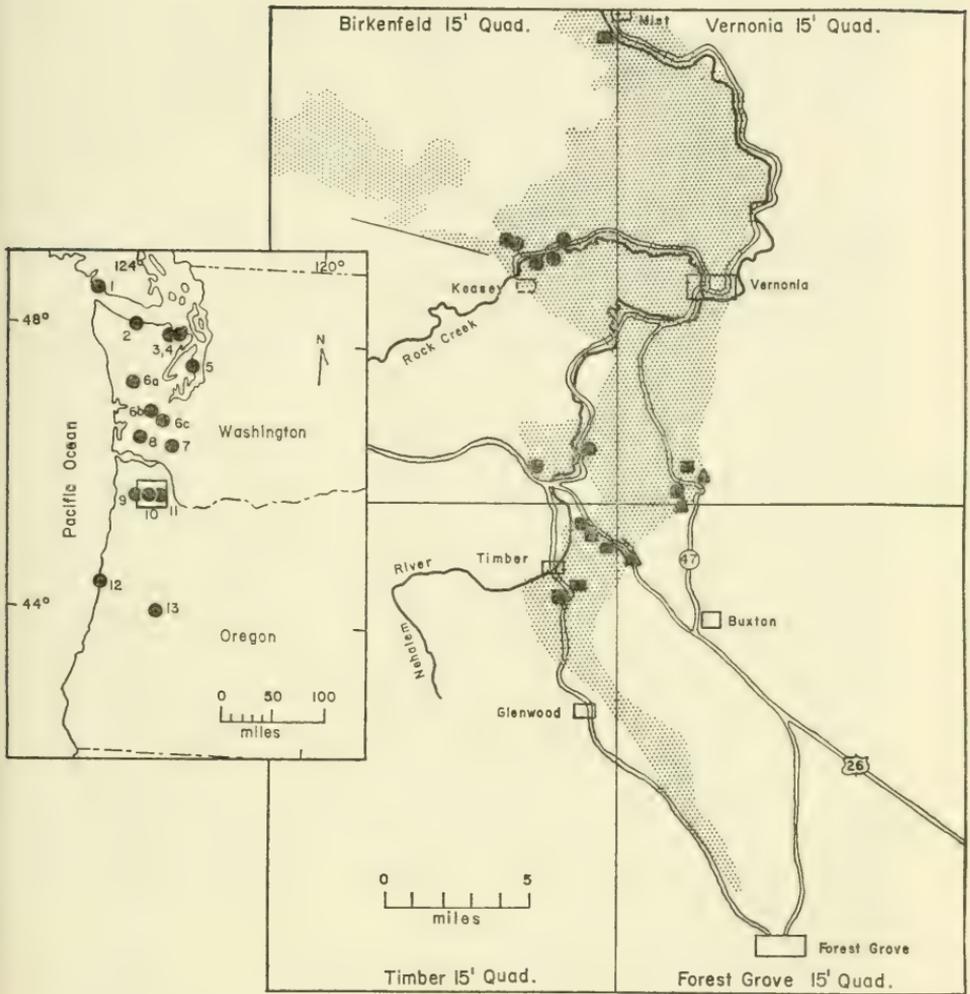
To all these people, I extend hearty thanks.

THE KEASEY FORMATION

STRATIGRAPHY

The Keasey Formation (Schenck, 1927, p. 457) consists of a maximum of 700 m of gray tuffaceous marine siltstone and massive mudstone discontinuously exposed in quarries, road and railroad cuts, and along major drainages in the upper Nehalem River basin in northwestern Oregon (Text-figure 1). The Keasey Formation overlies the late Eocene Cowlitz Formation, and although the contact is lithologically gradational, there is a distinct faunal break accompanying the transition from dark massive mudstone and pebbly siltstone to laminated siltstone (Hickman, 1974a). The Pittsburg Bluff Formation overlies the Keasey Formation with structural conformity; but the abrupt changes in fauna, lithology and inferred paleobathymetry suggest the presence of an unconformity, although perhaps of relatively small magnitude. Lithologic characteristics of the formation and its subdivision into three informal members are summarized by Warren and others (1945), Warren and Norbistrath (1946), and Van Atta (1971b); and the sedimentary petrology is discussed by Van Atta (1971a). A composite columnar section for the formation appears in Text-figure 5.

The lower member, as recognized in this report, consists of 0 to 150 m of dark gray, highly micaceous, laminated siltstone and interbedded mudstone. Glauconitic layers are not uncommon. The member thins southward in the Nehalem River basin and is best developed at the original type locality of the formation (Schenck, 1927) along Rock Creek and adjacent logging roads to the north. A number of distinctive mollusk species are restricted to this member, including *Bathybembix columbiana* (Dall, 1909), new species of *Conus*, *Solariella*, and *Fusinus*, and two new turrid species



Text-figure 1. — Index maps. Location of formations in the Pacific Northwest referred to in text and generalized distribution of the Keasey Formation in the upper Nehalem River basin in Oregon, showing important fossiliferous outcrops in the lower (●), middle (■), and upper (▲) members. 1. Carmanah Point Beds, 2. Twin River Formation, 3. Marrowstone Shale, 4. Quimper Sandstone, 5. Blakeley Formation, 6. Lincoln Creek Formation, 7. Gries Ranch Beds, 8. Willapa River "Keasey" Beds, 9. Cowlitz Formation, 10. Keasey Formation, 11. Pittsburg Bluff Formation, 12. Alesia Formation, 13. Eugene Formation.

described below. This fauna also occurs in the deep-water facies in southwestern Washington (the Willapa River "Keasey" Beds near Holcomb) and identifies a biostratigraphic unit of zonal magnitude partially equivalent to the tentatively defined "*Turricula columbiana*" megafaunal zone of Durham (1944). Redefinition of this zone is deferred until completion of systematic treatment of the mollusk fauna. The assemblage of the lower member is distinct from that of the siltstone and dark massive mudstone beds of the underlying Cowlitz Formation, which comprise an unnamed zone of "Tejon" (provincial late Eocene) age characterized by the presence of *Nehalemia hieroglyphica* Hickman, 1974; *Ficopsis cowlitzensis* Weaver, 1912; *Conus vaderensis* Weaver and Palmer, 1922; and *Siphonalia sopenahensis* (Weaver, 1912).

The middle member of the Keasey Formation includes 500 m of predominantly light gray highly tuffaceous siltstone and mudstone beds with occasional ash layers and calcareous concretionary beds. Massive mudstone beds characteristic of the upper portion of the member are quarried for use in the manufacture of lightweight building blocks, and several large quarries provide excellent exposures of the member. The middle member contains the richest molluscan fauna in the formation and is tentatively divisible into two distinct assemblage zones, although further work is prerequisite to formal definition. A large number of species make first appearances in the middle member, including *Nemocardium weaveri* (Anderson and Martin, 1914); new species of *Conus*, *Fulgurofusus*, *Conomitra*, and *Bruclarkia*; and seven new turrid species described herein. The middle member may be partially equivalent to the *Molopophorus stephensoni* megafaunal zone of Durham (1944).

The upper member of the formation consists of 50 m of alternating light to dark gray tuffaceous siltstone and mudstone characterized by numerous well-indurated calcareous beds and concretionary siltstone layers. The member is relatively more resistant and forms a prominent topographic ridge in the eastern part of the basin that has necessitated construction of several railroad and highway tunnels. The fauna of this member is not so rich in species as that of the middle member, but a number of distinctive forms are present, including *Acesta oregonensis* (Clark, 1925) and *Porterius gabbi* (Dickerson, 1917) as well as characteristic concentrations of bundles

of basal root tuft spicules of hexactinellid sponges. This member is correlated with the *Molopophorus stephensoni* megafaunal zone of Durham (1944). Correlation of the biostratigraphic, lithostratigraphic, and chronostratigraphic units employed in this report is presented in Text-figure 6.

AGE AND CORRELATION

The Keasey Formation has traditionally been considered either exclusively Oligocene or latest Eocene to Oligocene in age (Schenck, 1927; Moore and Vokes, 1953; Warren and others, 1945; Warren and Norbistrath, 1946; Durham, 1954) or alternatively "Eo-Oligocene" in the standard West Coast chronology of Weaver and others (1944). It is referable to the lower part of the Refugian Stage of Schenck and Kleinpell (1936). The lower Refugian (*Uvigerina cocoensis* Zone) is now generally regarded as late Eocene in the benthonic foraminiferal chronology (Kleinpell, 1938; Kleinpell and Weaver, 1963; Rau, 1966, 1967). However, the Refugian Stage is still poorly tied to planktonic standards. The entire Refugian has been considered late Eocene on the basis of planktonic Foraminifera (Lipps, 1967) as well as calcareous nannoplankton (Brabb and others, 1971), although the evidence is meager in both cases. Calcareous plankton is conspicuously rare in most of the deep-water facies in the Pacific Northwest, and McKeel and Lipps (1972) attribute its restriction during the provincial late Eocene and Oligocene to high runoff of terrestrial water. Their data from Refugian rocks of the Newport embayment in Oregon (based on seven planktonic Foraminifera and five calcareous nannoplankters) suggest uppermost Eocene or basal Oligocene. A more diverse nannoflora (19 species) from the northern Olympic Peninsula in Washington (Worsley and Crecelius, 1972) indicates that the Refugian falls entirely within the Oligocene.

The question of the age of the Refugian Stage is bound up not only in problems of correlation, but also in unresolved international controversy over the location of the Eocene-Oligocene boundary. This problem is beyond the scope of this report, but it is important to note that conflicting ages for the Refugian may partially reflect differences of opinion over placement of the boundary. Following traditional provincial molluscan standards, the age of the Keasey Formation is herein regarded as earliest Oligocene.

Although the Refugian Stage was originally proposed as both a microfaunal and megafaunal based time-stratigraphic unit (Schenck and Kleinpell, 1936), it has drifted into microfaunal usage; and the informal "Keasey" and "Lincoln" Stages of Weaver and others (1944) and Durham (1944) have been employed as approximate chronostratigraphic megafaunal equivalents of the lower and upper Refugian respectively. Addicott (1972, 1973) restricted the "Keasey Stage" to provincial usage in the Pacific Northwest and employed Refugian as a provincial California megafaunal stage. The "Keasey Stage" lacks formal definition, although coincidence with the boundaries of the Keasey Formation is generally assumed.

In standard usage, the "Keasey Stage" comprises a single biostratigraphic unit, the tentatively defined "*Turricula columbiana*" megafaunal zone of Durham (1944). However, the zonal boundaries, as defined by the type section, are not coincident with those of the formation and stage as generally indicated in the literature. The type section of the zone is along Rock Creek in the lower member of the formation. The characteristic recurring mollusk assemblage in this section does not occur in the middle and upper members, which are faunally as well as lithologically distinct (Warren and others, 1945; Warren and Norbistrath, 1946; Hickman, unpub. data). Biostratigraphic distributions of turrid species outlined in this report suggest three- or four-fold subdivision of the formation (Text-figure 5), although formal biostratigraphic zonation and emendation of chronostratigraphic terminology are deferred until data are complete for other mollusk species.

FAUNAL CHARACTERISTICS

The general faunal composition of the Keasey Formation is reviewed by Warren and others (1945), Warren and Norbistrath (1946), and Moore and Vokes (1953). Although systematic treatment of the mollusk fauna is incomplete, a few important species have been described (Dall, 1909; Anderson and Martin, 1914; Clark, 1925; G. D. Hanna, 1924; Durham, 1937, 1944; and Hickman, 1972). Taxonomic composition and characteristics of the mollusk fauna are outlined by Hickman (1974b).

The high diversity of turrid gastropod species (greater than 50% of the total neogastropod fauna) is one of the most outstand-

ing characteristics of the fauna. Mesogastropods include primarily carnivorous taxa such as large epitoniids, cymatiids, a cassid, and a diverse and rich naticid fauna. Large trochids of the genus *Bathybembix* Crosse, 1893, and the biogeographically and evolutionarily interesting homalopomatine species *Phanerolepida oregonensis* Hickman, 1972, are among the noteworthy constituents of the archaeogastropod fauna. The bivalve fauna includes a high proportion of protobranch species (47%) and characteristically deep-water pteriomorphs including thin-shelled pectinids and propeamussiids and giant limids of the genus *Acesta* H. and A. Adams, 1858. Heterodont diversity is low, and two of the families represented (Thyasiridae and Lucinidae) are well adapted for filter feeding in food-poor environments such as the bathyal zone often affords.

An outstanding characteristic of the Keasey Formation is the diversity of non-mollusk groups, comprising a number of unusual taxa that are today restricted to deep water. The groups represented include benthonic and planktonic Foraminifera (Cushman and Schenck, 1928; Warren and others, 1945), two crinoid species (Moore and Vokes, 1953), two echinoids, three asteroids, and an ophiuroid (Zullo and others, 1962), a pogonophoran (Adegoke, 1967), three corals (Durham, 1942; Zullo and others, 1962), two decapod crustaceans (Warren and others, 1945; Steere, 1957), nine genera of sharks (Welton, 1972, 1973), and a flora including terrestrial angiosperms and gymnosperms, a marine angiosperm, a coralline alga, and diatoms (Moore and Vokes, 1953; Zullo and others, 1962). Reported here for the first time are a brachiopod, calcareous nannoplankton, radiolarians, ostracodes, and bundles of hydrated silica rods representing basal root tufts of hexactinellid sponges, as well as hexactinellid spicules (microscleres) of several different types.

PALEOBATHYMETRY AND PALEOCLIMATOLOGY

Previous paleobathymetric interpretations of the Keasey Formation rest on a variety of evidence. Bathyal depths (greater than 200 m) are suggested by the modern bathymetric ranges of genera and analogous living species over a range of invertebrate and vertebrate groups (Moore and Vokes, 1953; Zullo and others, 1964; Hickman, 1972; Welton, 1973). This method of analysis is inconclusive, however, for it involves unwarrantable assumptions of physiological

constancy over millions of years of geologic time and fails to distinguish between deep water and cold shallow water in taxa with thermally regulated bathymetric distributions. The Keasey mollusk fauna does have a cooler aspect than provincial late Eocene ("Tejon") faunas, for it comprises a number of genera (e.g. *Scaphander*, *Margarites*, *Bathybembix*) that are now restricted to high latitudes off western North America or that occur in deep water only at lower latitudes (e.g. *Thyasira*, *Accesta*, *Fusitriton*). Moore and Vokes (1953) suggested that upwelling of cold water could support such a fauna in shallow water but cited articulation of weakly hinged bivalves and delicate crinoid skeletons as evidence for the deepwater hypothesis.

Van Atta (1971a) suggested a shallow-water shelf environment for the Keasey Formation from analyses of the rocks. However, sedimentary paleobathymetric criteria are not so well developed as biologic. The paucity of published analyses of bathyal sediments and rudimentary state of knowledge of bathyal sedimentation processes (Stanley, 1969) may explain Van Atta's failure to recognize this environment.

Deep-water interpretation of Keasey bathymetry adopted here is based on the taxonomic structure method of bathymetric interpretation described by Hickman (1974b). Percent composition of mollusk species in major taxonomic groups in the Keasey Formation matches composition of modern bathyal faunas and is believed to reflect a characteristic mode of participation of mollusks in trophic structure at these depths. This approach is free of the temperature factor and recognizes that the depth distributions and optima of genera have changed over geologic time. Striking similarities between the mollusk fauna of the Keasey Formation and that of the bathyal zone in Sagami Bay, Pacific Coast of central Honshu, led Hickman (1972) to assume temperatures of 6° - 8° C (cool but not cold bathyal) for the Keasey Formation.

Benthonic foraminiferal faunas provide supporting evidence of progressive deepening from an outer neritic environment in the Cowlitz Formation to bathyal in the Keasey. Important bathymetric evidence includes the appearance of abundant costate uvigerinids in the Keasey and the living isobathyal species *Melonis pompilioides* (Fichtel and Moll), which occurs along the Pacific Coast in depths

ranging from 1200 - 2300 m and at temperatures of 2° - 3° C (Bandy and Chierici, 1966). The presence of globigerines in the Keasey Formation and absence of other morphotypic planktonic foraminiferal groups is characteristic of cold water masses (Cifelli, 1969) and suggests climatic cooling.

The climatic component of cooling in northwestern Oregon across the Cowlitz-Keasey Formation boundary is part of a well-documented deterioration initiated throughout the Pacific Coast Tertiary at the beginning of the provincial Oligocene. Evidence for polar cooling and progressive intensification of the latitudinal thermal gradient lies in the shifting spatial and temporal patterns of faunal organization from a highly diverse cosmopolitan Eocene fauna to the modern series of provincial faunas of decreasing poleward diversity. Details of latitudinal faunal differentiation have been refined through application of increasingly precise paleozoogeographic methods (*e.g.* Addicott, 1970b).

Early interpretations of this climatic deterioration viewed it as a gradual progressive cooling (*e.g.* Dickerson, 1917; Smith, 1910, 1919; Durham, 1950, 1954), although there is a growing and diverse body of evidence for an initial abrupt worldwide chilling over a period of a few million years (Bramlette, 1955; Dorman, 1966; Hornibrook, 1967; Wolfe and Hopkins, 1967; Devereux, 1967; Cifelli, 1969; Benson, 1975). Though the separate phenomena listed by these authors are not entirely synchronous by radiometric dates or biostratigraphic correlation, it is highly probable that they represent the same event. The "Tejon"- "Keasey" megafaunal stage transition in the Pacific Northwest offers an additional example of dramatic mid-Tertiary cooling within the time span indicated by the above authors. I am able to find no published evidence for this event in the Belgian and North German Paleogene sequences, but it exhibits considerable overlap with the span within which the Eocene-Oligocene boundary controversy is being debated and should be considered as a possible datum for fixing the boundary.

THE PALEOGENE DEEP-WATER FACIES IN THE PACIFIC NORTHWEST

Cool bathyal molluscan and foraminiferal biofacies are also well

developed elsewhere in the provincial late Eocene and Oligocene of the Pacific Northwest in thick continuous stratigraphic sections.

Some of the most remarkable deep-water sequences occur in the southern Olympic Peninsula, where over 2700 m of Paleogene tuffaceous sandstone, siltstone, and mudstone, primarily of the Lincoln Creek Formation, dip southward off the underthrust core of the Olympic Mountains. Rau (1966) sampled the Foraminifera in four measured sections through these beds and concluded that lower neritic to upper bathyal depths and cool to cold water temperatures prevailed during the Paleogene. Some of the species recorded by Rau, however, suggest greater depths. *Gyrodina soldanii* d'Orbigny and *Pullenia bulloides* d'Orbigny, which occur throughout these sections, are living benthonic foraminiferal species typical of a cold lower bathyal biofacies (Bandy, 1961). Another common species, *Cassidulina crassipunctata* Cushman and Hobson, is morphologically analogous to the deep cold-water species *C. laevigata* Cushman and Hobson, 1935 according to Smith (1971). Costate and hispid uvigerinids as well as other species with living morphological counterparts (for example, Bandy, 1961) indicate middle bathyal or greater depths. The mollusks from this sequence have been sampled by Armentrout (1973), and the material that I have seen is definitely indicative of cool deep water, comparable to the inferred environments of Keasey deposition.

Massive fine-grained mudstone beds of the late Eocene to early Miocene Lincoln Creek Formation are remarkably constant in lithologic character and foraminiferal biofacies throughout southwestern Washington (Rau, 1966; Beikman and others, 1967). Costate and hispid uvigerinids, globose *Pullenia*, small *Eponides* and other morphological indicators of the bathyal zone also occur in Keasey equivalent beds in the Willapa River valley in southwestern Washington (Rau, 1951), with a bathyal mollusk fauna.

The development of high turrid diversity and large species populations is characteristic over much of the deep-water facies, the richest assemblages occurring in the Keasey Formation and Lincoln Creek Formation.

An outstanding characteristic of latest Eocene and Oligocene formations throughout the Pacific Northwest is that they are markedly tuffaceous, including occasional thin water-laid ash beds.

This is particularly true of the deep-water facies. Proximity of terrestrial andesitic volcanic vents is inferred as well as the development near shore of a slope-type sedimentary setting. Similar tuffaceous deep-water sedimentary facies around the margin of the North Pacific in tectonically mobile belts contain rich parallel molluscan biofacies (Hickman, 1972) suggesting a relationship between tectonic setting and biofacies development.

Traditional eugeosynclinal tectonic models for the Pacific Northwest (Snively and Wagner, 1963, 1964; Snively and others, 1968) fail to provide a coherent framework for synthesis of available sedimentary data. An alternative plate tectonic model, on the other hand, provides a basis for remarkably consistent interpretation of Paleogene sedimentary facies relationships. Under this interpretation the development of widespread deep-water facies does not require special explanation as it does in the traditional view of paleogeography and tectonic setting. Widespread late Eocene and Oligocene massively bedded tuffaceous fine-grained sedimentary units, including the Keasey Formation, are here interpreted as an arc-trench gap assemblage (Dickinson, 1971, 1974), deposited adjacent to a young magmatic arc of low relief and marked proximity in a series of deep-water basins that were separated from the trench by a topographic high marked by emergent islands of early and middle Eocene basalt. Westward shifting of the axis of sedimentation during the Oligocene and subsequent uplift of the Coast Range resulted in disappearance of basins of marine deposition within the inferred arc-trench gap area by the beginning of the Miocene. Westward shifting of the axis of sedimentation (Snively and Wagner, 1963, 1964) presumably follows prograde migration of an inferred trench and is accompanied by retrograde migration of the volcanic arc (Peck and others, 1964), conforming with the typical pattern of arc-trench system evolution proposed by Dickinson (1973).

TURRID CLASSIFICATION

GENERAL CONSIDERATIONS

The family Turridae has a deserved reputation as one of the most taxonomically complex families of prosobranch gastropods, comprising a large number of generic and specific taxa that display

a broad range of shell form. Throughout a long history of attempts to reduce nomenclatural confusion and establish a satisfactory classification, turrids have maintained a resistant front against the taxonomic methodology that has sufficed in other gastropod families. This is primarily a result of gradual variation in shell and anatomical characters combined with lack of correlation among variation patterns for those characters.

The difficulties of working with extant turrid taxa are compounded in paleontological studies, where only shell characters are available. Recent documentation of two turrid shells of almost identical morphology containing animals of different anatomy (Smith, 1967a) cannot be lightly dismissed, nor can documentation of striking differences in radular morphology (McLean, 1971) between living species that would be more closely classified on shell morphology alone. While introducing a cautionary note, these instances do not justify one current view that shell characters should be abandoned completely. This view is reasonable only insofar as it refuses to condone overlooking soft parts when they are available, but wrongly implies that no sense can be made of turrid phylogeny using the rich Cenozoic fossil record of the family. Although it is almost certain that convergence has produced distantly related "species pairs" in the fossil record, the viable assumption remains that most apparently closely knit morphological groups of fossil turrids had equally close biological affinities, as is demonstrably true of most morphologically similar modern groups. This is hypothesized to be even more true in several of the morphologically conservative deep-water taxa that are treated in this report.

Although it is impossible to test hypotheses regarding the biologic affinity of contemporaneous species using shell characters alone, the paleontologist has a simple criterion for evaluating a closely knit morphological group consisting of a series of species arranged sequentially over geologic time. The presence of highly ordered patterns in character variation within the time sequence supports close biologic affinity, since it is highly improbable that such patterns could arise from random unrelated evolutionary events in separate lineages.

HIGHER TAXONOMY

Problems of turrid classification at higher taxonomic levels

center around disagreements over character weighting. A few early attempts at higher classification were based on a single feature (e.g. Fischer's 1883 scheme based on the form of the operculum). Although most authors acknowledge the desirability of considering a number of characters, certain crucial characters are so poorly associated with one another that some character states must have evolved independently in several lineages while others may be truly monophyletic in origin. It is difficult to ascertain which of the commonly used characters, if any, are monophyletic. Grant and Gale (1931) and Powell (1942) summarized some of the early, largely unsatisfactory, classificatory approaches.

Powell's (1966) monumental contribution to turrid taxonomy evaluated 549 generic and subgeneric names in the family, grouping them into nine subfamilies based on shell characters. Subjectively defined features of the labial sinus are heavily weighted in this classification, which, in spite of its difficulties, applies equally well to fossil and living species and correlates with a large body of biogeographic and stratigraphic data. In spite of the utility of the classification, Powell's assumptions about the evolution of the turrid radula have been seriously attacked by subsequent authors (Morrison, 1966; Maes, 1971; McLean, 1971). Specifically, Powell (1964, 1966) suggested that the toxoglossate radula has evolved independently from prototypic dentition in different turrid subfamilies.

The family Turridae is placed in the superfamily Conacea of the Neogastropoda along with other families that have been characterized as "toxoglossate" carnivores. It is well documented, however, that the specialized hollow barbed marginal radular dentition and associated neurotoxic apparatus of the truly toxoglossate condition characterizes only a portion of the family, and Morrison (1966) suggested their segregation as a separate family. If the toxoglossate radula is of strictly monophyletic origin (Morrison, 1966; Maes, 1971; McLean, 1971) and radular characters are utilized as first order criteria in subfamily classification, then we must accept the independent evolution of numerous apparently identical states in shell characters in different segments of the family. The most recent classification (McLean, 1971) utilizes five shell and opercular characters in addition to three first order radular characters, with the inevitable introduction of new taxa at the subfamily level and a more

complex classification (15 subfamilies). In spite of its complexity, it is a more manageable framework for treating extant genera, its major drawback being its inability to deal with the fossil record.

Turrid radular evolution and associated complex modifications of the alimentary canal are still poorly understood, and there are indications that other basic anatomical dichotomies may cut across groupings currently based on radular morphology and (or) shell morphology. The hypothesis that the so-called toxoglossate condition is polyphyletic cannot be discounted without closer examination. Within the toxoglossate subfamilies that have been proposed, several distinct types of detached marginal teeth are present, presumably representing a variety of stages in the evolution of the true hollow, barbed toxoglossate tooth that functions like a hypodermic needle. These include broad "partially rolled" teeth interpreted by Morrison (1966) and Maes (1971) as primitive precursors of the toxoglossate state, and slender (presumably more tightly rolled) solid teeth such as those described by Smith (1967b) as "deeply grooved." Smith proposed the idea that such unbarbed teeth function to make a wound and that poison flows along the tooth rather than being hypodermically injected, implying potential underlying differences in proboscis anatomy. Smith's (1967b) description of two new proboscis types in the Turridae, in fact, suggests important anatomical dichotomies that are yet to be correlated with other characters. Subsequent anatomical studies (Sheridan and others, 1973) and detailed histological and functional morphological analysis (Shimek, 1975) of toxoglossate species increases understanding of turrid evolution, although a natural classification of both fossil and living turrids is not yet possible.

The problems discussed above are most serious in the treatment of extinct genera and species of questionable generic allocation, and especially in the Paleogene where one encounters combinations of character states unlike anything in the modern fauna. However, many Paleogene species are readily assigned to extant genera with morphologically similar living species. The shell characters employed at this taxonomic level are so much more refined and better correlated than those employed at the subfamily level that the question of anatomical correlations is less likely to arise.

GENERIC AND SPECIFIC TAXONOMY

There is no single character or set of shell characters than can be applied uniformly at the generic or specific level within the Turridae. Many turrid genera are well defined on the basis of a number of common features of shell morphology displayed by species of obvious close relationship. A major problem is posed, however, by a large number of species exhibiting a unique major discontinuity in one or two characters. The solution to this problem is often the erection of a monotypic genus.

Nearly 20% of the turrid genera and subgenera evaluated by Powell (1966) are monotypic, and one third of these are based on species from Australia or New Zealand, where taxonomists have more often based genera on differences in a single character. Differences in a protoconch character such as ornamentation, shape, or number of whorls are often employed. Other features that have provided sole bases for monotypic genera include descriptive characterization of unique combinations of anal sinus characters, unique sculptural modes or the presence or absence of special sculptural features, apertural shape or peculiar apertural modifications, and a variety of presence-absence characters such as parietal tubercles, callus pad, pillar plications, or notch in the anterior canal. Relative length and curvature of the anterior canal have been employed as well as size range of the adult shell.

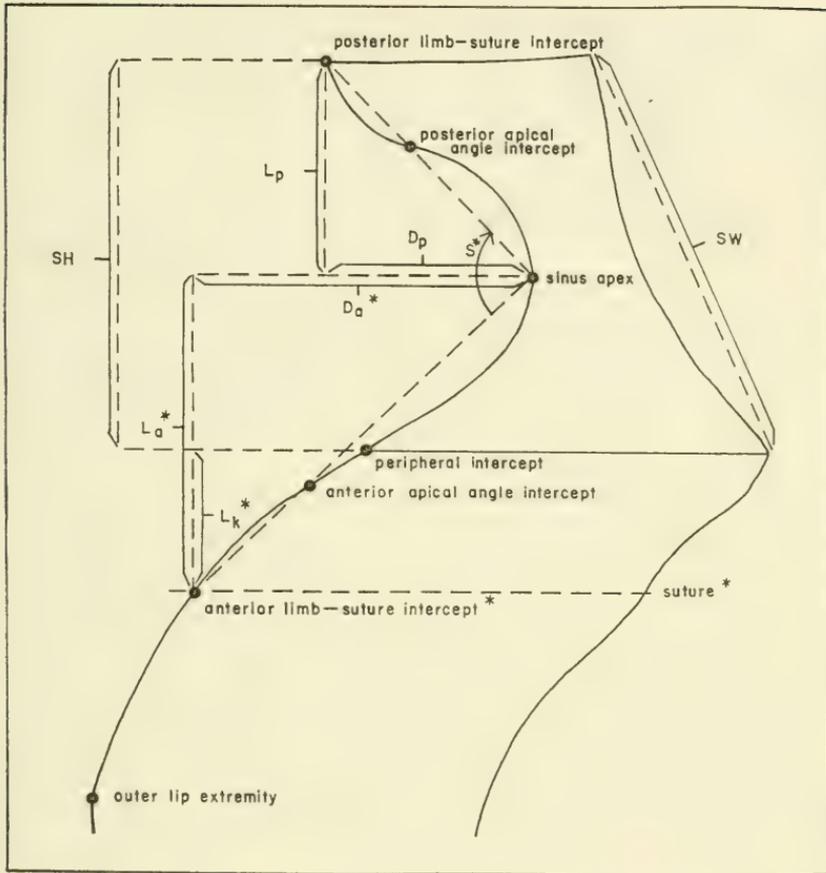
Many of these same characters are employed at the species level, although, in general, quantitative characters are applied more often at the specific level and seldom in generic differentiation. Turrid species are most often distinguished on the basis of differences in number, arrangement and kind of spiral and axial sculptural elements and differences in profile that are related to differences in relative rates of major components of growth. These are typically expressed in such terms as steepness of shoulder slope, relationship of whorl height to whorl diameter, or height of spire relative to height of body whorl. The relative usefulness of these characters can only be evaluated when they are measured in populations of specimens. In general, I have found characters of the anal sinus to be most useful (*i.e.* least variable within a population). New anal sinus characters used at the generic and specific levels in this study are defined and discussed below.

CHARACTERS AND CHARACTER STATES

Taxonomic confusion often arises from misuse of the term "character." Powell (1942, 1966), for example, referred to both the protoconch and the operculum as taxonomic characters, when, in fact, they are both complex shell features. Like the adult shell, they have many characters, some of which are more indicative of biological affinity than others. The number of protoconch whorls, their size, or rate of inflation may be ecologically controlled and not even useful at the species level, whereas ornamentation or whorl shape may be extremely useful for distinguishing genera and, for the diagonally reticulate protoconch of the Daphnellinae, useful for recognition of a subfamily.

A major recurring hypothesis in this study is that shell characters can be much more useful in turrid taxonomy if they are more carefully chosen and their states more rigorously defined. This hypothesis has been applied particularly to the labial sinus or posterior notch in the outer lip for deflection of the exhalent current carrying wastes from the mantle cavity. As a presence-absence character, it is the presence of the sinus (and not a radular character) that distinguishes the family. The sinus is a particularly good feature to use with fossils because it is generally well preserved on the shell as traces of growth lines. Furthermore, it is a complex and highly variable feature with a large number of geometric characters whose states can be quantitatively expressed. It is also functionally significant, since variation in its position and configuration reflects anatomical differences in the posterior pallial complex.

The only sinus character that has heretofore been employed unambiguously and effectively is the position of the sinus (*i.e.* the location of the apex or point of maximum indentation in the outer lip profile). The dichotomy of position employed by both Powell (1966) and McLean (1971) — whether on the shoulder slope or on the periphery — splits off the subfamily Turrinae Swainson, 1840, from all other subfamilies. Dealing with the other subfamilies, however, authors have failed to define characters and character states objectively. The position of the apex on the shoulder slope is generally described as "high," "central", or "low", and likewise the shape is subjectively described as "U-shaped", "V-shaped", "broadly concave", "subtubular", etc. The depth of the sinus has also been em-



Text-figure 2. — Geometry and measurements of the turrid anal sinus portrayed on a composite diagram of a body and spire whorl. Asterisks denote applicability only to sinus traces on spire whorls. L_p — height of posterior limb, L_a — height of anterior limb, D_p — posterior notch depth, D_a — anterior notch depth, S — sinus angle, SW — shoulder width, SH — shoulder height, L_k — height of sinus anterior to keel.

ployed, either as a “shallow” — “deep” dichotomy or with the use of adverbs such as “moderately.” The resulting descriptions of anal sinus configuration may be verbally complicated and contain information about a number of characters, but it is nonetheless possible that two outer lip profiles with identical verbal descriptions may be different in details of geometry.

	CHARACTERS	INTERPRETATION
$\frac{L_a - L_k}{SW}$	position of sinus on shoulder slope	.5 = central >.5 = upper shoulder slope <.5 = lower shoulder slope
S	sinus depth	>90° = shallow <90° = deep
$\frac{D_p}{D_a}$	relative position of sinus limb intercepts	1 = symmetric >1 = asymmetric, with posterior limb extending farther <1 = asymmetric, with anterior limb extending farther
$\frac{L_a - L_k}{L_a}$	position of peripheral keel intercept on basal limb	.5 = central <.5 = low, basal limb represented mainly on shoulder slope >.5 = high, basal limb represented mainly between keel & suture
NON-QUANTITATIVE CHARACTERS		CHARACTER STATES
	shape of posterior sinus limb	concave convex sigmoid* a. concavo-convex b. convexi-concave
	shape of anterior sinus limb	concave convex sigmoid* a. concavo-convex b. convexi-concave

*The relative lengths of concave and convex segments of a sigmoid sinus can be determined numerically to provide an additional quantitative character.

The potential of measurements involving the anal sinus was suggested by Gibson (1962) who used three such measures in analyses of turrids from the Maryland Miocene. It is not clear from Gibson's brief explanation of symbols precisely how the measurements were made, nor did he explicitly define characters from the measurements. The measurements, however, when paired in scattergrams with measurements of other shell dimensions, help to separate large populations from one another.

Text-figure 2 illustrates the geometry of the turrid anal sinus as utilized herein and shows the manner in which seven measurements are made. From the diagram and measurements, quantitative char-

acters are designated and the states of qualitative characters are defined. These characters are useful both in generic and specific differentiation. At the species level they are most helpful for characters with low variance and at the generic level when there is low standard error of the means in the species populations one hopes to cluster. They also permit precise description of specimens when, as is most often the case, populations are of insufficient size to treat statistically.

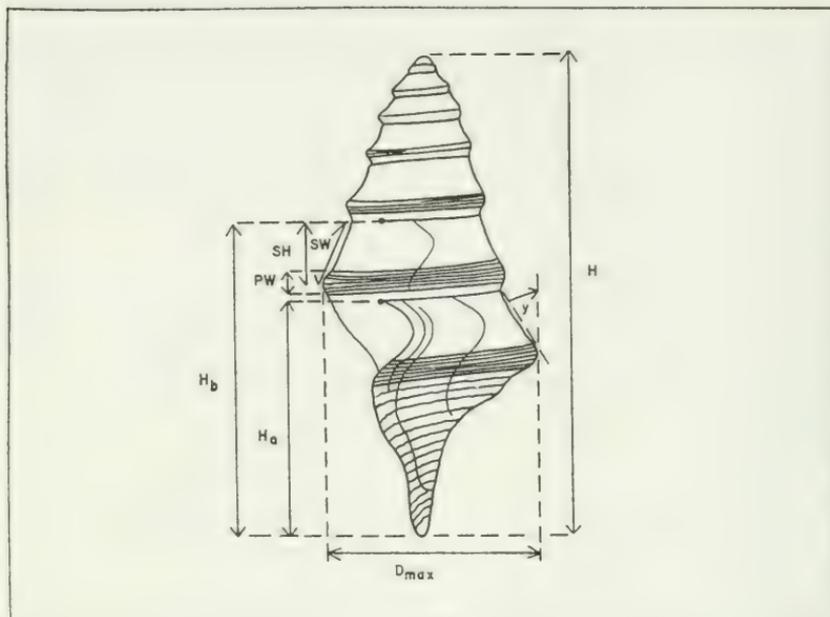
Statistical measures have been used only where appropriate and necessary to the clear distinction of taxa. In most instances the use of the characters outlined in Text-figure 2 has revealed pronounced discontinuities, although several specific discriminations are based on highly significant pairwise analyses of variance in overlapping populations.

Text-figure 3 provides a general orientation to the turrid shell and demonstrates the manner in which measurements of additional major dimensions are made. Shell height and maximum diameter are useful in specification of size ranges in populations, but their ratio is not generally useful in taxonomy. Two quantitative characters that are employed in species differentiation are the relative sizes of the body whorl and spire whorls, H/H_b , and the ratio of shoulder width to maximum peripheral diameter, SW/D_{max} . Although differences in relative peripheral widths, PW/SW , may be significant, they were not measured because characters of peripheral ornamentation (numbers of spiral bands or tubercles per whorl) provided more easily measured discontinuities.

DEEP-WATER TURRIDIS

The abundance of turrid species is one of the major bases for deep-water interpretation of Paleogene mollusk faunas in the Pacific Northwest (Hickman, 1974b). Text-figure 4 illustrates the increasing percentage of turrid species in modern neogastropod faunas with depth, compiled from the literature (Hickman, 1974b). The percent species composition of turrids in the Keasey Formation (55%) clearly identifies it with modern bathyal composition.

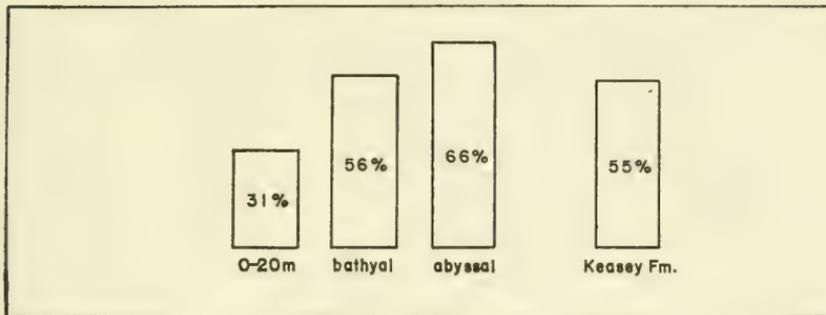
Little is known about modern deep-water turrids, for most species are based on one or a few dredged specimens. Population



Text-figure 3. — Definition of measurements of major dimensions of the turrid shell. H — height, D_{max} — maximum diameter, H_a — height of aperture, PW — width of periphery, SW — width of shoulder slope, SH — height of shoulder slope, H_b — height of body whorl, y — shoulder slope angle.

sizes greater than 50 specimens for 7 of the Paleogene species treated in this report represent the largest collections of deep-water turrid material known to me. These seven species occur at some of the highest frequencies and densities among mollusk species in the deep-water Paleogene facies in the Pacific Northwest. Data from relatively detailed sampling of the bathyal zone in Sagami Bay, Japan, (Okutani, 1964, 1968) suggest that high frequency and density are equally characteristic of some living deep-water turrid species.

A major difference between Paleogene and modern deep-water turrid faunas is the proportional representation of toxoglossate and non-toxoglossate species. Although the more advanced turrid subfamilies are represented in shallow-water Paleogene faunas (Powell, 1966, for geologic ranges), the deep-water faunas examined in the course of this study consist exclusively of species falling within the



Text-figure 4. — Percent species composition of turrids in neogastropod faunas from different depth zones.

non-toxoglossate subfamilies Turrinae, Turriculinae, and Clavinae. While turrine and turriculine species continue to comprise a significant proportion of described living deep-water turrid species in the Eastern Pacific (35%), there is an impressive additional component of toxoglossate borsoniine (17%) and daphnelline (42%) species falling in exclusively deep-water genera that are not reported from the fossil record (*e.g.* *Xanthodaphne* Powell, 1942; *Pleurotomella* Verrill, 1873; *Phymorhynchus* Dall, 1908; *Gymnobela* Verrill, 1884). To compare the Keasey fauna, which consists exclusively of non-toxoglossate turrine and turriculine species, with the living Oregon deep-water fauna, I examined unworked collections (courtesy of James H. McLean) at the Los Angeles County Museum of Natural History and was again struck by the predominance (greater than 50%) of small-shelled borsoniine and daphnelline species, many of them undescribed, in addition to the more familiar non-toxoglossate species. Late Cenozoic adaptive radiations of toxoglossate lineages into deep water are inferred, coupled with reduction in non-toxoglossate diversity. It is perhaps remarkable that this shift in proportional representation of toxoglossate and non-toxoglossate species has occurred without altering the proportion of turrids in neogastropod faunas over the past 40 million years.

Other characteristics of deep-water Paleogene turrids include high within-assemblage diversity — as many as seven species in an assemblage apparently representing a single habitat. This suggests feeding specialization and perhaps prey specificity. Shell size in

adults of many of these species is relatively large (greater than 30 mm), and shells are often thin and delicate. Ornamentation often is finer and more complex than in shallow-water species. Many have a prominently keeled or noded peripheral demarcation, and spiral sculpture predominates over axial.

The number, arrangement, and relative strength of sculptural elements may be highly variable in a large population and comparable to that in shallow-water turrid species. If the control of this variation is genetic, it contradicts the theory that variability is reduced in the deep sea (Gooch and Schopf, 1972).

USE OF TURRID IN BIOSTRATIGRAPHIC CORRELATION OF THE PALEOGENE DEEP-WATER FACIES

INTRODUCTION

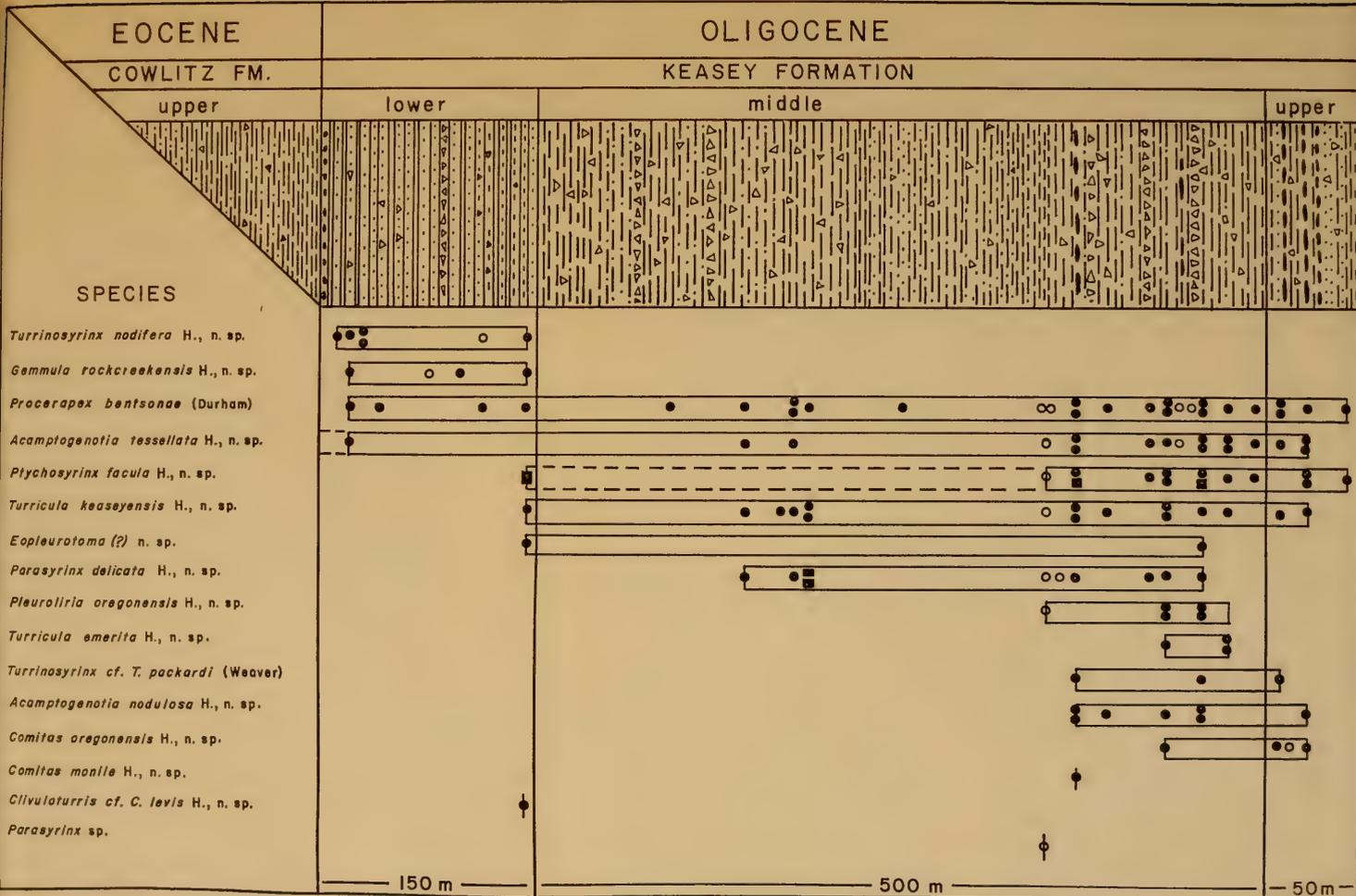
The use of turrid gastropods in provincial biostratigraphy has been restricted by inadequate taxonomic knowledge of the group. A major function of the systematic treatment below is to provide the biostratigraphic prerequisite definitions and revisions that will permit easy recognition of species.

Species concepts for some of the most common turrids in the Pacific Northwest Paleogene have been confused because of mixed syntypic lots (notably those of Weaver, 1912, 1916). Furthermore, the importance of the anal sinus was not recognized in the early years, and many diagnoses fail to mention the feature. Closely related species have been assigned to different genera, sometimes in different subfamilies, obscuring their affinities, while distantly related forms have been treated as close congeners.

Turrids are, however, among the most abundant and frequently encountered species in the deep-water facies. They are often exceptionally well preserved and easily recognized from fragments, particularly the ornately sculptured species. The anal sinus is likewise preserved even on fragmentary specimens as successive traces of the outer lip in the growth lines.

FINE SUBDIVISION OF STRATIGRAPHIC SEQUENCES

Many turrid species have narrowly restricted stratigraphic distributions within the Pacific Northwest Paleogene sequence, although the ranges of most species are poorly known. Intensive



Text-figure 5. — Stratigraphic ranges of turrid species in the Keasey Formation and composite columnar section. Open circles denote uncertainty of correct relative stratigraphic position and squares denote occurrence of variant forms.

stratigraphically controlled collecting is prerequisite to establishing ranges. Text-figure 5 illustrates the occurrences and ranges of 15 taxa within the Keasey Formation and serves to demonstrate the kind of range definition that is possible with turrids.

Although there are patterns in the stratigraphic distributions, no two species exhibit precisely the same range. Four stratigraphically distinct turrid assemblages occur in the formation: (1) a relatively low diversity assemblage in the lower member including two restricted species (*Turrinosyrinx nodifera* Hickman, n. sp. and *Gemmula rockcreekensis* Hickman, n. sp.). This assemblage is enriched at the top of the member by the appearance at low abundances of three species that are more abundant in higher assemblages; (2) a low diversity assemblage of four species [*Procerapex bentsonae* (Durham), *Acamptogenotia tessellata* Hickman, n. sp., *Turricula keaseyensis* Hickman, n. sp., and *Parasyrinx delicata* Hickman, n. sp.]. The four species are moderately abundant and relatively long-ranging, occurring throughout most of the formation in association with different sets of species in other assemblages; (3) a high diversity assemblage in the upper part of the middle member, marked by the appearance of six new species [*Pleuroliria oregonensis* Hickman, n. sp., *Turricula emerita* Hickman, n. sp., *Turrinosyrinx* cf. *T. packardi* (Weaver), *Acamptogenotia nodulosa* Hickman, n. sp., *Comitas (Boreocomitas) oregonensis* Hickman, n. sp., and *Comitas (Boreocomitas) monile* Hickman, n. sp.]. Long-ranging species occur at peak abundances in this assemblage, while species restricted to the assemblage are relatively less abundant; (4) a moderately diverse assemblage of species in the upper member that all occur at low density. This assemblage becomes increasingly impoverished at successively higher stratigraphic horizons within the upper member.

These four assemblages do not provide sufficient basis in themselves for formal biostratigraphic subdivision, but they support data (Hickman, unpub.) from the distribution of other mollusk species in the Keasey Formation and will be used with those data in formal definition and revision of biostratigraphic and chronostratigraphic units.

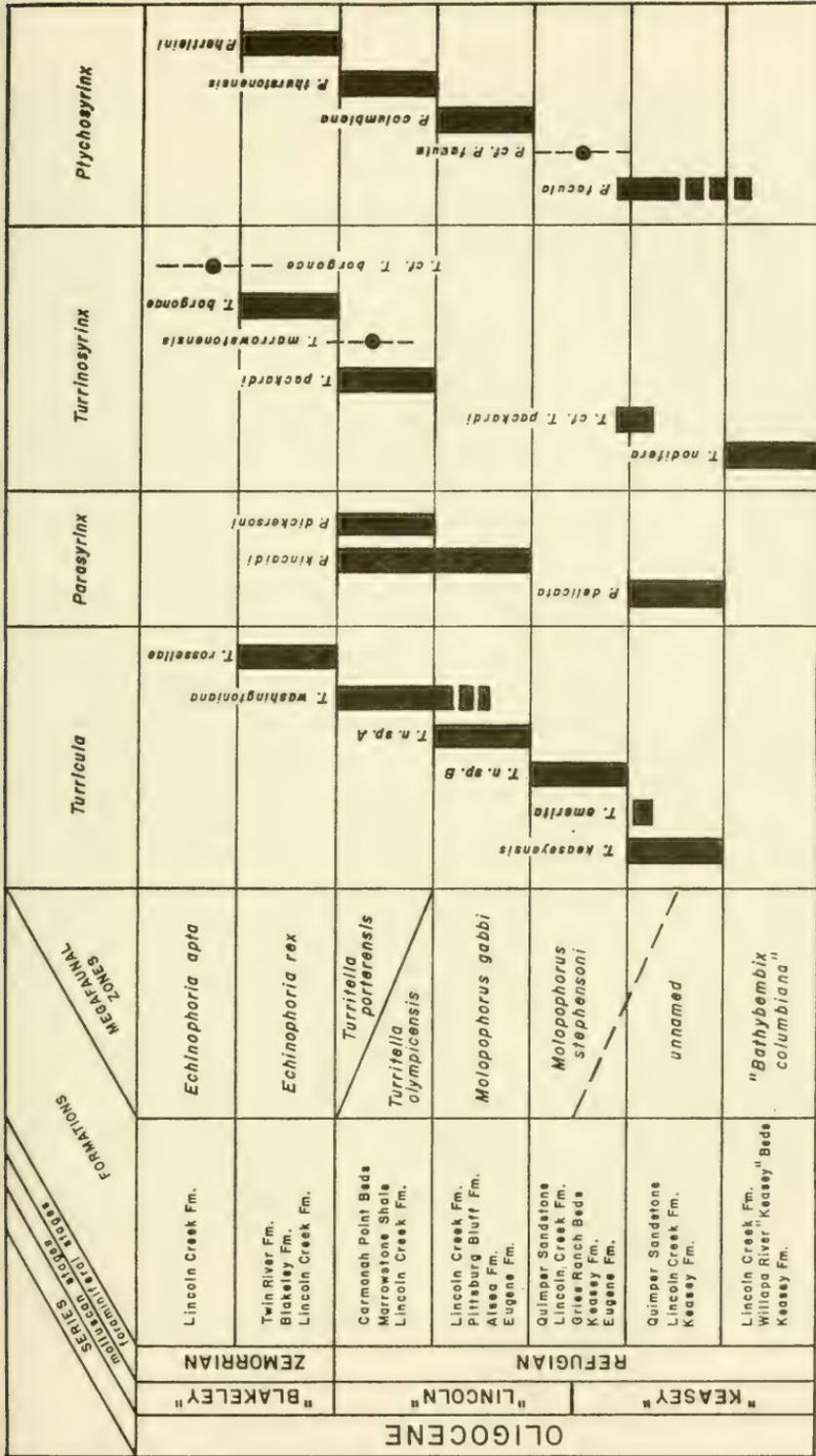
Prognosis for similar fine subdivision of deep-water stratigraphic sequences using turrid gastropods is good, especially for the thick

continuous Oligocene sections in the southern Olympic Peninsula and elsewhere in southwestern Washington.

INTRAPROVINCIAL CORRELATION

Turrid genera represented in the Keasey Formation are broadly useful in intraprovincial correlation at the zonal level throughout the Oligocene of the Pacific Northwest. The most useful of these are *Turricula*, *Parasyrinx*, *Turrinosyrinx*, and *Ptychosyrinx*. The ranges and occurrences of closely related species in these four genera are summarized in Text-figure 6. Ranges for the younger species are not firmly established. In nearly all cases, however, occurrences are limited to strata within a single molluscan megafaunal zone.

Although it is not necessarily the case that the species in these series represent direct phylogenetic lineages, it is possible to discern morphological trends or directions of adaptation that are biostratigraphically significant in themselves. These are most pronounced in *Turrinosyrinx*, which exhibits three parallel morphological trends: (1) the apex of the anal sinus is situated progressively higher on the shoulder slope in successively younger species within the provincial sequence, (2) the peripheral band is progressively narrower, and (3) the position of the intersection of the suture and the body whorl during coiling becomes progressively lower or farther anterior (Text-figure 6). In *Ptychosyrinx* there is a trend in three species [*P. facula* Hickman, n. sp.; *P. columbiana* (Anderson and Martin); *P. thurstonensis* (Weaver)] toward simplification of spiral sculpture including the disappearance of nodes on the periphery, reduction in the number of fine spiral elements, and development of a broad heavy peripheral band. The nodose condition reappears later in the Oligocene sequence, however, in *P. hertleini* (Durham) and may never have fully disappeared. In *Parasyrinx* there are parallel morphological trends in *P. delicata* Hickman, n. sp., *P. kincaidi* (Weaver), and *P. dickersoni* (Weaver) involving (1) successive lowering of the position of the apex of the anal sinus on the shoulder slope, (2) widening of the peripheral band, (3) increase in the ratio of shoulder width to maximum peripheral diameter, and (4) increase in relative length of the anterior canal and in relative total shell height (Text-figure 12 and Table 1). Comparable morphological trends in *Turricula* are not so apparent, although there is a general trend toward



Text-figure 6. — Ranges and occurrences of species of *Turricula*, *Parasyrinx*, *Turritiosyrinx*, and *Ptychostryx* exhibiting morphological trends within the provincial Oligocene sequence. Molluscan megafaunal zones are modified after Durham (1944).

relative steepening of the shoulder slope and decrease in maximum peripheral diameter as in *Parasyrinx*.

INTERPROVINCIAL CORRELATION

A major problem in biostratigraphic classification and correlation of the Paleogene deep-water facies is the geographic isolation of basins during the late Eocene and Oligocene. Although many turrid species show narrow geographic restriction or endemism, there are several notably wide-ranging forms of interprovincial significance. For example, *Acamptogenotia tessellata* Hickman, n. sp. and *Procerapex bentsonae* (Durham), which have nearly identical ranges based on numerous occurrences within the Keasey Formation in northwestern Oregon (Text-figure 5), also occur together at 48° N latitude in the northeastern Olympic Peninsula and again in southern California between 35° and 36° N latitude.

SYSTEMATIC PALEONTOLOGY

The majority of the specimens examined in this study are housed at the U.S. National Museum of Natural History and were collected either by the author or in conjunction with the preliminary geologic mapping of the upper Nehalem River basin in Oregon (Warren and others, 1945). Locality data are recorded at the institutions where material is housed and are not presented herein. Locality numbers and type numbers cited in systematic accounts are identified as to institution by the following abbreviations:

ANSP	Academy of Natural Sciences, Philadelphia, Pa.
CAS	California Academy of Sciences, San Francisco
LACM	Los Angeles County Museum of Natural History
SU	Stanford University, Museum of Paleontology
SU H	Stanford University, Holman locality
SU NP	Stanford University, Northern Pacific locality
SUPTC	Stanford University, Paleontology Type Collection
UCMP	University of California, Berkeley, Museum of Paleontology
UO	University of Oregon, Eugene, Museum of Natural History
UW	University of Washington, Seattle, Burke Museum
USGS	U.S. Geological Survey, Washington, D.C., Cenozoic locality register
USGS M	U.S. Geological Survey, Menlo Park, Ca., Cenozoic locality register
USNM	U.S. National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Superfamily **CONACEA**Family **TURRIDAE**Subfamily **TURRICULINAE**Genus **TURRICULA** Schumacher, 1817

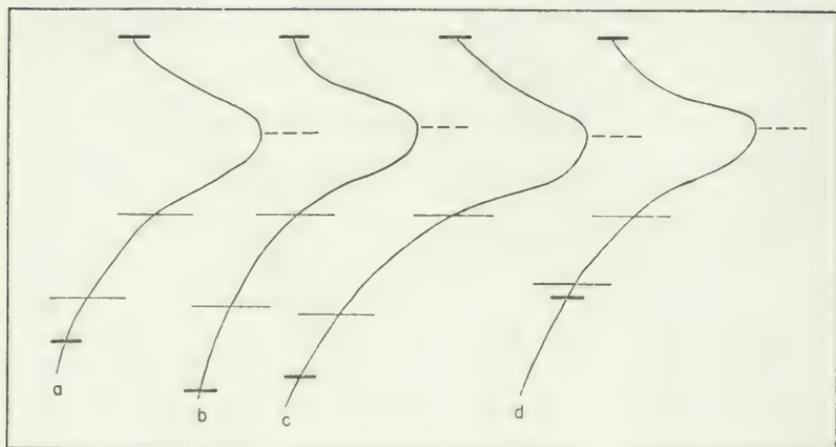
Type species (by monotypy): *Murex tornatus* Dillwyn, 1817. Recent, Indo-Pacific.

The generic name *Turricula* has been applied in a broad sense to a large number of living and fossil elongate-fusiform shells in which the anal sinus is on the shoulder slope. With refinement of turriculine classification and the addition of generic categories based on differences in protoconch, anal sinus, opercular, and radular morphology, *Turricula* has become more restricted in application to a group of living species in the warm shallow-water Indo-Pacific fauna. The name has been applied perhaps too indiscriminately and extensively to Cenozoic species in the United States and Europe, but it is still useful when names based on more specialized and sometimes unique species prove inappropriate.

A group of closely related elongate-fusiform species in the provincial Oligocene of the Eastern Pacific exhibits a complex of turriculine shell characters that are close to those of *Turricula*, *s. s.* Particularly striking is the similarity in configuration of the anal sinus (Text-figure 7), which is moderately deep (less than 90°), asymmetrically U-shaped and restricted to a narrow region of the shoulder slope by a spiral ridge, line, or groove that bisects the posterior limb of the sinus and coincides with the limb in its region of maximum parallelism to the suture and periphery (Pl. 1, fig. 18).

Insolentia Finlay, 1926, has been employed for a similar group of Paleogene species in New Zealand and Australia that are distinguished by a tall, polygyrate protoconch.

Knefastia Dall, 1919, has been applied to species in the Pacific Northwest Oligocene complex (Durham, 1944; Powell, 1966). Although the anal sinus configuration of *Knefastia* is similar, this tropical shallow-water Eastern Pacific group characteristically has larger, thicker, and more coarsely ornamented shells with broader anterior canals. Two species of *Knefastia* reported from the Cali-



Text-figure 7. — Comparative anal sinus configuration of four Paleogene species of *Turricula*, from camera lucida tracings of growth lines on body whorls, adjusted to uniform shoulder height. Heavy lines denote posterior and anterior sutures, light lines denote boundaries of peripheral keel, and dashed line denotes apex of sinus. a. *T. keaseyensis* Hickman, n. sp.; b. *T. emerita* Hickman, n. sp.; c. *T. washingtoniana* (Weaver); d. *T.*, n. sp. B.

fornia Miocene (Addicott, 1970a, p. 131) apparently represent the earliest records of *Knefastia*, *s. s.*

The species here assigned to *Turricula* cannot be traced back into the Eocene. Eocene Pacific Coast fusiform turriculine species are more closely related morphologically to *Fusiturricula* Woodring, 1928, and *Pleurofusua* de Gregorio, 1890, and exhibit closer affinities with forms in the European and the U.S. Gulf Coast Eocene.

***Turricula keaseyensis* Hickman, n. sp.**

Pl. 1, figs. 5-7, 11, 12;
Text-figure 7a

Knefastia aff. *K. washingtoniana* (Weaver), Vokes, 1945 (checklist) in Warren and others, U.S. Geol. Sur. Oil and Gas Inv. Prelim. Map 42.

Description. — Shell of moderate size (\bar{x} = 20 mm), fusiform, with a turreted spire and long, slender, twisted, unnotched anterior canal; whorls 6, apical whorls worn or broken on all material at hand; shoulder slope smoothly polished, slightly concave, and sloping at an angle of 42° from the axis of coiling; anal sinus deep (less than 90°), asymmetrically U-shaped, with its apex located slightly above

mid-slope and consisting of a short sigmoid (convexi-concave) posterior limb and sigmoid (concavo-convex) anterior limb with a long convex segment merging in a broad protractive sweep with the outer lip; posterior sinus limb-traces intersected by faint spiral ridge on well-preserved specimens; peripheral band broad and prominent, set with 12 to 17 robust elongate nodes that are crossed by 5 to 7 unrotating spiral bands separated by fine-incised lines; remainder of body whorl and anterior canal ornamented by approximately 20 spiral bands of equal to subequal strength, separated by fine-incised lines; suture abutting, following base of peripheral nodes throughout coiling; inner lip with thin inductura.

Dimensions of holotype. — Height (incomplete) 17.6 mm; maximum diameter 9.2 mm.

Material examined. — Seventy-seven specimens.

Variation. — Aside from variation in the number of peripheral nodes per whorl, this species is relatively constant in its morphology at all localities where it has been collected. It is less variable than its close relative *T. washingtoniana* of the Lincoln Creek Formation.

Stratigraphic distribution. — *Turricula keaseyensis* is one of the most abundant species in collections from the middle member of the Keasey Formation, occurring throughout the member. A single specimen was collected at locality USGS 15309, at the top of the lower member. At this locality it is associated with a different set of species, including *Bathybembix columbiana* (Dall) and other species that are restricted to the lower member. *T. keaseyensis* also occurs at two localities in the upper member but does not range upward into the Pittsburg Bluff Formation (Text-figure 5).

Holotype. — USNM 216375. *Figured paratypes.* — USNM 216376, 216377, 216378. *Unfigured paratypes.* — USNM 216379 (height 17.8 mm), 216380 (height 9.3 mm).

Type locality. — Middle member, Keasey Formation: USGS 25038.

Other localities. — Lower member, Keasey Formation: USGS 15309. Middle member: USGS 15267, 15268, 15276, 15279, 15280, 15281, 15282, 15517, 15602, 25030, 25031, 25039. Upper member: USGS 15518, 25032.

Comparative notes. — *Turricula keaseyensis* is most closely related to *T. washingtoniana*, but the two species are clearly dif-

ferentiated by the angle of slope of the shoulder ($\bar{x} = 42.2^\circ$, s. e. = 0.60 in *T. keaseyensis*; $\bar{x} = 34.6^\circ$, s. e. = 0.34 in *T. washingtoniana*). There is no overlap in the values of this angle in two populations of 20 individuals each, and the resultant characteristic whorl profiles of the two species are intuitively recognizable in most instances. The peripheral nodes in *T. keaseyensis* are more robust, axially elongate and laterally compressed. The ornamentation of the base uniformly consists of flat spiral bands of nearly equal strength, in contrast to the 2 to 3 heavy spiral cords demarcating the basal constriction in *T. washingtoniana*. The anal sinus in *T. keaseyensis* tends to be shallower than in *T. washingtoniana*, but the configuration is sufficiently variable in both species to render it least valuable as a distinguishing criterion.

Turricula emerita Hickman, n. sp.

Pl. 1, figs. 14-18;
Text-figure 7b

Description.— Shell large (45 mm), robust, with a tall, slender spire and moderately long, flexed, unnotched anterior canal; spire height greater than height of aperture plus canal; whorls 7, apex abraded; shoulder slope moderately steep, inclined at 36° to the axis of coiling and occupying posterior $2/3$ of spire whorls, surface wrinkled from close-crowded traces of labial sinus and bearing a prominent spiral ridge at $1/3$ distance from suture to periphery, intersecting and subparallel to posterior limb of anal sinus; peripheral nodes 12 to 15, distinct, axially elongate and connected by undulating spiral bands on early whorls, becoming faint to indistinct and overridden by crowded protractive growth lines on later whorls; base ornamented by 20 or more fine undulose spiral bands, gradually becoming obsolete anteriorly on canal; inner lip with thin to moderately well-developed inductura.

Emerita is a Latin adjective meaning "retired from service."

Dimensions of holotype.— Height 41.9 mm; maximum diameter 16.2 mm.

Material examined.— Thirteen specimens.

Variation.— *Turricula emerita* seems to be relatively constant in morphology and is easily recognized by its large size and steep shoulder slope. The degeneration of the sculpture pattern on later whorls initially suggested that the large specimens might be gerontic

individuals of *T. keaseyensis*. Comparison of equivalent growth stages, however, shows that the shoulder slope is consistently steeper in the large form (36°) as opposed to *T. keaseyensis* (42°).

Stratigraphic distribution. — *Turricula emerita* has a more restricted distribution than *T. keaseyensis*, occurring only within the upper 60 m of the middle member of the Keasey Formation (Text-figure 5). It has been collected at three localities in the middle member and co-occurs with *T. keaseyensis* at two of the three localities.

Holotype. — USNM 216381. *Figured paratypes.* — USNM 216382, 216383. *Unfigured paratypes.* — USNM 216384 (height 36.5 mm), 216385 (height 27.9 mm), 216386 (height 25.5 mm), 216387 (height 22.3 mm), 216388 (height 33.5 mm).

Type locality. — Middle member, Keasey Formation: USGS 25031.

Other localities. — Middle member, Keasey Formation: USGS 15267, 15508.

Comparative notes. — *Turricula emerita* is distinguished from other Paleogene turriculine species by its large size, characteristic close crowding of growth lines on the shoulder slope and periphery, and more prominent development of the subsutural ridge that is typical of the group. It combines characters of two closely related species, *T. keaseyensis* and *T. washingtoniana*, with a pattern of spiral ornamentation similar to the former species and a shoulder slope angle and whorl profile more comparable with the latter. *T. emerita* may represent an offshoot specialized on larger prey if predator size is correlated with prey size in turrids.

Turricula washingtoniana (Weaver, 1912)

Pl. 1, figs. 1-4;
Text-figure 7c

Pleurotoma washingtoniana Weaver, 1912, Washington Geol. Sur., Bull. 15, p. 78 (in part ?), pl. 3, fig. 31.

Not *Turris washingtonianus* Weaver, 1916, Univ. Washington Pubs. Geol., vol. 1, No. 1, pl. 4, fig. 45.

Turricula washingtonensis (Weaver), Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, p. 533 (in part), pl. 98, figs. 16, 22, not pl. 98, fig. 17.

Clavatula (Knefastia) washingtoniana (Weaver), Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 188.

Discussion. — Although the figure accompanying Weaver's (1912) original description clearly identifies one of the most common species in the Lincoln Creek Formation, no holotype was designated,

and two separate species are represented in the type lot. The other "syntype" (so-called by Weaver, 1943), figured as *Turris washingtonianus* Weaver (Weaver, 1916), is a specimen of *Turris kincaidi* Weaver, 1916 (discussion of *Parasyrinx kincaidi*). Weaver figured a third specimen that he assigned to this species in 1943 (pl. 98, fig. 16), although he mistakenly identified it by the same type number (CAS 545) assigned to the specimen figured in 1912. This third specimen is not in the type collection at the California Academy of Sciences and is apparently lost. Syntype CAS 545 (Weaver, 1912, pl. 3, fig. 31) is here designated as lectotype of *Turricula washingtoniana*.

Turricula washingtoniana is a slender, high-spired, fusiform turrid exhibiting considerable variation in detail of spiral ornamentation and in the number and strength of peripheral nodes. The species is easily recognized, however, by the characteristic division of the body whorl into three approximately equal regions: (1) a smooth, polished, steeply sloping, concave shoulder slope lacking spiral ornamentation and inclined at an angle of 35° to the axis of coiling, (2) a region between the periphery and basal constriction set with prominent spiral cords of equal or alternating strength that are undulatory where they cross the lower portion of the peripheral node row, and (3) a constricted anterior canal ornamented by fine, decreasingly prominent spiral threads. The peripheral nodes vary from rounded to axially elongate and are crossed on their lower portions by three or four undulating spiral bands separated by fine-incised grooves. Although Weaver (1912) recorded 16 nodes on the body whorl, the mean number of nodes in a sample of 100 specimens from the Lincoln Creek Formation is 13. The mean is not the same at all localities nor is the range. Twelve nodes are typical in the least variable populations, while specimens with 16 nodes tend to occur in more variable populations with specimens having as few as 10 nodes on the body whorl. The number of nodes does not vary appreciably during ontogeny, although several specimens were noted as having higher node counts on early whorls.

Spiral ornamentation between the base of the nodes and the basal constriction typically (Pl. 1, figs. 1, 2) consists of two prominent spiral cords separated by an interspace of approximately equal width, sometimes containing an intercalated secondary spiral. The

abutting suture follows the posteriormost of the prominent spirals throughout coiling. On some specimens (Pl. 1, figs. 3, 4) the two prominent spirals are replaced by as many as six fine, more close-spaced spirals of equal or subequal strength.

Protoconchs are consistently missing or worn but appear to have two, possibly three, rounded whorls. Early postnuclear whorls are carinate for several turns before nodes appear. The anterior canal is long, slender, and slightly recurved. There is no evidence in any of the material I have examined, including the lectotype, of the "one faint plication" of the columella referred to in Weaver's original description. A parietal inductura is present and varies from a thin wash through which unresorbed ornament is visible to a relatively heavy deposit.

The anal sinus is deep (less than 90°) and asymmetric, with a short upper limb and apex situated on the upper half of the shoulder slope (Text-figure 7). The anterior limb of the sinus tends to be shallowly concave, while the posterior limb is convex and intersected on unweathered specimens by a faint spiral ridge. The geometry of the sinus is similar in all of the Pacific Northwest Paleogene species, and the range of variation displayed in successive traces on one individual may be as great as the range for the species to which it belongs.

Material examined.—Three hundred ninety-five specimens (Lincoln Creek Formation), 14 specimens (Carmanah Point Beds), 6 specimens (Quimper Sandstone).

Stratigraphic distribution.—*Turricula washingtoniana* is one of the characteristic species of the *Turritella porterensis* megafaunal zone (Text-figure 6). It is one of the most abundant species in the Porter Bluffs section of the Lincoln Creek Formation, the type section of the zone, and also occurs at equivalent horizons in the lower part of the type section of the Lincoln Creek Formation northwest of Galvin, Washington. On Vancouver Island, British Columbia, *T. washingtoniana* occurs in equivalent beds at Carmanah Point (SU NP 137). In the northeastern Olympic Peninsula, *T. washingtoniana* occurs as low as the middle portion of the Quimper Sandstone (UCMP A1811 and CAS 217) in beds assigned to the *Molophorus gabbi* megafaunal zone of Durham (1944). I have not been able to evaluate Vokes (1945, checklist) report of this species in

the Pittsburg Bluff Formation in Oregon, and Moore (in press) does not report it from the formation.

Lectotype. — CAS 545. *Hypotypes*. — SUPTC 10200, 10201. USNM 216389, 216390.

Localities. — Lincoln Creek Formation: UW 90 (type locality). UW 352, 251h, A303; UCMP 4212, A9, A1635, A1636, A1637, A8372, A8723, A8724; USGS 18948, 18949, 18950, 18951, 18952, 18683, 18974, 18976, M1730, M1731, M4068; CAS 193, 194, 189, 924, 34235; SU 40, H 12, NP 53, NP 54, NP 55, NP 50, NP 211. Carmanah Point Beds: SU NP 137; USGS M5927. Quimper Sandstone?: SU NP 152. Quimper Sandstone: UCMP A1811; CAS 217.

***Turricula rossellae* (Durham, 1944)**

Pl. 1, fig. 9

Turricula kincaidi (Weaver), Tegland, 1933, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 23, No. 3, pp. 126-127, pl. 10, figs. 12, 13.

Clavatula (Knefastia) rossellae Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 188, pl. 14, figs. 11, 16.

Knefastia rossellae Durham, Powell, 1966, Auckland Inst. Mus. Bull. 5, p.31.

Discussion. — *Turricula rossellae* is distinguished from other Pacific Northwest Paleogene species by its flatter spire profile and coarser spiral ornamentation. The species is not well known, and heretofore was reported only from the type Blakeley Formation. A single specimen from the Twin River Formation (USGS M4404) is similar to the holotype and indicates that the species is more widespread in the provincial late Oligocene "Blakeley Stage" of Weaver and others (1944). Three additional specimens were collected by John Armentrout on the West Fork of the Satsop River in the southern Olympic Peninsula from beds assigned to the *Echinophoria rex* megafaunal zone of Durham (1944). The spire height and apical angle vary in these specimens, and the apex of the anal sinus is situated higher on the shoulder slope than in other material I have seen; but the robust sculpturing is typical of the species. In both the Twin River and Lincoln Creek material the peripheral nodes become obsolete on later whorls.

Material examined. — Six specimens.

Hypotype. — USNM 216391 (USGS M4404, Twin River Formation).

Other localities. — Lincoln Creek Formation: UW B1341, B1342. Blakeley Formation: UCMP 681 (type locality).

Turricula, n. sp. A

Pl. 1, fig. 10

Discussion.—An incomplete specimen of a *Turricula* from the Alsea Formation in Oregon (Text-figure 1) exhibits characters of both *T. washingtoniana* and *T. emerita*. The prominent spiral cords anterior to the periphery and more rounded peripheral nodes suggest the former species, while the prominence and crowding of growth lines recording successive traces of the labial sinus and the prominence of the subsutural ridge are characteristic of *T. emerita*. Material is yet insufficient for formal description.

Stratigraphic position.—The sole specimen is from the lower part of the Alsea Formation. Associated mollusks indicate that the locality is stratigraphically higher than the highest occurrence of *T. emerita*, but it is not clear whether it is lower than the lowest occurrence of *T. washingtoniana* or equivalent to a horizon within the range of that species.

Figured specimen.—USNM 216392. (USGS M2612, Alsea Formation).

Turricula, n. sp. B

Pl. 1, fig. 8; Text-figure 7d

Discussion.—Small fragmentary specimens of a high-spired *Turricula* occur in the lower part of the Quimper Sandstone in the northeastern Olympic Peninsula in Washington. Although the material at hand is insufficient for a new name, the species is readily distinguished from other Paleogene species by its smaller size (less than 20 mm), narrower form, and by the presence of fine spiral ornamentation on the steep shoulder slope as well as on the base. The configuration of the anal sinus is similar to that of other species in the complex (Text-figure 7d).

Stratigraphic distribution.—*Turricula*, n. sp. B occurs at three localities within the *Molopophorus stephensoni* megafaunal zone of Durham (1944). The stratigraphic range of the species is bracketed by older records of *T. keaseyensis* and younger records of *T. washingtoniana* (Text-figure 6).

Figured specimen.—SUPTC 10202. (SU NP 148, Quimper Sandstone).

Other localities.—Quimper Sandstone: UCMP A1802, A3697.

Genus **COMITAS** Finlay, 1926

Type species (by original designation): *Surcula oamarutica*

Suter, 1917 (= *Drillia fusiformis* Hutton, 1877). Oligocene, New Zealand.

Comitas has been broadly interpreted by Powell (1966, 1969) to include a variety of large-shelled austral deep-water Cenozoic species. They are often of light build; sculptured by protractively oblique axial folds, wrinkles, or nodes and numerous fine spiral threads; and the anal sinus is usually shallow (greater than 90°) with its apex low on the shoulder slope. The characters listed above intergrade with characters more normally associated with *Turricula* Schumacher, 1817, the shallow-water Indo-Pacific counterpart of *Comitas*, and the distinction between the two genera is not always clear. Powell (1966, 1969) relied on the operculum to separate the two genera. However opercular characters have not been recorded for most species, and it is possible that the genera are polyphyletic as currently construed, based on shell characters that are controlled more by temperature- and depth-related factors than a single genetic dichotomy.

Although the type species of *Comitas* and *Turricula* both have narrow fusiform shells, with long anterior canals, species with stout biconic profile and short clavine-type truncated anterior canals have been assigned to both genera. These claviform species lack the heavy callus pad that is typical of the subfamily Clavinae, however, and, therefore, appear to be more appropriately located in the Turriculinae. Radulae are unrecorded for these species.

Comitas, s. s. has not been confidently recognized outside of the Indo-Pacific, although it is present in that region throughout most of the Cenozoic.

Subgenus **BOREOCOMITAS** Hickman, n. subgen.

Type species: *Comitas (Boreocomitas) oregonensis* Hickman, n. sp. Middle and upper members, Keasey Formation, early Oligocene, Oregon.

Boreocomitas is proposed for a claviform group of Paleogene species in the Pacific Northwest. They share with Indo-Pacific *Comitas, s. s.* a broad shallow turriculine anal sinus with anterior limb confluent with the broad protractive sweep of the outer lip as well as the tendency toward protractive oblique axial folds or nodes at the periphery. The posterior sinus limb is sigmoid (convexi-

concave). Although there is moderate development of callus on the inner lip, it is not a massive pad as in the Clavinae, nor is there any constriction of the anal sinus by a parietal tubercle. *Boreocomitas* is distinct in the pronounced concave constriction of the body whorl anterior to the periphery and the twisted fasciolate anterior canal. The surface of the shell is typically sculptured with fine spiral threads, which may be less well developed to obsolete on the shoulder slope. The protoconch is missing or worn on all specimens examined, but it is apparently paucispiral, lies in the same cone as the spire, and is tilted apically.

The name *Boreocomitas* is selected for historical zoogeographic reasons, in recognition of the basically austral distribution of the genus. Penetration and brief establishment of a branch of this deep-water turriculine stock in the North Pacific during global cooling is a reasonable hypothesis in spite of the apparent disjunction.

Comitas (Boreocomitas) oregonensis Hickman, n. sp. Pl. 1, fig. 13;
Pl. 2, figs. 8, 11-14; Text-figure 8c, d, e

Description.—Shell moderately large, biconic, and of light build, with short anterior canal and relatively short spire; height of spire about equal to that of aperture plus canal; teleoconch whorls seven; protoconch badly worn, apparently tilted apically; spire whorls carinated anteriorly; shoulder slope convex, ornamented by six or seven spiral threads separated by broader interspaces; spirals fewer on early whorls, arising by intercalation; trace of anal sinus on shoulder slope broad and shallow, its apex immediately posterior to periphery; periphery consisting of three close-spaced spiral threads that are drawn into about 15 protractively oblique irregular axial wrinkles on the body whorl, following the forward sweep of the anterior limb of the anal sinus; base of body whorl concave, ornamented by about 15 spiral threads that tend to be slightly more prominent than those on the shoulder slope; outer lip thin, protracted and slightly fluted at the termination of spiral threads; inner lip with moderately well-developed callus that is most prominent on the twisted and slightly notched anterior canal, where it forms a ridge margining the siphonal fasciole.

Dimensions of holotype.—Height 29.1 mm; maximum diameter 13.9 mm.

Material examined. — Five specimens.

Variation. — The most variable characters in the five specimens on which the species is based are the number, strength, and spacing of spiral threads on the shoulder slope. The anteriormost spiral is particularly heavily developed on one of the paratypes (USNM 216395), although numerous fine close-spaced spiral threads are present there on another (USNM 216394). The latter specimen occurs stratigraphically lower, but additional specimens are necessary before stratigraphically significant patterns of variation can be assessed. The configuration of the anal sinus is also variable, particularly the posterior limb, which varies from markedly sigmoid, with a concave posterior and convex anterior segment, to nearly straight. The anal sinuses of three separate specimens are illustrated for comparison in Text-figure 8c-e. A shallow stromboid-type notch is present in the anterior portion of some growth lines, but it is not a consistent feature even on one individual.

Stratigraphic distribution. — This species has been collected from the upper member and highest portion of the middle member of the Keasey Formation, in contrast to *Comitas biconica* Hickman, n. sp., which occurs only in the underlying Cowlitz Formation and *C. monile* Hickman, n. sp., which occurs at a single locality lower in the middle member of the Keasey Formation (Text-figure 5).

Holotype. — USNM 216393. *Figured paratypes.* — USNM 216394, 216395; SUPTC 10203. *Unfigured paratype.* — USNM 216396 (fragment).

Type locality. — Upper member, Keasey Formation: USGS 15518.

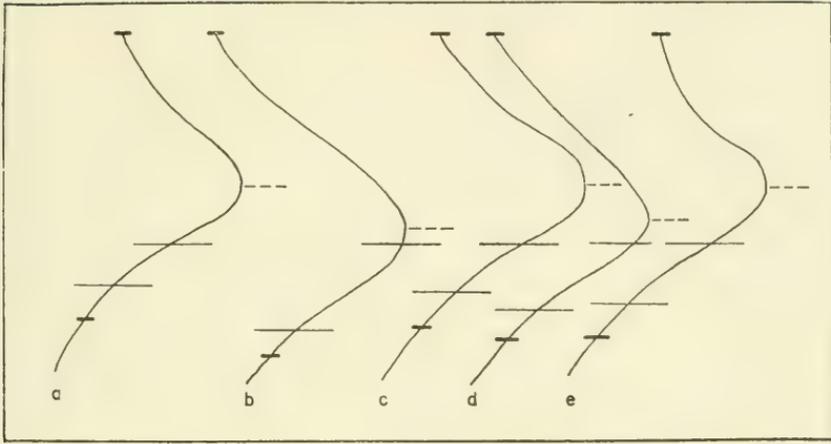
Other localities. — Middle member, Keasey Formation: USGS 15267. Upper member: USGS 25032; SU H 40.

Comparative notes. — This species is distinguished from its congeners by relatively greater adult size; fewer, more irregular, and more obliquely produced peripheral nodes; and more conspicuously ornamented shoulder slope. The anal sinus is illustrated in Text-figure 8.

***Comitas (Boreocomitas) biconica* Hickman, n. sp.**

Pl. 2, figs. 4-7;
Text-figure 8a

Description. — Medium sized, biconic, teleoconch with approxi-



Text-figure 8.—Comparative anal sinus configuration of three Paleogene species of *Comitas* (*Boreocomitas*), n. subgen., from camera lucida tracings of growth lines, adjusted to uniform shoulder height. Heavy lines denote posterior and anterior sutures, light lines denote boundaries of peripheral keel, and dashed line denotes apex of sinus. a. *C. biconica* Hickman, n. sp.; b. *C. monile* Hickman, n. sp.; c., d., e. tracings from three different specimens of *C. oregonensis* Hickman, n. sp.

mately six whorls, protoconch abraded on all specimens at hand; shoulder gently concave, with spiral ribbing strongest at periphery and suture, obsolete on central part of slope; two spirals immediately anterior to suture puckered or beaded at intersection with growth lines; apex of anal sinus marked by prominent spiral rib low on shoulder slope; sinus shallow (greater than 90°), asymmetric, with a short sigmoid (convexi-concave) posterior limb and protracted sigmoid (concavo-convex) anterior limb merging with a broadly convex outer lip; periphery consisting of three prominent close-spaced spiral cords, each undulating to produce 20 horizontally elongate nodes with interspaces of approximately equal width on body whorl; node rows not aligned vertically but slightly oblique, following trace of anterior limb of sinus; base concave, gradually tapering to short, twisted, and weakly fasciolate anterior canal ornamented by 12 to 13 spiral threads; inner lip with thin inductura to moderately well-developed callus, restricted parietally so that it does not extend into the labial sinus; suture slightly adpressed, situated immediately anterior to the periphery throughout coiling.

Dimensions of holotype. — Height 20.0 mm; maximum diameter 10.5 mm.

Material examined. — Four specimens.

Variation. — The few specimens upon which this species is based are similar to one another in proportion and details of ornamentation. However, further collections are required to define the variability of the species.

Stratigraphic distribution. — *Comitas biconica* is restricted to the upper portion of the Cowlitz Formation in northwestern Oregon (Text-figure 1) and represents the lowest stratigraphic occurrence of the subgenus.

Holotype. — USNM 216397. *Figured paratypes.* — USNM 216398; SUPTC 10204. *Unfigured paratype.* — SUPTC 10205 (height 21.0 mm).

Type locality. — Cowlitz Formation: USGS 15533.

Other localities. — Cowlitz Formation: USGS 15296; SU H 46, SU Acc. 30327.

Comparative notes. — *Comitas monile* Hickman, n. sp. of the middle member of the Keasey Formation differs from *C. biconica* in its relatively broader periphery, more convex base and shoulder slope, finer and more numerous basal spirals, and by the configuration of the anal sinus, which is illustrated in Text-figure 8. *C. oregonensis* Hickman, n. sp. of the middle and upper members of the Keasey Formation is distinguished by its greater adult size; more oblique, fewer, and more irregular axial nodes; and its more distinctly ornamented shoulder slope.

***Comitas (Boreocomitas) monile* Hickman, n. sp.**

Pl. 2, figs. 1-3;
Text-figure 8b

Description. — Shell of medium size, relatively thin, biconic, with a short spire and pronounced basal constriction; protoconch unknown: shoulder slope concave, polished, with faint spiral threads except for a strong spiral immediately posterior to the periphery; periphery consisting of three prominent moniliform cords separated by fine-incised grooves, each with 19 nodes that are aligned nearly vertically; base strongly convex anterior to keel and ornamented by numerous fine spiral threads of subequal prominence and spacing; anal sinus shallow, with a sigmoid (convex-concave) posterior limb

occupying most of the shoulder slope, apex on a prominent spiral cord on anteriormost portion of slope; sigmoid (concavo-convex) anterior sinus limb produced well beyond limit of posterior limb; successive traces of outer lip with faint stromboid-type sinus anteriorly; suture slightly appressed, situated immediately anterior to periphery throughout coiling; details of parietal lip and canal not known.

The specific name *monile* is a Latin noun of neuter gender meaning "a necklace".

Dimensions of holotype. — Height (incomplete) 17.3 mm; maximum diameter 10.9 mm.

Material examined. — Three specimens.

Variation. — Material at hand is insufficient to determine variability in this species.

Stratigraphic distribution. — The three specimens upon which the above description is based come from a locality in the middle member of the Keasey Formation, approximately 120 m below the top of the member and 60 m below the lowest occurrence of *C. oregonensis* (Text-figure 5). The range of the species and its biostratigraphic potential remain to be established.

Holotype. — USNM 216399. *Paratypes.* — USNM 216400, 216401.

Type locality. — Middle member, Keasey Formation: USGS 15280.

Comparative notes. — This species is most readily distinguished from its congeners by its relatively broader maximum diameter and more densely ornamented base, as well as by a more peripherally situated anal sinus (Text-figure 8).

The **ACAMPTOGENOTIA** Group

Two new species in the Keasey Formation share a complex of characters which place them in the genus *Acamptogenotia* Rovereto, 1899, heretofore restricted in its usage to a group of Eocene to Pliocene species in Europe and the southeastern United States. Analysis of these species and comparison with material from the Gulf Coast, Europe, and New Zealand, permits a new interpretation of the evolutionary relationships and biogeography of a number of heretofore poorly understood generic categories that have been used in a restricted geographic or temporal sense.

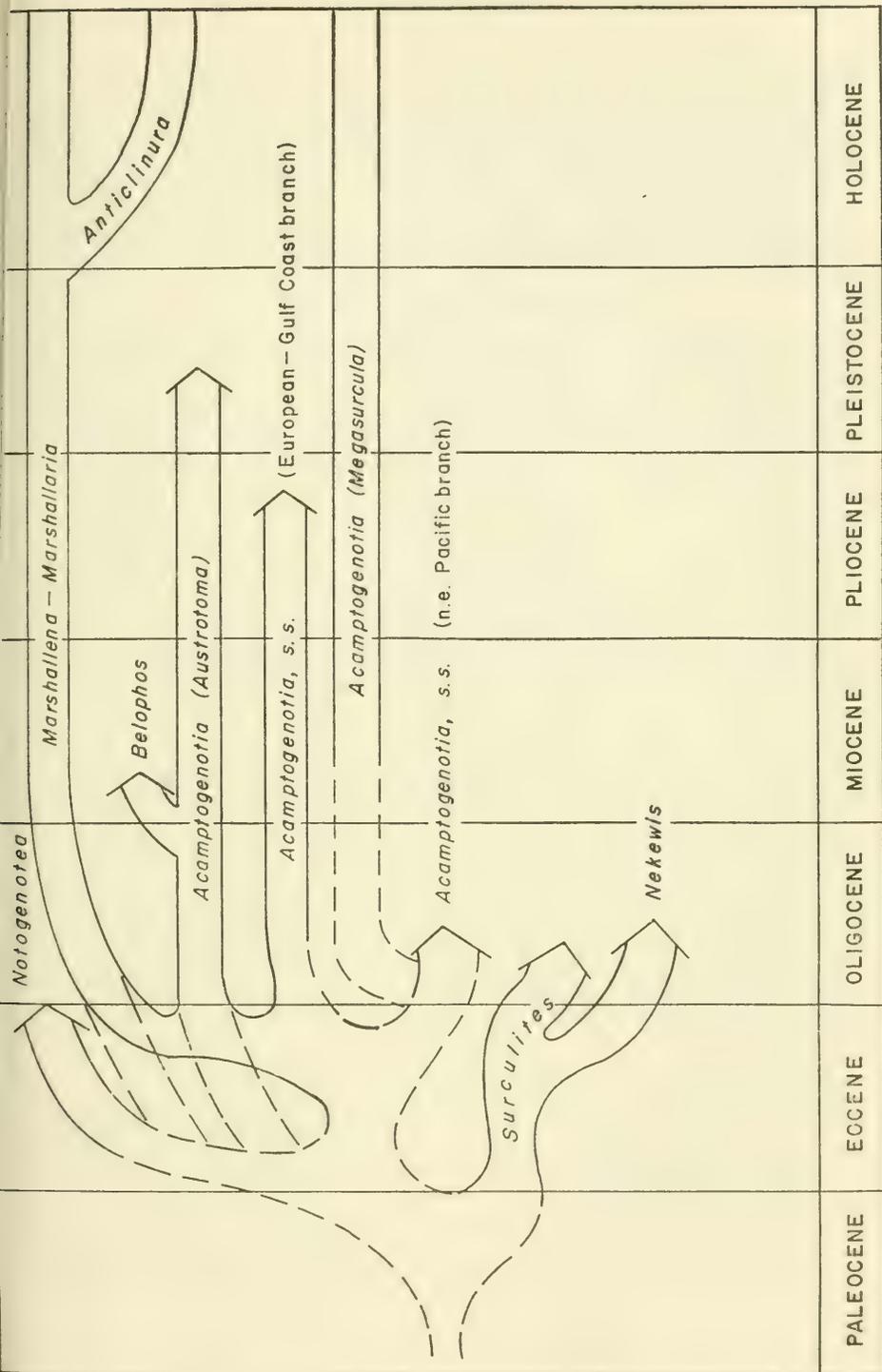
Acamptogenotia is here interpreted as consisting of three subgenera: *Acamptogenotia*, s. s.; *Austrotoma* Finlay, 1924; and *Megasurcula* Casey, 1904. *Belophos* Cossmann, 1901, is tentatively regarded as a monotypic Miocene fourth subgenus of *Acamptogenotia*, although it may not be significantly different from *Austrotoma*, in which case it would have priority as the name for a single Australo-Neozealandic subgenus. *Surculites* Conrad, 1865, is regarded as a prototypic form for the entire complex, with *Nekeewis* Stewart, 1926, as an Eocene-Oligocene offshoot restricted to the northeastern Pacific.

The phylogenetic relationships of these taxa, hypothesized from morphological relationships as well as temporal and spatial components of biogeography, are presented in Text-figure 9 and discussed below.

Species in the *Acamptogenotia* group are characterized by their large biconic shells, with a stout body whorl and short broad anterior canal that is notched and fasciolate. They are further distinguished by an unusually shallow arcuate anal sinus (concave) occupying the shoulder slope. Many species, particularly those occurring in deep-water assemblages, have a finely tessellate to ornately nodulose or granulate sculpture that is particularly striking in some of the Paleogene forms.

Marshallena Allen, 1927, and *Marshallaria* Finlay and Marwick, 1937, in the Indo-Pacific and *Anticlinura* Thiele, 1934, in the Eastern Pacific, with species restricted to deep water, are related to this group by large size, shallow anal sinus, and tendency to produce similarly ornate sculpture patterns. They differ in having relatively long and unnotched anterior canals.

Widely divergent opinions have been expressed regarding the familial and subfamilial allocations of these taxa. Early Tertiary genera such as *Surculites* and *Nekeewis* are usually excluded from the Turridae, following Wrigley (1939) and Powell (1966), although some authors (e.g. Grant and Gale, 1931; Beets, 1942; and Marks, 1951) compare or synonymize *Nekeewis* with *Clinura* Bellardi, 1875, in the toxoglossate turrid subfamily Thatcheriinae. *Acamptogenotia* is sometimes placed with *Genota* H. and A. Adams, 1853, in the toxoglossate subfamily Conorbinae (Powell, 1942; Glibert, 1960), although Powell (1966, 1969) later removed it to the Turriculinae.



Text-figure 9.—Hypothesized phylogenetic relationships of genera and subgenera in the *Acamptogenoita* group.

Megasurcula, the only North Pacific genus in this group with living representatives, has a primitive non-toxoglossate radula (McLean, 1971, fig. 43) characteristic of the subfamily Turriculinae. The wish-bone marginals of living representatives of the predominantly Tertiary genus *Marshallena* provide evidence of turriculine affinities of the austral (Indo-Pacific) branch of the group.

Genus **SURCULITES** Conrad, 1865

Type species (by monotypy): *Surcula* (*Surculites*) *annosa* Conrad, 1865. Eocene, New Jersey.

Wrigley (1939) argued that the arcuate growth lines on the shoulder slope of both the type of *Surculites* and the better known British Eocene species *S. errans* (Solander, 1766) do not constitute a true turrid sinus. He was not able to provide an alternative familial allocation but suggested that the affinities of the genus were closer to the Fusinidae or Buccinidae. The anal sinus of the California Eocene species *S. mathewsonii* (Gabb, 1864) is illustrated (Text-figure 10a) with those of other species in the *Acamptogenotia* group (Text-figures 10 and 11) — including unquestionable turrids — to demonstrate the similarity in configuration within the group.

Surculites differs from *Acamptogenotia* in its more fusiform shape and unnotched anterior canal. The body whorl is often bicarinate, and the peripheral carina marks an abrupt break between a broad, flat to shallowly concave, shelflike shoulder slope and a flat-sided to slightly convex anterior body whorl. The finely tessellate to granular texture of the shell of *S. mathewsonii* (Pl. 2, fig. 15) is similar to that of other forms included in the *Acamptogenotia* group.

Although *Surculites* is restricted to the Eocene elsewhere in the world, specimens from the provincial Oligocene of the Pacific Coast apparently represent the genus. Material is fragmentary and, therefore, treated under open nomenclature.

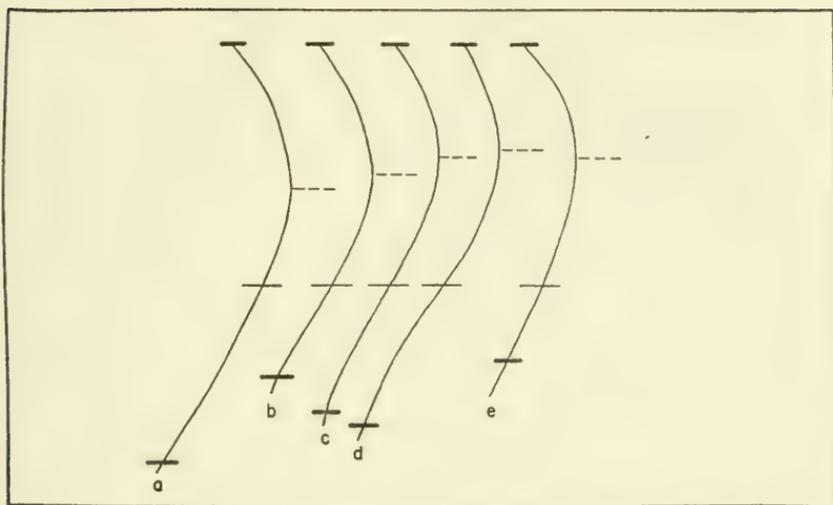
Surculites sp.

Pl. 2, fig. 16

? *Surculites* sp. A Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 186.

? *Surculites* sp. B Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 186.

Discussion. — Durham (1944) reported two poorly preserved specimens of *Surculites*, one from the Marrowstone Shale and the



Text-figure 10. — Comparative anal sinus configuration in Paleogene species of *Surculites* and *Nekevis* from camera lucida tracings of growth lines adjusted to uniform shoulder height. Heavy lines denote posterior and anterior sutures, light line denotes periphery, and dashed line denotes apex of sinus. a. *S. mathewsonii* (Gabb); b. *N. washingtoniana* (Weaver); c. *N. io* (Gabb); d. *N. cf. N. nehalemensis* (Anderson and Martin); e. *N. nehalemensis* (Anderson and Martin).

other from the Twin River Formation in Washington (Text-figure 1). A specimen from the Lincoln Creek Formation represents a third provincial Oligocene occurrence of this species in Washington. Shell material is well preserved, but the specimens are broken and crushed or distorted. In addition to the broad shallow anal sinus, the species exhibits a characteristic sharply keeled periphery and tabular whorl profile. The body whorl is divided by a second weaker carination that does not appear on the spire whorls which are parallel to the axis of coiling anterior to the periphery.

Material examined. — Three specimens.

Stratigraphic distribution. — *Surculites* sp. is restricted to the provincial Oligocene *Turritella porterensis* and *Echinophoria rex* zones (Text-figure 6).

Figured specimen. — USNM 216414. (USGS M1729, Lincoln Creek Formation).

Other localities. — Twin River Formation: UCMP A3690. Marrowstone Shale: UCMP A3695.

Genus **NEKEWIS** Stewart, 1926

Type species (by original designation): *Fasciolaria washingtoniana* Weaver, 1912. Late Eocene, Washington, Oregon, Alaska.

Nekewis is an Eocene-Oligocene offshoot of *Surculites*, retaining a long, although twisted and fasciolate, anterior canal that is shallowly notched. The genus is unique in the development of a spinose periphery, undulose collared suture, and exaggeratedly broad concave shoulder slope and concave base. It shares with both *Surculites* and *Acamptogenotia* the shallow anal sinus and granulose sculpture, which is particularly ornate in the type of the genus, *N. washingtoniana*. Close relationship to *Surculites* is further implied by the position of the apex of the anal sinus, which is higher on the shoulder slope in *Nekewis* and *Surculites* (Text-figure 10) than in any of the subgenera of *Acamptogenotia* (Text-figure 11).

Nekewis has been inappropriately synonymized with *Clinura* Bellardi, 1875 (Grant and Gale, 1931; Beets, 1942; Marks, 1951). The anal sinus of the Miocene type species of *Clinura*, as pointed out by Powell (1966), is comparable to that of *Thatcheria* Angas, 1877, in the extremely long lower limb that swings forward confluent with the outer lip.

Nekewis is represented by three distinctive species in the Pacific Coast Paleogene: (1) ?*Fasciolaria io* Gabb, 1864 (a variable species including forms described as *Surcula ioformis* Anderson and Hanna, 1925, and *S. alizensis* Anderson and Hanna, 1925), of the late Eocene ("Tejon") of California (Pl. 3, fig. 2); (2) *Fasciolaria washingtoniana* Weaver, the type species of the genus and also a late Eocene ("Tejon") species (Pl. 3, figs. 1, 3); and (3) *Thais nehalemensis* Anderson and Martin, 1914, of the early Oligocene of Washington and Oregon (Pl. 3, figs. 8, 9, 13). *Nekewis* (?) *scowensis* Durham, 1944, is not a *Nekewis*, and the lack of preserved growth lines indicating a shoulder sinus makes it doubtful that the species is a turrid.

The genus seems to be endemic to the Paleogene of the north-eastern Pacific. Stewart (1926, p. 422) suggested several possible representatives of the genus in Europe and the Gulf Coast, but his concept of *Nekewis* did not extend beyond the combination of a shallow anal sinus and noded periphery, and, therefore, included species that are more appropriately placed elsewhere. The only

strikingly similar combination of characters that I have been able to find outside of the Pacific Coast Paleogene is in Cossmann's figures (1896, pl. 7, figs. 11, 12) of *Pleurotoma bonellii* Bellardi, 1839. It is not clear, however, what species Cossmann is figuring, because Bellardi's figure of the same species (1877, pl. 7, fig. 13) is different and characteristically *Acamptogenotia*, *s. s.* An Italian Pliocene specimen that compares closely with Bellardi's figure is illustrated herein (Pl. 4, figs. 13, 14) for comparison. Glibert (1960, p. 25) identified this species as *Clinura*, although the hypotype material (and illustrations, so far as one can tell) exhibit the shallow anal sinus of the *Acamptogenotia* group of turriculine genera.

Nekewis washingtoniana (Weaver, 1912) Pl. 2, fig. 18; Pl. 3, figs. 1, 3;
Text-figure 10b

Fasciolaria washingtoniana Weaver, 1912, Washington Geol. Sur., Bull. 15, p. 52, pl. 1, fig. 5.

Surcula washingtoniana (Weaver), Dickerson, 1915, California Acad. Sci., Proc., ser. 4, vol. 5, pl. 10, figs. 7a, 7b.

Bursa washingtoniana (Weaver), Dickerson, 1915, California Acad. Sci., Proc., ser. 4, vol. 5, pp. 64-65 (in part), pl. 7, fig. 4 (not pl. 7, fig. 6 = *Ranella washingtoniana* Weaver, 1912).

Nekewis washingtoniana (Weaver), Stewart, 1926, Acad. Nat. Sci. Philadelphia, Proc., vol. 78, p. 422; Turner, 1938, Geol. Soc. America, Spec. Pap. 10, p. 70 (in part), pl. 16, fig. 2, not pl. 16, fig. 4; Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, p. 531, pl. 98, fig. 11, 18, pl. 103, fig. 11.

Surculites (Clinura) washingtonianus (Weaver), Grant and Gale, 1931, San Diego Soc. Nat. Hist., Mem. 1, p. 494.

Discussion.—This species is represented by numerous well-preserved specimens from the Cowlitz Formation in Washington (Text-figure 1). There are 11 to 12 short flat sharp spines aligned vertically in each of three rows marking the periphery of the body whorl. Both the shoulder slope and base are markedly concave and are ornamented by numerous fine spiral threads of several ranks, forming small granules where they intersect numerous equally fine growth lines. The suture undulates, following the anteriormost row of spines throughout coiling. The anterior canal is long, slender, twisted, and fasciolate, and lacks the pronounced notch characteristic of species of *Acamptogenotia*.

Material examined.—Twenty-two specimens.

Stratigraphic distribution.—*Nekewis washingtoniana* is confined to rocks of "Tejon" age in Washington and Oregon. A single specimen from the Stillwater Formation ("Domengine Stage") in

the Gulf of Alaska constitutes the earliest record of the species. In California *N. washingtoniana* is allopatrically replaced in the "Tejon Stage" by populations of the close-related congener *N. io* and its variants. A specimen of *N. io* from the Tejon Formation is illustrated (Pl. 3, fig. 2) for comparison with *N. washingtoniana*.

Lectotype. — CAS 7563. This is the specimen figured with the original description and subsequently referred to by Weaver (1943) as the "holotype". It is here designated as lectotype.

Figured hypotypes. — USNM 216415, 216416. (Cowlitz Formation: USGS 25725).

Other localities. — Cowlitz Formation: UW 37 (type locality), UW 232, A1447, A9298; UCMP B5830, B5832; SU NP 113. Lower Coaledo Formation: UCMP A858. Stillwater Formation: USGS 4397.

Nekewis nehalemensis (Anderson and Martin), 1914 Pl. 3, figs. 8, 9, 13;
Text-figure 10c

Thais nehalemensis Anderson and Martin, 1914, California Acad. Sci., Proc., ser. 4, vol. 4, pp. 83-84, pl. 6, fig. 3.

Nekewis nehalemensis (Anderson and Martin), Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, pp. 449-450, pl. 88, figs. 1, 2; Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, pp. 184-185, pl. 14, figs. 13, 20.

Discussion. — The type locality of *Nekewis nehalemensis* and its stratigraphic position are uncertain, as pointed out by Durham (1944, p. 185). The locality cited by Anderson and Martin in the original description is in the Scappoose Formation of provincial late Oligocene age ("Blakeley Stage") in northwestern Oregon. Preservation and matrix of the type specimen are not, however, that of the Scappoose Formation; and the species has not been collected subsequently either at the alleged type locality or in older formations in the upper Nehalem River basin in northwestern Oregon.

Specimens comparing closely with the holotype of *Nekewis nehalemensis* have been collected in the lower part of the Quimper Sandstone in the northeastern Olympic Peninsula in Washington (Text-figure 1). The species is similar to *N. washingtoniana* in profile, with concave shoulder slope and base and three rows of vertically aligned spines at the periphery. The spines are blunter than in *N. nehalemensis*, however, and the rows more widely spaced, with a tendency toward vertical fusion of spines into axial sculpture. *N.*

nehalemensis is also distinguished by a lower spire and less steeply sloping shoulder.

Material examined. — Five specimens.

Stratigraphic distribution. — The stratigraphic distribution of this species is difficult to define, owing to the uncertain provenance of the holotype. Collections of the species in Washington are all from the lower portion of the Quimper Sandstone (*Molopophorus stephensoni* megafaunal zone of Durham, 1944).

Hypotypes. — UCMP 35458, 35459; SUPTC 10208, 10209.

Localities. — CAS 168 ? (type locality). Quimper Sandstone: UCMP A1802; SU NP 148.

Nekewis cf. **N. nehalemensis** (Anderson and Martin, 1914) Pl. 2, fig. 17;
Text-figure 10d

Discussion. — A single worn specimen in the Schenck Collection at Stanford University from the lower part of the Eugene Formation in Oregon (Text-figure 1) is similar to *Nekewis nehalemensis*. Preservation is too poor for positive identification, but the broad concave shoulder slope and shallow anal sinus (Text-figure 10) identify it as *Nekewis*, and the low spire suggests *N. nehalemensis*. The ornamentation of the body whorl, although weak, differs in a more broadly reticulate pattern anterior to the periphery. It is perhaps of biostratigraphic significance that the lower part of the Eugene Formation shows the greatest faunal similarity in terms of shared species with the lower portion of the Quimper Sandstone (Hickman, 1969, p. 15), where *N. nehalemensis* occurs.

Figured specimen. — SUPTC 10210 (Schenck Coll. Acq. No. 3136).

Locality. — Eugene Formation: UO 29.

Genus **ACAMPTOGENOTIA** Rovereto, 1899

= *Pseudotoma* Bellardi, 1875, non Gray, 1825

Type species (by monotypy): *Murex (Pleurotoma) intortus* Brocchi, 1814. Miocene-Pliocene, Europe.

Subgenus **ACAMPTOGENOTIA**, s. s.

Although the type species of the genus is a Neogene species, European Paleogene species of *Acamptogenotia* s. s. are similar

morphologically to the type, and reports of "*Pseudotoma*" *intorta* from the Paleogene are common in the older literature. These biconic shells are moderately large (up to 50 mm), with a concave shoulder slope, shallow anal sinus, and a broad robust body whorl that is readily distinguished from that of *Nekewis* by its convex basal profile and shorter, broader anterior canal. The canal is twisted, fasciolate, and imperceptibly to moderately notched.

In its elongate form, the Neogene type of *Acamptogenotia* (Pl. 4, figs. 12, 15) approaches the form of the Eastern Pacific subgenus *Megasurcula*, although the anterior canal is not so deeply notched. Paleogene species tend to have smaller, relatively broader shells and are generally more similar to species of the New Zealand and Australian subgenus *Austrotoma*. A specimen of *Acamptogenotia morreni* (de Koninck, 1838) from the Oligocene (Rupelian Stage) of Germany, from the Schenck Collection at Stanford University, is illustrated (Pl. 4, figs. 6, 7) for comparison with the type species and related Paleogene species discussed below. The subsutural fold in this species does not occur on the type species and is cited by Powell (1966) as a distinguishing character of *Austrotoma*, although it apparently is missing on some *Austrotoma* species.

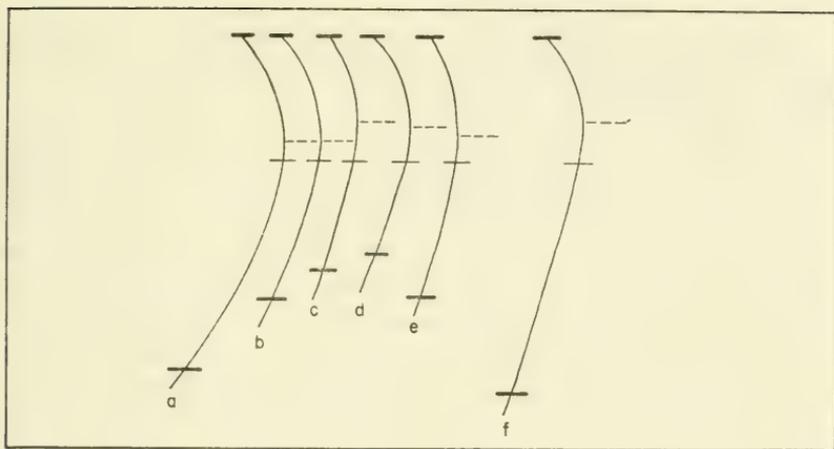
The new species in the Keasey Formation are assigned to *Acamptogenotia*, *s. s.*, although they also exhibit some characters more often associated with *A. (Austrotoma)*. In their broad shoulder slope, spinose periphery, and undulating suture, they approach *Nekewis*, although the canal is short and broadly open and the base stoutly convex as in *Acamptogenotia*. These species exhibit particularly well the ornately granulose or nodulose sculpture that is best developed on deep-water representatives of the group. The generic affinity of geographically disjunct European, Australo-Neozelandic, and Northeastern Pacific groups of Paleogene species is substantiated by similarity of anal sinus configuration and position of the sinus apex on the anterior shoulder slope (Text-figure 11).

***Acamptogenotia (Acamptogenotia) tessellata* Hickman, n. sp.**

Pl. 3, figs. 4-7, 10, 11, 12, 14; Text-figure 11d

Nekewis aff. *N. washingtoniana* (Weaver), Vokes, 1945 (checklist), in Warren and others, U.S. Geol. Sur. Oil and Gas Inv. Prelim. Map 42; Warren and Norbistrath, 1946, Amer. Assoc. Petrol. Geol., Bull., vol. 30, pt. 1, No. 2, p. 227.

Nekewis washingtonensis (Weaver), new subsp., Moore and Vokes, 1953, U.S. Geol. Sur., Prof. Paper 233-E, p. 119.



Text-figure 11.—Comparative anal sinus configuration in species of *Acamptogenotia*, *s. s.* and *Acamptogenotia* (*Austratoma*) from camera lucida tracings of growth lines adjusted to uniform shoulder height. Heavy lines denote posterior and anterior sutures, light line denotes periphery, and dashed line denotes apex of sinus. a. *A. intorta* (Brocchi); b. *A. morreni* (de Koninck); c. *A. bonellii* (Bellardi), d. *A. tessellata* Hickman, n. sp.; e. *A. nodulosa* Hickman, n. sp.; f. *A. (Austratoma) lawsi* Powell.

Description.—Shell of moderate size (up to 23 mm), stout, biconic, with a large body whorl, aperture higher than spire; shoulder slope relatively broad, steep, and concave, inclined to axis of coiling at 33°, covered with fine tessellate sculpture consisting of up to 15 close-spaced fine spiral threads intersected by equally fine and closely spaced growth lines marking successive traces of the broad shallow anal sinus; periphery ornamented by 11 to 13 blunt spines representing the most prominent development of nodulose axials that extend posteriorly with decreasing prominence onto the shoulder slope and anteriorly with decreasing prominence and eventual obsolescence on the base; base ornamented by 12 to 14 crisp primary spiral threads with fine intercalated secondary threads, crossed by numerous fine growth lines; protoconch missing to badly worn on all material at hand; suture undulose, lacking subsutural fold; anterior canal short, twisted, and fasciolate; parietal lip with thin to moderate inductura, ornament usually resorbed but sometimes faintly visible through inductura in parietal region.

Dimensions of holotype.—Height (incomplete) 17.9 mm; maximum diameter 10.5 mm.

Material examined. — Eighty-one specimens.

Variation. — *Acamptogenotia tessellata* is relatively constant in outline and proportions. It is usually well preserved and is one of the most easily recognizable gastropod species in the Keasey Formation. Variation is exhibited primarily in the number and relative strength of spiral sculptural elements on the shoulder slope and base and in the prominence of peripheral spines. These kinds of variation occur at all localities; thus rigorous analysis of sculptural variation would not be apt to disclose biostratigraphically significant patterns. The spiral sculpture pattern varies during growth, and comparable growth stages must be selected for meaningful comparison.

Stratigraphic distribution. — *Acamptogenotia tessellata* is a relatively long-ranging species, occurring in the Provincial Eocene and Oligocene "Tejon", "Keasey", and "Lincoln" stages. The "Tejon" record is based on one specimen of a variant from the Cowlitz Formation in Oregon, and the "Lincoln" record on one specimen (Pl. 3, fig. 12) from the middle Quimper Sandstone in Washington (*Molophorus gabbi* zone of Durham, 1944). The species is most abundant in the "Keasey Stage" and its stratigraphic distribution in the three members of the Keasey Formation is summarized in Text-figure 5. *A. tessellata* also occurs in the California deep-water Oligocene Tumey Sandstone member of the Kreyenhagen Formation.

Holotype. — USNM 216402. *Figured paratypes.* — USNM 216403, 216404, 216405. *Unfigured paratypes.* — USNM 216406 (height 16.7 mm), 216407 (height 13.5 mm), 216408 (height 11.9 mm). *Referred specimen.* — CAS 55736.

Type locality. — Middle member, Keasey Formation: USGS 25031.

Other localities. — Lower member, Keasey Formation: USGS 25026. Middle member: USGS 15267, 15268, 15280, 15282, 15508, 15517, 15602, 25030, 25034, 25038, M3862. Upper member: USGS 15518, 25032. Quimper Sandstone: CAS 217. Cowlitz Formation: USGS 15255. Kreyenhagen Formation: SU 2361.

Comparative notes. — In early checklists this species was compared with *Nekewis washingtoniana* (see synonymy). It is readily distinguished by the convex outline of the base of the body whorl and relatively shorter canal, as well as smaller adult shell size and differences in ornamentation. It differs from *Acamptogenotia nodu-*

losa Hickman, n. sp. in having tessellate sculpture on a shoulder slope that is broader and lacking a subsutural cord. *A. tessellata* has a broader shoulder slope than is typical of European Paleogene species of *Acamptogenotia*, s. s. and New Zealand Paleogene species of the subgenus *Austrotoma*.

Acamptogenotia (Acamptogenotia) nodulosa Hickman, n. sp.

Pl. 4, figs. 1-4; Text-figure 11e

Nckewis, n. sp. Vokes, 1945 (checklist) in Warren and others, U.S. Geol. Sur. Oil and Gas Inv. Prelim. Map 42.

Description. — Shell moderately large (up to 33 mm), biconic, with a robust body whorl truncated anteriorly by a short, twisted and weakly fasciolate canal; spire slightly less than height of aperture; shoulder slope concave and inclined to axis of coiling at about 40°, ornamented by three to five well-defined and finely nodulose spiral cords with finely nodulose intercalated threads of varying prominence depending on distance from point of inception; spiral cord or cords submarginal to adpressed suture particularly prominent, conveying impression of a subsutural fold; base with approximately 20 equal or subequal nodulose spiral cords, the posterior three of greatest prominence and ornamented by 12 to 20 rounded nodes, aligned vertically and fused into axials that extend anteriorly over 1/3 to 1/2 of the base before becoming obsolete; protoconch apparently paucispiral, but worn or broken on all specimens examined; anal sinus shallow, concave, occupying shoulder slope, its apex situated centrally; inner lip with moderately well-developed inductura.

Dimensions of holotype. — Height (nearly complete) 26.4 mm; maximum diameter 13.4 mm.

Variation. — Although *A. nodulosa* is readily identifiable even as fragments by its nodulose sculpture, there is considerable variation in the number and relative strength of sculptural elements, most notably the number of axial elements, which ranges from 12 to 20 in material examined. Additional material is required to define the range of variation for the species.

Stratigraphic distribution. — Unlike its long-ranging congener, *A. tessellata*, this species is restricted to the upper portion of the middle member and lowermost portion of the upper member of the Keasey Formation (Text-figure 5). It occurs at seven localities in a maximum of 180 m of section.

Holotype. — USNM 216409. *Figured paratypes*. — USNM 216410, 216411. *Unfigured paratypes*. — USNM 216412 (height 22.4 mm), 216413 (height 15.0 mm).

Type locality. — Middle member, Keasey Formation: USGS 15280.

Other localities. — Middle member, Keasey Formation: USGS 15267, 15279, 15602 (= type locality), 15508, 25031. Upper member: USGS 15581.

Comparative notes. — *Acamptogenotia nodulosa* is unique among Pacific Northwest Paleogene turrids in its nodulose sculpture. It is most similar to *A. tessellata* which is described and differentiated above. The prominent subsutural cording of this species as well as its general proportions give it a resemblance to species of the New Zealand subgenus *Austrotoma*, although it lacks the deep notch and ridge-bordered fasciole characteristic of species in the austral complex.

Subgenus **AUSTROTOMA** Finlay, 1924

Type species (by original designation): *Bathytoma excavata* Suter, 1917. Early Miocene (Clifdenian Stage), New Zealand.

Topotypes of the early Miocene (Otaian Stage) *Austrotoma lawsi* Powell, 1942, are illustrated (Pl. 4, figs. 5, 8, 9, 11) to show the similarity of the austral species to European species of *Acamptogenotia*, *s. s.* and new species described above from the Paleogene of Washington and Oregon.

Although it is important to recognize the unique features of the Australo-Neozelandic fauna, to do so repeatedly at the generic level in a family as complex as the Turridae obscures hierarchical relationships. *Austrotoma*, long considered the most characteristic of the endemic austral Tertiary turrid genera (Powell, 1969), provides a striking example of a complex of 24 described species that are not only closely related to one another but also part of a line of turrid evolution that has produced offshoots in other parts of the world during the Cenozoic.

The subsutural fold that has been cited as differentiating *Austrotoma* from *Acamptogenotia* does separate the respective type species, but there are species of *Austrotoma* lacking the fold and two of the *Acamptogenotia* species figured in this report (Pl. 4, figs. 6, 7, 13, 14) exhibit the fold. *Austrotoma* consistently differs from *Acampto-*

genotia, *s. s.* in having a deeply notched anterior canal and ridge-margined fasciole, but *Megasurcula* and *Austrotoma* share these two features. Although the living type species of *Megasurcula* is readily differentiated from European Paleogene species of *Acamptogenotia*, *s. s.*, the Miocene-Pliocene type of *Acamptogenotia* is intermediate in many respects between early Miocene *Megasurcula* species from the Pacific Coast and the living *Megasurcula* species.

Patterns in shell morphology, biogeography, and biostratigraphy in the *Acamptogenotia* group all suggest that *Austrotoma* is an offshoot of the more wide-ranging *Acamptogenotia*, *s. s.*

As previously mentioned, *Belophos* Cossmann, 1901, may be the proper name for this austral subgenus. *Belophos* is monotypic, based on a species from the early Miocene of Tasmania and Victoria; and it has been regarded by Powell (1966, 1968) as having generic status on the basis of its unique protoconch and predominance of axial sculpture. Pending examination of the type species, I tentatively regard *Belophos* as a fourth subgenus of *Acamptogenotia*.

Subgenus **MEGASURCULA** Casey, 1904

Type species (by subsequent designation, Stewart, 1927): *Pleurotoma (Surcula) carpenteriana* Gabb, 1865. Pliocene-Recent, northeastern Pacific.

Specimens of the living *Megasurcula carpenteriana* reach the largest adult size recorded in the *Acamptogenotia* group (100 mm), but smaller shelled extinct species share with *M. carpenteriana* the shallow anal sinus and biconic profile, with a large body whorl truncated anteriorly by a broad, short, twisted anterior canal. *Megasurcula* is not known prior to the Miocene, and its ancestry cannot be traced with certainty back into *Acamptogenotia*, *s. s.* or *Austrotoma*, although Miocene species in the northeastern Pacific are morphologically closer to both *Acamptogenotia*, *s. s.* and *Austrotoma* than to the living type of the genus. Mid-Tertiary distributions of these three subgenera suggest that *Megasurcula* arose from the boreal Pacific branch of *Acamptogenotia*, *s. s.* in the northeastern Pacific.

Moore (1963) and Addicott (1970a) provide good descriptions and illustrations of the West Coast Miocene *Megasurcula* species, and only *M. wynootcheensis* (Weaver, 1912) is figured (Pl. 4, fig. 10), to illustrate similarities with species in other subgenera.

Genus **PARASYRINX** Finlay, 1924

Type species (by original designation): *Pleurotoma alta* Harris, 1897. Oligocene-Miocene, New Zealand.

The cochlespirine genera comprise a distinctive, predominantly deep-water group of turrids with relatively thin, glossy-textured, pagodaform shells and a prominent serrated or sharply keeled periphery. An enlarged unicuspid central radular tooth provided the basis for separation of the subfamily Cochlespirinae (Powell, 1942). However, Powell later (1966) merged the subfamily with the Turriculinae, on evidence that the large central tooth not only occurs in a variety of turriculine, turrine, and clavine genera, but is not a consistent feature in the so-called cochlespirine forms.

Although large cold-water cochlespirine representatives of the genus *Aforia* Dall, 1889, have been recognized and utilized biostratigraphically in the Pacific Northwest Tertiary (Javidpour, 1973), there are a number of small pagodaform species in this group that have escaped attention. These species have been referred to such diverse generic categories as *Turris*, *Spirotropis*, *Cryptogemma*, *Aforia*, *Irenosyrinx*, and *Makiyamaia*.

Shells of the Pacific Northwest Paleogene cochlespirine species are smooth-keeled and distinct from the peripherally serrate or frilled forms in the European and Caribbean-Southeastern United States belonging to the long-ranging and geographically widespread genus *Cochlespira* Conrad, 1865 (= *Ancistrosyrinx* Dall, 1881). A remarkably similar group of pagodaform smooth-keeled Paleogene species is recorded from the New Zealand Tertiary, under the names *Parasyrinx* Finlay, 1924, and *Lirasyrinx* Powell, 1942. Protoconch differences that distinguish the monotypic *Lirasyrinx* are here considered of questionable value, and *Parasyrinx* is employed for the group, without subgeneric distinctions.

Similar smooth-keeled forms also appear in the Japanese Tertiary, although they have, like the Pacific Northwest species, been treated under other generic names. *Pleurotoma subdeclivis* Yokoyama, 1926, has been applied to a variety of Japanese Tertiary turrids, including specimens with a sharply carinate periphery, constricted basal profile, and long anterior canal closely resembling the type of *Parasyrinx*. Broad interpretation of this species stems

from Yokoyama's original discussion and illustration (1926b, p. 367; pl. 42, fig. 4) of a long-canaled carinate hypotype from the upper Miocene to lower Pliocene Tonohama Group in Shikoku under *P. subdeclivis*, although his holotype from the Kakegawa Group (Yokoyama, 1926a, p. 329; pl. 38, fig. 8) has a short canal and rounded whorls.

Spirotropis G. O. Sars, 1878, was applied for many years to the heterogeneous *P. subdeclivis* group, until the clavine affinities of the thin-shelled and short-canaled *Spirotropis* were more broadly recognized. MacNeil (1960, p. 107) included both morphological types of *P. subdeclivis* in his concept of *Makiyamaia* (ex Kuroda ms.), and Powell (1966, p. 75) considered *Makiyamaia* more appropriate than *Spirotropis* for Japanese Tertiary species. However, the type of *Makiyamaia*, the living *Pleurotoma coreanica* Adams and Reeve, 1850, is a unique species, not closely related to the carinate cochlespirine group. The shell is moderately robust and the anterior canal is relatively short, twisted, and broader than in Tertiary cochlespirine forms. The operculum is unlike that of any modern cochlespirine species, having an ovate outline and mediolateral nucleus as in *Clavatula* and *Turricula*. The radula has not been reported, and the affinities of the genus are here considered closer to *Turricula* than to any other turrid genus. Japanese Tertiary forms here considered representative of *Parasyrinx* include not only Neogene taxa such as *P. acuticarinata* (Shuto, 1961) but also Paleogene species such as *P. kurodae* (Shuto and Ueda, 1963).

Cochlespirine species with small, glossy, pagodaform shells are particularly diverse in the Paleogene of the Pacific Northwest. Most of the species discussed below are typically cochlespirine, with the anal sinus on the shoulder slope. These species are assigned to *Parasyrinx*. Another group of species of superficially similar form is differentiated by an anal sinus with its apex immediately posterior to or on the peripheral keel, with most or all of the anterior limb of the sinus in front of the keel. For these species, typified by *Turris packardi* Weaver, 1916, the name *Turrisosyrinx* is proposed. A third name, *Clivuloturris*, is proposed for a species in which the apex of the anal sinus is uniquely situated immediately anterior to the peripheral keel, a position heretofore unrecorded in the Turridae. The wide variation in the position of the sinus relative to the periphery in this

group of otherwise closely similar species represents a case in which the traditional means of differentiating the subfamilies Turrinae and Turriculinae seems to be highly artificial and arbitrary.

Parasyrinx delicata, Hickman, n. sp.

Pl. 5, figs. 12-16, 18;
Text-figure 12a

Description.— Shell thin, glossy, pagodaform, with slender straight, unnotched anterior canal; protoconch of two small smooth whorls, lacking the carination typical of later whorls; postnuclear whorls with a prominent sharp anterior keel that appears double in worn specimens through development of a median groove; suture simple and abutting; shoulder slope concave, polished, and smooth except for numerous fine growth lines; body whorl abruptly constricted anterior to peripheral keel and ornamented by 25 to 30 fine spiral threads of subequal prominence; sinus moderately deep and rounded, asymmetric, with its apex on or slightly above mid-shoulder; posterior sinus limb short and sigmoid (convexi-concave) or concave; anterior limb sigmoid (concavo-convex) to nearly straight and longer than posterior limb; ornamentation resorbed on inner lip, sometimes with a thin inductura.

Dimensions of holotype.— Height (incomplete) 15.8 mm; maximum diameter 7.3 mm.

Material examined.— Thirty specimens.

Variation.— *Parasyrinx delicata* is one of the most variable turrids in the Keasey gastropod fauna, exhibiting diverse anal sinus geometry and whorl profile. Two characters were analyzed statistically. A measure of the position of the apex of the anal sinus on the shoulder slope is achieved by calculating the ratio of the distance from the apex to the middle of the peripheral carina ($L_a - L_k$) to shoulder width (SW). Similarly, whorl profile is reflected in the ratio of shoulder width (SW) to maximum peripheral diameter (D_{max}). Derivation of these characters is summarized in Text-figures 2 and 3. Values for both characters were calculated for a population from the Keasey Formation as well as for the closely related but stratigraphically higher species *Parasyrinx kincaidi* (Weaver, 1916) from the Lincoln Creek Formation in Washington. The results are summarized in Table 1. These results, coupled with analysis of variance, indicate that (1) both populations are moderately variable with respect to both characters, (2) the Keasey population is more

Table 1

Statistical comparison of three Oligocene populations of *Parasyrinx* with respect to position of the anal sinus on the shoulder slope and whorl profile.

Species	N	$(L_a - L_w)/SW$			$S4/D_{max}$		
		range	\bar{x}	s.e.	range	\bar{x}	s.e.
<i>P. kincaidi</i>	18	.41 - .66	.531 ± .012		.28 - .38	.329 ± .007	
<i>P. delicata</i>	16	.50 - .74	.622 ± .019		.23 - .37	.286 ± .012	
<i>P. dickersoni</i>	11	.39 - .53	.459 ± .013		.27 - .40	.336 ± .013	

variable with respect to both characters, and (3) while the two populations overlap, they are, nonetheless, significantly different ($p < 0.005$) with respect to both characters.

Stratigraphic distribution. — *Parasyrinx delicata* occurs only in the middle member of the Keasey Formation and is most common in the uppermost 150 m of the member (Text-figure 5). Specimens at two localities approximately 300 m below the top of the middle member differ from other specimens in having fine spiral threads on the shoulder slope as well as on the base of the shell (Pl. 5, fig. 18). Specimens from this portion of the formation are poorly preserved and not sufficiently abundant to permit stratigraphic or taxonomic evaluation of the significance of this character. *P. delicata* is replaced in the overlying Pittsburg Bluff Formation by *P. kincaidi*.

Holotype. — USNM 216417. *Figured paratypes.* — USNM 216418, 216419, UCMP 14195. *Unfigured paratypes.* — USNM 216420 (height 15.8 mm), 216421 (height 9.0 mm).

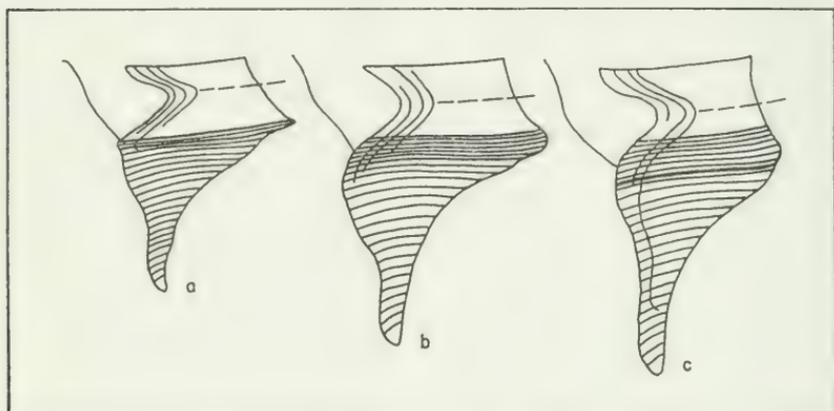
Type locality. — Middle member, Keasey Formation: USGS 25031.

Other localities. — Middle member, Keasey Formation: USGS 15267, 15281, 15282, 15508, 15602, 25030, 25034, 25038, 25039; UCMP A5020.

Comparative notes. — This species is closely allied to the stratigraphically higher Lincoln Creek species *Parasyrinx kincaidi*, as pointed out above. *P. kincaidi* has a relatively broader shoulder and narrower peripheral diameter than the Keasey species, and the apex of the anal sinus is relatively lower on the shoulder slope (Table 1). Due to overlap in these parameters (Table 1), it may not be possible to assign a given specimen to one species or the other without

additional criteria. The character of the peripheral carina provides another distinction. The periphery of the Keasey species is an unornamented sharp carina, while in the Lincoln Creek species the periphery is more broadly rounded and bears six or seven spiral threads, with occasional development of node-like swellings on later whorls. The lectotype of *P. kincaidi* is illustrated for comparison with *P. delicata* (Pl. 5, figs. 2, 3), and the labial profiles and whorl profiles for the two species are contrasted in Text-figure 12.

The *Parasyrinx delicata* — *P. kincaidi* species pair also resembles the Lincoln Creek species *P. dickersoni* (Weaver, 1916). The distinguishing characteristics of the latter species are outlined below.



Text-figure 12. — Anal sinus, labial profile, whorl profile, and basic ornamentation pattern in three closely related Oligocene species of *Parasyrinx*. Scale is adjusted to uniform shoulder height. Dashed lines denote position of apex of anal sinus. a. *P. delicata* Hickman, n. sp.; b. *P. kincaidi* (Weaver); c. *P. dickersoni* (Weaver).

Parasyrinx sp.

Pl. 5, fig. 9

Discussion. — A poorly-preserved specimen from the lower member of the Keasey Formation is distinct from specimens of *Parasyrinx delicata* from the middle member of the formation in its narrower, less sharply keeled form and in the presence of fine spiral threads on the shoulder slope. Inadequate preservation and insufficient material make it impossible to compare the specimen with other described *Parasyrinx* species.

Figured specimen. — USNM 216423.

Locality. — Lower member, Keasey Formation: USGS 15309.

Parasyrinx kincaidi (Weaver, 1916) Pl. 2, figs. 9, 10; Pl. 5, figs. 1-3, 5;
Text-figure 12b

Turris kincaidi Weaver, 1916, Univ. Washington Pubs. Geol., vol. 1, No. 1, p. 64, pl. 4, fig. 45.

Turris washingtonianus Weaver, 1916, Univ. Washington Pubs. Geol., vol. 1, No. 1, p. 53, pl. 5, fig. 67.

Spirotropis kincaidi (Weaver), Grant and Gale, 1931, San Diego Soc. Nat. Hist., Mem. I, p. 548; Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, p. 522 (in part), pl. 97, figs 18, 19, *not* fig. 29.

Not Turricula kincaidi (Weaver), Tegland, 1933, Univ. California Pubs. Bull. Dept. Geol. Sci. 23(3), pp. 126-127, pl. 10, figs. 12, 13 [= *Clavatula* (*Knefastia*) *rossellae* Durham, 1944].

Turricula washingtoniana (Weaver), Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, p. 533 (in part), pl. 98, fig. 17.

"*Turris*" *kincaidi* Weaver, Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 180 (hypotype UCMP 35435).

Not "Turris" cf. *kincaidi* Weaver, Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 180 (hypotypes UCMP 35436, 35437).

Makiyamaia kincaidi (Weaver), Shuto and Ueda, 1963, Japanese Jour. Geol. and Geog., vol. 34, No. 1, p. 8.

Discussion. — The concept of this species has never been clear. Weaver (1943) recognized that populations in the Lincoln Creek Formation were variable, but he did not attempt to define the range of variation, with the result that specimens have been inappropriately allocated to the taxon. It is hoped that the foregoing discussion of inter- and intra-population variation in the *P. kincaidi* — *P. delicata* species pair will help provide a more rigorous definition of the Lincoln Creek species. It should be noted that the lectotype of *P. kincaidi* does not have peripheral nodes, considered characteristic of the species by Weaver (1943, p. 522).

In addition to a poorly defined range of variation, the concept of *P. kincaidi* has been clouded by nomenclatural problems. In 1916, Weaver figured (pl. 4, fig. 45) a specimen that was identified in the plate caption (p. 56) as *Turris washingtonianus*. There was no mention of it in the text or in the faunal lists of the paper. Weaver's intention became clear in 1943 (p. 533) when he included the name in the synonymy of an earlier described species, *Pleurotoma washingtoniana* Weaver, 1912, refiguring the specimen (CAS 560) and referring to it as a syntype of *P. washingtoniana*. The specimen, however, is *Parasyrinx kincaidi*, with the characteristic periphery and anal sinus of the species. The mixed syntypic lot of *Pleurotoma washingtoniana* casts the concept of that species into some confusion, and the reader is referred to the discussion of *P. washingtoniana* for designation of a lectotype.

Leucosyrinx kincaidi Dall, 1919, is an entirely separate species, an Alaskan deep-water, strongly carinate form known only from the holotype. It is an *Aforia*.

Material examined. — Fifty-four specimens.

Stratigraphic distribution. — Within the Lincoln Creek Formation, *P. kincaidi* is restricted to strata falling within the *Turritella porterensis* megafaunal zone of Durham (1944). The species also occurs in the Pittsburg Bluff Formation (Moore, in press) in the upper Nehalem River basin in Oregon.

Lectotype. — CAS 470. Although Weaver (1943) referred to this specimen as "holotype", it was not named in the original description. Following Weaver's intent, it is here designated as lectotype. *Syntypes.* — CAS 470A, 470B. *Figured hypotypes.* — USNM 216424, 216425, 216426, 216427.

Localities. — Lincoln Creek Formation: UW 256 (type locality), UW 352, 574-e, A251-e, A575-B5; SU NP 50, NP 53, NP 211; USGS 15681, 18947, 18949, 18950, 18951, M1730, M1731, M4068; UCMP A9, A1637; CAS 189, 194, 922. Pittsburg Bluff Formation: USGS 15264, 15310, 15310d, 15588, M3856, M3857, M3871, M3872, M3878.

Parasyrinx aff. *P. kincaidi* (Weaver, 1916)

Pl. 5, fig. 4

Discussion. — Three specimens from CAS locality 217 in the northeastern Olympic Peninsula ("on the west shore of Washington Harbor, 4 miles south of Port William") show close affinity to Weaver's species from the Lincoln Creek Formation. The specimens differ in exhibiting fine to well-developed spiral threads on the shoulder slope as well as on the base. This character has not been observed in populations of *P. kincaidi* from the Lincoln Creek Formation, although it is not considered adequate basis for formal taxonomic distinction at this time. The position and configuration of the anal sinus [$(L_a - L_k)/SW \bar{x} = .509$] suggests this species rather than *P. delicata* or *P. dickersoni*.

Stratigraphic distribution. — The stratigraphic position of these three specimens is uncertain, although the assemblage contains several species characteristic of the Porter Bluffs section of the Lincoln Creek Formation [e.g. *Turricula washingtoniana* (Weaver, 1912) and *Priscofusus chehalisensis* (Weaver, 1912)]. The locality

corresponds closely in description to UCMP A1811, which Durham (1944) identified as the middle portion of the Quimper Sandstone and assigned to his *Molopophorus gabbi* megafaunal zone. Lithologic similarity of the matrix also suggests middle Quimper. If so, *Parasyrinx* aff. *P. kincaidi* is stratigraphically intermediate in occurrence between *P. delicata* on one hand and *P. kincaidi* and *P. dickersoni* on the other.

Figured specimen. — CAS 55738. *Referred specimens.* — CAS 55739, 55740.

Locality. — Quimper Sandstone (?): CAS 217.

Parasyrinx dickersoni (Weaver, 1916)

Pl. 5, figs. 6-8, 11:
Text-figure 12c

Turris dickersoni Weaver, 1916, Univ. Washington Pubs. Geol., vol. 1, No. 1, p. 55, pl. 5, fig. 64.

Not *Surcula dickersoni* (Weaver), Dickerson, 1917, California Acad. Sci., Proc., ser. 4, vol. 7, No. 6, p. 161, pl. 31, figs. 3a, 3b (= *Spirotropis winlockensis* Effinger, 1938).

Spirotropis dickersoni (Weaver), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem. I, p. 548; Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, pp. 521-522, pl. 97, figs. 15, 16; Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 182 (hypotypes UCMP 35445, 35446).

Makiyamaia dickersoni (Weaver), Shuto and Ueda, 1963, Japanese Jour. Geol. and Geog., vol. 34, No. 1, p. 8.

Discussion. — *Parasyrinx dickersoni* is one of the most variable turrid species in the Lincoln Creek Formation, resembling both *P. kincaidi* and *P. delicata*. Statistical comparison of two characters, $(L_a - L_x)/SW$ and SW/D_{max} , shows different mean values for both characters in populations of each of the three species (Table 1), and pairwise analysis of variance demonstrates that the populations are distinct.

The following criteria are offered for distinguishing *P. dickersoni*: (1) *P. dickersoni* has a relatively narrow and high-spined shell, apparently resulting from both a higher rate of translation of a similar generating curve (Raup, 1966) and from a greater proportion of whorl height to whorl diameter. The periphery is located farther posterior on the spire whorls of *P. dickersoni*, and the shoulder slope is relatively steeper. *P. dickersoni* and *P. kincaidi* overlap considerably with respect to the latter character and are not distinguishable, but the differences between *P. dickersoni* and *P. delicata* are significant ($p < 0.01$). (2) The apex of the anal sinus in *P. dickersoni*

is relatively lower on the shoulder slope than in either *P. kincaidi* or *P. delicata*, and differences in both cases are highly significant ($p < 0.001$). The anal sinuses and labial profiles for the three species are contrasted in Text-figure 12. (3) The aperture of *P. dickersoni* is relatively narrower, and the aperture height constitutes a smaller proportion of total shell height.

Effinger (1938, p. 386) suggested that *P. dickersoni* is closely related to *Spirotropis winlockensis* of the early Oligocene Gries Ranch Beds (Toutle Formation) in southwestern Washington (Text-figure 1). The generic allocation of Effinger's species is problematic; perhaps it belongs in *Suavodrillia* Dall, 1918.

Material examined. — Twenty-one specimens.

Stratigraphic distribution. — *P. dickersoni* does not occur in the Keasey Formation, and it appears to be restricted to that portion of the Lincoln Creek Formation that falls within the *Turritella porterenensis* megafaunal zone of Durham (1944).

Lectotype. — CAS 471 (cited by Weaver, 1943, as "holotype").

Syntype. — CAS 471A. *Figured hypotypes.* — SUPTC 10217, 10218.

Localities. — Lincoln Creek Formation: UW 256 (type locality), UW 352, B1341, A573; SU NP 53, NP 54, NP 55; USGS 18951; CAS 189, 193.

Genus **TURRINOSYRINX** Hickman, n. gen

Type species: *Turris packardi* Weaver, 1916. Oligocene, Oregon, Washington, and British Columbia.

A group of glossy pagodaform shells that superficially resembles *Parasyrinx* is distinguished by a shallow anal sinus (greater than 90°) with its apex far anterior on the shoulder slope, often appearing to be on the periphery where that feature is broad or indistinctly demarcated. Very little, if any, of the anterior limb of the sinus is represented on the shoulder slope in these species. The group is restricted to the Paleogene of the Pacific Northwest.

Because of their cochlespirine form, these species are placed within the Turriculinae, in spite of the anomalous position of the anal sinus. The sinus characters of this group and of the new genus *Cliculoturris*, described below, strongly suggest that the difference between the subfamilies Turrinae and Turriculinae is arbitrary and not of the same order of importance as characters used to differentiate other turrid subfamilies.

Turrinosyrinx is characterized by a relatively thin and large fusiform shell with a prominent peripheral carination. The anal sinus is shallow (greater than 90°), and the apex is immediately posterior to or on the periphery. The concave shoulder slope may be smooth or ornamented by spiral threads. The anterior canal is of moderate length, straight to slightly deflected, and unnotched. The arcuate outer lip is shallowly indented anteriorly to form a stromboid notch. The protoconch seems to be smooth and paucispiral, but it is imperfectly preserved on all material examined.

In addition to the type species, *T. packardi*, the following are assigned to *Turrinosyrinx*: *T. nodifera* Hickman, n. sp.; *Cryptogemma borgenae* Tegland, 1933; and *Irenosyrinx marrowstonensis* Durham, 1944.

Powell (1966, p. 44) listed the latter two species as characteristic of the genus *Aforia* Dall, 1889. The anal sinus in *Aforia* is deeper (less than 90°), and the anterior limb is well represented on the shoulder slope, although the apex of the sinus may be situated on the anterior portion of the slope. Paleogene species of *Aforia* also differ in their bicarinate body whorl profile, in contrast to the convex constriction of the shell anterior to the periphery in *Turrinosyrinx*.

***Turrinosyrinx packardi* (Weaver, 1916)**

Pl. 5, figs. 17, 19, 21;
Text-figure 13b

Turris packardi Weaver, 1916, Univ. Washington Pubs. Geol., vol. 1, No. 1, p. 55, pl. 5, fig. 64.

Aforia packardi (Weaver), Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, No. 2, p. 517, pl. 97, fig. 3.

"*Aforia*" *packardi* (Weaver), Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Soc., vol. 27, No. 5, p. 184; Javidpour, 1973, Veliger, vol. 5, No. 3, pp. 202-203, fig. 5.

Discussion. — The concept of this species has not been clearly defined. Although Weaver (1943, p. 517) considered it an abundant species in the Lincoln Creek Formation, specimens closely resembling the lectotype are rare in large collections from the formation. There are no published references to primary types aside from the well-preserved specimen originally figured by Weaver, although a specimen in the California Academy of Sciences type collection (CAS 343A) is labeled "paratype". This specimen represents a new genus and species described below, *Clivuloturris levis* Hickman, which is more abundant in the Lincoln Creek Formation than *T. packardi*.

Although *Turrinosyrinx packardi* has a whorl profile similar to species of *Parasyrinx* described above, it is readily differentiated by the position of the anal sinus, which has its apex far anterior on the shoulder slope, with most of the lower limb of the sinus anterior to the periphery. The peripheral keel consists of two prominent spiral cords, with strong spirals of decreasing strength on the convex base and faint spirals on the shoulder slope.

Material examined. — Eleven specimens.

Stratigraphic distribution. — *Turrinosyrinx packardi* is restricted to the *Turritella porterensis* megafaunal zone ("Lincoln Stage") of Durham (1944) in the Lincoln Creek Formation (Text-figures 1 and 6). Populations of *T. packardi* from coeval beds at Carmanah Point, Vancouver Island, British Columbia (Text-figure 1), compare closely with the holotype; and a specimen from USGS M5927 is figured for comparison (Pl. 5, fig. 19).

Lectotype. — CAS 473. This is the only specimen of the taxon that has been figured or referred to in the literature and is here designated as lectotype. Specimen 473A was apparently intended as a syntype and has incorrectly influenced the concept of the species: it is assigned to *Clivuloturris levis* Hickman, n. sp. *Figured hypotype.* — USNM 216428. (Carmanah Point Beds).

Localities. — Lincoln Creek Formation: UW 256 (type locality); SU NP 211 (= UW 256). Carmanah Point Beds: USGS M5927.

Turrinosyrinx* cf. *T. packardi (Weaver, 1916)

Pl. 5, figs. 10, 20

Discussion. — Three specimens from the middle and upper members of the Keasey Formation are similar to the holotype of *T. packardi*. The apex of the shallow anal sinus is similarly located, immediately posterior to the periphery. The suture lies just anterior to the periphery on spire whorls, so that the successive traces of the sinus on spire whorls are markedly asymmetrical, with little of the anterior limb visible. The development of low nodes on the peripheral spiral cords and the tendency for stronger spirals to develop on the shoulder slope differentiate these specimens from typical *T. packardi*.

Material examined. — Three specimens.

Stratigraphic distribution. — Highest and lowest stratigraphic occurrences of the species define a range of approximately 180 m in

the upper part of the middle member and lower part of the upper member of the Keasey Formation (Text-figure 5).

Figured specimens. — USNM 216429, 216430.

Localities. — Middle member, Keasey Formation: USGS 15280, 25031. Upper member: USGS 15315.

Turrinosyrinx nodifera Hickman, n. sp.

Pl. 6, figs. 4, 5, 9;
Text-figure 13a

Description. — Shell moderately large, of seven or eight whorls, including a smooth protoconch of two whorls; profile pagodaform, with a prominent peripheral angulation separating concave posterior and anterior slopes; posterior slope marked by 10 to 12 spiral cords with interspaces of approximately equal width; peripheral angulation rounded and bearing four spiral cords, with a tendency for faint oblique axial swellings to develop on later whorls, following the contour of the anterior limb of the anal sinus; concave base and anterior canal marked by approximately 20 fine spiral cords, separated by fine grooves posteriorly and increasingly broader interspaces anteriorly; canal straight, unnotched, broken on most specimens; anal sinus shallow (greater than 90°), with the apex far anterior on the shoulder slope or on the periphery, asymmetric, with a long sigmoid (convexi-concave) posterior limb and short sigmoid (concavo-convex) anterior limb; inner lip with ornament resorbed; suture slightly adpressed and positioned immediately anterior to peripheral angulation throughout coiling.

Dimensions of holotype. — Height (incomplete) 17 mm; maximum diameter 12.1 mm.

Material examined. — Twenty-five specimens.

Variation. — Decortication, recrystallization, exfoliation, breakage, and diagenetically produced distortions render material inadequate for detailed analysis of morphological variation. The species, nevertheless, appears to be less variable than most turrid species treated in this report; and specimens are readily identified from fragments.

Stratigraphic distribution. — *Turrinosyrinx nodifera* has been collected only from the lower member of the Keasey Formation, where it is one of the characteristic species. It occurs at six localities that range from near the base to near the top of the member (Text-figure 5).

Holotype. — USNM 216431. *Figured paratypes*. — USNM 216432, 216433. *Unfigured paratype*. — USNM 216434 (height 18.7 mm).

Type locality. — Lower member, Keasey Formation: USGS 25026.

Other localities. — Lower member, Keasey Formation: USGS 15263, 15309, 25027, 25270; SU NP 3.

Comparative notes. — *Turrinosyrinx nodifera* represents the lowest stratigraphic occurrence of the *Turrinosyrinx* species complex in the Pacific Northwest Paleogene, although it is not implied here that it represents the ancestral form or that the Paleogene species represent an evolutionary lineage. However, Oligocene species of *Turrinosyrinx*, when arranged in order of stratigraphic appearance, do exhibit three morphological trends (Text-figure 13): (1) the apex of the anal sinus is located progressively higher on the shoulder slope in successively younger species, (2) the peripheral band becomes progressively narrower, and (3) the intersection of the suture and the body whorl is situated progressively farther anterior.

Turrinosyrinx nodifera is distinguished from other Paleogene species by its relatively broader and more rounded periphery and more numerous and closely-spaced spiral ornamentation. It is the only species in which the ornamentation of the shoulder slope is of equal prominence to that on the base and anterior canal. It is also the only species that tends to form nodelike swellings at the periphery.

***Turrinosyrinx marrowstonensis* (Durham, 1944)**

Pl. 6, fig. 1;
Text-figure 13c

Irenosyrinx marrowstonensis Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 180, pl. 14, fig. 5.

Aforia marrowstonensis (Durham), Powell, 1966, Auckland Inst. Mus., Bull., 5, p. 44.

Discussion. — This species is represented by a single specimen from the Marrowstone Shale ("Lincoln Stage"), Quimper Peninsula, Washington (Text-figures 1, 6). The shallow anal sinus, with its apex on the anterior shoulder slope, and the concave profile of the body whorl anterior to the periphery identify this species as *Turrinosyrinx*. The anal sinus of the holotype is illustrated in Text-figure 13c. *T. marrowstonensis* is distinguished from the younger ("Blakeley Stage") *T. borgenae* and *T. cf. T. borgenae* by less prominent

angulation of the whorls, with the periphery relatively farther anterior on the spire whorls. It is distinguished from *T. packardi* and *T. nodifera* by its relatively narrower peripheral diameter and more elevated spire as well as by differences in ornamentation and configuration of the anal sinus.

Holotype. — UCMP 35438.

Type locality. — Marrowstone Shale: UCMP A3695.

Turrinosyrinx borgenae (Tegland, 1933) Pl. 6, fig. 2; Text-figure 13d

Cryptogemma borgenae Tegland, 1933, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 23, No. 3, p. 125, pl 10, figs. 9, 10, 11.

Hemipleurotoma borgenae (Tegland), Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, pp. 525-526, pl. 98, fig. 9.

Irenosyrinx borgenae (Tegland), Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 180.

Aforia borgenae (Tegland), Powell, 1966, Auckland Inst. Mus., Bull., 5, p. 44.

Discussion. — The holotype is the best preserved and most complete specimen of this species known to me. Specimens from the type Blakeley Formation in Washington are generally fragments, although they are easily recognized by the relatively broad and steep shoulder slope that is marked primarily by numerous close-spaced fine traces of the posterior limb of the anal sinus and faint traces of spiral ornamentation. The carination of the spire whorls is similar to that of several Paleogene species of *Aforia*. *Aforia* species have a distinctively different anal sinus that is deep (less than 90°) and higher on the shoulder slope, so that the posterior limb of the sinus is well represented. Paleogene *Aforia* species are further distinguished by bicarination of the body whorl.

The characteristic anal sinus of this species is illustrated in Text-figure 13d, and further means of distinguishing it are presented in the discussions of related Paleogene species.

Material examined. — Eight specimens.

Stratigraphic distribution. — *T. borgenae* is restricted to the *Echinophoria rex* megafaunal zone of Durham (1944) and has not been positively identified outside of the Blakeley Formation. A similar form from coeval or slightly younger beds in the Lincoln Creek Formation is discussed below.

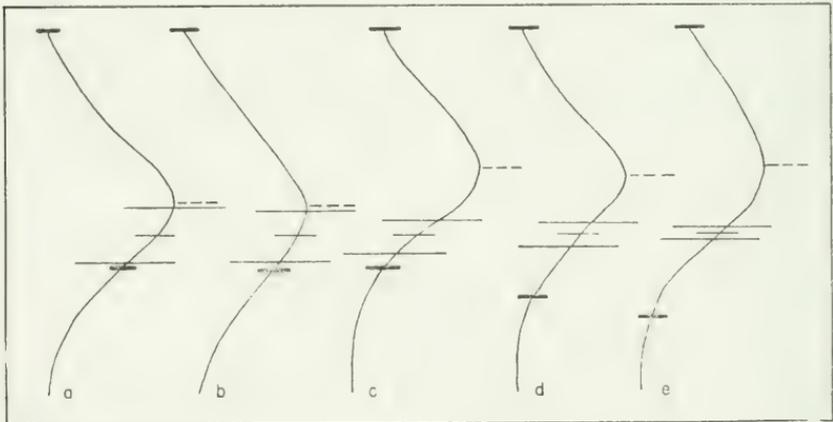
Holotype. — UCMP 32172. (type Blakeley Formation).

Other localities. — Blakeley Formation: SU NP 103, Schenck Coll. Acc. no. 2731.

Turrinosyrinx cf. **T. borgenae** (Tegland, 1933) Pl. 6, fig. 3; Text-figure 13e

Discussion.— A single specimen from the upper part of the Lincoln Creek Formation is similar to *T. borgenae* (Tegland) of the Blakeley Formation but exhibits a significantly different anal sinus. The specimen comes from a horizon that is equivalent to or slightly younger than the type Blakeley fauna, and the assemblage in which it occurs includes such typical Blakeley species as *Modiolus restorationensis* Van Winkle, 1918, and *Bathybembix washingtoniana* (Dall, 1909).

The apex and anterior canal of the specimen are missing, but other features of the four intact whorls identify it as *Turrinosyrinx* and permit detailed comparison with other provincial Oligocene species. The anal sinus of this species is illustrated along with those of other species of *Turrinosyrinx* in Text-figure 13. The position of the periphery on the spire whorls is relatively farther posterior than in any of the other Oligocene species but is most similar to that of *T. borgenae*. The anal sinus, which is characteristically situated with its apex on the anterior portion of the shoulder slope, is shallower than that of other *Turrinosyrinx* species, including *T. borgenae*, and



Text-figure 13.— Comparative anal sinus configuration in successively younger species of *Turrinosyrinx* Hickman, n. gen., from camera lucida drawings adjusted to uniform distance from posterior suture to bisector of peripheral keel. Heavy lines denote posterior and anterior sutures, light lines denote boundaries of periphery and its bisector, and dashed line denotes position of sinus apex. a. *T. nodifera* Hickman, n. sp.; b. *T. packardi* (Weaver); c. *T. marrowstonensis* (Durham); d. *T. borgenae* (Tegland); e. *T.* cf. *T. borgenae* (Tegland).

the posterior limb is concave. In most other species the posterior limb is sigmoid (convexi-concave). The specimen from the Lincoln Creek Formation and *T. borgenae* both have relatively smooth shoulder slopes with faint spiral bands, the periphery marking the initiation of well-developed spiral cords.

Figured specimen.—SUPTC 10219.

Locality.—Lincoln Creek Formation: SU NP 208. This locality is in the upper part of the type section of the Lincoln Creek Formation in beds of "Blakeley" age exposed along the Chehalis River between Galvin and Independence, Washington (Text-figure 1).

Borsonella ? nuncapatia Hanna, 1924, nomen dubium

Turris lincolnensis Van Winkle, 1918, Univ. Washington Pubs. Geol., vol. 1, No. 2, p. 92.

Not Turris lincolnensis Anderson and Martin, 1914, California Acad. Sci., Proc., ser. 4, vol. 4, pp. 88-89, pl. 6, fig. 8.

Borsonella ? nuncapatia Hanna, 1924, California Acad. Sci., Proc., ser. 4, vol. 13, p. 158 (new name); Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, p. 523.

Irenosyrinx (?) *nuncapatia* (Hanna), Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 180.

Discussion.—The nomenclatural history of this taxon is exceptionally rich considering that the sole specimen on which the concept was based was destroyed before a name was ever published. According to Weaver (1943), the specimen was accidentally destroyed while it was being mounted for photography. Furthermore, the name originally proposed was a junior primary homonym of a species described four years earlier. From the original description one may infer that the species belongs in the *Turrisosyrinx* complex, but because the critical characters are not mentioned in the description, the name must be considered a *nomen dubium*.

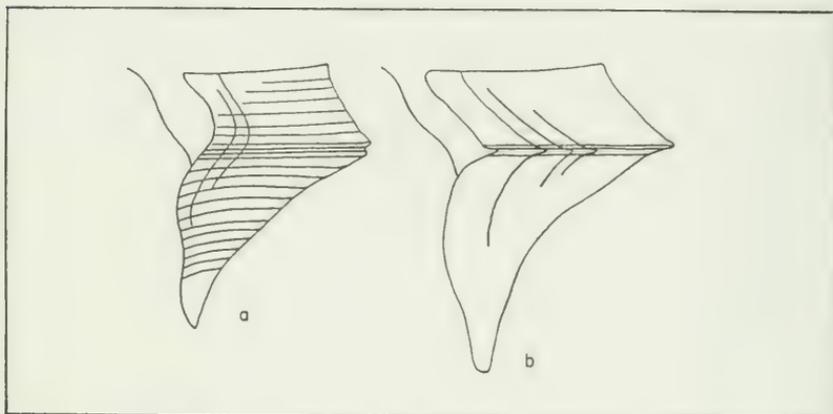
Genus **CLIVULOTURRIS** Hickman, n. gen.

Type species: *Clivuloturris levis* Hickman, n. sp. Middle Oligocene, Lincoln Creek Formation, Washington.

A slender pagodaform species from the Lincoln Creek Formation, similar in profile to species of *Parasyrinx* and *Turrisosyrinx*, exhibits a labial sinus unlike that of any turrid known to me. The trace of the posterior limb of the sinus occupies the entire shoulder slope and crosses the sharp peripheral keel to form a narrow notch on the underside of the keel, between the keel and a minor spiral ridge. The spiral ridge is accentuated by the overlapping traces of the

anterior limb of the sinus, which runs along it before turning onto the base of the shell. The anal sinus and labial profile of *Clivoloturris* are illustrated, along with those of *Turrinosyrinx*, in Text-figure 14.

Clivoloturris is represented by the type species and by a second species that is still poorly known and is treated in open nomenclature below. Characteristics of the genus are tentatively the same as those of the type species as described below.



Text-figure 14.— Comparison of anal sinus configuration, labial profile, whorl profile, and basic ornamentation pattern in the type species of a. *Turrinosyrinx* and b. *Clivoloturris*.

Subfamilial allocation of *Clivoloturris* is questionable, for the traditional distinction between the non-toxoglossate Turrinae and Turriculinae does not admit the possibility of an anal sinus having its apex anterior to the periphery. Because of the glossy shell and similarity of form of *C. levis* to certain of the cochlespirine species, it is placed with the Turriculinae. As suggested in the discussion of *Turrinosyrinx*, the desirability of retaining the Turrinae and Turriculinae as separate subfamilies is questionable except as a matter of convenience or custom.

***Clivoloturris levis* Hickman, n. sp.**

Pl. 6, figs. 6, 7, 10, 11;
Text-figure 12b

?*Turris packardi* Weaver, 1916, Univ. Washington Pubs. Geol., vol. 1, No. 1, p. 55 (in part).

Description.— Shell thin, medium-sized (up to 20 mm high), with a pagodaform spire and straight, slender, unnotched anterior

canal; surface glossy; whorls about nine, including a smooth globose protoconch of two whorls that lack the keel of later whorls; shoulder slope concave, smooth and glossy, lacking spiral ornamentation, bordered posteriorly by abutting suture and anteriorly by sharp unornamented peripheral keel; base strongly constricted, also glossy, and lacking spiral ornamentation; anal sinus deep (less than 90°) with its apex immediately anterior to the peripheral keel, between the keel and a minor spiral ridge on the underside of the keel, appearing to be on the peripheral keel in worn specimens and on early whorls where the spiral cord is not developed; carination of spire whorls occurring low on whorl, immediately posterior to suture; inner lip with a thin to moderately well-developed inductura.

The name *levis* is a latin adjective meaning "smooth."

Dimensions of holotype. — Height (incomplete) 17.7 mm; maximum diameter 10.6 mm.

Material examined. — Twenty specimens.

Variation. — The holotype of *Clivuloturris levis* is an incomplete large specimen, selected because it best illustrates the unique shape and position of the anal sinus. Specimens are often worn and chalky, particularly at the periphery, causing the keel to appear doubled. This false double keel is not to be confused with the double keel of *Turritosyrinx packardi* which consists of two prominent spiral cords.

Stratigraphic distribution. — *Clivuloturris levis* is restricted to the *Turritella porterenis* megafaunal zone (Durham, 1944). The species occurs in the type section of the Lincoln Creek Formation near Galvin, Washington, as well as in the Porter Bluffs section (type *Turritella porterenis* Zone) of the Lincoln Creek Formation. *C. levis* also occurs in coeval unnamed beds on the Columbia River at Knappton in southeastern Washington (CAS locality 611).

Holotype. — SUPTC 10220. *Paratypes.* — SUPTC 10221, 10222. *Referred specimen.* — CAS 55737.

Type locality. — Lincoln Creek Formation: SU NP 50.

Other localities. — Lincoln Creek Formation: SU NP 53, NP 54; UW 352, 256, 571-c; UCMP A9, A8372; CAS 193. Unnamed beds at Knappton, Washington, CAS 611.

Comparative notes. — The unique anal sinus of *Clivuloturris levis* differentiates it from all other Pacific Northwest Paleogene

turrid species. In whorl profile it is strikingly similar to *Parasyrinx delicata* of the Keasey Formation. The similarity is most striking in worn specimens, which tend to exhibit a false double keel in both species. In addition to differences in anal sinus configuration and position, *C. levis* differs from pagodaform *Parasyrinx* and *Turrinosyrinx* species in total lack of spiral ornamentation on the base and anterior canal.

Clivuloturris cf. **C. levis** Hickman

Pl. 6, fig. 8

Discussion. — A single small (less than 10 mm) turrid from the middle member of the Keasey Formation represents the earliest occurrence of the genus *Clivuloturris*. The specimen is somewhat worn, and the apex of the anal sinus is on the sharp peripheral keel as in worn specimens of *C. levis* from the stratigraphically higher Lincoln Creek Formation. It is distinct from *C. levis* in exhibiting a second carination of the body whorl, situated twice as far anterior to the peripheral keel as the path of the suture. The second carination is thus not visible on spire whorls.

Stratigraphic position. — *Clivuloturris* cf. *C. levis* occurs stratigraphically lower than the typical form of the species and represents the earliest occurrence of the genus.

Figured specimen. — USNM 216435.

Locality. — Middle member, Keasey Formation: USGS 25036.

Genus **AFORIA** Dall, 1889

Type species (by original designation): *Pleurotoma circinata* Dall, 1873. Pliocene to Recent, North Pacific.

Although *Aforia* does not occur in the Keasey Formation, it is a characteristic cochlespirine genus in the younger Oligocene and Neogene cold, deep-water facies. Specimens are not abundant but are striking in their large adult sizes (greater than 60 mm). *Aforia campbelli* Durham, 1944, the oldest representative of the genus, occurs in the Pittsburg Bluff Formation (Moore, in press) as well as in the Lincoln Creek Formation in Washington. Javidpour (1973) discussed the Oligocene species and noted several evolutionary trends, and the reader is referred to her treatment for additional information about the group.

The Oligocene species of *Aforia* differ from living species, including the type, in the bicarinate body whorl profile. The anterior

keel is especially prominent and may justify subgeneric distinction of the group.

Subfamily **TURRINAE**

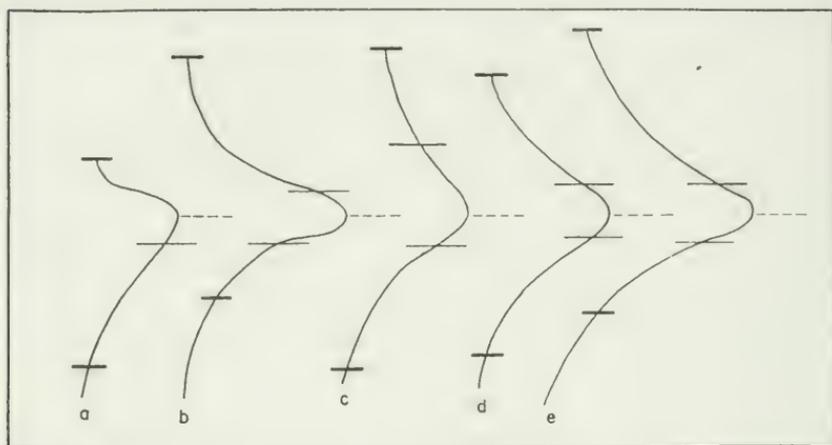
Genus **EOPLEUROTOMA** Cossmann, 1889

Type species (by original designation): *Pleurotoma multicostrata* Deshayes, 1834. Eocene, Europe.

Eopleurotoma is a large genus of Paleocene and Eocene turrids distributionally centered in Europe and the southeastern United States. Several poorly understood fusiform turrid species in the Paleogene of the Eastern Pacific exhibit the flexuous axial ornamentation that is characteristic of the genus. Vokes (1939) proposed *Eopleurotoma* (?) *traski* for an axially ribbed species from the "Domengine Stage" in California. *Drillia ornata* Dickerson, 1915, of the upper Eocene Cowlitz Formation ("Tejon Stage") in Washington also bears generic similarity to *Eopleurotoma*. The specimens discussed below from the Keasey Formation in Oregon represent the highest stratigraphic occurrence of this group on the Pacific Coast. Generic allocation of these species is not clear and cannot be properly evaluated until better material is available.

Eopleurotoma (?) n. sp., aff. *Eopleurotoma* (?) *ornata* (Dickerson), 1915
Pl. 6, fig. 12; Text-figure 15a

Discussion.—Two incomplete and worn specimens from separate localities in the Keasey Formation are distinct from other Keasey turrids in having flexuous axial ribbing and a distinctive anal sinus. Although the Keasey specimens differ from *Eopleurotoma* (?) *ornata* (Dickerson) of the Cowlitz Formation in details of ornamentation and proportion, they share a similar anal sinus configuration. The posterior limb of the sinus descends nearly vertically for a short distance from the suture over a low broad spiral band before it swings abruptly into the deep asymmetrical U-shaped notch (less than 90°), which is restricted to the concave anterior $2/5$ of the shoulder slope. The concavo-convex anterior limb of the anal sinus is longer than the posterior limb and more protractively oblique than the axial ribs. The anterior canal is relatively short, slender, and slightly recurved but unnotched. The anal sinus of this species is illustrated in Text-figure 15, along with the anal sinuses of other turrid genera treated in this report.



Text-figure 15.—Comparative anal sinus configuration in five turrine genera represented in the Keasey Formation, from camera lucida tracings of growth lines. Heavy lines denote posterior and anterior sutures, light lines denote boundaries of periphery and its bisector, and dashed line denotes apex of anal sinus. a. *Eopleurotoma* (?), n. sp. aff. *E. (?) ornata* (Dickerson); b. *Gemmula rockcreekensis* Hickman, n. sp.; c. *Proccrapex bentsonae* (Durham); d. *Ptychosyrinx facula* Hickman, n. sp.; e. *Pleuroliria oregonensis* Hickman, n. sp.

Figured specimen.—USNM 216436.

Localities.—Lower member, Keasey Formation: USGS 15309.
Middle member: USGS 25031.

Genus **GEMMULA** Weinkauff, 1875
(= *Hemipleurotoma* Cossmann, 1889)

Type species (by subsequent designation, Cossmann, 1896): *Pleurotoma gemmata* Hinds in Reeve, 1843; *non* Conrad, 1835 (= *Gemmula hindsiana* Berry, 1958). Holocene, tropical eastern Pacific.

Although the type of *Gemmula* is a small-shelled tropical eastern Pacific species (Pl. 7, fig. 14), the genus is of worldwide distribution. A post-Miocene adaptive radiation of large-shelled (greater than 30 mm high) turrine lineages has resulted in distributional clustering of *Gemmula* and its allies in the Indo-West Pacific. A different pattern prevailed during the Paleogene (Powell, 1964), when *Gemmula* and allied small-shelled (less than 30 mm high) turrine offshoots were clustered in Europe and the southeastern United States.

Although gemmate turrids are present in the Paleogene of the Pacific Northwest, they are not obviously congeneric with Atlantic forms, having undergone a series of separate, and as yet undocumented, adaptive radiations, producing a number of short-lived genera and species. Powell (1964, 1966) did not recognize *Gemmula* s. s. in the Pacific Coast Tertiary of North America, although the name has been broadly applied in the California Eocene (Keen and Bentson, 1944). Examination of Pacific Coast Paleogene gemmate species with peripheral labial notches reveals several distinct groups, none of which fits into *Gemmula* as it is normally constituted: (1) a group of small species typified by *Gemmula wattsi* Anderson and Hanna, 1925, in which the final nuclear whorl bears protractive arcuate axial ornamentation similar to that of *Gemmula*, but which differs in having a shallow posterior siphonal notch (greater than 90°), (2) a group typified by *Gemmula fasteni* Weaver and Palmer, 1922, with a short anterior canal and paucispiral, smooth, bluntly rounded protoconch and shallow posterior siphonal notch, and (3) a group exemplified by *Gemmula bentsonae* Durham, 1944, with a smooth, atypically tall polygyrate protoconch, shallow anal sinus, and a unique peripheral configuration combined with a distinctive pattern of ornamentation. Only the last group occurs in the deep-water facies, and it will be treated separately below.

Glibert (1960) subdivided *Gemmula* into three groups on the basis of plication, partial plication, or non-plication of the inner shell surface of the outer lip. Although this set of characters shows some systematic correlation with variation in prominence of the gemmate peripheral band, it does not seem to be related to distinctive variations in protoconch and sinus characters and is probably limited in usefulness to the delimitation of provincial European Cenozoic species groups. The ridges within the aperture on the interior portion of the outer lip are not characteristic of *Gemmula* alone, but also occur in other turrine genera, including the type species of *Lophiotoma* Casey, 1904; *Polystira* Woodring, 1928; and *Turris* Röding, 1798. In fact, plications are absent in the type species of *Gemmula*. Although present in *Polystira albida*, the type species of *Polystira*, they are absent in the Pacific counterpart, *P. nobilis* (Hinds, 1843).

A single species, restricted to the lower member of the Keasey

Formation, represents the only occurrence in the Pacific Coast Paleogene of a form having the deep (less than 90°) slotlike anal sinus and coglike periphery of *Gemmula*, *s. s.*

***Gemmula rockcreekensis* Hickman, n. sp.**

Pl. 7, figs. 13, 21, 22;
Text-figure 15b

Description. — Shell small, fusiform, with a moderately high turreted spire and slender anterior canal; protoconch missing on all specimens examined; postnuclear whorls about five, with an unornamented concave shoulder slope and heavy gemmate peripheral keel immediately posterior to suture, bearing approximately 20 bluntly squarish nodes per revolution; body whorl large, ornamented by three prominent subperipheral spiral cords, the anterior cord marking an abrupt constriction of the canal and giving the body whorl a bicarinate outline; canal ornamented by three to five progressively weaker spiral cords; anal sinus with nearly symmetrical subparallel limbs, forming a narrow and relatively deep (75°) slot with its apex on the peripheral band; inner lip smooth and uncalloused, a sharp boundary demarcating the initiation of ornamented canal.

Dimensions of holotype. — Height (incomplete) 14.1 mm; maximum diameter 8.2 mm.

Material examined. — Twelve specimens.

Variation. — Variations observed in the limited material at hand, such as apparent lack of nodes on the peripheral carina, are attributed to poor preservation, notably exfoliation and decortication of shell material.

Stratigraphic distribution. — *Gemmula rockcreekensis* occurs only in the lower member of the Keasey Formation along Rock Creek (Text-figure 1), where the member is approximately 150 m thick. It is known from four localities encompassing 120 m within the lower member (Text-figure 5).

Holotype. — USNM 216437. *Figured paratype.* — USNM 216438. *Unfigured paratype.* — USNM 216439 (in matrix).

Type locality. — Lower member, Keasey Formation: USGS 15309.

Other localities. — Lower member, Keasey Formation: USGS 15307, 25026; SU Acc. 25771.

Comparative notes. — *Gemmula rockcreekensis* is distinguished

from all other West Coast Paleogene turrine species by the deep anal sinus that is characteristic of the genus. The shell is larger and more coarsely ornamented than in any of the turrine species described from the Eocene. The anal sinus of *G. rockcreekensis* is illustrated in Text-figure 15 for comparison with the sinuses of other Paleogene turrine genera discussed in this report.

Genus **PROCERAPEX** Hickman, n. gen.

Type species: *Gemmula bentsonae* Durham, 1944. Early Oligocene; Washington, Oregon, and California.

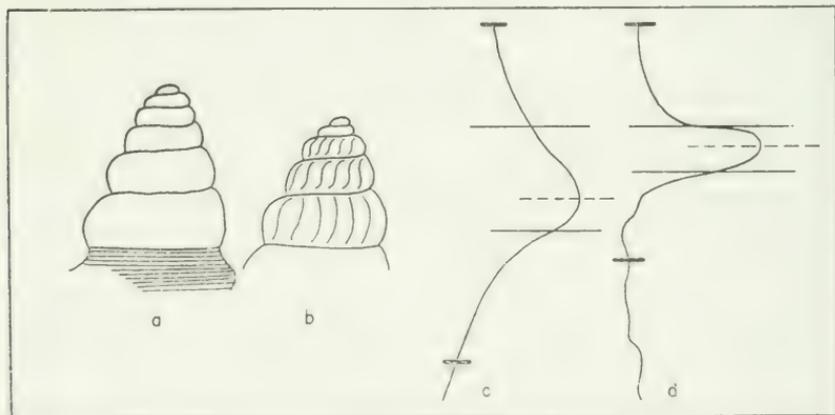
Pacific Coast Paleogene peripherally beaded turrids with high spires and relatively long, straight anterior canals and a labial sinus on the peripheral carina traditionally have been placed in *Gemmula* Weinkauff, 1875. Examination of these species reveals a number of differences separating them both from the type species and from other modern and Neogene species assigned to *Gemmula*. The most pronounced difference is the lack of a tall polygyrate axially costate protoconch. A variety of protoconch types in the Paleogene species that I have examined suggests that they are not a closely related natural group, an observation which is also supported by variation in other shell characters. In most of these species the sinus is shallow, in contrast to the characteristic slotlike sinus of *Gemmula*. Although species in the Pacific Coast Paleogene may well represent several offshoots of the main gemmate stem of the Turridae, they are offshoots that proliferated in a provincial context during the Eocene and Oligocene as lineages of relatively short duration that did not carry over into the Miocene.

One of the most striking of these provincial turrids is a large "gemmulid" with rounded peripheral nodes, shallow labial sinus, smooth polygyrate protoconch, and characteristic sculpture consisting of alternating fine spiral cords and interspaces of approximately equal width. It is restricted to the provincial early Oligocene, but it appears in both shelf and slope facies at widely separated localities in Washington, Oregon, and California. A suite of over 150 specimens from 24 localities in the Keasey Formation permits analysis of the range of variation at the specific level as well as characterization of a new genus, *Procerapex*.

The distinctive generic characters of *Procerapex* are: (1) a tall

unornamented protoconch of five to six rounded whorls. The protoconch of the new genus is contrasted with the axially costate protoconch of *Gemmula* in Text-figure 16; (2) a shallow labial sinus with an angle of 120° that is slightly below the middle of the broad peripheral node row (labial sinus and peripheral features of *Gemmula* and *Procerapex* are contrasted in Text-figure 16); (3) peripheral nodes consisting of rounded swellings in contrast to the laterally compressed nodes of *Gemmula* and its allies, which typically exhibit vertical fusion of two or more series of node rows to produce a coglike periphery; (4) ornamentation consisting of regular alternation of low spiral cords with interspaces of equal width. The spiral cords are of uniform heaviness, in marked contrast to the basic turrine pattern of spiral cords and keels of unequal strength and unequal distance from one another, often generating a fluted outer lip.

Although *Procerapex* is monotypic, the type species is abundant and widespread, occurring in five different formations and over 40 localities representing at least as many discrete stratigraphic horizons in Washington, Oregon, and California.



Text-figure 16.—Comparison of the distinctive protoconchs and anal sinuses of a, c. *Procerapex* and b, d. *Gemmula*.

Procerapex bentsonae (Durham, 1944) Pl. 6, figs. 13-19; Text-figure 16a, c

Gemmula, n. sp. Durham, Zimmerman, 1944, Amer. Assoc. Petrol. Geol., Bull., vol. 28, No. 7, p. 963.

Gemmula bentsonae Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 184, pl. 14, figs. 14, 17; Hickman, 1969, Mus. Nat. Hist. Univ. Oregon, Bull. 16, p. 97, pl. 13, figs. 20-23.

Discussion. — A supplementary description of *Procerapex bentsonae*, based on 39 specimens from the Eugene Formation in Oregon, was presented by Hickman (1969). Keasey populations are similar to Eugene populations, although the mean number of peripheral nodes is 12 in the Eugene and 13 in the Keasey. A specific character that occurs in all populations is a puckering of the sutural collar that occurs in many deep-water gastropod species. The peripheral nodes or swellings are set on four to six spiral cords that are more closely spaced than the cords anterior and posterior to the periphery. The cords continue across the nodes. There are typically three to five spiral cords on the shoulder and three to five spiral cords between the periphery and the anterior suture on spire whorls. The profile of the body whorl anterior to the periphery is gently convex.

Many specimens in the Keasey Formation have been drilled by naticid gastropods, and incidences of shell damage that were subsequently repaired during growth are common and sometimes spectacular (Pl. 6, fig. 15). *P. bentsonae* is the most abundant turrid species in the Keasey Formation. The long straight anterior canal is broken on most specimens, but the maximum diameter of the body whorl serves as a good index to the original height of a specimen. Inferred heights of specimens from the Keasey Formation range from 24 mm to 80 mm. Spire whorls are more often preserved intact, and the distinctive protoconch of *P. bentsonae* is illustrated on Plate 6, figure 16.

Material examined. — Keasey Formation: 157 specimens. Eugene Formation: 40 specimens. Quimper Sandstone: 10 specimens. Tumey sandstone member, Kreyenhagen Formation: 3 specimens. Lincoln Creek Formation: 4 specimens.

Variation. — Specimens of *Procerapex bentsonae* do not exhibit any systematic stratigraphic patterns of variation in the Keasey Formation, and the species is remarkably uniform in shell characters compared with many Paleogene turrid species. The most variable characters are the amount of swelling of the peripheral nodes and the number, prominence, and spacing of spiral ribs. A specimen with prominent nodes and coarse ribs (Pl. 6, fig. 13) is contrasted with a specimen of the same size with subdued nodes and fine, more numerous, spiral ribs (Pl. 6, fig. 14), both from the same locality (USGS 25031) in the middle member of the Keasey Formation.

Stratigraphic distribution. — *Procerapex bentsonae* ranges throughout all three members of the Keasey Formation, although it is absent from both the underlying Cowlitz Formation and the overlying Pittsburg Bluff Formation. In Washington the species occurs at correlative horizons in the Lincoln Creek Formation and Quimper Sandstone. The species also occurs at a single locality in central California. Three specimens listed as *Gemmula*, n. sp. by Zimmerman (1944) in collections at Stanford University from the Tumey Sandstone member of the Kreyenhagen Formation are indistinguishable from Washington and Oregon specimens. The associated Tumey fauna is indicative of bathyal depths.

Holotype. — UCMP 35454. *Paratypes.* — UCMP 35455, 35456, 35457. *Figured hypotypes.* — USNM 216440, 216441, 216442, 216443, 216444, 216445, 216446.

Localities. — Lower member, Keasey Formation: USGS 15309, 15584, 25026, SU NP 3. Middle member: USGS 15267, 15268, 15274, 15276, 15279, 15280, 15281, 15282, 15283, 15508, 15517, 15602, 25030, 25031, 25033, 25034, 25037, 25038, M3862; SU H 33, H 36, H 38. Upper member: USGS 15518, 15601, 15315. Quimper Sandstone: UCMP A1802 (type locality), SU NP 148, NP 153. Lincoln Creek Formation: SU NP 277. Eugene Formation: UO 2537, 2538, 2539, 2540, 80, 2251, 2553, 2554, 2558, SU Acc. 3482. Tumey sandstone member, Kreyenhagen Formation: SU 2361.

Genus **PTYCHOSYRINX** Thiele, 1925

Type species (by original designation): *Pleurotoma (Subulata) bisinuata* Martens, 1901. Living; East Africa, Somaliland — Zanzibar, 818-1362 m.

Species comprising a poorly understood group of small (usually less than 10 mm high) gemmate turrids in the Pacific Northwest Tertiary have been placed in a variety of genera but are most often assigned to the deep-water claviform genus *Suavodrillia* Dall, 1918. In spite of the clavine appearance imparted by the short anterior canal in these forms, the apex of the anal sinus is clearly on the periphery and not on the lower shoulder slope as in *Suavodrillia*. These species are more appropriately assigned to *Ptychosyrinx* Thiele. Living turrids with similar characters are known only from deep water (greater than 200 m) and have been assigned to a variety

of genera. A group of similar species with short spires and short-twisted anterior canals in the tropical eastern Pacific comprises the genus *Cryptogemma* Dall, 1918. *Ptychosyrinx* is more widely distributed in deep-water basins (Powell, 1964), although its distribution is centered in the tropical western Pacific, where the subgenus *Kuroshioturris* Shuto, 1961, includes a group of species differentiated on the basis of protoconch features.

Ptychosyrinx chilensis Berry, 1968, is the only species reported from the Eastern Pacific. The holotype, which was not figured or designated by number in the original report, is in the Berry collection. Three specimens from the same area as the holotype, off Coquimbo, Chile, have been deposited at the Los Angeles County Museum of Natural History. One of these specimens is figured here for comparison with the Paleogene species from the northeastern Pacific (Pl. 7, figs. 1, 6). The Chilean species is most readily distinguished by shell size, which is large for the genus.

A small-shelled species of *Ptychosyrinx* occurs in the Hawaiian deep-water fauna. Three specimens collected from 284-290 fathoms off Maui and Molokai are in the collection at Stanford University and are identified in Dall's handwriting as "*Turris incilis*," his unpublished manuscript name. The species is yet to be described.

The concept of *Ptychosyrinx* was restricted for many years to species with a spoutlike notch in the anterior portion of the outer lip in addition to the anal siphonal notch. Powell (1964) pointed out that the bisinuate outer lip is not a constant feature at the species level and has expanded the concept of the genus to include species lacking the spout, placing *Bathybermudia* Haas, 1949, in synonymy with *Ptychosyrinx*.

Consistent features of the genus, in addition to the short, twisted anterior canal, include: (1) a prominent to faint subsutural spiral cord; (2) a relatively broad and shallow anal sinus (compared with *Gemmula*, *s. s.* and its allies) that is bluntly V-shaped, greater than 90°, and symmetrical on spire whorls; and (3) an abrupt constriction of the anterior canal immediately anterior to the second or third prominent spiral band beyond the periphery. The anterior canal may exhibit a slight notch and weak fasciole. The geometry of the anal sinuses of three Paleogene species of *Ptychosyrinx*, as well as that of the living *P. chilensis*, is illustrated in Text-figure 17.

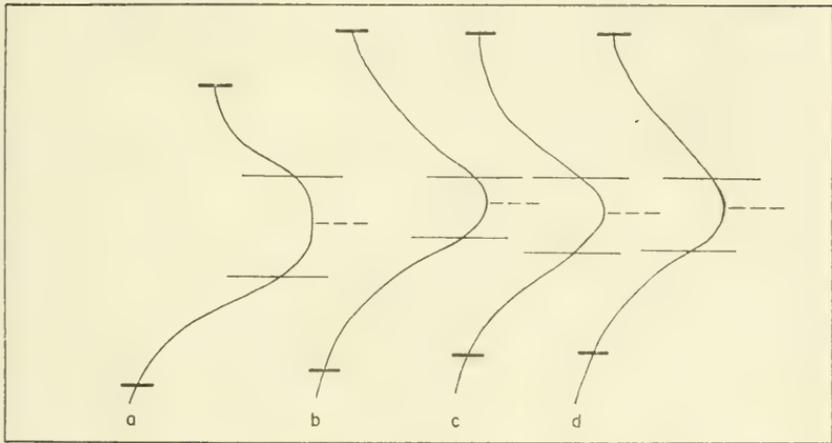
The presence of gemmules on the peripheral carina is not a diagnostic character of the Paleogene representatives of the genus. Some species include both gemmate and non-gemmate individuals within their populations, and individuals that produce gemmules on early whorls may have a smooth peripheral carina on later whorls.

Species in the Pacific Northwest Paleogene assigned to *Ptychosyrinx* include: *Turris thurstonensis* Weaver, 1916 (Lincoln Creek and Blakeley Formations); *Suavodrillia herleini* Durham, 1944 (Blakeley Formation); *Drillia columbiana* Anderson and Martin, 1914 (Pittsburg Bluff Formation); *Ptychosyrinx facula* Hickman, n. sp. (Keasey Formation); and *Ptychosyrinx* cf. *P. facula* Hickman (Quimper Sandstone). *Turris worcesteri* Van Winkle, 1918, was proposed for a poorly preserved specimen that falls within the broad range of variation of Weaver's *Turris thurstonensis*, described earlier from the same locality in the Lincoln Creek Formation. A single specimen of a short-spined species from the Quimper Sandstone, in the collection at Stanford University (Locality NP 53) represents a new species of the closely related deep-water genus *Cryptogemma*.

Turris thurstonensis is the only one of the previously described species that is well represented in collections and abundant at its type locality. Fifty-five specimens from a locality in the Lincoln Creek Formation (SU NP 150) have been examined. Strikingly, they exhibit the same patterns of variation occurring in a comparable sample of the new species in the Keasey Formation.

Ptychosyrinx also occurs in the Miocene of the Pacific Coast, where it has been referred to most recently as *Thesbia* Jeffreys, 1867, or *Xenuroturris* Iredale, 1929. Moore (1963, p. 48) and Addicott (1970a, p. 128) both noted the difficulty in generic allocation of the Miocene forms, and nomenclatural confusion has obscured their relationship to the Paleogene species.

The biostratigraphic potential of this group in the deep-water facies of the provincial Oligocene of the Pacific Northwest is high, for the genus ranges throughout the time interval and is represented by a number of species with relatively short stratigraphic ranges (Text-figure 6) and large species populations. In view of the range of specific variability that can occur, it will be necessary to define more accurately the species that are currently based on a paucity of material.



Text-figure 17.—Comparative anal sinus configuration in species of *Ptychosyrinx*, from camera lucida drawings of growth lines. Heavy lines denote posterior and anterior sutures, light lines denote boundaries of periphery, and dashed line denotes position of apex of anal sinus. a. *P. chilensis* Berry; b. *P. facula* Hickman, n. sp.; c. *P. columbiana* (Anderson and Martin); d. *P. thurstonensis* (Weaver).

Ptychosyrinx facula Hickman, n. sp.

Pl. 7, figs. 2-5, 7, 9, 12;
Text-figure 17b

Description.—Shell small (mean height = 9.9 mm; mean maximum diameter = 4.5 mm), with a tall spire but short, slender, twisted and unnotched anterior canal; apical whorls missing from all specimens examined; anal sinus a shallow V with its blunt apex on the nodose peripheral keel; limbs symmetrical as they appear in growth line traces on the spire whorls, posterior limb sigmoid (convex-concave), with a long shallowly convex posterior segment, anterior limb sigmoid (concavo-convex) with a long convex anterior segment; anterior sinus limb extending slightly farther than posterior limb; shoulder slope narrow and shelflike, with a prominent subsutural cord and with or without fine spiral threads; periphery with flattened, bluntly triangular nodes (mean = 14 per whorl), appearing rounded on worn specimens, occasionally with two or three spiral threads visible between nodes; body whorl anterior to periphery usually ornamented by three major spirals, with the suture following the middle spiral throughout coiling and the anterior spiral marking the abrupt constriction of the anterior canal; canal orna-

mented by minor spiral threads; inner lip without callus, a sharp boundary demarcating ornamented canal from smooth shell interior.

Facula is a Latin noun of feminine gender meaning "little torch."

Dimensions of holotype. — Height 9.5 mm; maximum diameter 4.5 mm.

Material examined. — Fifty-six specimens.

Variation. — The most variable characters in *Ptychosyrinx facula* are the number of nodes per whorl (which remains constant throughout coiling in an individual) and the number, arrangement, and relative prominence of primary and secondary spiral elements of sculpture anterior to the periphery. Specimens from the lower member of the formation have a higher mean number of nodes on the periphery (18 per whorl). This difference may be of biostratigraphic significance and utility but does not warrant formal taxonomic distinction. A second variant is characterized by a lower mean number of nodes (11 per whorl), associated with a distinctively simplified pattern of spiral ornamentation. This second variant occurs with the typical form at two localities near the top of the middle member of the Keasey Formation. Both variants will be treated separately below. A well-preserved specimen from the type locality exhibits a smooth peripheral carina with no traces of nodes on either the body whorl or spire whorls (Pl. 7, fig. 9).

Stratigraphic distribution. — *Ptychosyrinx facula* occurs in all three members of the Keasey Formation, although it is most abundant in the upper portion of the middle member. Specimens from the lower member have a high mean number of peripheral nodes per whorl, while specimens from the upper member are morphologically indistinguishable from those in the middle member. *P. columbiana* (Anderson and Martin) occurs in the overlying Pittsburgh Bluff Formation.

Holotype. — USNM 216447. *Figured paratypes.* — USNM 216448, 216449, 216450. *Unfigured paratypes.* — USNM 216451 (height 7.2 mm), 216452 (height 7.8 mm).

Type locality. — Middle member, Keasey Formation: USGS 25031.

Other localities. — Lower member, Keasey Formation: USGS

15309. Middle member: USGS 15267, 15268, 15280, 25033, 25034, 25038, M3862. Upper member: USGS M3863, 15601, 25032.

Comparative notes.— Adult specimens of *Ptychosyrinx thurstonensis* are larger (20 mm high) than adult *P. facula* and the periphery consists of a relatively broad unornamented low flat band, in contrast to the nodes of *P. facula*, which are set on two or three fine spiral threads. *P. hertleini* (Durham) has more weakly developed peripheral nodes that are more numerous than on *P. facula* (24 per whorl). The periphery is relatively higher on the whorl in the former species, and the area between the periphery and the basal constriction is relatively broader and more highly sculptured. *Ptychosyrinx*, n. sp., aff. *P. facula* from the Quimper Sandstone is most similar to the new species as well as being most closely related in stratigraphic position. It is differentiated by its more slender form as well as differences in ornamentation described below.

***Ptychosyrinx facula* Hickman, variant A**

Pl. 7, fig. 10

This variant includes specimens with a high mean number of nodes per whorl (18). The major spiral cords tend to be more vigorously developed than in the typical form, but the number and arrangement of both major and minor spiral elements is comparable in the two. Variant A may be biostratigraphically significant, for it occurs only in the lower member of the Keasey Formation where the typical form has not been collected. It occurs at a single locality, however, which is insufficient to establish its stratigraphic range.

Material examined.— Five specimens.

Figured specimen.— USNM 216453.

Locality.— Lower member, Keasey Formation: USGS 15309.

***Ptychosyrinx facula* Hickman, variant B**

Pl. 7, fig. 8

Unlike the variant described above, variant B occurs at the same localities as the typical form of the species and has no biostratigraphic significance. It is characterized by a low mean number of nodes per whorl (11), a smooth, unornamented shoulder slope, and a simplification of sculpture anterior to the periphery to a single basal keel and one or two faint spiral threads on the anterior canal.

Material examined.— Three specimens.

Figured specimen.— USNM 216454.

Localities.— Middle member, Keasey Formation: USGS 15280, 25031.

Ptychosyrinx, n. sp. aff. **P. facula** Hickman, n. sp.

Suavodrillia cf. *worcesteri* (Van Winkle), Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 183.

Discussion. — A unique specimen of a *Ptychosyrinx* from the lower part of the Quimper Sandstone in the northeastern Olympic Peninsula appears to be related to *P. facula*. Durham (1944) compared the specimen with *P. worcesteri* (= *P. thurstonensis*), but the similarity to the new Keasey species is even more striking, particularly the distinct fine nodes on the periphery. The specimen does not fall within the observed range of variation in *P. facula*. The specimen is much more slender, with a steeper shoulder slope and less prominent periphery. The periphery is also relatively lower on the body whorl, and the area between the periphery and basal constriction is relatively narrower.

Referred specimen. — UCMP 35451.

Locality. — Quimper Sandstone: UCMP A1802.

Ptychosyrinx columbiana (Anderson and Martin, 1914) Text-figure 17c

Drillia columbiana Anderson and Martin, 1914, California Acad. Sci., Proc., ser. 4, vol. 4, p. 94, pl. 7, figs. 4a, 4b.

Thesbia columbiana (Anderson and Martin), Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, p. 537, pl. 99, fig. 13.

Discussion. — This small-shelled species, described from the Pittsburg Bluff Formation in Oregon, is discussed by Moore (in press) and will not be treated in detail here. It is readily distinguished from *Ptychosyrinx facula* of the underlying Keasey Formation by the absence of nodes on the peripheral keel, although Moore notes a range of variation in the number, strength, and arrangement of spiral sculptural elements that is parallel to the range exhibited in populations of the new Keasey species. A form of *P. columbiana* having a relatively broad straplike peripheral keel is similar to one of the forms of the Lincoln Creek species, *P. thurstonensis*, although the band is even broader in the latter. *P. thurstonensis* is distinguished by its larger adult size and more robust form, tending toward more simplified sculpture patterns.

Ptychosyrinx thurstonensis (Weaver, 1916)

Pl. 7, figs. 15, 16;
Text-figure 17d

Turris thurstonensis Weaver, 1916, Univ. Washington Pubs. Geol., vol. 1, No. 1, p. 54, pl. 5, figs. 79, 80.

- Turris worcesteri* Van Winkle, 1918, Univ. Washington Pubs. Geol., vol. 1, No. 2, p. 91, pl. 7, fig. 21.
- Antiplanes thurstonensis* (Weaver), Tegland, 1933, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 23, No. 3, p. 125, pl. 10, fig. 4.
- Suavodrillia thurstonensis* (Weaver), Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, p. 519, pl. 97, fig. 7; Durham, 1944, Univ. California Pub., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 183 (hypotype UCMP 5449).
- Turricula worcesteri* (Van Winkle), Weaver, 1943, Univ. Washington Pubs. Geol., vol. 5, pt. 2, pp. 533-534, pl. 98, figs. 19, 20, 23, 24.
- Suavodrillia worcesteri* (Van Winkle), Durham, 1944, Univ. California Pubs., Bull. Dept. Geol. Sci., vol. 27, No. 5, p. 183 (hypotype UCMP 35450).

Discussion.—This species is distinguished by larger adult size (20 mm high) than other Paleogene species. The periphery is marked by a relatively broad unornamented band in most specimens, but the width of the band, its position relative to the suture, and the number and strength of spiral elements anterior to the periphery are all variable. Some specimens examined show development of nodes on the peripheral carina, particularly on early whorls.

Material examined.—Eighty-nine specimens.

Stratigraphic distribution.—The Lincoln Creek species, *P. thurstonensis*, occurs higher than *P. facula* of the Keasey Formation and appears to be restricted to the *Turritella porterensis* and *Echino-phoria rex* megafaunal zones (Text-figure 6).

Hypotypes.—USNM 216455, 216456.

Localities.—UW 256 (type locality), 352, 574-D; USGS 18950, 18951, M1731; UCMP A9, A1610; CAS 611, 189; SU NP 51, NP 56, NP 50, NP 211, NP 298 (Lincoln Creek Formation).

***Ptychosyrinx hertleini* (Durham, 1944)**

Pl. 7, fig. 11

Suavodrillia hertleini Durham, 1944, Univ. California Pub., Bull. Dept. Geol. Sci., vol. 27, No. 5, pp. 182-183, pl. 14, fig. 1; Powell, 1966, Auckland Inst. Mus., Bull. 5, p. 82.

Discussion.—Although Durham described the apex of the anal sinus as “situated on the shoulder”, the term “shoulder” refers to the periphery rather than to the shoulder slope. It is a typical small *Ptychosyrinx*, distinguished from older Paleogene species by its flat-sided body whorl profile and periphery situated relatively far posterior on the whorl. Numerous fine spiral threads of several ranks are developed in the region between the periphery and the basal constriction. The periphery is faintly noded, and the nodes are more numerous (24 per whorl) as well as more poorly defined than on

P. facula. The subsutural cord characteristic of the genus is particularly well developed in this species.

Material examined. — Three specimens.

Stratigraphic distribution. — This is the youngest and most poorly known of the Oligocene *Ptychosyrinx* species, occurring within the *Echinophoria rex* megafaunal zone of Durham (1944) in outcrops of the Blakeley Formation in Seattle, Washington. The stratigraphic range of the species may overlap with that of *P. thurstonensis*, which occurs in the *E. rex* zone in the type Blakeley Formation. Specimens are not common at these localities, and additional material is necessary to define fully the stratigraphic and morphologic distinctions between *P. thurstonensis* and *P. hertleini*.

Holotype. — UCMP 35447.

Type locality. — Blakeley Formation: UCMP A1803.

Genus **PLEUROLIRIA** de Gregorio, 1890

Type species (by original designation): *Pleurotoma (Pleuroliria) supramirifica* de Gregorio, 1890. Eocene, Gulf Coast of United States.

The generic names *Polystira* Woodring, 1928, *Pleuroliria* de Gregorio, 1890, and *Lophiotoma* Casey, 1904, as well as a number of subgeneric names, can be applied with certainty only to their type species within a large polyphyletic group of fossil and living fusiform turrine species sculptured with spiral cords and keels and having a siphonal notch located on the periphery. *Pleuroliria* has generally been applied to small Eocene and Oligocene species with weak sculpture and a multispiral protoconch and *Polystira* to large, more strongly sculptured Miocene-Holocene species with paucispiral protoconchs. Many species, however, do not fit either branch of the above dichotomy.

Lack of pronounced discontinuity in any one shell character and lack of correlation of variation patterns among shell characters in these forms makes it difficult to establish meaningful taxa at the generic and subgeneric levels. It is apparent that no satisfactory classification can be derived for this group of turrids using shell characters alone, and it is highly possible that anatomical or immunological studies of living species in the group will sort out forms that would not have been placed together on the basis of shell characters.

Pleuroliria s. l. is employed herein as a form genus, with its concept expanded to include a group of bicarinate species with a strong peripheral carination and strong single or double basal carination and a deep (less than 90°) but not slotlike peripherally located anal sinus. Glibert (1955) proposed *Oxytropa* for European Oligocene species with a pronounced constriction of the anterior canal and bicarinate body whorl profile. He unfortunately designated as type the Holocene tropical Eastern Pacific *Pleurotoma oxytropis* Sowerby, 1834, which fits more readily into *Polystira*. *Oxytropa* was placed, justifiably, in synonymy by Powell (1964, 1966).

Pleuroliria oregonensis Hickman, n. sp.

Pl. 7, figs 17-20;
Text-figure 15e

Description.— Shell relatively small (less than 30 mm tall), fusiform; protoconch missing on all specimens examined; spire consisting of about four postnuclear whorls, with a broad and gently concave unornamented shoulder slope and prominent carination immediately posterior to the suture of the following whorl; body whorl bicarinate, with a strong peripheral carination and somewhat weaker anterior carination setting off the constricted slender anterior canal; a third weak spiral cord usually present between carinations of body whorl; outer lip lacking ridges on inner surface; parietal lip with thin inductura; anal sinus narrow (less than 90°) but not slotlike, leaving an asymmetrical trace on spire whorls.

Dimensions of holotype.— Height 27.7 mm; maximum diameter 10 mm.

Material examined.— Twelve specimens.

Variation.— Detailed diagnosis of *Pleuroliria oregonensis* is limited by poor preservation. All specimens are worn, some exhibiting highly polished surfaces. Although major spiral sculpture is preserved, it is possible that fine sculpture of low relief has been removed. Two specimens, including the holotype, have suggestions of faint nodes on the peripheral keel of earlier whorls. The peripheral keel is particularly strongly developed on one specimen from USGS 15268.

Stratigraphic distribution.— *Pleuroliria oregonensis* is restricted to a stratigraphic sequence approximately 60 m thick at the top of the middle member of the Keasey Formation (Text-figure 5). The species has been collected at six horizons within this interval.

Holotype. — USNM 216457. *Figured paratypes*. — USNM 216458, 216459. *Unfigured paratypes*. — USNM 216460 (height 20.1 mm), 216461 (height 19.8 mm), 216462 (height 14.8 mm), 216463 (height 11.8 mm).

Type locality. — Middle member, Keasey Formation: USGS 15267.

Other localities. — Middle member, Keasey Formation: USGS 15268, 15508, 15517, 25031, 25038.

Comparative notes. — *Polystira englishi* Addicott, 1970a, of the California middle Miocene is the only other Pacific Coast Tertiary species in the *Pleuroliria-Polystira* complex. It is more closely allied morphologically to the Holocene shallow-water tropical Eastern Pacific species *Polystira oxytropis* and *P. picta* (Reeve, 1843).

Specimens of *Polystira kurodae* (Makiyama, 1927) figured by Shuto (1961, pl. 8, figs. 2, 3, 4) from the early Pliocene of Japan are strikingly similar to the new Keasey species. The Japanese species occurs in a fauna that contains a high proportion of turrids and a structural composition (Hickman, 1974b) that suggests depths similar to those represented in the Keasey Formation. Another species that is similar to the Keasey species is the European Oligocene (Rupelian Stage) form described by Glibert (1955) as *Turris (Oxytropia) pseudovolgeri*. The relationships of these species may be clarified by direct comparison of better preserved material than is currently available, although the geographic and temporal discontinuities involved raise the possibility of parallel development from separate ancestral turrid stocks.

CONCLUSIONS

Investigations of deep-water turrid gastropods from the early Oligocene Keasey Formation in northwestern Oregon and their congeners in the Paleogene deep-water facies of the northeastern Pacific provide data in the areas of systematics, evolution, paleoecology, biogeography, and biostratigraphy. Some of the most important general conclusions follow.

(1) Turrid gastropod species comprise the same high proportion of the neogastropod fauna in the Keasey Formation and Lincoln Creek Formation that they do in modern bathyal faunas, with

a predominance of species in the subfamilies Turriculinae and Turrinae. The component of borsoniine and daphnelline species in modern cool to cold bathyal faunas is the result of late Cenozoic adaptive radiation of toxoglossate groups into deep water.

(2) Turrid species occur at high relative frequency and density within the total mollusk fauna in the Paleogene deep-water facies, although material is sparsely distributed and requires intensive collecting. This characteristic facilitates establishment of population based species concepts and makes the group particularly well suited for use in biostratigraphy.

(3) Large (greater than 50 individuals) species populations analyzed are as variable morphologically as turrid species occurring in shallow water, suggesting that the bathyal environment in which they lived was not so stable or homogeneous as is often assumed.

(4) Shell of deep-water Paleogene species are large for the family (in many cases greater than 30 mm high) and are often thin and delicate, with a preponderance of forms having prominent keeled, noded or spinose peripheral demarcations set off by markedly constricted basal profiles. Glossy shell texture is common as are highly ornate fine tessellate and nodulose ornamentation patterns. Signs of predation are common, both bore holes of naticid gastropods and subsequently repaired shell breakage, suggesting a higher degree of trophic complexity than is often assumed for environments below 200 m.

(5) There is no character or set of characters that can be employed universally at a given taxonomic level within the Turridae. Although radular morphology and details of soft anatomy, particularly within the alimentary system, are prerequisite to definition of natural groupings at the subfamily level; shell characters, when carefully defined, are eminently utilizable at the generic and specific levels, producing taxa whose affinities are supported in complex inferred evolutionary and biogeographic patterns that are too highly ordered to be coincidental.

(6) Use of new quantitative and qualitative anal sinus characters provides the most rigorous means of delineating turrid genera and subgenera.

(7) Documentation of morphological trends in species of *Turricula*, *Parasyrinx*, *Turrinosyrinx*, and *Ptychosyrinx* through the pro-

vincial Oligocene sequence provides new biostratigraphic markers for the deep-water facies. Potential for detailed refinement of Paleogene biostratigraphy based on turrids is demonstrated for the Keasey Formation, where four district assemblages of turrids occur in a 700 m sequence. The ranges of species within the sequence are based on occurrences at numerous stratigraphic horizons.

(8) *Procerapex bentsonae* (Durham) and *Acamptogenotia tessellata* Hickman, n. sp., are useful in interprovincial correlation of the California and Pacific Northwest early Oligocene deep-water facies.

(9) Although the Paleogene deep-water facies of the north-eastern Pacific contains indigenous (now extinct) genera, there are striking paleozoogeographic ties with the Japanese and Australo-Neozelandic fauna during the Oligocene and even broader ties with the European and Gulf Coast-Caribbean faunas during the Eocene. Five genera (*Comitas*, *Acamptogenotia*, *Parasyrinx*, *Ptychosyrinx*, and *Pleuroliria*) are recognized for the first time in the Paleogene of the northeastern Pacific. The *Acamptogenotia* group of genera provides a striking example of a Cenozoic complex comprising both widespread taxa and endemic offshoots resulting from unique evolutionary experimentation in widely separated provincial contexts.

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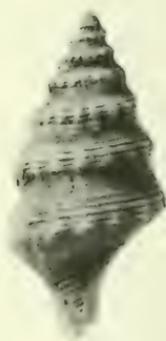
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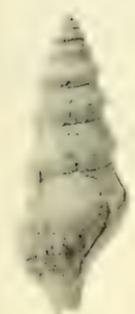
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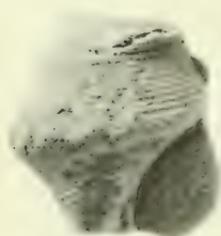
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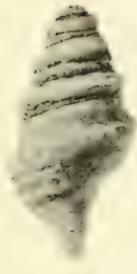
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No. 293

A LEWIS G. WEEKS PUBLICATION

TWO FORAMINIFERAL ASSEMBLAGES FROM THE
DUPLIN MARL IN GEORGIA AND SOUTH CAROLINA

By

S. M. HERRICK

1976

Paleontological Research Institution
Ithaca, New York 14850, U.S.A.

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U.S.A.

BULLETINS
OF
AMERICAN
PALEONTOLOGY

(Founded 1895)

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Paleontological Research Institution
Ithaca, New York 14850, U.S.A.

Library of Congress Card Number 76-23285

Printed in the United States of America
Arnold Printing Corporation

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TWO FORAMINIFERAL ASSEMBLAGES FROM THE DUPLIN MARL IN GEORGIA AND SOUTH CAROLINA¹

S. M. HERRICK²

ABSTRACT

Foraminifera from the Duplin Marl exposed near Doctortown, Georgia, on the Altamaha River and from three wells, two in coastal Chatham County, Georgia, and one at the north end of Hilton Head Island, South Carolina, are of Pliocene age. The fauna from Doctortown is early middle Pliocene in age; that from the three wells is early Pliocene in age based on the occurrence of *Globigerina nepenthes* Todd and *Globorotalia menardii* (d'Orbigny) (right coiling). The fauna identified from Doctortown has 83 species in 46 genera; the fauna identified from the wells has 64 species in 39 genera. The faunas have predominantly the same species, but the few significant differences in planktonic species suggest the difference in age mentioned above. Paleoecologic conditions suggest a shallow, warm, shelf sea similar to that now found off the east coast of Florida.

INTRODUCTION

In June 1962, the writer collected fossiliferous material from an exposure of Duplin Marl situated on the right bank of the Altamaha River, 60 feet downstream from the bridge of the Seaboard Coast Line Railroad near Doctortown, Wayne County, Georgia. This is 4.5 miles northeast of Jesup, on the east side of U.S. Highway 82, and at railroad milepost 59.4 (Text—fig. 1). From this exposure, an excellent fauna of smaller Foraminifera of 83 species and 46 genera was obtained. During this investigation, a similar but significantly different assemblage of smaller Foraminifera made up of 64 species assigned to 39 genera was recovered from three wells situated in coastal Georgia and South Carolina (Text—fig. 1). Except for *Cibicides sapeloensis* Darby and Hoyt, these two foraminiferal assemblages have not been previously reported from Georgia or South Carolina.

ACKNOWLEDGMENTS

The writer wishes to thank the Georgia Geological Survey¹ for defraying the major part of the expense connected with the illustra-

1. Publication authorized by Director, U.S. Geological Survey.

2. Geologist, retired, U.S. Geological Survey, Atlanta, Ga.

tions and P. F. Huddlestun² for reviewing identifications of the globigerinids. Ruth Todd³ kindly checked the status of *Bulimina gracilis* Cushman (*B. gracilis* = *B. elongata* d'Orbigny). The writer is especially indebted to T. G. Gibson⁴ for a microfossiliferous sample of Duplin Marl from an exposure situated 1 mile west of Natural Well, Duplin County, North Carolina, and for reviewing this report. Illustrations of the fossil specimens were by Mrs. Paul J. Drake, Atlanta, Georgia. Text figures 1 and 2 were drafted by W. G. Hester, cartographer, U. S. Geological Survey, Atlanta, Georgia. Photo (Figure 83), courtesy of S. M. Pickering.

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LITHOLOGY OF THE DUPLIN MARL

The lithology of the Duplin Marl at the Doctortown locality is shown below in a section taken from Cooke (1943, pp. 99-100). The Foraminifera from this locality were derived from Unit 2.

Wicomico? Formation (Pleistocene)	Feet
6. Yellow and mottled argillaceous sand.....	10
5. White and yellow cross-bedded sand containing thin layers of small quartz pebbles.....	10
Duplin Marl (Miocene)	
4. Red and yellow stratified sand, probably leached marl, containing thin clay laminae.....	10
3. Calcareous fossiliferous sand or marly friable marl.....	1
2. Bluish sand containing <i>Pecten eborius</i> , <i>Mactra congesta</i>	4
Hawthorn Formation (Miocene)	
1. Coarse bluish or greenish compact clayey sand. To water's edge.....	7

The lithology of the Duplin Marl as observed in the three wells (Text—fig. 2) consisted of brownish-gray, silty, phosphatic, sandy marl. The depths from which the subsurface assemblage was derived are shown in Table 1. As noted in the above section, the thickness of the Duplin Marl at Doctortown is 15 feet. The approximate thickness of this formation in Bft. 315 amounted to 25 feet,



Text-figure 1.—Index map of fossil locality and wells.

the corresponding thicknesses in GGS 772 and GGS 381 amounting to 30 feet and 28 feet, respectively. From these thicknesses, it is evident that there has been some coastward thickening of the Duplin Marl.

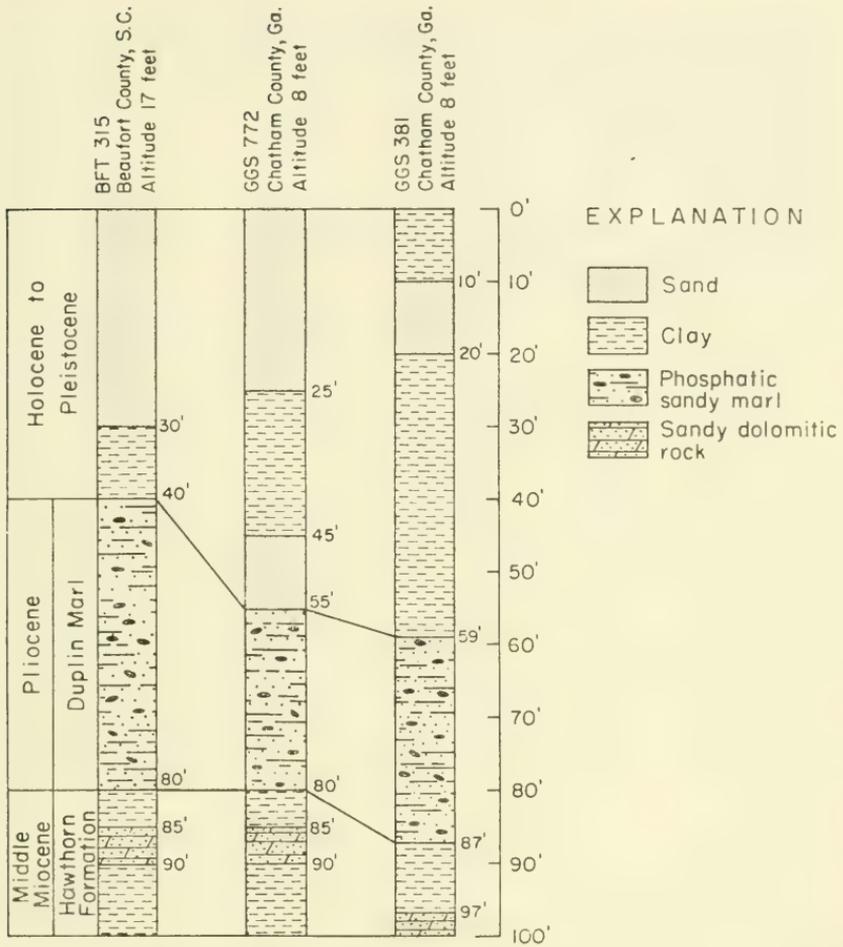
FAUNAL COMPOSITION

In relative abundance, both faunas are dominated by benthonic species, most of which have reported ranges upward into Holocene. The benthonic fauna at Doctortown consisted of 77 species and 46 genera of which 20 species were common to abundant. The benthonic fauna of the subsurface assemblage was composed of 56 species and 29 genera, 13 of which were common to abundant. Seven species were common to abundant in both assemblages. Of the latter, *Elphidium clavatum*, *Cibicides duplinensis*, *C. lobatulus* "var.," and *Hanzawaia concentrica* were dominant in both faunas. The Foraminifera identified from the Duplin Marl at Doctortown and from the three wells are listed in Table 1 and are described in the "systematic catalog" which follows.

In general, the planktonics of both assemblages were the same, but were relatively more abundant in the subsurface assemblage: six species belonging to four genera were identified in the Doctortown fauna, while nine species assigned to five genera were recovered from wells. *Globorotalia acostaensis* and *Globigerinoides obliquus* occurred commonly in both faunas. The majority of the planktonic species included in this report have reported ranges extending into the Holocene, the exceptions including *Globigerinoides obliquus*, which ranges into the early Pleistocene, *Globorotalia acostaensis* and *Sphaeroidinellopsis subdehiscens* with ranges extending into the late Pliocene, and *Globigerina nepenthes* becoming extinct at the close of early Pliocene time, according to published reports.

CORRELATION

Looking at the two assemblages as a whole, two previously described faunas show affinities with them, but particularly with the assemblage from the Doctortown locality. One such fauna was described by Copeland (1964) from the Duplin Marl at Natural Well, Duplin County, North Carolina, the other described by Cushman (1930) and Akers (1972) from the Duplin Marl (*Cancellaria* zone) at Jackson Bluff, Leon County, Florida. On the basis of



Text-figure 2. — Logs of three wells penetrating Duplin Marl in Georgia and South Carolina.

planktonic species and Akers' report the Doctortown fauna is regarded as early middle Pliocene in age. According to P. F. Huddleston (oral communication, June 1973) species indicative of such an age-determination include *Sphaeroidinellopsis subdehiscens* and the commonly occurring species *Globigerinoides rubra*. Owing to the fact that *Globigerina nepenthes* was not found in the Doctortown fauna but was well represented in the subsurface fauna, the subsurface assemblage is older, *i.e.* earliest Pliocene in age.

PALEOECOLOGY

Because the specimens composing the subsurface assemblage were derived from well cuttings (not cores), specific counts for comparative purposes, particularly of the planktonics, were not practicable. Except for the benthonic species, meaningful conclusions as to depths represented by the two assemblages were not possible. About the most that may be said, therefore, is that both faunas represent a shallow, warm, shelf sea similar to that now found off the east coast of Florida. One might also add that generic composition — nonionids and cassidulinids together with much more abundant planktonic specimens in the subsurface assemblage — suggests a more open, somewhat deeper shelf sea in coastal Georgia and South Carolina as compared with that at the Doctortown locality.

DISCUSSION OF SPECIES

No attempt is made in this report to describe individual species, as adequate descriptions already exist in the literature. Likewise, inclusion of extended synonymies is purposely avoided. In most instances, only the original reference with occasional references to species, specimens of which are contained in the writer's personal collection, are included.

The letters GGS and Bft (Text — fig. 1) represent an abbreviation of Georgia Geological Survey and an abbreviation of Beaufort, a county in South Carolina. The letters denoting relative abundance of individual species (Table 1) are arbitrary figures. Thus R (rare) denotes 1-3 specimens observed; F (frequent), 4-10 specimens; C (common), 11-20 specimens; A (abundant), over 20 specimens.

Table 1. — Frequency chart of two foraminiferal assemblages from the Duplin Marl of Georgia and South Carolina
 A, abundant; C, common; F, frequent; R, rare

Foraminifera	Surface	Subsurface		
	Doctor-	GGs,	GGs,	Bft.
	town	772	381	315
	Outerop	60-	59-	55-
	Sample	65'	79'	60'
	Wayne	Chatham		Beaufort
	County, Ga.	County, Ga.		County, S.C.
<i>Textularia articulata</i> d'Orbigny	R			
<i>T. candeiana</i> d'Orbigny	R			
<i>T. gramen</i> d'Orbigny	F			F
<i>T. mayori</i> Cushman	F			
<i>Nodosaria catesbyi</i> d'Orbigny	R		R	
<i>Lagena clavata</i> (d'Orbigny)				R
<i>L. costata amphora</i> Reuss	R			
<i>L. laevis</i> (Montagu)		R		R
<i>L. semistriata</i> Williamson	R	R		
<i>L. substriata</i> Williamson				F
<i>L. sulcata</i> (Walker and Jacob)		R		R
<i>L. tenuis</i> (Bornemann)		R		
<i>Lenticulina americana</i> (Cushman)	R	F	R	R
<i>L. mayi</i> Cushman and Parker	R			
<i>Globulina caribaea</i> d'Orbigny	R			
<i>G. gibba</i> d'Orbigny	F			
<i>G. inaequalis</i> Reuss	F	R		R
<i>Guttulina austriaca</i> d'Orbigny	R	R		C
<i>G. caudata</i> d'Orbigny	R			
<i>G. pseudocostatula</i> McLean	A			
<i>Pseudopolymorphina rutila</i> (Cushman)	R			
<i>P. sp.</i>			R	
<i>Sigmomorphina pearceyi</i> Cushman and Ozawa	R			
<i>S. terquemiana</i> (Fornasini)	C	R	R	R
<i>S. undulosa</i> (Terquem)	R			
<i>Laryngosigma williamsoni</i> (Terquem)	R			
<i>Oolina hexagona scalariformis</i> (Williamson)	C	R	R	F
<i>Fissurina orbignyana lacunata</i> (Burrows and Holland)	R			
<i>F. lucida</i> (Williamson)	R			
<i>F. marginatoperforata</i> (Seguenza)	R			
<i>Parafissurina marginata</i> (Walker and Jacob)	R			
<i>Nonion grateloupi</i> (d'Orbigny)	R	F		R
<i>N. pizarrense</i> W. Berry		C	A	A
<i>Nonionella atlantica</i> Cushman	F	F	R	
<i>Astrononion glabrellum</i> (Cushman)	R			
<i>Elphidium advena</i> (Cushman)	C			
<i>E. clavatum</i> Cushman	A	A	R	F
<i>E. gunteri</i> Cole	R	R		F
<i>E. incertum</i> (Williamson)	C	F		
<i>E. poeyanum</i> (d'Orbigny)	A	F		R
<i>E. varium</i> Buzas	C			

<i>Plectofrondicularia</i> cf. <i>P. longistriata</i>				
Le Roy	R			
<i>Nodogenerina advena</i> Cushman and Laiming	R			
<i>Buliminella curta</i> Cushman	F	F	R	F
<i>B. elegantissima</i> (d'Orbigny)	A	R		R
<i>Robertina</i> cf. <i>subteres</i> (H. B. Brady)	R			
<i>Bulinina elongata</i> d'Orbigny	F	A	C	A
<i>B. marginata</i> d'Orbigny		R		
<i>Virgulina fusiformis</i> Cushman		R	R	
<i>V. punctata</i> d'Orbigny	R	R		R
<i>Bolivina advena</i> Cushman	F	R		R
<i>B. marginata</i> Cushman	F			
<i>B. marginata multicostata</i> Cushman	F			
<i>B. paula</i> Cushman and Cahill	F	R	R	
<i>B. plicatella</i> Cushman	C	R		R
<i>B. cf. suteri</i> Cushman and Renz	R			
<i>B. sp.</i>		R	R	
<i>Reussella spinulosa</i> (Reuss)	C	R		A
<i>Uvigerina auberiana</i> d'Orbigny	R	R	R	R
<i>U. canariensis</i> d'Orbigny	R			
<i>U. subperegrina</i> Cushman and Kleinpell	F	R	R	R
<i>Angulogerina occidentalis</i> (Cushman)	A	C	F	A
<i>Trifarina bradyi</i> Cushman		R		R
<i>Discorbis valvulatus</i> (d'Orbigny)		R		
<i>D. vilardeboanus</i> (d'Orbigny)		R		
<i>Buccella mansfieldi</i> (Cushman)	A	A	R	A
<i>Conorbina orbicularis</i> (Terquem)	C			
<i>Rosalina floridana</i> (Cushman)	C			
<i>R. subaraucana</i> (Cushman)	A		R	R
<i>R. turrita</i> (Cushman)	C	C		F
<i>Valvulineria</i> sp.	R	R	C	F
<i>Gyroidina orbicularis</i> d'Orbigny	R			
<i>Eponides antillarum</i> (d'Orbigny)	R			
<i>E. cf. E. regularis</i> Phleger and Parker		R		
<i>Poroeponides lateralis</i> (Terquem)	R			
<i>Ammonia beccarii</i> (Linné)	R	C	R	R
<i>Cancris sagra</i> (d'Orbigny)	R	R		R
<i>C. sagra communis</i> Cushman and Todd	R			
<i>Amphistegina lessonii</i> d'Orbigny	C			
<i>Cymbaloporetta squamosa</i> (d'Orbigny)	R			R
<i>Cassidulina crassa</i> d'Orbigny	F	C	R	R
<i>C. laevigata</i> d'Orbigny		C	C	F
<i>C. laevigata carinata</i> Cushman	R			
<i>C. subglobosa</i> Brady	R			
<i>Cassidulinoides bradyi</i> (Norman)		R		
<i>Globigerina bulloides</i> d'Orbigny	C	R	F	F
<i>G. nepenthes</i> Todd		R	R	R
<i>Globigerinoides obliquus</i> Bolli and Bermudez				
<i>G. quadrilobatus</i> (d'Orbigny)	C	A	F	A
<i>G. rubra</i> (d'Orbigny)	F	A	C	A
	C	R		R

<i>Orbulina universa</i> d'Orbigny				R
<i>Sphaeroidinellopsis subdehiscens</i> Blow	R	R	R	
<i>Globorotalia acostaensis</i> Blow	C	F	C	A
<i>G. menardii</i> (d'Orbigny)	R ¹	R		R
<i>Planulina depressa</i> (d'Orbigny)	R	C	C	C
<i>Cibicides americanus</i> (Cushman)	R			R
<i>C. duplinensis</i> Copeland	A	R	A	C
<i>C. lobatulus</i> (Walker and Jacob)	A	A	A	A
<i>C. lobatulus</i> (Walker and Jacob)				
var.	A		F	C
<i>C. sapeloensis</i> Darby and Hoyt	F	R		
<i>Hanzawaia concentrica</i> (Cushman)	A	A	A	A
<i>Planorbulina mediterranensis</i> d'Orbigny		R		

¹Reported by P. F. Huddlestun. Oral communication, June, 1973.

SYSTEMATIC CATALOG

Family **TEXTULARIIDAE** d'Orbigny, 1846

Genus **TEXTULARIA** Defrance, 1824

Textularia articulata d'Orbigny

Textularia articulata d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 250, pl. 15, figs. 16-18.

Two specimens from the Doctortown fauna are tentatively placed here. Both specimens have an acute periphery with a suggestion of a peripheral keel, the latter apparently diagnostic of this species.

Textularia candeiana d'Orbigny

Pl. 8, figs. 1 a-b

Textularia candeiana d'Orbigny, 1839, Foraminifères in de la Sagra, Histoire physique, politique et naturelle de l'île de Cuba, p. 143, pl. 1, figs. 25-27.

The pointed initial end, rounded periphery, and much inflated final pair of chambers characterize this species which occurred rarely but typically in the Doctortown fauna.

Textularia gramen d'Orbigny

Pl. 8, fig. 2

Textularia gramen d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 248, pl. 15, figs. 4-6; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 17, pl. 1, figs. 5a-b.

The compressed test with strongly divergent sides and subacute periphery differentiate this species from *T. mayori* with which it might be confused.

Textularia mayori Cushman

Pl. 8, fig. 3

Textularia mayori Cushman, 1922, Carnegie Inst. Washington Publ. 311, p. 21, pl. 2, fig. 1; 1930, Florida Geol. Sur., Bull. 4, p. 17, pl. 1, figs. 6-8.

The generally spinose peripheral projections, particularly of the adult chambers, differentiate this species from most others.

Family **NODOSARIIDAE** Schultze, 1854Genus **NODOSARIA** Lamarck, 1812**Nodosaria catesbyi** d'Orbigny

Nodosaria catesbyi d'Orbigny, 1839, Foraminifères *in* de la Sagra, Histoire physique, politique et naturelle de l'Ile de Cuba, p. 16, pl. 11, figs. 8-10; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 28, pl. 5, fig. 4.

Genus **LAGENA** Walker and Jacob, 1798**Lagena clavata** (d'Orbigny)

Oolina clavata d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 24, pl. 1, fig. 2.

Lagena clavata (d'Orbigny), Mackie, 1859, Recreative Sci., vol. 1, p. 148, fi. 13; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 29, pl. 5, figs. 6a-b.

Lagena costata amphora Reuss

Pl. 8, fig. 6

Lagena amphora Reuss, 1862(1863), Akad. Wiss. Wien, Sitzungsber., vol. 46, pt. 1, p. 330, pl. 4, fig. 57.

Lagena costata (Williamson) var. *amphora* Reuss, Cushman, 1930, Florida Geol. Surv., Bull. 4, p. 31, pl. 5, fig. 8.

Its pyriform shape and few but continuous costae characterize this species.

Lagena laevis (Montagu)

Pl. 8, fig. 7

"*Serpula (Lagena) laevis ovalis*" Boys and Walker, 1784, Testacea minuta rariora, p. 3, pl. 1, fig. 9.

Lagena laevis (Montagu), Williamson, 1848, Ann. Mag. Nat. Hist., 3d ser., vol. 1, p. 12, pl. 1, figs. 1, 2.

The subpyriform shape, smooth exterior, and long neck characterize this species.

Lagena semistriata Williamson

Pl. 8, fig. 8

Lagena striata (d'Orbigny) var. *semistriata* Williamson, 1848, Ann. Mag. Nat. Hist., 2d ser., vol. 1, p. 14, pl. 1, figs. 9, 10.

Lagena semistriata Williamson, Jones, Parker, and H. B. Brady, 1866, Foraminifera of the Crag, p. 34, pl. 4, fig. 6.

This species is characterized by its pyriform shape, long cylindrical neck, bulbous base, and few costae which are limited on the basal part of the test.

Lagena substriata Williamson

Pl. 8, fig. 9

Lagena substriata Williamson, 1848, Ann. Mag. Nat. Hist., 2d ser., vol. 1, p. 15, pl. 1, fig. 12; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 31, pl. 5, fig. 14.

The subspherical shape and numerous fine costae define this species.

Lagena sulcata Jacob

Pl. 8, fig. 10

"*Serpula (Lagena) striata sulcata rotundata*" Boys and Walker, 1784, *Testacea minuta rariora*, p. 2, pl. 1, fig. 6.

Serpula Lagena sulcata Jacob, 1798, in Adams Essays on the microscope, p. 634, pl. 14, fig. 5.

Lagena sulcata Jacob, H. B. Brady, 1884, Challenger Rept., vol. 9, p. 462, pl. 57, figs. 23, 26, 33, 34; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 31, pl. 5, fig. 10.

The globular initial chamber with numerous coarse costae identify this species. One specimen was recovered from a well.

Lagena tenuis (Bornemann)

Pl. 8, fig. 11

Ovulina tenuis Bornemann, 1855(1856), Deutsch. Geol. Gesell., Zeitschr., vol. 7, p. 13, pl. 1, figs. 3a-b.

Lagena tenuis (Bornemann), Reuss, 1865, Acad. Roy. Belgique, Bull., Cl. Sci., 2d ser., vol. 15, p. 141, pl. 1, figs. 7-9.

Its pyriform shape and few costae, which are confined to the base of the test, identify this species. A single specimen was recovered from a well.

Genus **LENTICULINA** Lamareck, 1804**Lenticulina americana** (Cushman)

Pl. 8, fig. 5

Cristellaria americana Cushman, 1918, U.S. Geol. Sur., Bull. 676, p. 50, pl. 10, figs. 5, 6.

Robulus americanus (Cushman), Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 24, pl. 3, figs. 7a-b.

This species was originally described from the Duplin Marl of South Carolina.

Lenticulina mayi (Cushman and Parker)

Pl. 8, fig. 4

Robulus mayi Cushman and Parker, 1931, Cushman Lab. Foraminifera Research Contr., vol. 7, pt. 1, p. 2, pl. 1, figs. 3-5.

This species was originally described from the Miocene of California. Occasional specimens resembling this species were found in the Doctortown fauna. There is a possibility that these specimens may represent young, immature forms of *L. americana*.

Family **POLYMORPHINIDAE** d'Orbigny, 1839Genus **GLOBULINA** d'Orbigny, 1826**Globulina caribaea** d'Orbigny

Pl. 9, fig. 22

Globulina caribaea d'Orbigny, 1839, Foraminifères in de la Sagra, Histoire physique, politique et naturelle de l'île de Cuba, p. 130, pl. 2, figs. 7, 8.

Rare specimens with spinose surfaces occurred in the Doctortown fauna.

Globulina gibba d'Orbigny

Globulina gibbs d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 266, No. 19, Modèles, No. 63; 1846, Foraminifères in de la Sagra, Histoire physique, politique et naturelle de l'île de Cuba, p. 227, pl. 13, figs. 13, 14; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 34, pl. 5, fig. 21.

This species occurred frequently in the Doctortown fauna.

Globulina inaequalis Reuss

Globulina inaequalis Reuss, 1850, Akad. Wiss. Wien., Denkschr., vol. 1, p. 377, pl. 48, fig. 9; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 35, pl. 5, fig. 22.

This species occurred frequently in the Doctortown but rarely in two wells (Table 1).

Genus **GUTTULINA** d'Orbigny, 1839**Guttulina austriaca** d'Orbigny

Pl. 9, figs. 17, 19

Guttulina austriaca d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 223, pl. 12, figs. 23-25.

Guttulina caudata d'Orbigny

Pl. 9, fig. 18

Guttulina caudata d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 266, No. 16.

The figured specimen lacks the initial spine but otherwise seem to fit this species.

Guttulina pseudocostatula McLean

Pl. 9, figs. 20, 21

Guttulina costatula Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 33, pl. 5, fig. 15.

Guttulina pseudocostatula McLean, 1956, Bull. Amer. Paleont., vol. 36, No. 160, p. 334, pl. 40, figs. 8, 10-16.

The abundant Doctortown specimens lack the initial spine but otherwise are identical with McLean's figures and description and with those collected by the writer from Jackson Bluff, Leon County, Florida.

Genus **PSEUDOPOLYMORPHINA** Cushman and Ozawa, 1928**Pseudopolymorphina rutila** (Cushman)

Pl. 9, fig. 24

Polymorphina regina H. B. Brady, Parker, and Jones var. *rutila* Cushman, 1923, U.S. Geol. Sur., Prof. Paper 133, p. 34, pl. 5, figs. 7, 8.

Pseudopolymorphina rutila (Cushman), Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., vol. 77, art. 6, p. 100, pl. 26, figs. 3a-b; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 36, pl. 5, fig. 20.

This is one of the most distinctive species in the Doctortown fauna in which it occurred rarely.

Pseudopolymorphina sp.

Pl. 9, fig. 23

The figured specimen was recovered from a well. It resembles

P. rutila but lacks external costae as well as an initial spine; it is recorded for future reference.

Genus **SIGMOMORPHINA** Cushman and Ozawa, 1928

Sigmomorphina pearceyi Cushman and Ozawa

Sigmomorphina pearceyi Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., vol. 77, art. 6, p. 132, pl. 35, figs. 2, 3.

One specimen, which apparently belongs here, was found in the Doctortown fauna.

Sigmomorphina terquemiana (Fornasini)

Pl. 9, fig. 25

Polymorphina amygdaloides Reuss var. *terquemiana* Fornasini, 1900, Soc. Geol. Ital., Boll., vol. 19, p. 136.

Sigmomorphina semitecta (Reuss) var. *terquemiana* (Fornasini), Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., vol. 77, art. 6, p. 129, pl. 33, figs. 4, 5; pl. 34, figs. 2, 3; pl. 35, fig. 1.

This species occurred commonly in the Doctortown fauna but rarely in the fauna recovered from wells. (See Table 1.)

Sigmomorphina undulosa (Terquem)

Polymorphina undulosa Terquem, 1878, Soc. Géol. France, Mém., 3d ser., p. 41, pl. 3(8), figs. 352-c.

Sigmomorphina undulosa (Terquem), Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., vol. 77, art. 6, p. 131, pl. 34, figs. 4, 5.

One specimen from the Doctortown fauna is tentatively retained under this species.

Family **GLANDULINIDAE** Reuss, 1860

Genus **LARYNGOSIGMA** Loeblich and Tappan, 1953

Laryngosigma williamsoni (Terquem)

Pl. 9, fig. 26

Polymorphina williamsoni Terquem, 1878, Soc. Géol. France, Mém., ser. 3, t. 1, No. 3, p. 37.

Sigmomorphina williamsoni (Terquem), Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., vol. 77, art. 6, p. 138, pl. 38, figs. 3, 4.

Laryngosigma williamsoni (Terquem), Loeblich and Tappan, 1953, Smithsonian Misc. Coll., vol. 121, No. 7, p. 85.

Rare specimens belonging to this species were found in the Doctortown fauna.

Genus **OOLINA** d'Orbigny, 1839

Oolina hexagona scalariformis (Williamson)

Pl. 8, figs. 15, 16

Entosolenia squamosa (Montagu) var. *scalariformis* Williamson, 1858, On the Recent Foraminifera of Great Britain, p. 13, pl. 1, fig. 30.

Lagena hexagona (Williamson) var. *scalariformis* (Williamson), Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 30, pl. 5, figs. 7a-b.

Oolina hexagona scalariformis (Williamson) Puri, 1953, Florida Geol. Sur., Bull. 36, p. 117, pl. 21, figs. 4, 5.

The prominent surficial pits and longitudinal costae character-

ize this little species which occurred commonly in the Doctortown fauna and in samples from all three wells (Table 1).

Genus **FISSURINA** Reuss, 1850

Fissurina orbignyana lacunata (Burrows and Holland) Pl. 8, fig. 14

Lagena casrensis H. B. Brady (not Schwager), 1884, Challenger Rept., vol. 9, p. 485, pl. 60, figs. 1, 2.

Lagena lacunata Burrows and Holland, in Jones, 1895, On the Foraminifera of the Crag, p. 205, pl. 7, fig. 12.

Lagena orbignyana var. *lacunata* Burrows and Holland, Sidebottom, 1910, Manchester Lit. Philos. Soc., Mem., vol. 54, No. 16, p. 19, pl. 2, fig. 14; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 32, pl. 5, figs. 13a-b.

Fissurina orbignyana lacunata (Burrows and Holland), Puri, 1953, Florida Geol. Sur., Bull. 36, p. 115, pl. 26, figs. 2, 3.

The peripheral keels inside of which is a raised rim on either side of the test identify this species which occurred rarely in the Doctortown fauna.

Fissurina lucida (Williamson) Pl. 8, fig. 13

Entosolenia marginata (Montagu) var. *lucida* Williamson, 1848, Ann. Mag. Nat. Hist., 2d ser., vol. 1, p. 17, pl. 2, fig. 17.

Lagena lucida (Williamson), Reuss, 1862(1863), Akad. Wiss. Wien, Sitzungsber., vol. 46, pt. 1, p. 324, pl. 2, figs. 25, 26.

This small species occurred rarely in the Doctortown fauna.

Fissurina marginatorperforata (Seguenza) Pl. 8, fig. 12

Lagena marginatorperforata Seguenza, 1880, Accad. Naz. Lincei, Atti, Cl. Sci., ser. 3, vol. 6, p. 332, pl. 17, fig. 34; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 32, pl. 5, fig. 12.

The coarsely perforate test seems to be characteristic of this species. It is possible that this small species belongs under *Lagena* as noted in the above synonymy.

Genus **PARAFISSURINA** Parr, 1947

Parafissurina marginata (Montagu)

"*Serpula (Lagena) marginata*" Boys and Walker, 1784, Testacea minuta rariora, p. 3, pl. 1, fig. 7.

Vermiculum marginatum Montagu, 1803, Testacea Britannica. . . , vol. 2, p. 524.

Parafissurina marginata (Montagu), Puri, 1953, Florida Geol. Sur., Bull. 36, p. 127, pl. 26, fig. 9.

A single specimen from the Doctortown fauna is questionably referred to this species. No. 29915 PRI.

Family **NONIONIDAE** Schultze, 1854

Genus **NONION** Montfort, 1808

Nonion grateloupi (d'Orbigny) Pl. 9, figs. 27a-b

Nonionina grateloupi d'Orbigny, 1826, Ann. Sci. Nat. Paris, vol. 7, p. 294, No. 19.

Nonion grateloupi (d'Orbigny), Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 36, pl. 6, figs. 1-3.

This species occurred rarely but typically in the Doctortown fauna.

Nonion pizarrense W. Berry

Nonion pizarrensis W. Berry, 1928, Jour. Paleont., vol. 1, p. 269, text fig. 1 (1-3).

Nonion pizarrense W. Berry, Cushman and Cahill, 1933, U.S. Geol. Sur., Prof. Paper 175-A, p. 20, pl. 7, figs. 3a-b.

This species was not observed in the Doctortown fauna but occurred commonly to abundantly in all three wells (Table 1).

Genus **NONIONELLA** Cushman, 1926

Nonionella atlantica Cushman

Pl. 9, figs. 28a-c

Nonionella atlantica Cushman, 1947, Cushman Lab. Foram. Research Contr., vol. 23, pt. 4, p. 90, pl. 20, figs. 4, 5.

This small, delicate nonionellid occurred frequently in the Doctortown fauna and in two of the wells (Table 1).

Genus **ASTRONONION** Cushman and Edwards, 1937

Astrononion glabrellum (Cushman)

Pl. 10, fig. 29

Nonion glabrellum Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 38, pl. 6, figs. 6a-b.

Astrononion gabrellum (Cushman), Puri, 1953, Florida Geol. Sur., Bull. 36, p. 145, pl. 26, figs. 4, 5.

The stellate umbilical region differentiates this form from other nonionids.

Genus **ELPHIDIUM** Montfort, 1808

Elphidium advena (Cushman)

Pl. 10, figs. 30, 31a-b

Polystomella advena Cushman, 1922, Carnegie Inst. Washington, Pub. 311, p. 56, pl. 9, figs. 11, 12.

Elphidium advenum (Cushman), Cushman, 1930, U.S. Nat. Mus., Bull. 104, pt. 7, p. 25, pl. 10, figs. 1, 2; 1930, Florida Geol. Sur., Bull. 4, p. 40, pl. 7, figs. 7a-b.

Elphidium clavatum Cushman

Pl. 10, figs. 33, 38, 40

Elphidium incertum (Williamson) var. *clavatum* Cushman, 1930, U.S. Nat. Mus., Bull. 104, pt. 7, p. 20, figs. 10a-b.

Elphidium clavatum Cushman, Cushman, 1953, emend. Loeblich and Tappan, Smithsonian Misc. Coll., vol. 121, No. 7, pp. 98-99, pl. 19, figs. 8-10; Buzas, 1965, Smithsonian Misc. Coll., vol. 145, No. 8, p. 23, pl. 3, figs. 3a-b, 4a-b; 1965, Smithsonian Misc. Coll., vol. 149, No. 1, p. 58, pl. 2, figs. 6, 7; pl. 3, figs. 1, 2.

As noted by Buzas (1965, p. 59) and shown in the figured specimens, this is an extremely variable species. Probably the best distinguishing character is the umbilical region which contains several bosses, but varies in area compared to the remainder of the test. Also, this species has short retral processes which vary in

number and arrangement. This species occurred so abundantly as to dominate the Doctortown fauna. It occurred abundantly to rarely in the subsurface assemblage (Table 1).

Elphidium gunteri Cole Pl. 10, figs. 35, 36

Elphidium gunteri Cole, 1931, Florida Geol. Sur., Bull. 6, p. 34, pl. 4, figs. 9, 10.

Elphidium incertum (Williamson) Pl. 10, fig. 34

Polystomella umbilicatula var. *incerta* Williamson, 1858, On The Recent Foraminifera of Great Britain, Roy. Soc., p. 44, pl. 3, figs. 82, 82a.

Elphidium incertum (Williamson), Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 39, pl. 7, figs. 2a-b.

Elphidium limatulum Copeland, 1964, Bull. Amer. Paleont., vol. 47, No. 215, pp. 263-264, pl. 37, figs. 5a-b.

Undoubtedly, as pointed out by Buzas (1965, p. 22), many of the forms assigned to this species belong under *E. clavatum*. Copeland (1964) gave an excellent description and figure of a specimen, which he regarded as new but which, in the writer's opinion, belongs under *E. incertum*.

Elphidium poeyanum (d'Orbigny) Pl. 10, fig. 32; Pl. 11, figs. 41, 42

Polystomella poeyana d'Orbigny, 1839, Foraminifères in de la Sagra, Histoire physique, politique et naturelle de l'île de Cuba, p. 55, pl. 6, figs. 25, 26.

Elphidium poeyanum (d'Orbigny), Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 39, pl. 7, figs. 3, 4.

Elphidium varium Buzas Pl. 10, figs. 37, 39

Elphidium varium Buzas, 1965, Smithsonian Misc. Coll., vol. 145, No. 8, p. 21, pl. 2, fig. 7; pl. 3, figs. 1, 2a-b; Smithsonian Misc. Coll., vol. 149, No. 1, p. 61, pl. 3, fig. 5.

This species was observed only in the Doctortown fauna, where it occurred commonly. However, some of the specimens that are here regarded as *E. varium* may more properly belong under *E. clavatum*, which, as noted above, is an extremely variable species.

Family **HETEROHELICIDAE** Cushman, 1927

Genus **PLECTOFRONDICULARIA** Liebus, 1903

Plectofrondicularia cf. **longistriata** Le Roy Pl. 11, fig. 44

Plectofrondicularia longistriata Le Roy, 1939, Natuurw. tijdschr. Ned.-Indie, ser. 6, pt. 9, p. 241, pl. 5, figs. 4-6.

One partially broken specimen from the Doctortown fauna is tentatively referred to this species.

Genus **NODOGENERINA** Cushman, 1927

Nodogenerina advena Cushman and Laiming Pl. 11, fig. 45

Nodogenerina advena Cushman and Laiming, 1931, Jour. Paleont., vol. 5, p. 106, pl. 11, figs. 19a-b; Cushman and Ponton, 1932, Florida Geol. Sur., Bull. 9, p. 75, pl. 11, fig. 10.

This species, though occurring somewhat rarely in the Doctortown fauna, is distinctive.

Family **BULMINIDAE** Jones, 1875

Genus **BULIMINELLA** Cushman, 1911

Buliminella curta Cushman Pl. 11, fig. 47

Buliminella curta Cushman, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 2, p. 33, pl. 5, fig. 13; 1930, Florida Geol. Sur., Bull. 4, p. 43, pl. 8, fig. 4.

This species, which was originally described from the West Coast, occurred frequently in the Doctortown fauna and frequently to rarely in the subsurface fauna (Table 1).

Buliminella elegantissima (d'Orbigny) Pl. 11, fig. 46

Bulimina elegantissima d'Orbigny, 1839(1843), Voyage dans l'Amérique méridionale, vol. 5, pt. 5, Foraminifères, p. 51, pl. 7, figs. 13, 14.

Buliminella elegantissima (d'Orbigny), Cushman, 1911, U.S. Nat. Mus., Bull. 71, pt. 2, p. 89; 1925, Cushman Lab. Foram. Research Contr., vol. 1, pts. 1-4, p. 40, pl. 6, figs. 5a-b; 1930, Florida Geol. Sur., Bull. 4, p. 42, pl. 8, figs. 2, 3.

This species occurred abundantly in the Doctortown fauna but only rarely in two wells.

Genus **ROBERTINA** d'Orbigny, 1846

Robertina cf. subteres (H. B. Brady) Pl. 11, fig. 50

Bulimina subteres H. B. Brady, 1881, Quart. Jour. Micr. Sci., vol. 21, p. 55; 1884, Challenger Rept., vol. 9, p. 403, pl. 50, figs. 17, 18.

Robertina subteres (H. B. Brady), Cushman and Parker, 1947, U.S. Geol. Sur., Prof. Paper 210-D, p. 76, pl. 18, fig. 19; Puri, 1953, Florida Geol. Sur., Bull. 36, p. 138, pl. 19, figs. 5, 6.

One partially broken specimen was found in the Doctortown fauna. This species was recorded by Puri from the *Cancellaria* zone of the Choctawhatchee Formation of Florida, hence its occurrence at the Doctortown locality is not out of line.

Genus **BULIMINA** d'Orbigny, 1826

Bulimina elongata d'Orbigny Pl. 11, fig. 48

Bulimina elongata d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 187, pl. 11, figs. 19, 20.

Bulimina gracilis Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 43, pl. 8, figs. 5a-b.

This species occurred frequently in the Doctortown fauna and commonly to abundantly in all three wells (Table 1). In both assemblages this species consisted of slender, elongate and short, stocky forms, both apparently representative of this species. The short, stock form is figured on Plate 11 of this report.

Bulimina marginata d'Orbigny Pl. 11, fig. 49

Bulimina marginata d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 269, pl. 12, figs. 10-12.

One specimen of this species was recovered from a well (Table 1).

Genus **VIRGULINA** d'Orbigny, 1826**Virgulina fusiformis** Cushman

Virgulina fusiformis Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 45, pl. 8, figs. 8a-b.

Virgulina punctata d'Orbigny Pl. 11, fig. 51

Virgulina punctata d'Orbigny, 1839, Foraminifères in de la Sagra, Histoire physique, politique et naturelle de l'Ile de Cuba, p. 139, pl. 1, figs. 35, 36.

Genus **BOLIVINA** d'Orbigny, 1839**Bolivina advena** Cushman Pl. 11, fig. 52

Bolivina advena Cushman, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pts. 1-4, p. 29, pl. 5, figs. 1a-b.

This species occurred typically in the Doctortown fauna.

Bolivina marginata Cushman

Bolivina marginata Cushman, 1918, U.S. Geol. Sur., Bull. 676, p. 48, pl. 10, fig. 1; 1930, Florida Geol. Sur., Bull. 4, p. 45, pl. 8, figs. 9a-b.

Bolivina marginata multicostata Cushman Pl. 11, fig. 55

Bolivina marginata Cushman var. *multicostata* Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 46, pl. 8, figs. 13, 14.

This species occurred typically in the Doctortown fauna.

Bolivina paula Cushman and Cahill Pl. 11, fig. 53

Bolivina paula Cushman and Cahill, 1932, in Cushman and Ponton, Florida Geol. Sur., Bull. 9, p. 84, pl. 12, figs. 6a-b; 1933, U.S. Geol. Sur., Prof. Paper 175-A, p. 26, pl. 8, figs. 14a-b.

Bolivina plicatella Cushman Pl. 11, fig. 54

Bolivina plicatella Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 46, pl. 8, figs. 10a-b.

This small but distinctive bolivinid occurred commonly in the Doctortown fauna but rarely in two wells.

Bolivina cf. suteri Cushman and Renz Pl. 11, fig. 56

Bolivina suteri Cushman and Renz, 1941, Cushman Lab. Foram. Research Contr., vol. 17, pt. 1, p. 18, pl. 3, fig. 9.

One specimen recovered from the Doctortown fauna seems typical of this species as figured by Cushman and Renz. There is a possibility that this specimen may belong under *B. subspinescens* Cushman, an extremely variable species.

Bolivina sp. Pl. 11, fig. 43

Two small bolivinid specimens were recovered from wells (Table 1). Both were small, consisting of few biserially arranged chambers, the final pair much inflated. This small species is recorded for future reference.

Genus **REUSSELLA** Galloway, 1933**Reussella spinulosa** (Reuss) Pl. 11, fig. 57

Verneuilina spinulosa Reuss, 1850, Akad. Wiss. Wien, Denkschr., vol. 1, p. 374, pl. 47, fig. 12.

Reussia spinulosa (Reuss), Schwager, 1877, Com. geol. ital., Boll., vol. 8, p. 26, pl. fig. 66; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 48, pl. 8, figs. 17a-b.

Typical specimens representative of this species occurred commonly in the Doctortown fauna and abundantly to rarely in two wells (Table 1).

Genus **UVIGERINA** d'Orbigny, 1826**Uvigerina auberiana** d'Orbigny Pl. 12, figs. 58, 60

Uvigerina auberiana d'Orbigny, 1839, Foraminifères in de la Sagra, Histoire physique, politique et naturelle de l'Ile de Cuba, p. 106, pl. 2, figs. 23, 24; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 49, pl. 9, fig. 7.

Rare specimens of this species were found in the Doctortown and subsurface assemblages.

Uvigerina canariensis d'Orbigny Pl. 12, fig. 59

Uvigerina canariensis d'Orbigny, 1839, Foraminifères in Barker-Webb and Berthelot, Histoire naturelle des Îles Canaries, vol. 2, p. 138, pl. 1, figs. 25-27.

One specimen fitting D'Orbigny's description and figures was found in the Doctortown fauna.

Uvigerina subperegrina Cushman and Kleinpell Pl. 12, figs. 61, 62

Uvigerina subperegrina Cushman and Kleinpell, 1934, Cushman Lab. Foram. Research Contr., vol. 10, pt. 1, p. 12, pl. 2, figs. 9-11.

This species, originally described from the West Coast, shows variation from elongate to short, small forms, the latter resembling *U. parvula* Cushman, a Recent uvigerinid. It occurred frequently in the Doctortown fauna but only rarely in the subsurface assemblage (Table 1).

Genus **ANGULOGERINA** Cushman, 1927**Angulogerina occidentalis** (Cushman) Pl. 12, figs. 63, 64

Uvigerina angulosa Cushman (not Williamson), 1922, Carnegie Inst. Washington, Pub. 311, p. 34, pl. 5, figs. 3, 4.

Uvigerina occidentalis Cushman, 1923, U.S. Nat. Mus., Bull. 104, pt. 4, p. 169.
Angulogerina occidentalis (Cushman), Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 30, pl. 9, figs. 8, 9.

This species occurred abundantly in the Doctortown fauna and frequently to abundantly in the subsurface assemblage.

Genus **TRIFARINA** Cushman, 1923

Trifarina bradyi Cushman Pl. 12, fig. 65

Trifarina bradyi Cushman, 1923, U.S. Nat. Mus., Bull. 104, pt. 4, p. 99, pl. 22, figs. 3-9.

Family **DISCORBIDAE** Ehrenberg, 1838

Genus **DISCORBIS** Lamarck, 1804

Discorbis valvulatus (d'Orbigny)

Rosalina valvulata d'Orbigny, 1826, Annales Sci. Nat., vol. 7, p. 271, no. 4.

Discorbis valvulata (d'Orbigny), Cushman, 1921, U.S. Nat. Mus., Proc., vol. 59, p. 59, pl. 14, figs. 4, 5; 1930, Florida Geol. Sur., Bull. 4, p. 53, pl. 10, figs. 5a-c.

The keeled periphery and limbate sutures seem to be the important characteristics to look for in this species which occurred rarely in one well.

Discorbis vilardeboanus (d'Orbigny)

Rosalina vilardeboana d'Orbigny, 1839, Voyage dans l'Amérique méridionale, vol. 5, pt. 5, Foraminifères, p. 44, pl. 6, figs. 13-15.

Discorbis vilardeboana (d'Orbigny), Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 52, pl. 10, figs. 3a-c.

One specimen from a well in Chatham County, Georgia, is tentatively placed here.

Genus **BUCCELLA** Andersen, 1952

Buccella mansfieldi (Cushman) Pl. 13, figs. 77a-b; 78a-b

Eponides mansfieldi Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 54, pl. 11, figs. 1a-c.

The majority of specimens assigned to this species are somewhat smaller than typical representatives of this species. The species occurred abundantly in the Doctortown fauna and in two of the three wells studied (Table 1).

Genus **CONORBINA** Brotzen, 1936

Conorbina orbicularis (Terquem) Pl. 12, figs. 68a-b

Rosalina orbicularis Terquem, 1876, Animaux sur la plage de Dunkerque, p. 75, pl. 9, figs. 4a-b.

Discorbis orbicularis (Terquem), Berthelin, 1878, Foraminifères de Borgneuf et Pornichet, p. 39, No. 63.

Discorbis mira Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 52, pl. 10, figs. 2a-c.

Conorbina orbicularis (Terquem), Parker, 1954, Bull. Mus. Comp. Zoology, vol. 111, No. 10, p. 522, pl. 8, figs. 13, 14.

This small and fragile discorbid occurred commonly in the Doctortown fauna.

Genus **ROSALINA** d'Orbigny, 1826**Rosalina floridana** (Cushman) Pl. 12, figs. 66a-b; 67*Discorbis floridana* Cushman, 1922, Carnegie Inst. Washington, Pub. 311, p. 39, pl. 5, figs. 11, 12.

This species occurred commonly in the Doctórtown fauna.

Rosalina subaraucana (Cushman) Pl. 12, figs. 70a-b;
Pl. 13, figs. 71a-b; 72a-b*Discorbis subaraucana* Cushman, 1922, Carnegie Inst. Washington, Pub. 311, p. 41, pl. 7, figs. 1, 2; 1930, Florida Geol. Sur., Bull. 4, p. 52, pl. 10, figs. 1a-c.

This species occurred abundantly in the Doctortown fauna but rarely in the subsurface assemblage (Table 1).

Rosalina turrita (Cushman) Pl. 12, figs. 69a-b*Discorbis turrita* Cushman, 1918, U.S. Geol. Sur., Bull. 676, p. 59, pl. 14, fig. 2.

This is a small but distinctive discorbid.

Family **ROTALIIDAE** Ehrenberg, 1839Genus **VALVULINERIA** Cushman, 1926**Valvulineria** sp. Pl. 13, figs. 73a-b

Specimens representative of this species did not seem to fit any previously described species belonging under this genus, as far as the writer was able to determine. It is recorded here for future reference.

Genus **GYROIDINA** d'Orbigny, 1826**Gyroidina orbicularis** d'Orbigny Pl. 13, figs. 74a-b*Gyroidina orbicularis* d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, vol. 7, p. 278, Modeles No. 13.

One specimen, which apparently belongs here, was found in the Doctortown fauna.

Genus **EPONIDES** Montfort, 1808**Eponides antillarum** (d'Orbigny) Pl. 13, figs. 75a-b*Rotalina antillarum* d'Orbigny, 1839, Foraminifères in de la Sagra, Histoire physique, politique et naturelle de l'Île de Cuba, p. 75, pl. 5, figs. 4-6.*Eponides antillarum* (d'Orbigny), Cushman, 1931, U.S. Nat. Mus., Bull. 104, pt. 8, p. 42, pl. 9, figs. 2a-c; Cushman and Ponton, 1932, Florida Geol. Sur., Bull. 9, p. 93, pl. 14, figs. 1a-c.

This species occurred rarely in the Doctortown fauna.

Eponides cf. **regularis** Phleger and Parker Pl. 13, figs. 76a-b*Eponides regularis* Phleger and Parker, 1951, Geol. Soc. America, Mem. 46, pt. 2, p. 22, pl. 11, figs. 3a-b, 4a-c.

One specimen representative of this species was recovered from a well.

Genus **POROEPONIDES** Cushman, 1944

- Poroeponides lateralis** (Terquem) Pl. 14, figs. 79a-b
Rosalina lateralis Terquem, 1878, Soc. Géol. France, Mém., ser. 1, vol. 3, p. 25, pl. 2(7), figs. 11a-c.
Eponides lateralis (Terquem), Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 55, pl. 10, figs. 7a-c.
Poroeponides lateralis (Terquem), Cushman, 1944, Cushman Lab. Foram. Research, Spec. Pub. 12, p. 34, pl. 4, fig. 23.

This species occurred rarely in the Doctortown fauna.

Genus **AMMONIA** Brunnich, 1772

- Ammonia beccarii** (Linné) Pl. 14, figs. 81a-b, 82
Nautilus beccarii Linné, 1759, Syst. Nat., ed. 10, p. 710.
Ammonia beccarii (Linné), Buzas, 1965, Smithsonian Misc. Coll., vol. 149, No. 1, p. 62, pl. 4, figs. 1a-b.

Some of the specimens described in the literature as varieties of *A. beccarii* are included under this species in this report.

Genus **CANCERIS** Montfort, 1808

- Canceris segra** (d'Orbigny) Pl. 14, fig. 80
Rotalina segra d'Orbigny, 1839, Foraminifères in de la Sagra, Histoire physique, politique et naturelle de l'île de Cuba, p. 77, pl. 5, figs. 13-15.
Canceris segra (d'Orbigny) Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 56, pl. 11, figs. 4a-c.

Canceris segra communis Cushman and Todd

- Canceris segra* (d'Orbigny) var. *communis* Cushman and Todd, 1942, Cushman Lab. Foram. Research Contr., vol. 18, pt. 4, p. 79, pl. 19, figs. 8-16; pl. 20, fig. 1.

Two well-preserved specimens representative of this species, which is much larger than *C. segra*, were found in the Doctortown fauna.

Family **AMPHISTEGINIDAE** Cushman, 1927

Genus **AMPHISTEGINA** d'Orbigny, 1826

- Amphistegina lessonii** d'Orbigny Pl. 14, fig. 83
Amphistegina lessonii d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 304, No. 3, pl. 17, figs. 1-4; Modeles, No. 98; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 57, pl. 11, figs. 5a-c.

This species occurred commonly in the Doctortown fauna but was not observed in the subsurface assemblage.

Family **CYMBALOPORIDAE** Cushman, 1927

Genus **CYMBALOPORETTA** Cushman, 1928

- Cymbaloporetta squamosa** (d'Orbigny) Pl. 14, figs. 84a-b
Rotalia squamosa d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 272, No. 8.
Cymbaloporetta squamosa (d'Orbigny) Cushman, 1931, U.S. Nat. Mus., Bull. 104, pt. 8, p. 83, pl. 16, figs. 4a-c.

This species occurred rarely in the Doctortown fauna and in one well.

Family **CASSIDULINIDAE** d'Orbigny, 1839

Genus **CASSIDULINA** d'Orbigny, 1826

Cassidulina crassa d'Orbigny Pl. 14, fig. 86

Cassidulina crassa d'Orbigny, 1839, Voyage dans l'Amérique méridionale, vol. 5, pt. 5, Foraminifères, p. 56, pl. 7, figs. 18-20; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 58, pl. 11, figs. 6a-b.

This species occurred frequently in the Doctortown fauna and commonly to rarely in the subsurface assemblage (Table 1).

Cassidulina laevigata d'Orbigny Pl. 14, fig. 87

Cassidulina laevigata d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, No. 1, p. 282, pl. 15, figs. 4, 5; Modeles, No. 41.

This species occurred frequently to commonly in the subsurface assemblage, but was not observed in the Doctortown fauna.

Cassidulina laevigata carinata Cushman Pl. 14, fig. 85

Cassidulina laevigata d'Orbigny var. *carinata* Cushman, 1922, U.S. Nat. Mus., Bull. 104, pt. 3, p. 124, pl. 25, figs. 6, 7; 1930, Florida Geol. Sur., Bull. 4, p. 58, pl. 11, fig. 7.

Cassidulina laevigata carinata Cushman, Puri, 1953, Florida Geol. Sur., Bull. 36, p. 128, pl. 23, figs. 5, 6.

This small carinate cassidulinid occurred rarely in the Doctortown fauna.

Cassidulina subglobosa H. B. Brady Pl. 14, fig. 88

Cassidulina subglobosa H. B. Brady, 1881, Quart. Jour. Micr. Soc., vol. 21, p. 30 (60); 1884, Challenger Rept., Zoology, vol. 9, p. 430, pl. 54, figs. 17a-c.

This species occurred rarely in the Doctortown fauna.

Genus **CASSIDULINOIDES** Cushman, 1927

Cassidulinoides bradyi (Norman) Pl. 14, fig. 89

Cassidulina bradyi Norman, 1880, in Wright, Belfast Nat. Field Club, Proc., p. 152.

Cassidulinoides bradyi (Norman), Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 58, pl. 11, fig. 8.

A single specimen was recovered from a well (Table 1).

Family **GLOBIGERINIDAE** Carpenter, Parker and Jones, 1862

Genus **GLOBIGERINA** d'Orbigny, 1826

Globigerina bulloides d'Orbigny Pl. 14, fig. 90

Globigerina bulloides d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 277, No. 1; Modeles, Nos. 17, 76.

Specimens of this species occurred commonly in the Doctortown fauna and frequently to rarely in the subsurface assemblage (Table 1).

Globigerina nepenthes Todd

Pl. 15, fig. 91

Globigerina nepenthes Todd, 1947, U.S. Geol. Sur., Prof. Paper 280-H, p. 301, pl. 78, figs. 7a-b.

This significant species, indicative of early Pliocene age, occurred rarely in all three wells but was not observed in the Doctortown fauna.

Genus **GLOBIGERINOIDES** Cushman, 1927

Globigerinoides obliquus Bolli

Globigerinoides obliqua Bolli, 1957, U.S. Nat. Mus., Bull. 215, p. 113, pl. 25, figs. 9, 10; text fig. 21, No. 5.

This species occurred commonly in both assemblages (Table 1).

Globigerinoides quadrilobatus (d'Orbigny)

Globigerina quadrilobata d'Orbigny, 1846, Foraminifères fossiles due bassin tertiaire de Vienne, p. 164, pl. 9, figs. 7-10.

This species occurred commonly to abundantly in each of the three wells but only frequently in the Doctortown fauna (Table 1).

Globigerinoides rubra (d'Orbigny)

Globigerina rubra d'Orbigny, 1839, Foraminifères in de la Sagra, Histoire physique, politique et naturelle de l'Ile de Cuba, p. 82, pl. 4, figs. 12-14.

This species occurred commonly in the Doctortown fauna but only rarely in two wells.

Genus **ORBULINA** d'Orbigny, 1826

Orbulina universa d'Orbigny

Pl. 15, fig. 92

Orbulina universa d'Orbigny, 1839, Foraminifères in de la Sagra, Histoire physique, politique et naturelle de l'Ile de Cuba, p. 3, pl. 1, fig. 1.

Rare specimens occurred in one well.

Genus **SPHAERODINELLOPSIS** Banner and Blow, 1959

Sphaeroidinellopsis subdehiscens Blow

Sphaeroidinella dehiscens subdehiscens Blow, 1959, Bull. Amer. Paleont., vol. 39, No. 178, p. 195, pl. 12, figs. 71, 72.

Family **GLOBOROTALIIDAE** Cushman, 1927

Genus **GLOBOROTALIA** Cushman, 1927

Globorotalia acostaensis Blow

Globorotalia acostaensis Blow, 1959, Bull. Amer. Paleont., vol. 39, No. 178, pp. 208-210, pl. 17, figs. 106a-c, 107.

This species occurred commonly to abundantly in both assemblages (Table 1).

Globorotalia menardii (d'Orbigny) Pl. 15, figs. 93a-b

Rotalia menardii d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, vol. 7, p. 60, pl. 12, figs. 1a-c.

All specimens were right coiling.

Family **ANOMALINIDAE** Cushman, 1927

Genus **PLANULINA** d'Orbigny

Planulina depressa (d'Orbigny) Pl. 15, figs. 94a-b, 95a-b

Truncatulina depressa d'Orbigny, 1839, Voyage dans l'Amérique méridionale, vol. 5, pt. 5, Foraminifères, p. 39, pl. 6, figs. 4-6.

Planulina depressa (d'Orbigny) Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 60, pl. 12, figs. 2a-c.

This species occurred only rarely in the Doctortown fauna but commonly in the subsurface assemblage.

Genus **CIBICIDES** Montfort, 1808

Cibicides americanus (Cushman) Pl. 16, figs. 100a-b

Truncatulina americana Cushman, 1918, U.S. Geol. Sur., Bull. 676, p. 63, pl. 20, figs. 2, 3; pl. 21, fig. 1.

Cibicides americana (Cushman), Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 61, pl. 12, figs. 5a-c.

This species occurred rarely in the Doctortown fauna and in a well.

Cibicides duplinensis Copeland Pl. 15, figs. 96a-b

Cibicides duplinensis Copeland, 1964, Bull. Amer. Paleont., vol. 47, No. 254, p. 276, pl. 40, figs. 3a-c.

It is one of the four species that dominated both assemblages — *Elphidium clavatum*, *Cibicides duplinensis*, *Cibicides lobatulus* and its varieties, and *Hanzawaia concentrica* (Cushman).

Cibicides lobatulus (Jacob) Pl. 15, figs. 98a-b

Nautilus lobatula Jacob, 1798, in Adams Essays on the microscope, p. 642, pl. 14, fig. 36.

Cibicides lobatulus (Jacob), Cushman, 1927, Jour. Paleont., vol. 1, p. 170, pl. 27, figs. 12, 13.

This species occurred abundantly in both assemblages.

Cibicides lobatulus (Walker and Jacob) "var." Pl. 15, figs. 97a-b;
Pl. 16, figs. 102a-b; 103a-b; 104

Several different species, as for example, *C. sublobus* and *Dyocibicides biserialis*, probably belong here. *C. lobatulus* "var." occurred commonly to abundantly in both assemblages (Table 1).

Cibicides sapeloensis Darby and Hoyt

Pl. 16, figs. 99a-c

Cibicides sapeloensis Darby and Hoyt, 1964, Jour. Paleont., vol. 38, No. 1, p. 70, pl. 18, figs. 1-7.

Genus **HANZAWAIA** Asano, 1944**Hanzawaia concentrica** (Cushman)

Pl. 16, figs. 101a-b

Truncatulina concentrica Cushman, 1918, U.S. Geol. Sur., Bull. 676, pp. 64-65, pl. 21, figs. 3a-c.

Cibicides concentrica (Cushman), Cushman, 1930, Florida Geol. Sur., Bull. 4, pp. 61, 62, pl. 12, figs. 4a-c.

This species occurred abundantly in both assemblages (Table 1).

Family **PLANORBULINIDAE** Schwager, 1877Genus **PLANORBULINA** d'Orbigny, 1826**Planorbulina mediterranensis** d'Orbigny

Planorbulina mediterranensis d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, vol. 7, p. 280, pl. 14, figs. 4-6; Modeles No. 79.

Part of a broken specimen belonging to this species was recovered from a well.

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PLATES

The illustrated specimens (hypotypes) are deposited in the Paleontological Research Institution, Nos. 29900-30011.

EXPLANATION OF PLATE 8

Unless otherwise stated, illustrations are of specimens from the Doctortown assemblage.

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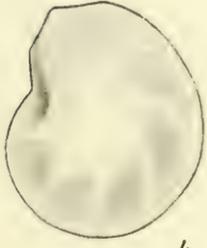
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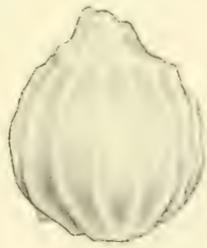
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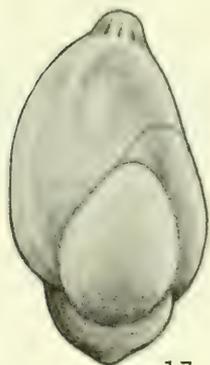
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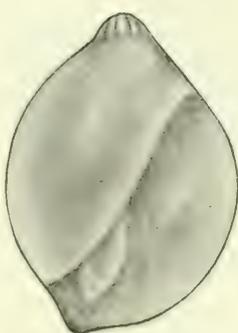
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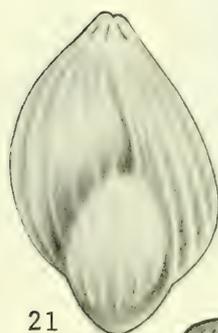
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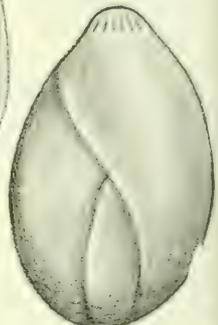
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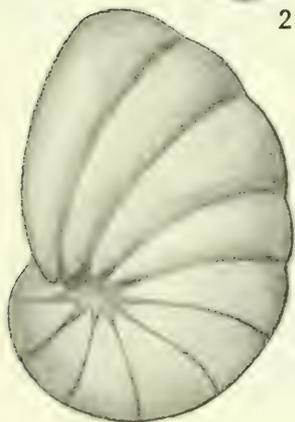
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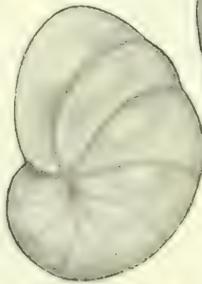
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27b



28a



28c



28b

EXPLANATION OF PLATE 9

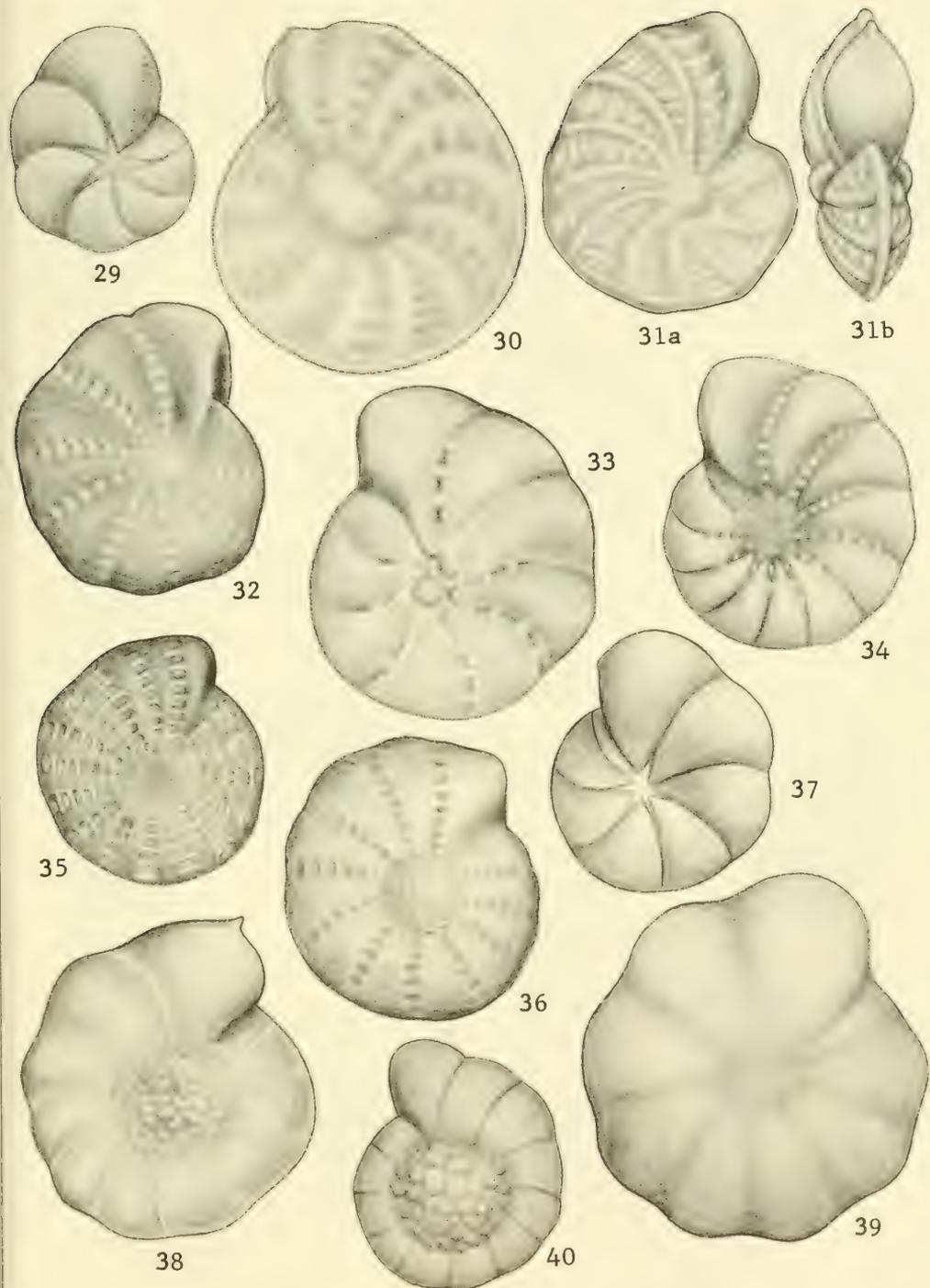
Unless otherwise stated, illustrations are of specimens from the Doctortown assemblage.

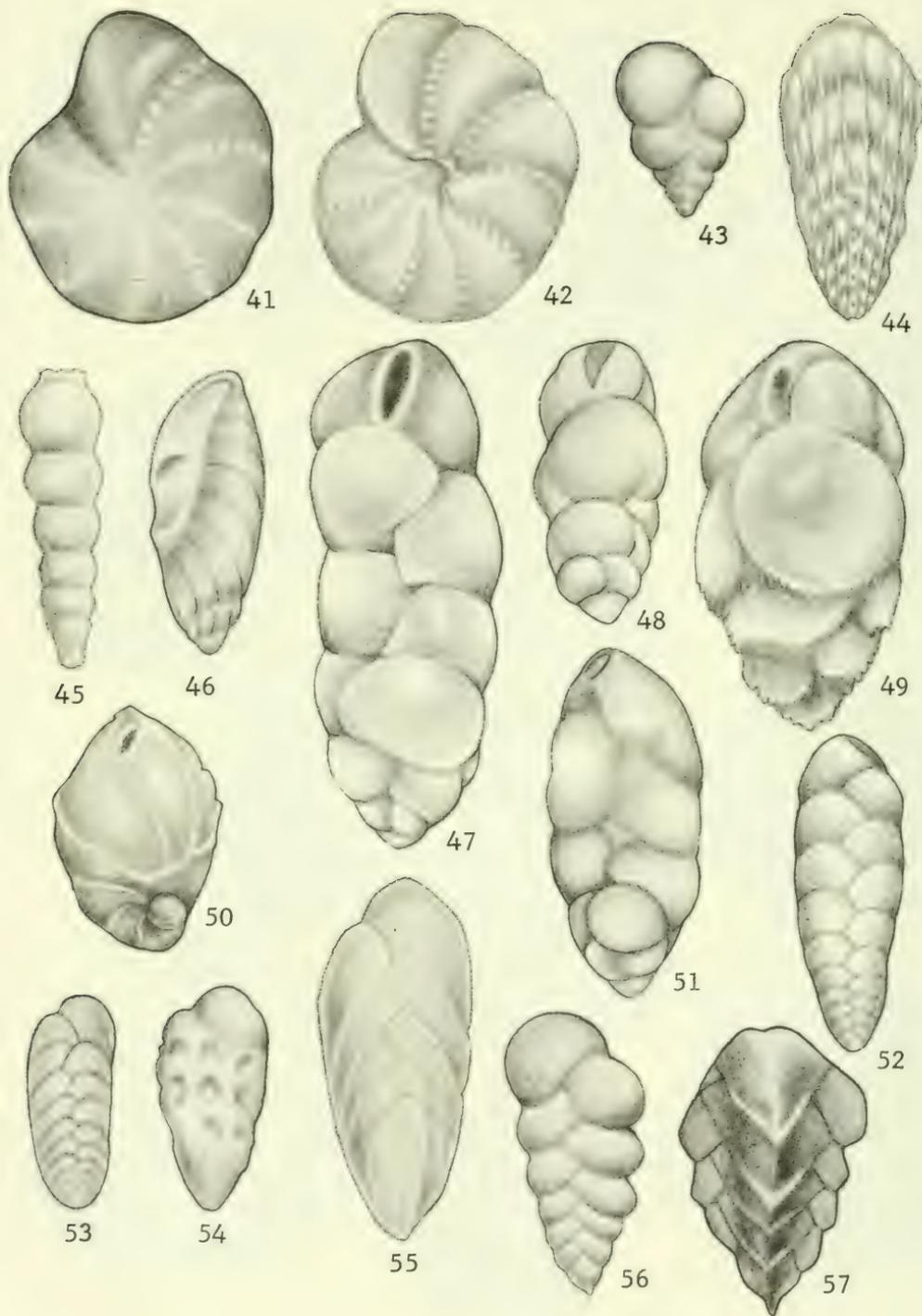
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EXPLANATION OF PLATE 11

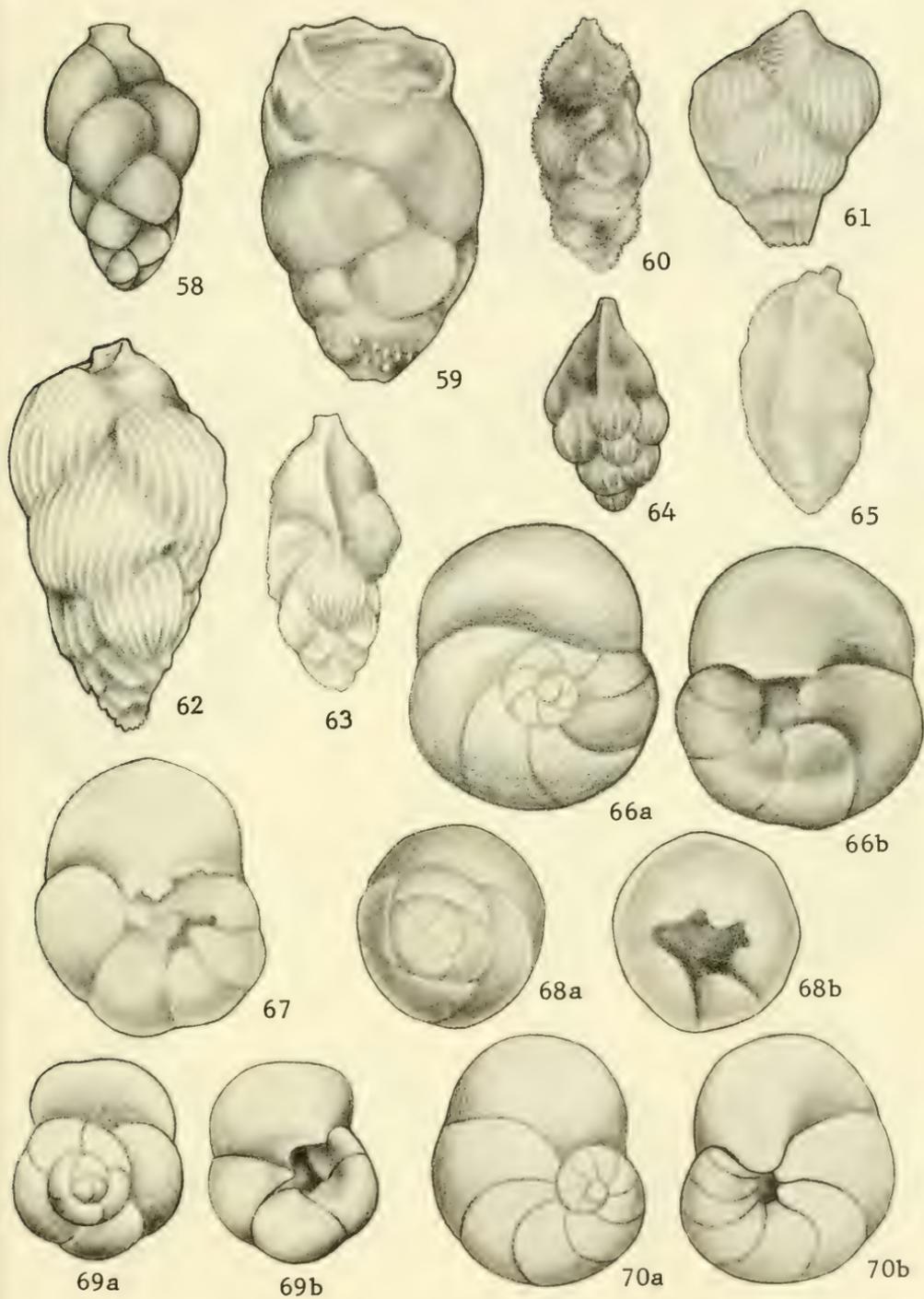
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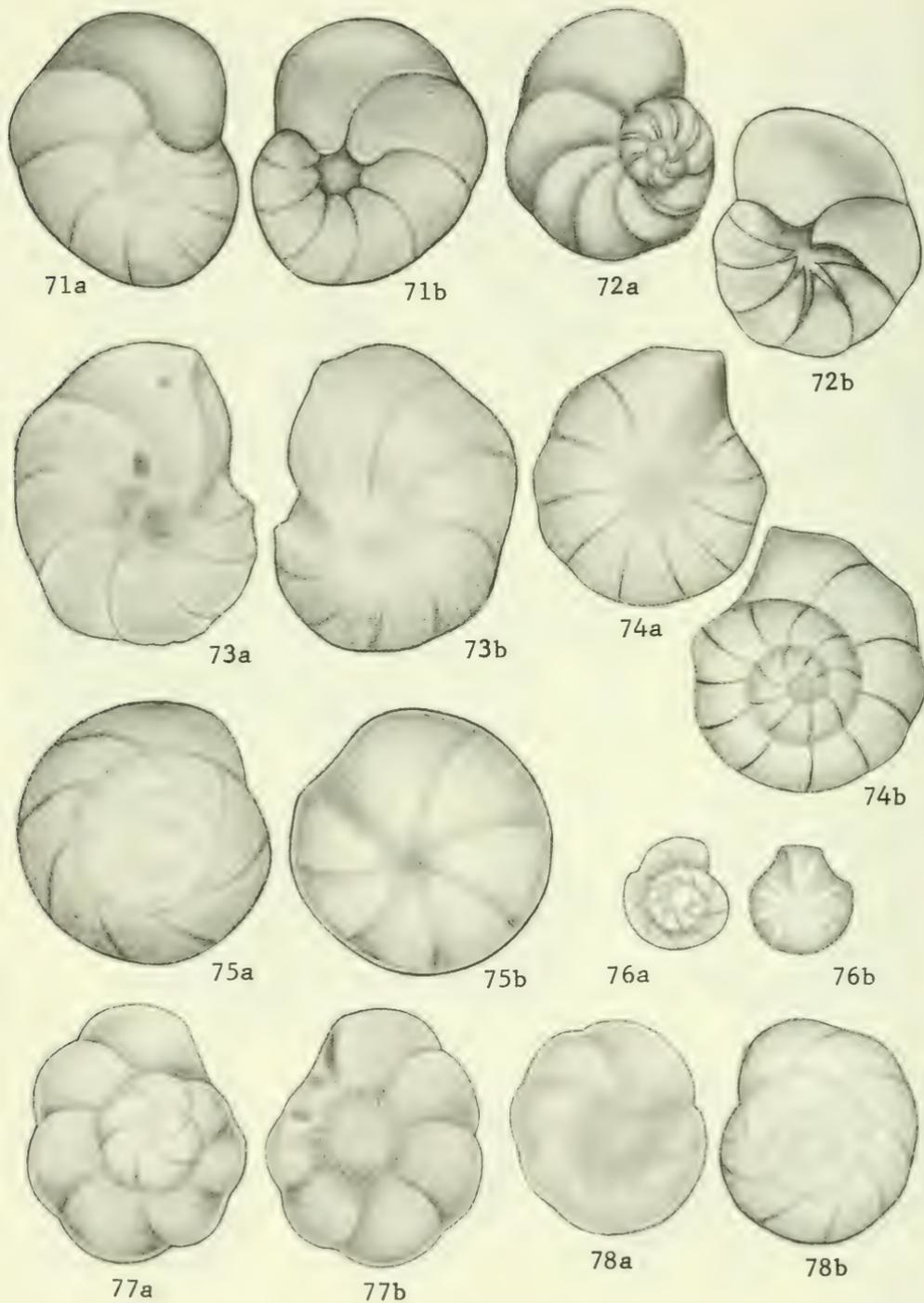
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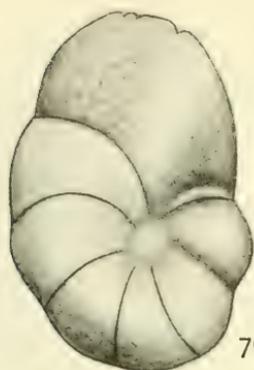
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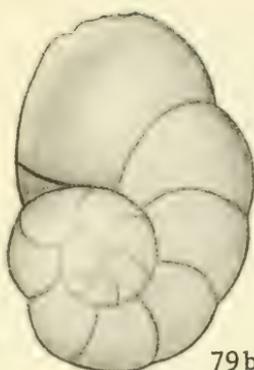
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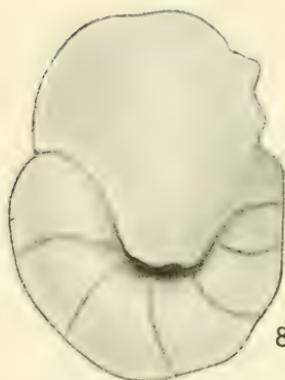
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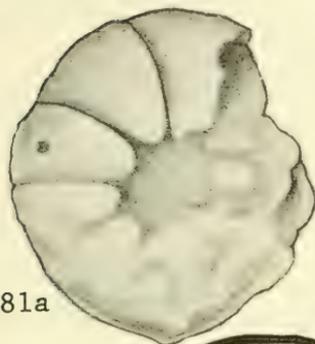
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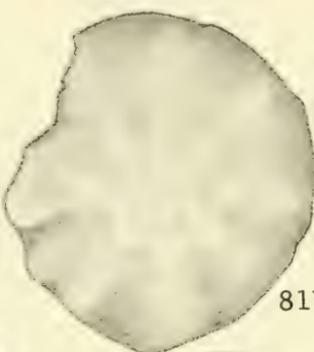
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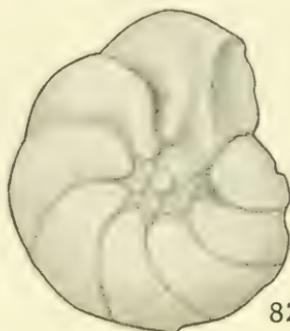
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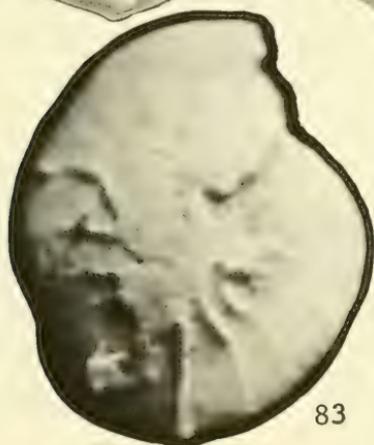
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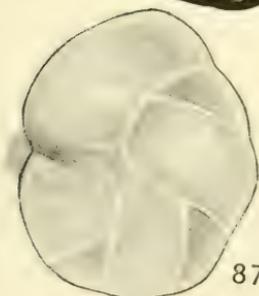
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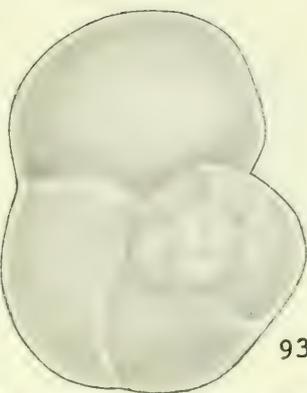
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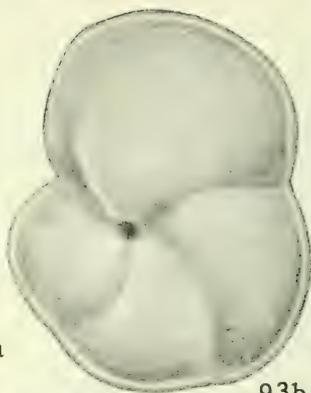
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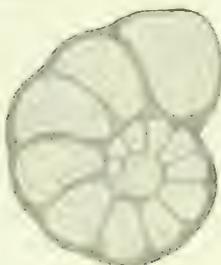
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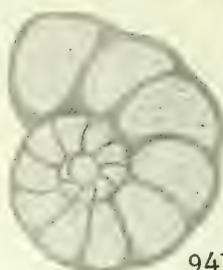
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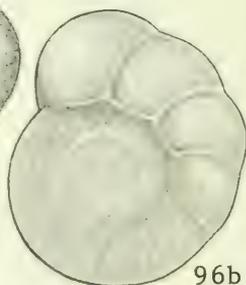
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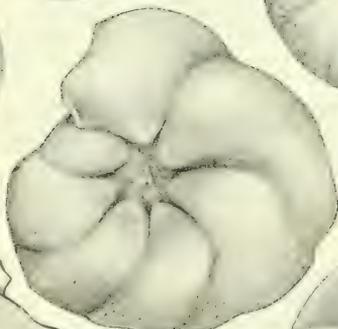
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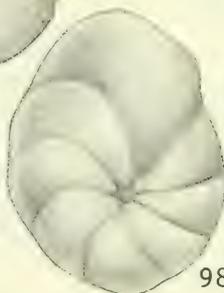
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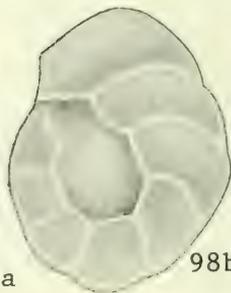
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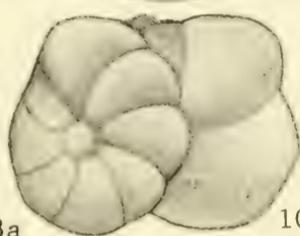
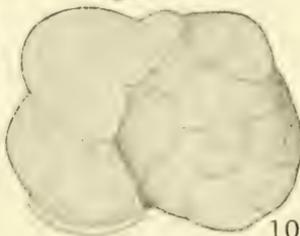
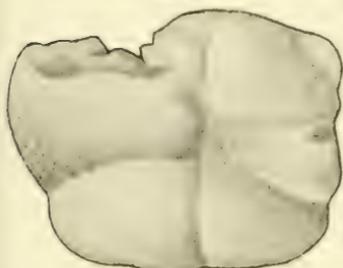
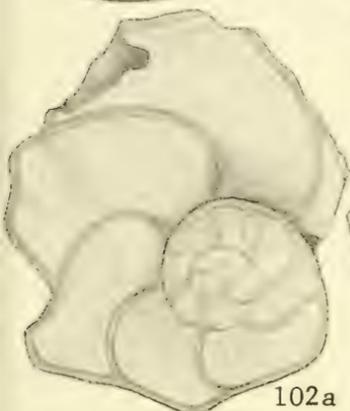
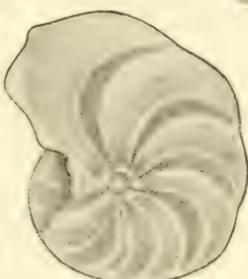
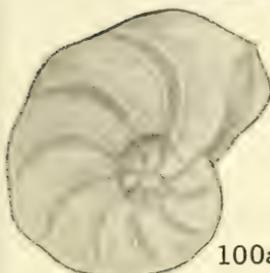
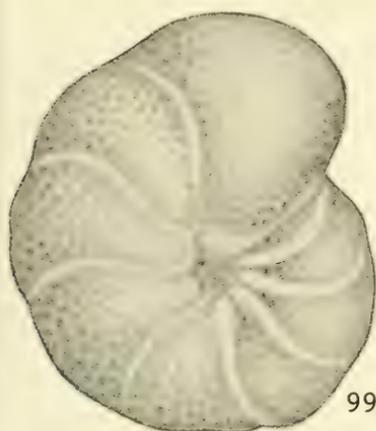
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NORTHEASTERN PACIFIC

By

LOUIE MARINCOVICH, JR.

1977

Paleontological Research Institution
Ithaca, New York 14850 U. S. A.

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BULLETINS
OF
AMERICAN
PALEONTOLOGY

(Founded 1895)

Vol. 70

No. 294

A Lewis G. Weeks Publication

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February 22, 1977

Paleontological Research Institution
Ithaca, New York 14850 U. S. A.

Library of Congress Card Number: 77-72605

We can see it now . . . this Linnaean obsession with classifying and naming, with fossilizing the existent . . . as [an] attempt to stabilize and fix what is in reality a continuous flux, and it seems highly appropriate that Linnaeus himself finally went mad; he knew he was in a labyrinth, but not that it was one whose walls and passages were eternally changing.

Fowles, 1970, p. 45

Printed in the United States of America
Arnold Printing Corporation

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CENOZOIC NATICIDAE (MOLLUSCA: GASTROPODA) OF THE NORTHEASTERN PACIFIC

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ABSTRACT

Marine gastropods of the worldwide family Naticidae occur commonly in Cenozoic strata including modern seas. The present systematic and taxonomic review of living species from the Arctic Ocean to northern Peru and of Cenozoic species from western North America reduces the number of recognized taxa. Of the 87 species included here, 58 have fossil records and 40 are extinct.

In order of their taxonomic value, the most significant features of naticids are umbilical morphology, shell form and sculpture, and calcareous opercular sculpture. Radular dentition is sometimes useful for characterizing generic taxa but not species. Using these criteria, the family in the northeastern Pacific is conservatively divided into 18 genera and 14 subgenera.

Living naticids occur in all shallow-water molluscan provinces of the northeastern Pacific and are especially diverse and abundant in the tropics. A sharp drop in species diversity at the boundary between subtropical and warm-temperate hydroclimates indicates the essentially tropical nature of the family. Correlation of some generic taxa, especially subgenera, with particular modern hydroclimates makes naticids useful in evaluating paleoclimatic and paleobiogeographic inferences. Periodic occurrences of tropical naticid subgenera in Tertiary strata of California, Oregon, and Washington, record northward incursions of tropical seas during former periods of warmer marine climate. Changes in composition of the fossil naticid faunas with latitude along this extensive coastline allows speculation on placement of biogeographic boundaries during some intervals of Tertiary time.

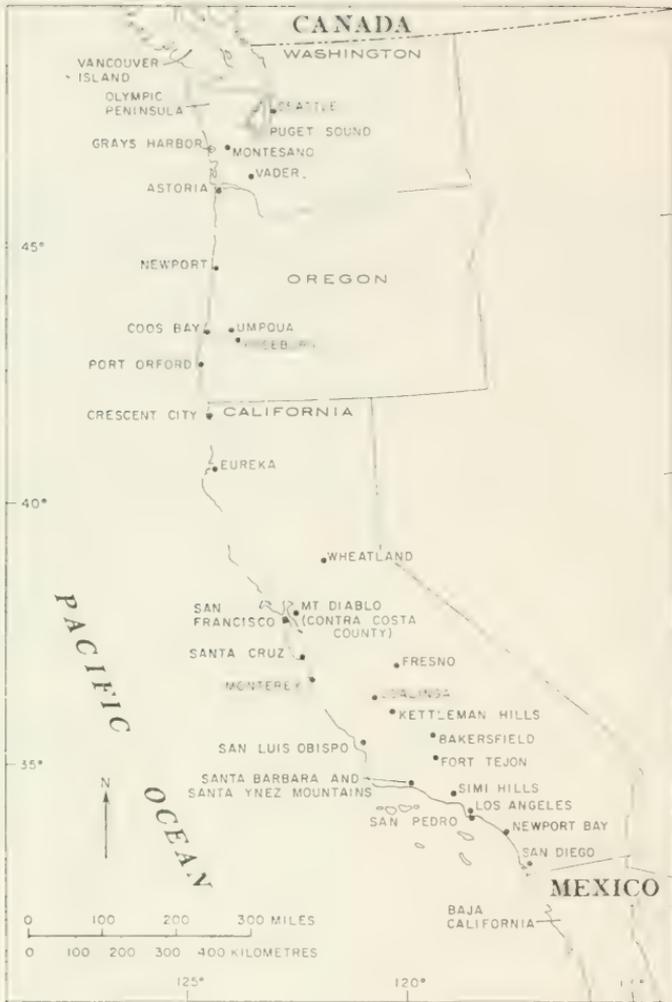
Many naticid species evolved or became extinct in response to Tertiary climatic fluctuations. Some species also had broad geographic distributions and are useful as regional biostratigraphic indicators, whereas others may be used for more local correlations.

The modern northeastern Pacific naticid fauna is largely derived from endemic Cenozoic ancestors. Two species are migrants from the Indo-Pacific region and two probably migrated across the polar region from the northern Atlantic. There are at least six pairs of homologous species between the modern tropical eastern Pacific and Caribbean faunas. Inferred phylogenetic relations among Cenozoic naticids of western North America suggest that most fossil species also evolved from endemic ancestors.

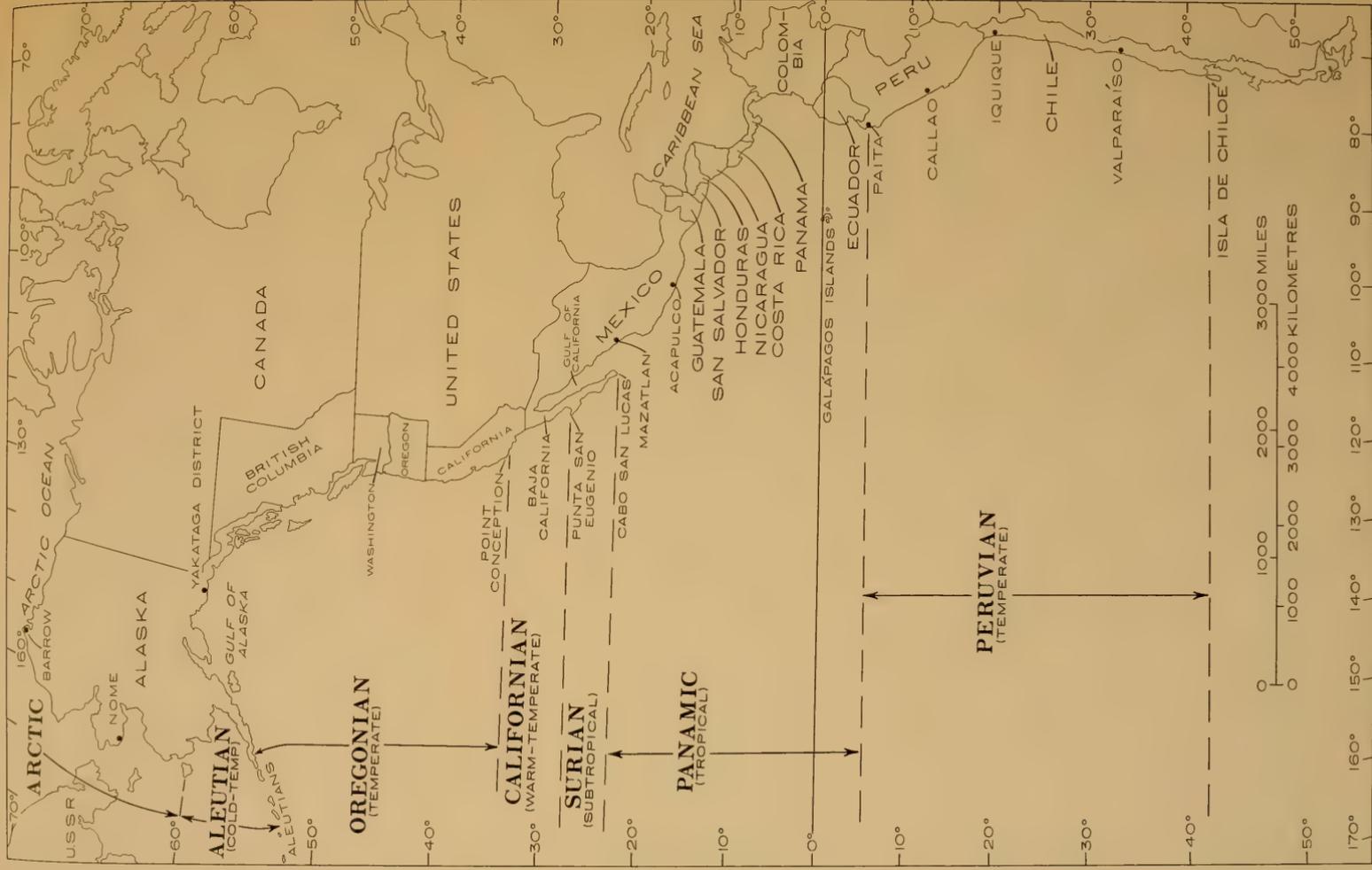
An apparent functional relationship between shells and calcareous opercula, previously undescribed in this family, occurs in the living species *Natica (Stigmaulax) elenae* Récluz and *N. (S.) broderipiana* Récluz.

INTRODUCTION

The family Naticidae is a large and morphologically homogeneous group of marine gastropods of worldwide distribution, living in habitats from the intertidal zone to the deep sea. Naticids are first recorded in the Early Jurassic (Carriker and Yochelson, 1968; Sohl, 1969a) but are most abundant in Cenozoic sediments including modern seas. Because this family is morphologically conservative, yet contains a large number of described genera and species, it is beset with difficult taxonomic and systematic problems that have discouraged workers. The present study is a review of living Natici-



Text-figure 2. West coast of the United States, showing geographic place names frequently mentioned in text.



Text-figure 1. Eastern Pacific Ocean, showing modern shallow-water faunal provinces and geographic place names frequently used in text.

dae from the Arctic Ocean to northern Peru, and of Paleocene through Pleistocene species of western North America from Alaska to southern California (Text-figs. 1, 2). Modern circumboreal species are included, but extratropical species of western South America have largely been excluded.

Naticids live on and within soft substrates, where they may be easily buried and preserved. They are routinely and abundantly present in the rich Cenozoic molluscan faunas of western North America. Even where the shells of naticids are not preserved, their former presence may be inferred by the beveled circular holes bored into their bivalve prey. However, their utility as zonal fossils has been limited by lack of comparative morphological studies and poorly documented stratigraphic occurrences. A major objective of this study has been to enhance the usefulness of naticids in stratigraphic correlation, in addition to clarifying their taxonomy and classification.

Neither Cenozoic nor modern naticids of the eastern Pacific have ever been reviewed critically. Prior to this century, worldwide accounts on the living species of the broadly defined genus *Natica* (*i.e.*, most Naticinae and Polinicinae species) were compiled by Philippi (1849-1853), Reeve (1855), G. B. Sowerby, II (1883), and Tryon (1886). Monographs of *Sigaretus* [*Sinum*] were done by Reeve (1864), G. B. Sowerby, II (1882), Weinkauff (1883), and Tryon (1886). These works are helpful in providing illustrations of many previously unfigured species, but they are largely uncritical and did not advance the study of naticid systematics. For instance, Tryon's (1886) ill-considered lumping of distinct species only confused later workers. Thiele (1931) and Wenz (1941) presented generic catalogs for worldwide mollusks that included living and fossil naticid taxa, respectively. Both works are still useful references, but they only list and characterize generic taxa without attempting significant systematic innovation. Wenz did place many genera into synonymy but did not substantiate his placements, some of which are questionable.

The living tropical eastern Pacific naticids have most recently been surveyed by Keen (1971) as part of an extensive faunal summary of the Panamic molluscan province, although critical evaluation of the family was not within the scope of that work. Additional information on these tropical species was furnished by Keen and

Coan (1975), based on the work of Marinovich (1973b). Dall (1921) listed the nominal living species from the extratropical north-eastern Pacific, Keen and Bentson (1944) did the same for Tertiary species of California, and Weaver (1943) gave an illustrated account of Tertiary naticids of Oregon and Washington, all as parts of larger faunal catalogs. Dall (1909b) made some useful generic comments in his account of Pliocene species of Oregon, and Grant and Gale (1931) did the same for genera and species from the Pliocene and Pleistocene of California.

Naticids of the cool-water Peruvian molluscan province, to the south of the region considered here, are poorly known. These species were included in this study during its early stages, but the small number of specimens available from that area discouraged the effort. Extensive collecting in Chile and Peru is necessary before the living and fossil naticids there can be thoroughly treated. The living nominal species of the Peruvian province were listed by Dall (1909a) and the Chilean Cenozoic species were cataloged by Philippi (1887).

ACKNOWLEDGMENTS

Study of Miocene to Holocene Naticidae was undertaken as my doctoral work (Marinovich, 1973b) at the University of Southern California under the guidance of William H. Easton. I wish to express my appreciation for his personal interest in and encouragement of my work, and for his evaluation of my dissertation. The late Orville L. Bandy, also of the University of Southern California, and James H. McLean, of the Natural History Museum of Los Angeles County, provided helpful criticism at that time. In addition, McLean allowed me access to his voluminous private notes and photographs and stimulated discussion of many taxonomic problems. Subsequently, further revisions were made after critical evaluation by Eugene V. Coan of Palo Alto, California, and Warren O. Addicott and Norman F. Sohl, of the United States Geological Survey. The early Tertiary portion of this study was completed while I enjoyed tenure as a Post-doctoral Research Associate in the Branch of Paleontology and Stratigraphy, United States Geological Survey, Menlo Park, California.

The success of such a study depends upon the cooperation of many colleagues for examining and procuring as many specimens as possible. For providing access to collections, for permission to borrow numerous specimens, and for other generous assistance, I am

indebted to R. Tucker Abbott, of the Delaware Museum of Natural History; Warren O. Addicott and Wendell P. Woodring, of the United States Geological Survey; Nibaldo Bahamonde N., of the National Museum of Natural History, Santiago, Chile; Tor A. Bakke, Zoological Museum, University of Oslo, Norway; S. Stillman Berry and Donald Shasky, Redlands, California; Alan G. Beu, New Zealand Geological Survey; Eugene Binder, Museum of Natural History, Geneva, Switzerland; Vincent Conde, Redpath Museum, Montreal, Canada; J. Wyatt Durham and Joseph H. Peck, University of California at Berkeley; William K. Emerson and William E. Old, American Museum of Natural History; A. Myra Keen, Stanford University; Rudolf Kilius, Museum Natural History, Humboldt Univ., Berlin; Jørgen Knudsen, Zoological Institute and Museum, Copenhagen, Denmark; James H. McLean and Edward C. Wilson, Natural History Museum of Los Angeles County; Jack D. Mount, of the University of California Riverside; George E. Radwin, San Diego Museum of Natural History; Robert Robertson, Academy of Natural Sciences of Philadelphia; Peter U. Rodda and Barry Roth, California Academy of Sciences; Joseph Rosewater, Harald A. Rehder, and Frederick J. Collier, National Museum of Natural History; Takeo Susuki and Louella R. Saul, University of California at Los Angeles; A. M. Testud, National Museum Natural History, Paris; Ruth D. Turner, Kenneth J. Boss, and Bernhard Kummel, Harvard University. For countless discussions of problems concerning Cenozoic biostratigraphy and correlations I wish to express my appreciation to my colleagues at the United States Geological Survey, Menlo Park, California. Finally, I should like to thank Kenji Sakamoto for his photographic work, Sara Boore, Susan Engwicht, and Natalie Miller for drafting text-figures, and Rose Trombley for preparing the manuscript for publication.

Doctoral work at the University of Southern California was supported in part by a grant from the Edwin C. Pauley Foundation and another (04-3-158-45) from the National Sea Grant Program, United States Department of Commerce, to the University of Southern California. Travel expenses while a student were partly financed by a grant from the Theodore Roosevelt Memorial Fund of the American Museum of Natural History.

PROCEDURES

The naticid shell (Text-fig. 10) is usually considered to be of primary taxonomic importance, but radular dentition and opercular

sculpture have also been used as bases for erecting genera. Even though radular dentition is of some utility in distinguishing genera (Odhner, 1913; Thiele, 1931; Azuma, 1961; Powell, 1951; Oyama, 1969), I have found it of little use in separating species. Except for a few species (Text-fig. 11), radular features are described under generic headings. In order of taxonomic value, the significant features of naticids are the umbilical areas, shell sculpture and form, and calcareous opercular sculpture. The operculum is of major importance when making the basic distinction between Naticinae and Polinicinae, but numerous species occur in which the morphology of the calcareous operculum is not taxonomically useful. The opercula of some modern species and nearly all fossil species are unknown. Shell sculpture is uncommon in the family and most commonly occurs as simple axial or spiral costae that are nearly identical among related species, so it is usually considered to be of only generic importance. However, the shape of the umbilical callus and the degree to which it conceals the umbilicus is of critical generic and specific value. Callus morphology is usually relatively consistent at the species level or varies through a distinct range. Environmental effects on callus shape are not documented but might occur in especially variable species such as *Neverita (Glossaulax) reclusiana* (Deshayes) or *Natica (Cryptonatica) clausa* Broderip and Sowerby. An attempt is made to emphasize characters permitting meaningful comparisons between living and extinct taxa.

The generic treatment used here is conservative because the family is in need of a thorough worldwide revision. The subgenera in this study have often been regarded as genera, but I feel that this ranking is premature and tends to conceal relationships between similar genus-group taxa. A review of worldwide naticid supraspecific taxonomy and classification would be necessary to shed new light on the generic allocations of some eastern Pacific species.

All data on fossil and modern occurrences given here are based on specimens I have seen, unless otherwise indicated, and an effort was made to locate specimens on which published range limits or unusual occurrences were based. Recorded stratigraphic occurrences are a combination of literature citations and my own observations, the latter indicated by initials of the institution housing the specimens. Age assignments of formations are based on the latest pub-

lished statements, modified in some cases by discussions with colleagues. As discussed more fully in the section on "Biostratigraphy and Inferred Phylogenetic Relations," formational age assignments are those of a provincial chronology based on mega-invertebrates and benthic foraminifers. About 29,000 fossil and Holocene specimens were examined.

Institutions cited in this study are listed below, along with abbreviations used in the text:

AHF	Allan Hancock Foundation, University of Southern California, Los Angeles, California; gastropod collection on permanent loan to Natural History Museum of Los Angeles County (LACM)
AMNH	American Museum of Natural History, New York, New York
ANSP	Academy of Natural Sciences, Philadelphia, Pennsylvania
BM(NH)	British Museum (Natural History), London, England
CAS	California Academy of Sciences, San Francisco, California
DMNH	Delaware Museum of Natural History, Greenville, Delaware
LACM	Natural History Museum of Los Angeles County, Los Angeles, California
MCZ	Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts
SDNHM	San Diego Natural History Museum, San Diego, California
SU	Stanford University, Stanford, California
UCB	University of California at Berkeley, California
UCD	University of California at Davis, California
UCLA	University of California at Los Angeles, California
UCR	University of California at Riverside, California
USC	University of Southern California, Los Angeles, California
USGS	United States Geological Survey, Menlo Park, California
USNM	National Museum of Natural History, Washington, D.C.

Specimens in the private collections of S. Stillman Berry and Donald Shasky, Redlands, California, were also examined.

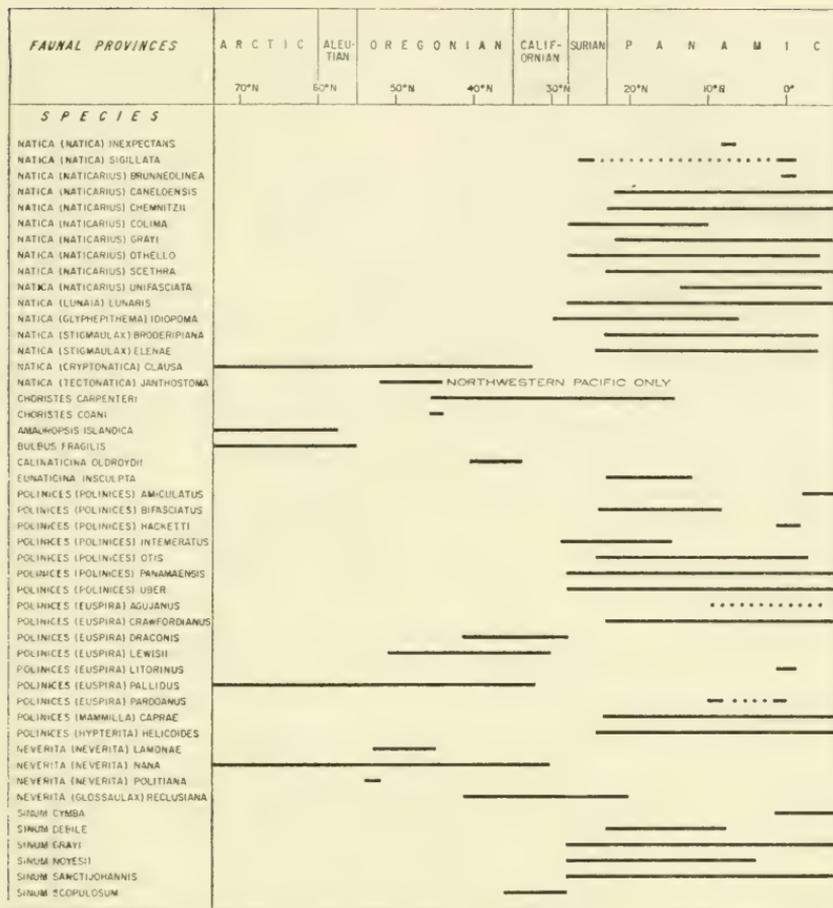
BIOGEOGRAPHY AND PALEOBIOGEOGRAPHY

BIOGEOGRAPHY

Text-figure 3 lists the living northeastern Pacific naticids and graphically gives their distributions in degrees of latitude and in relation to accepted shallow-water faunal provinces. This shows the family to be represented in all marine climatic zones, with its greatest diversity in the tropics. The sharp drop in species diversity at 28° N. (Punta San Eugenio, Baja California, Mexico), the boundary between subtropical and warm-temperate hydroclimates, indicates the essentially tropical nature of the family. Provincial segregation of naticids is also apparent at the generic level (Text-fig. 4). The correlation of some generic taxa, especially subgenera, with particular hydroclimatic zones makes naticids in this region useful for supporting paleobiogeographic and paleoclimatic inferences. As shown in Text-figure 3, five species live in Arctic latitudes, whereas nine are well established in the warm-temperate Californian province and 24 are found at the equator. The presence of this essentially warm-water family in high latitudes emphasizes the adaptive nature of Naticidae.

Naticinae in particular is a tropical subfamily. The subgenera *Natica*, *s.s.*, *Naticarius*, *Lunaia*, *Glypheapithema*, and *Stigmaulax* are found only in tropical and subtropical waters, except for a short northward extension of *Glypheapithema* into the Californian province (which may be due more to the occasional introduction of *Glypheapithema* larvae into the Californian province by warm northward-flowing countercurrents than to the presence of reproducing populations north of the subtropics; Zinsmeister (1974a). Except for *Lunaia*, which is not known elsewhere, these subgenera are also distinctly tropical groups in other regions.

The subgenera *Cryptonatica* and *Tectonatica*, each represented by one living species in this region, are exceptions among the Naticinae by living only in cold waters. *Natica* (*Tectonatica*) *janthostoma* Deshayes lives only in the northwestern Pacific today but occurs only in upper Cenozoic deposits of the northeastern Pacific. Its southernmost Cenozoic occurrence was in northern California, in the middle Pliocene to Pleistocene, and it occurs sparsely in Pleistocene deposits of the Bering Sea area. *Tectonatica* seems to be a largely tropical group elsewhere, as Woodring (1957) mentioned



Text-figure 3. Distribution of living northeastern Pacific naticids in degrees of latitude and in relation to shallow-water faunal provinces. Unconfirmed range data shown as dotted lines.

four species from the Caribbean, but further study may show it represented more extensively in middle latitudes.

Natica (*Cryptonatica*) *clausa* Broderip and Sowerby ranges southward to southern California, but is definitely a cold-water species characteristic of Aleutian and Arctic waters. It lives in southern latitudes at progressively greater depths in bottom water of Arctic temperature; it may live in as little as nine metres depth in Arctic Alaska but in no less than 150 metres off southern California. The optimal hydroclimate for this species is suggested not only by its shift in depth range but also by the size to which it grows. Arctic specimens average about 30 mm in height and 28 mm in diameter, whereas those from southern California are about 13 mm in height and 11.5 mm in diameter, with the same number of whorls per specimen. The steady southward decrease in size parallels the increasing depth habitat. The middle Miocene to early Pliocene species *N. (C.) oregonensis* (Conrad), the only other *Cryptonatica* in this region, lived in the somewhat cooler hydroclimate of Oregon and Washington, but not in the warm-temperate to subtropical middle and late Miocene marine basins of southern California.

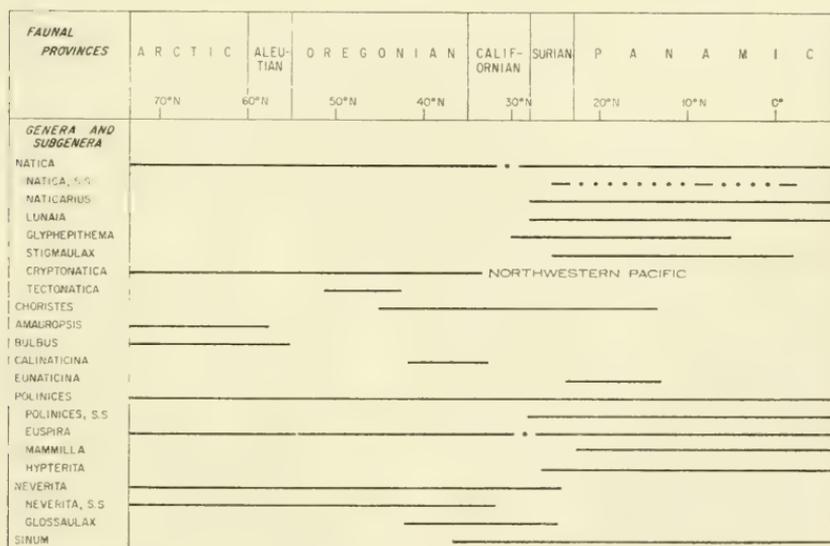
The first occurrence of *N. (C.) clausa* is in lower Miocene beds in Alaska, then in middle Miocene strata of Oregon, and in upper Miocene beds of northern California and Washington (Text-fig. 8). In middle Pliocene strata it occurs extensively throughout central California, and reached southern California during the late Pliocene. By the late Pleistocene it ranged into northern Baja California, farther south than its present range limit in offshore southern California. Its occasional presence in Neogene faunas of temperate aspect is probably due to upwelling cool water. Paleontologic evidence thus indicates a northern origin for *N. (C.) clausa* and *N. (C.) oregonensis* and suggests that *Cryptonatica* has long been established in cold hydroclimates.

Fossil specimens of *Cryptonatica* and *Tectonatica* have smaller and thinner shells than do modern specimens of the same species. The largest fossil of *N. (C.) clausa*, from the Pliocene of northern Washington, is 47 mm high and 46 mm in diameter and has a slightly thinner shell than an equivalent living specimen. The largest living specimen, from Alaska, measures 61 mm high and 54 mm in diameter. Similarly, the largest modern specimen of *N. (T.) janthostoma* is

57.4 mm \times 50.0 mm, whereas the largest fossil (lower Pliocene of Oregon) measures 34.3 mm \times 34.6 mm. The middle Miocene to early Pliocene species *N. (G.) oregonensis* attained 37.1 mm \times 29.6 mm but averaged about 24 mm \times 19 mm.

The northern Naticinae are distinct from the southern (tropical) species not only in thermal tolerance but also in general shell morphology. The modern *Cryptonatica* and *Tectonatica* species are larger and more globose, with proportionately thicker shells, more plainly ornamented opercula and drabber colors than species in southern subgenera. These distinctions have existed since at least the early Miocene and have been increasingly emphasized through time, judging by the size differences between fossil and modern specimens of the same species.

The northeastern Pacific Polinicinae generic taxa occur in a greater variety of marine climatic zones than do those of the Naticinae, although there is still some provincial segregation by subgenus (Text-fig. 4). Species of *Polinices*, s.s. occur in tropical waters, and some of them range throughout the tropical eastern Pacific. This subgenus is essentially restricted to the tropics worldwide in Cenozoic faunas. *Polinices (Polinices) panamaensis* (Récluz) is re-



Text-figure 4. Modern distribution of naticid generic taxa in degrees of latitude and in relation to shallow-water faunal provinces of the northeastern Pacific. Unconfirmed range data shown as dotted lines.

ported south of the tropics in the cool-water Peruvian faunal province, but the specimens on which this record is based have a somewhat different umbilical callus morphology than tropical specimens and may belong to a different species and even subgenus.

The subgenus *Euspira* shows a greater climatic range than *Polinices*, *s.s.* but is divided into an exclusively bathyal to abyssal southern group and a mainly neritic northern warm-temperate to Arctic group which do not overlap in distribution. The southern group consists of four obscurely known, deep-water species represented by little more than primary type material and they live in cold bottom waters. The northern *Euspira* group includes three relatively common species that range into shallow water. *Polinices (Euspira) draconis* (Dall) and *P. (E.) lewisii* (Gould) are large (the latter attains 166 mm height \times 131 mm diameter), closely related to each other, and have geologic histories that can be confidently traced to late Miocene ancestors in California. They are not closely related to the other northern *Euspira*, *P. (E.) pallidus* (Broderip and Sowerby), or to the southern deep-water *Euspiras*.

The tropical subgenera *Mammilla* and *Hypterita* are each represented by one species in the eastern Pacific. *Hypterita* includes only two described species, the type species, *Polinices (Hypterita) helicoides* (Gray) of the eastern Pacific, and the Miocene *P. (H.) nereidis* (Maury) from the Dominican Republic and Costa Rica (Woodring, 1957). *Mammilla* is represented only by *P. (M.) caprae* (Philippi) in the eastern Pacific but contains a number of species in the western Pacific. This species and *Eunaticina insculpta* (Carpenter) are the only Indo-Pacific representatives among north-eastern Pacific Naticidae. It is reported as a Pleistocene fossil in southwestern Mexico (Palmer and Hertlein, 1936).

Neverita, *s.s.* is essentially a northern temperate subgenus, with two obscure and one well-known species living in this region. The relatively rare Arctic species *N. (N.) nana* (Möller) occurs as far south as northern Baja California, but does so by living at progressively greater depths southward to maintain itself in bottom water of Arctic temperature, and *N. (N.) lamonae* Marinovich lives in bathyal depths from British Columbia to Oregon. The subgenus *Glossaulax* is represented only by *N. (G.) reclusiana* (Deshayes) which occurs in hydroclimates from cool-temperate to tropical. It is

found in middle Eocene to Holocene faunas in a bewildering variety of intergrading forms and is closely related to Tertiary species I have seen in collections from Japan, the Caribbean area, Central America, and western South America south to Chile.

Sinum, as elsewhere, is confined mainly to the tropics, although the most commonly collected species, *S. scopulosum* (Conrad), lives largely in a warm-temperate hydroclimate and even ranges slightly into temperate waters. It seems to have lived in an equally broad range of environments from the middle Oligocene onward, remaining a persistent if not common faunal element. None of the living Panamic *Sinums* is known as a fossil north of its present range.

There are five naticids with circumpolar distributions (Text-fig. 3). Of these, *Natica* (*Cryptonatica*) *clausa* Broderip and Sowerby and *Polinices* (*Euspira*) *pallidus* (Broderip and Sowerby) occur in Miocene deposits in the eastern Pacific and in Pliocene or Pleistocene strata in the northern Atlantic, suggesting a Pacific origin for both. As *Bulbus fragilis* (Leach) occurs in upper Pliocene beds in Alaska and in Pleistocene strata of Britain, this species also may have originated in the Pacific. *Amauropsis islandica* (Gmelin) and *Neverita* (*Neverita*) *nana* (Möller) are reported in Pleistocene beds in Britain but are unknown as fossils in the Pacific, suggesting an Atlantic origin. A northern migration also is probable for the north-eastern Pacific species *Polinices* (*Euspira*) *lewisii* (Gould) and the northwestern Atlantic *P. (E.) heros* (Say). Because *P. (E.) lewisii* apparently evolved from *P. (E.) galianoi* Dall in the northeastern Pacific during the early Pliocene (Text-fig. 9), *P. (E.) heros* is probably descended from *P. (E.) lewisii* by way of an eastward trans-Arctic migration in the early Pliocene or later.

Faunal migrations between the Pacific and Atlantic apparently took place during the episodic late Pliocene to Holocene openings of Bering Strait, as documented by Hopkins (1967a, 1967b) and Durham and MacNeil (1967). The earliest opening of Bering Strait took place in about late Miocene time, followed by closure and re-opening during the late Pliocene. The Bering seaway may have been intermittently open and closed since the late Pliocene (Durham and MacNeil, 1967). The naticid species noted here apparently migrated between oceans after the second major opening of Bering Strait, during the late Pliocene or later.

Comparisons of naticids from the northeastern and northwestern Pacific are difficult to make because little critical taxonomic work has been done on species of the latter area. For example, there are at least 14 nominal species in the Miocene to Holocene Japanese literature that are similar or identical to *Neverita* (*Glossaulax*) *reclusiana* (Deshayes) of the northeastern Pacific. There is also a vast and confusing array of Japanese Cenozoic Euspiras whose relationships have yet to be critically studied. Because the present west to east oceanic circulation along the north Pacific margin has prevailed since at least the Late Cretaceous (Sliter, 1972), many Cenozoic naticids of the northeastern Pacific have ancestors and relatives in Japan and adjacent areas. Meaningful comparison of the naticid faunas of the circumnorth Pacific must await a similar review of the northwestern Pacific species.

Expectably, several living tropical naticids of the eastern Pacific and Caribbean are closely related (Table 1). Other species-pairs may be recognized once the poorly known Caribbean naticid fauna is more carefully reviewed. During most of Tertiary time, essentially a single molluscan fauna lived in the Central American region, and the present-day isthmus was a series of islands. This geography persisted until the end of Miocene time (Emerson, 1967) or perhaps later (Woodring, 1966; Olsson, 1972), when tectonic uplift produced the present land connection between North America and South America. The modern tropical eastern Pacific and Caribbean molluscan faunas in large part have a common origin in the Central American Miocene fauna, as reflected in the number of homologous naticids in the two faunas. There is no known naticid species common to both modern faunas.

The tropical eastern Pacific naticid fauna, then, is largely derived from a more cosmopolitan Central American early and middle Tertiary fauna, owing only one species to migration from the Indo-Pacific region. This agrees with the general trend noted by Emerson (1967) for the eastern Pacific molluscan fauna to have a large Caribbean element and a minor Indo-Pacific one. As noted here, relatively few naticids are thought to have been introduced across the Arctic region from the North Atlantic. Thus, the eastern Pacific

tropical naticids have a more cosmopolitan ancestry, and the warm-temperate to cool-temperate species are more provincial. As will be discussed below, the lineages of many temperate-water northeastern Pacific naticids can be traced at least through endemic early and middle Tertiary ancestors.

TABLE 1. HOMOLOGOUS TROPICAL EASTERN PACIFIC AND CARIBBEAN NATICIDS.

TROPICAL EASTERN PACIFIC SPECIES	CARIBBEAN SPECIES
<i>Natica (Stigmaulax) broderipiana</i>	<i>Natica (Stigmaulax) cayennensis</i>
<i>Natica (Naticarius) chemnitzii</i>	<i>Natica (Naticarius) marochiensis</i>
<i>Natica (Glypheapithema) idiopoma</i>	<i>Natica (Glypheapithema) floridiana</i>
<i>Polinices (Polinices) otis</i>	<i>Polinices (Polinices) hepaticus</i>
<i>Polinices (Polinices) uber</i>	<i>Polinices (Polinices) lacteus</i>
<i>Sinum debile</i>	<i>Sinum perspectivum</i>

PALEOBIOGEOGRAPHY

The paleobiogeographic potential of naticids in this region derives from their dominant occurrence in the tropics, as demonstrated in the modern northeastern Pacific (Text-figs. 3, 4), and their common occurrence in widespread Cenozoic fossil deposits representing shallow-water, soft-bottom environments. Because the coastline of the western United States occupies about 15 degrees of latitude (about 33° N. to 48° N.) immediately north of the tropics (Text-fig. 2), it is well situated to record fluctuations of the tropical-extratropical boundary during former periods of warmer marine climate. Migrations of warm-water naticid taxa into higher latitudes at times during the Cenozoic have recorded periodic northward incursions of tropical seas.

Although general Cenozoic climatic trends have been described for the northeastern Pacific, as noted earlier, the development of shallow-water faunal provinces has not been well documented. Smith (1919), mainly using mollusks, noted the apparent beginnings of provincialism in western America in the Oligocene and its occurrence in later epochs, but essentially no further documentation has since been added. The accurate placement of Tertiary provincial boundaries and a history of their movements would require comprehensive faunal reviews. However, the history of a diverse and widespread group such as Naticidae does indicate the possible occurrence of provincialism in California during the late Paleocene and its more widespread presence in the late Eocene and later.

UPPER PALEOCENE

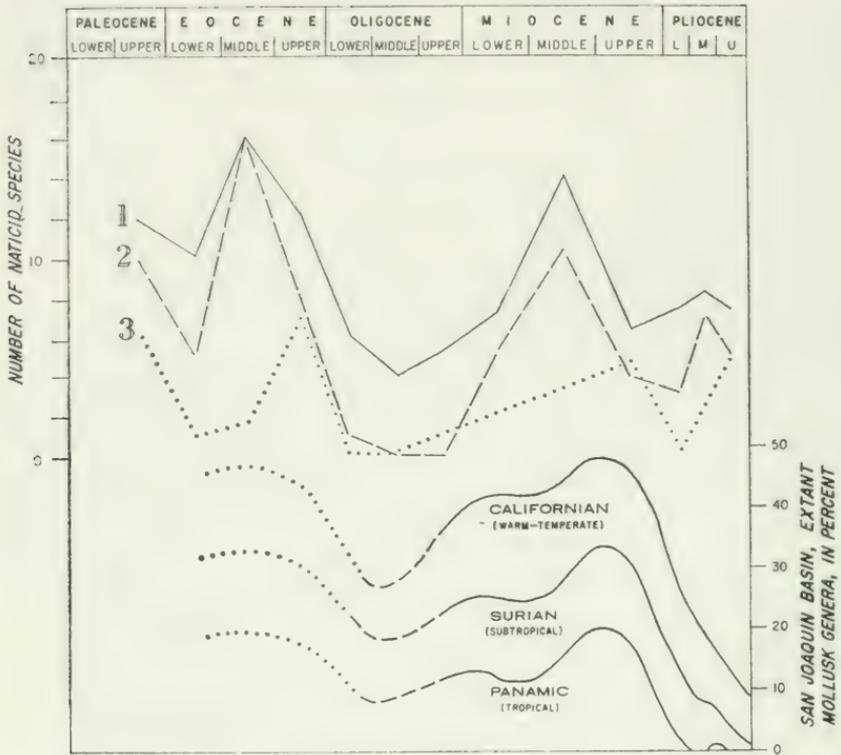
SPECIES	Martinez Formation, Simi Hills, Ventura County, California	Lodo Formation, Fresno County, central California	Martinez Formation type area, Contra Costa County, northern California	Meganos Formation type area, Contra Costa County, northern California
<u>Crommium pinyonensis</u> -----	x	x	---	---
<u>Ampullospira susanaensis</u> -----	x	---	---	---
<u>Amauroopsis martinezensis</u> -----	x	---	x	---
<u>Lacunaria striata</u> -----	x	x	x	---
<u>Gyrodes robustus</u> -----	x	---	---	---
<u>Polinices (Polinices) gesteri</u> ---	---	---	---	x
<u>Polinices (Polinices) hornii</u> ----	x	---	x	x
<u>Polinices (Polinices)</u>				
<u>susanaensis</u> -----	x	x	---	---
<u>Polinices (Euspira) nuciformis</u> --	---	x	---	x
<u>Polinices (Euspira) simiensis</u> ---	x	x	---	---
<u>Neverita (Neverita) globosa</u> -----	---	---	---	x
<u>Neverita (Neverita)</u>				
<u>washingtonensis</u> -----	---	x	---	---

Table 2. Occurrence of upper Paleocene naticid species at four localities in California.

For this discussion of naticid paleobiogeography, the west coast of the United States is arbitrarily divided into four areas: southern and central California, northern California, Oregon, and Washington (Text-fig. 2). Tertiary naticids north and south of this region are poorly known and not considered here. These four areas make up a coastline of about 1,900 kilometres (1,200 miles) and climatic gradients along it during the Tertiary were steep enough to promote provincialism among the naticids. Tables 2 to 6 show the known occurrences of naticid species during each subepoch. Paleocene data are given for California only, as Paleocene mollusks are not known in Oregon or Washington.

Table 2 shows the known Paleocene naticid fauna of southern and central California to be about twice as large as that of northern California, not surprising in view of the tropical affinities of the family. This difference may be due to climatic or geographic factors but may be in part an artifact of the northern formations having received less study. The mollusks of the Santa Susana Formation (Zinsmeister, 1974b) and Lodo Formation (Smith, 1975) have recently been reexamined, but those of the approximately coeval formations in northern California (Dickerson, 1914b; Clark and Woodford, 1927) are in need of restudy. No species is common to all four areas of upper Paleocene outcrops, and each of the faunas contains tropical taxa. Characteristically tropical ampullospirine and *Polinices*, *s.s.* species are especially well represented and abundant in the Simi Hills and are much less abundant to the north, whereas temperate-water taxa such as *Euspira* and *Neverita*, *s.s.* are relatively better represented in central and northern California. The known occurrences of late Paleocene naticids thus possibly indicate a strongly tropical fauna in southern California distinct from subtropical to warm-temperate faunas in northern California. Of special interest is *Gyrodus robustus* Waring in the Simi Hills strata, representative of a genus characteristic of Cretaceous strata worldwide but rare in Tertiary rocks.

Eocene strata along the margin of western North America are much more common than Paleocene rocks and generally contain a larger naticid fauna (Table 3). However, the early Eocene naticid fauna was greatly reduced from what it had been in the late Paleocene (Text-figs. 5, 6, 7). There were apparently no early Eocene



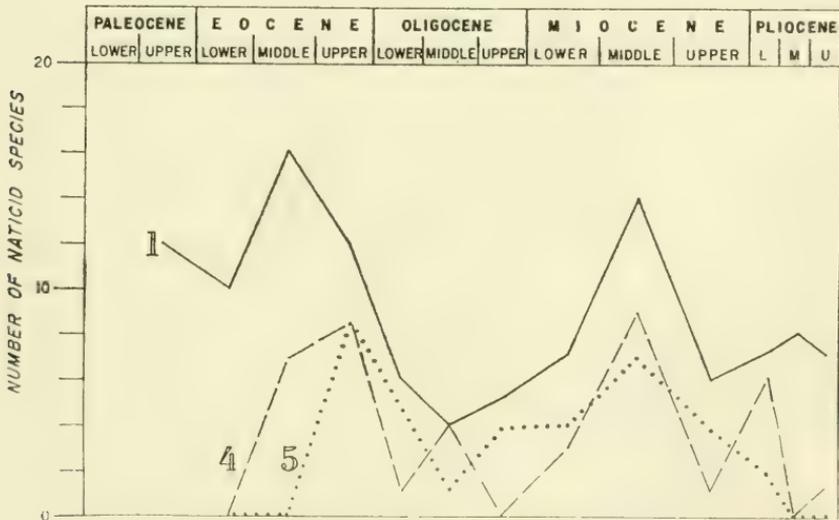
Text-figure 5. Species diversity of Tertiary Naticidae along the coast of the western United States, compared with idealized zoogeographic profiles for the Tertiary San Joaquin basin of southern California: curve 1, total naticid fauna of California, Oregon, and Washington; curve 2, central and southern California species only; curve 3, northern California species only. San Joaquin basin profiles from Addicott (1970b). Compare with Text-figure 6.

naticids in Washington and Oregon, only one in northern California, and five in southern and central California. Environmental stresses were such that the family retreated from higher latitudes it had occupied in the late Paleocene and was well represented only in southern and central California and presumably farther south. The sole naticid in northern California belongs in the temperate subgenus *Euspira*, whereas three of the five more southerly species are in characteristically tropical taxa.

In response to apparent climatic warming during the middle Eocene, naticids went through their greatest known burst of species diversity in this region: the number of species in southern and central California more than tripled, and seven species (mostly tropical)

lived as far north as Oregon, where apparently none had lived in the early Eocene. The faunal change in the intervening area of northern California, where one temperate species was replaced by two tropical ones, was not as dramatic but still signified a warmer climate. Unknown geographic or oceanographic factors may have discouraged proliferation of species in this area. No naticids had as yet appeared in Washington. The marked middle Eocene increase in naticid species was largely among tropical and subtropical taxa, with the remainder among temperate taxa. The dominantly tropical subfamily Naticinae made its earliest Cenozoic appearance in this region with three species in southern and central California. Middle Eocene naticid faunas were, therefore, of decidedly tropical aspect and apparently were best developed in southern and central California and in Oregon, with only two species in northern California, and none in Washington. Because all of the Oregon species occurred in California, naticids offer no evidence for faunal provincialism in the middle Eocene.

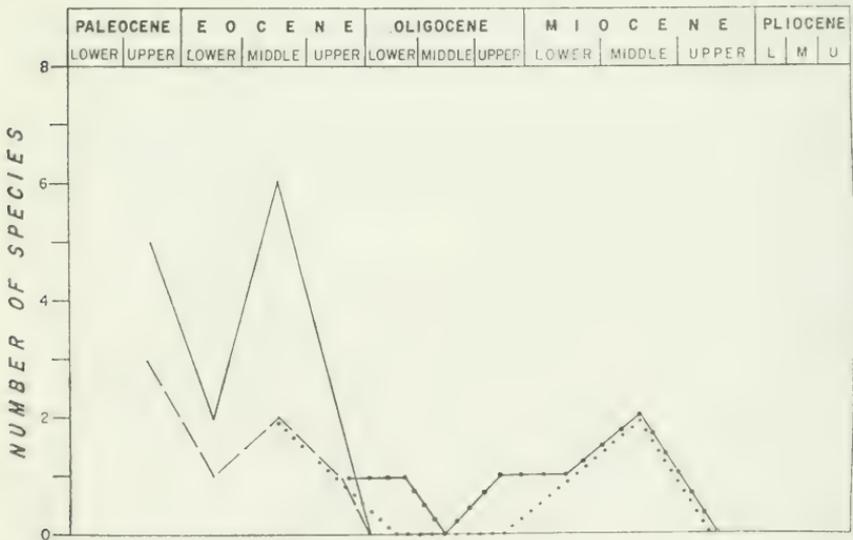
Following their diversity peak in the middle Eocene, there were major readjustments among naticids in the late Eocene. There was



Text-figure 6. Species diversity of Tertiary Naticidae along the coast of the western United States: curve 1, total naticid fauna of California, Oregon, and Washington; curve 4, Oregon species only; curve 5, Washington species only. Compare with Text-figure 5.

a general reduction of tropical species, especially sharp in southern and central California, and more species in higher latitudes, particularly in Washington. All seven species that became extinct between middle and late Eocene were in tropical taxa (*Ampullospirinae*, *Polinices*, *s.s.*, *Naticarius*) and their extinction reduced the southern and central California fauna by half. All ampullospirines north of central California were eliminated except for *Pachycrommium clarki* Stewart in Washington, and this reduction was especially severe in Oregon, where ampullospirines had made up more than half of the known naticid fauna. Accompanying the general extinction of tropical species throughout this region was the occurrence for the first time of temperate species in large numbers, especially in areas north of central California. This increase was most dramatic in Washington, where nine late Eocene species comprise the earliest Cenozoic naticids known north of Oregon.

The distribution of late Eocene Naticidae strongly suggests faunal provincialism in this region. Although each of the four areas had about the same number of species (Table 3), there was an apparent division between the fauna of the three northern areas and



Text-figure 7. Tertiary species diversity of selected tropical and subtropical naticid taxa in the western United States: solid line, *Ampullospirinae*; dashed line, *Polinices, s.s.*; dotted line, *Naticarius*; dashed and dotted line, *Natica, s.s.*

that of central and southern California. The three northern areas shared essentially the same fauna of mainly temperate species with the uncommon to rare occurrence of one or two tropical species, whereas half of the southern and central California fauna was of tropical species that were common to abundant and the other half was of temperate species that mostly occurred in much larger numbers to the north. Based on naticid distributions, the provincial boundary between a southern tropical fauna and a northern warm-temperate to subtropical fauna was at about 36° to 37° north latitude in present-day central California.

The transition from late Eocene to early Oligocene completed the extinction of many taxa, especially tropical ones, which had declined steeply from their middle Eocene diversity peaks (Text-fig. 7). Ampullospirines, *Polinices*, *s.s.*, and *Naticarius* became regionally extinct, the last taxon reappearing briefly in these latitudes only during the middle Miocene warming episode. Several presumably warm-temperate species of *Euspira* and *Neverita*, *s.s.* also died out and were partly replaced by additional *Euspiras*. The early Oligocene faunas from southern California to Oregon were apparently decimated, being reduced to one species at most, whereas five species survived in Washington. The small number of species known south of Washington (Text-figs. 5, 6) is surprising in view of the warm-water affinities of naticids and may result more from vagaries of preservation and collecting than from climatic and geographic factors. Considering that all of the Washington species belong in temperate to tropical generic taxa that should have been even better represented in the presumably warmer waters of California, a preservation or collecting bias is probable.

There are equally puzzling occurrences of species in middle and upper Oligocene strata from Washington to California (Table 4). Most middle Oligocene naticids are known from Oregon, with none from farther south and only one species from Washington, whereas most late Oligocene species are known from Washington with only one to the south in northern California. These occurrences are at odds with patterns of naticid distribution in modern seas and conflict with naticid paleobiogeographic trends throughout the rest of the Cenozoic in this region. The known occurrences of Oligocene naticids in this region probably do not faithfully represent original

Table 3. Occurrence of Eocene naticid species in California, Oregon, and Washington.
EOCENE

SPECIES	Southern and Central California		Northern California		Oregon		Washington		
	Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
<u>Crommium pinyonensis</u>	-	X	-	-	-	-	-	-	-
<u>Crommium andersoni</u>	-	X	-	-	-	X	-	-	-
<u>Tejonia moragaj</u>	-	X	X	-	X	-	-	-	-
<u>Pachycrommium clarki</u>	-	X	X	-	X	-	-	-	X
<u>Amaurellina caleocia</u>	-	X	-	-	-	-	-	-	-
<u>Euspirocrommium hewitti</u>	X	-	-	-	-	-	-	-	-
<u>Eocernina hannibali</u>	X	X	-	X	-	X	-	-	-
<u>Polinices (Polinices) gesteri</u>	X	X	-	-	-	-	-	-	-
<u>Polinices (Polinices) hornii</u>	-	X	X	-	X	-	X	-	X
<u>Polinices (Euspira) clementensis</u>	-	X	-	-	-	-	X	-	-
<u>Polinices (Euspira) holtoni</u>	-	-	-	-	-	-	X	-	X
<u>Polinices (Euspira) nuciformis</u>	X	X	X	-	X	-	X	-	X
<u>Neverita (Neverita) globosa</u>	-	X	X	-	X	-	X	-	X
<u>Neverita (Neverita) washingtonensis</u>	X	-	-	-	-	-	X	-	X
<u>Neverita (Glossaulax) reclusiana</u>	-	X	X	-	-	-	X	-	X
<u>Sinum obliquum</u>	-	X	X	-	-	-	X	-	X
<u>Natica (Natica) weaveri</u>	-	-	-	-	-	-	X	-	X
<u>Natica (Naticarius) domingiana</u>	-	X	-	-	-	-	-	-	-
<u>Natica (Naticarius) uvasana</u>	-	X	X	-	-	-	-	-	-
<u>Natica (Carinacca) rosenis</u>	-	X	-	-	-	-	-	-	-

Table 4. Occurrence of Oligocene naticid species in California, Oregon, and Washington.

SPECIES	OLIGOCENE											
	Southern and Central California						Oregon			Washington		
	Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper
<u>Polinices (Euspira) b'akeleyensis</u> -----	-	-	-	-	-	-	-	-	-	-	-	X
<u>Polinices (Euspira) lincolnensis</u> -----	-	-	-	-	-	-	-	X	-	-	X	-
<u>Polinices (Euspira) ramonensis</u> -----	-	-	-	-	-	X	-	-	-	-	-	-
<u>Neverita (Heverita) washingtonensis</u> -----	-	-	-	-	-	-	-	X	-	-	X	-
<u>Neverita (Glossaulax) reclusiana</u> -----	X	-	-	-	-	-	-	X	-	-	-	X
<u>Sinum obliquum</u> -----	-	-	-	-	-	-	-	-	-	-	X	-
<u>Sinum scopulosum</u> -----	-	-	-	-	-	-	-	X	-	-	X	-
<u>Natica (Natica) kanakoffi</u> -----	-	-	-	-	-	-	-	-	-	-	-	X
<u>Natica (Natica) weaveri</u> -----	-	-	-	-	-	-	X	-	-	-	-	-

patterns of distribution. Taking the data as a whole, however, a general upward trend in species diversity is seen after a low point in the early Oligocene.

Five early Miocene naticids are known from southern and central California, two species from northern California, three from Oregon, and four from Washington (Table 5). One of them, *Natica (Tectonatica) gabbi* Clark, is found from Washington to northern California and belongs in a subgenus confined to cool hydroclimates in the modern northwestern Pacific. It may, therefore, be an indicator, however slight, of an early Miocene provincial division located between northern California and the area to the south. The small known early Miocene naticid fauna may be an artifact of poor preservation and lack of collecting, as is probably the case for Oligocene faunas.

Naticids of the middle Miocene represent a Cenozoic peak of diversity and abundance second only to that of the middle Eocene (Text-figs. 5, 6, 7, Table 5). Although the total number of species in this region increased only by four, two of the new species belong to the tropical subgenus *Naticarius*, and the other two (*Euspiras*) are associated with warm-temperate molluscan faunas. A climatic thermal maximum (Addicott, 1968, 1969, 1970b) was responsible for this middle Miocene proliferation and resulted in flourishing naticid faunas from southern California to Washington. Tropical taxa were clearly not so well established as they had been in the middle Eocene (Text-fig. 7) but were definitely present throughout the region (Table 5). The best evidence for faunal provincialism at this time is the first Cenozoic appearance of the Arctic subgenus *Cryptonatica* in Oregon and Washington. In addition, three other species are common to Oregon and Washington that did not occur farther south. There may thus have been a provincial boundary between present-day Oregon and northern California. A second provincial boundary separating northern California, with its small naticid fauna, and southern and central California with its large fauna, may also have existed. The three northern California species occur farther south but they all belong to temperate subgenera, whereas the larger southern and central California fauna contains at least two tropical species. One of these species, *Natica (Naticarius) posuncula* Hanna and Hertlein, was abundant and is likely to have existed in

Table 5. Occurrence of Miocene naticid species in California, Oregon, and Washington.

SPECIES	MIOCENE									
	Southern and Central California		Northern California		Oregon		Washington			
	Lower	Middle	Upper	Lower	Middle	Upper	Lower	Middle	Upper	
<u>Polinices (Euspira) diabloensis</u>	-	-	X	-	-	-	-	-	-	X
<u>Polinices (Euspira) galianoi</u>	-	X	-	-	X	-	-	-	X	X
<u>Polinices (Euspira) lincolnensis</u>	X	X	-	-	-	X	-	X	X	-
<u>Polinices (Euspira) pallidus</u>	-	X	-	-	-	-	-	-	-	-
<u>Neverita (Neverita) kirkensis</u>	-	-	X	-	-	-	-	-	-	-
<u>Neverita (Glossaulax) andersoni</u>	X	X	X	-	X	X	-	X	-	-
<u>Neverita (Glossaulax) jamesae</u>	-	X	-	-	-	-	X	-	-	-
<u>Neverita (Glossaulax) reclusiana</u>	X	X	-	-	-	-	-	-	-	X
<u>Sinum perrini</u>	-	X	-	-	-	-	-	-	-	-
<u>Sinum scopulosum</u>	X	X	X	X	X	X	-	X	X	X
<u>Natica (Natica) clarki</u>	-	-	-	-	-	X	-	-	-	-
<u>Natica (Natica) kanakoffi</u>	X	-	-	-	-	X	-	X	X	-
<u>Natica (Naticarius) posuncula</u>	-	X	-	-	-	-	-	-	-	-
<u>Natica (Naticarius) teglandis</u>	-	X	-	-	-	X	-	X	-	-
<u>Natica (Cryptonatica) clausa</u>	-	-	-	-	-	X	-	-	-	X
<u>Natica (Cryptonatica) oregonensis</u>	-	-	-	-	-	-	-	X	-	-
<u>Natica (Tectonatica) gaboi</u>	-	-	-	X	-	-	X	-	-	-

northern California were conditions warm enough. Naticids thus suggest the presence of three molluscan provinces during the middle Miocene.

The total number of species dropped off sharply during the late Miocene in response to a cooling trend (Text-figs. 5, 6, 7). Because there were only six species living within the region, naticid distributions do not clearly show provincialism. The cold-water species *Natica (Cryptonatica) clausa* Broderip and Sowerby had moved as far south as northern California, from its middle Miocene southern range limit of Oregon, and may possibly indicate a provincial division between southern and central California and the areas to the north. However, species that had occurred abundantly in warm-water middle Miocene faunas, such as *Polinices (Euspira) galianoi* Dall, still were found as far north as Washington and do not suggest a strong climatic difference between northern and southern areas. A warm-temperate climate may have prevailed throughout the region, with the cold-water *N. (C.) clausa* present in northern shallow-water faunas due to upwelling.

The beginning of the Pliocene saw the extinction of *Neverita (Glossaulax) andersoni* (Clark), one of the species that had flourished during the middle Miocene thermal peak then declined afterward. The three early Pliocene species in southern and central California are all extant and indicate a temperate hydroclimate. The lack of early Pliocene naticids in northern California is due to an absence of suitable strata. Three of the six Oregon species are in the subgenera *Cryptonatica* and *Tectonatica*, which are distinctly cold-water taxa in the modern north Pacific, and two of the three are still living. There was almost certainly a provincial division between Oregon and California, but the absence of naticids from northern California makes placement of the provincial boundary uncertain. The early Pliocene hydroclimate in Oregon was as cool as today's or cooler.

Middle Pliocene naticid distributions are different from those of the early Pliocene (Table 6), as most species are known from southern and central California and none from north of northern California. Six of the seven southern and central California species are extant and five of them indicate a probable warm-temperate hydroclimate. The exception is *Natica (Cryptonatica) clausa*, a cold-water species probably introduced into the fauna by nearshore up-

welling of cold bottom water. The presence in the small northern California fauna of *Natica (Tectonatica) janthostoma* Deshayes as well as *N. (C.) clausa* suggests a cooler hydroclimate (temperate to cold-temperate) than prevailed in southern and central California. Middle Pliocene naticids are not known for sure north of California for lack of outcropping strata or uncertain age assignments of some formations. Occurrences of species in the late Pliocene were not notably different from those of the middle Pliocene and indicate no significant marine hydroclimatic changes. The most notable event at this time was the extinction of *Polinices (Euspira) galianoi* Dall, the last survivor of the several species that flourished during the middle Miocene climatic peak.

Pleistocene naticid paleobiogeography is largely unknown along the western coast of North America because most Pleistocene deposits of this region represent rocky shore environments in which naticids did not occur. Records of Pleistocene species are thus spotty and inadequate for discussion. Late Pleistocene molluscan provinces for the region from northern California to Baja California have been described by Valentine (1961) and Addicott (1966b).

PALEOCLIMATIC INFERENCES

The regional distribution of modern naticid species and generic taxa is so strongly influenced by water temperature that the range end-points of many taxa correspond to established zoogeographic boundaries (Text-figs. 3, 4). Because living naticids constitute a largely tropical family, the boundary between tropical and temperate provinces is especially well marked by changes among the genera, subgenera, and species. Many generic taxa and a few species have lived in this region continuously since the early Tertiary and aid in making inferences about Cenozoic shallow-water hydroclimates. Such inferences correlate well with the Tertiary climatic trends and attendant faunal changes described for the northeastern Pacific by Smith (1919) and refined by Durham (1950b) and Addicott (1968, 1969, 1970b).

Paleocene to middle Eocene shallow-water marine climates in this region (Text-fig. 5) have not yet been well documented in megafaunal studies, but were apparently characterized by tropical to subtropical larger invertebrates (Smith, 1919; Durham, 1950b;

Givens, 1974; Zinsmeister, 1974b) and benthic foraminifers (Mallory, 1959). Better megafaunal data are available for the late Eocene and younger epochs (Addicott, 1970b; Givens, 1974) which show a late Eocene cooling trend that continued into the early and middle Oligocene before reaching its thermal minimum. After the middle Oligocene there was a more or less steadily warming climate that peaked in the middle Miocene and was followed by a sharp cooling trend through the late Miocene and Pliocene (Text-fig. 5).

Early Tertiary naticid faunas of California, Oregon, and Washington were characterized by several Ampullospirinae species, some of which occurred abundantly; none survived past the Eocene. This subfamily is represented today in the eastern Pacific only by the circum-boreal *Amauropsis islandica* (Gmelin) which was introduced from the north Atlantic in the Pleistocene. Several *Amauropsis* species live in the Antarctic and Subantarctic region (Powell, 1951), and the subfamily is otherwise known in modern seas only by *Globularia fluctuata* (Sowerby, 1825) of the Philippine Islands. Most living ampullospirines occur in frigid seas, but virtually all Mesozoic and early Tertiary species are found in tropical and subtropical faunas. The disappearance of this subfamily from the northeastern Pacific at the end of the Eocene is clearly related to the sharp cooling episode of the late Eocene and early Oligocene. Because most extinct ampullospirines were clearly tropical animals, their presumed temperature preferences are expressed not by the several living *Amauropsis* species of polar regions but by the sole *Globularia* of the tropics.

In the northeastern Pacific north of Mexico, Paleocene marine strata crop out only in California and a small area in south-central Alaska (Addicott and Plafker, 1971), and naticids are known only from the California deposits. Of the 13 known upper Paleocene naticids from California, five species are Ampullospirinae, seven Polinicinae, and one Sininae. Associated molluscan faunas include numerous genera with tropical and subtropical affinities (e.g., *Glycymeris*, *Pinna*, *Propeamussium*, *Harpa*, *Volutocorbis*, *Pseudoliva*) and benthonic foraminifers also indicate warm surface waters (Mallory, 1959). Among the Polinicinae, generic taxa present are *Neverita*, *s.s.*, *Euspira*, and *Polinices*, *s.s.* The first two live mostly in temperate environments. *Polinices*, *s.s.*, however, is found exclusively in the

modern tropics (Text-fig. 4) and apparently occurs in Cenozoic deposits only in tropical faunas. The presence of *Polinices* (*Polinices*) *gesteri* (Dickerson), *P. (P.) hornii* (Gabb), and *P. (P.) susanaensis* Nelson during the late Paleocene in California is evidence for a tropical or subtropical climate. Five ampullospirine species in these faunas are further evidence for a tropical to subtropical late Paleocene climate.

Eocene strata of this region are much more widespread than Paleocene rocks and crop out extensively in California, Oregon, and Washington. Eocene naticids maintained the tropical to subtropical character they had in the late Paleocene but did show important changes within the epoch, as noted below. Ampullospirines showed the strongest changes from the Paleocene to Eocene: four of the five Paleocene species became extinct, and the sole survivor was joined by three new species. Besides being reduced to four species (Text-figure 7), early Eocene ampullospirines were also less abundant than their Paleocene counterparts. None of the early Eocene species occurred in great numbers, with the possible exception of *Eocernina hannibali* (Dickerson), whose stratigraphic range in lower Eocene rocks is not well documented. The nearly complete turnover in the ampullospirine fauna, plus reduction of species and populations during the early Eocene suggests less favorable conditions for this subfamily at the beginning of the Eocene. As tropical to subtropical conditions during the early Eocene are suggested by both megafossils (Vokes, 1939; Durham, 1950b; Givens, 1974) and benthic foraminifers (Mallory, 1959) in California and Washington, there was no apparent climatic shift to account for changes in the ampullospirids.

Early Eocene Polinicinae species, unlike ampullospirines, remained largely unchanged from the late Paleocene: two species became extinct and five continued into the Eocene, with no new species added. Two of the three species in the tropical subgenus *Polinices*, s.s. continued through the early Eocene, indicating continued warm water but verified early Eocene specimens belonging to this subgenus are not known north of California. In Sininae, *Sinum obliquum* (Gabb) first appeared during the early Eocene as the earliest known *Sinum* in the northeastern Pacific. Because living *Sinums* are almost all tropical, the appearance of *S. obliquum* may be taken as another expression of tropical conditions, although this species ap-

parently gave rise in the Oligocene to *S. scopulosum* (Conrad), a species that now ranges into temperate seas.

Cenozoic naticids of western North America were most diverse during the middle Eocene. Three additional species of Ampullospirinae, two of Polinicinae, and three of Naticinae made their first appearances, expanding the middle Eocene naticid fauna to 17 species. All of the new species occur in California and most are found in Oregon and Washington. The three *Natica* species are most significant, because they mark the earliest occurrence of Naticinae in the northeastern Pacific Tertiary. These Naticinae belong to subgenera found only in the tropics today and their presence during the middle Eocene suggests a warm climatic peak in this region that was not approached again until the middle Miocene. Further support for a middle Eocene thermal peak is given by three new ampullospirine species (Text-figure 7). The two Polinicinae that appeared in the middle Eocene are not especially suggestive of warm climates, although the subgenera to which they belong range into warm regions today. One of the new middle Eocene species, *Neverita (Glossaulax) reclusiana* (Deshayes), still lives abundantly in California and Mexico and is the longest-lived naticid in this region. A middle Eocene temperature rise in this region has been suggested (Addicott, 1970b) but is not yet well documented. Its occurrence based on naticids requires confirmation on broader faunal grounds and more precise definition of this climatic event would require better stratigraphic control of collections than was possible in this study.

At the close of the middle Eocene, naticid species were reduced from 17 to 13 and the naticid fauna became less strongly tropical. Only two of the six ampullospirines survived into the late Eocene, and the survivors were restricted in geographic range and abundance. For example, *Tejonia moragai* (Stewart) is found in middle Eocene rocks from southwestern Oregon to southern California, but occurs in upper Eocene deposits only in southern California. Naticinae species declined from three in the middle Eocene to two in the late Eocene by the extinction of two species and the appearance of a new one. The newly added species, *Natica (Natica) weaveri* Tegland, occurs anomalously in cool-water faunas of Oregon and Washington despite belonging to a characteristically tropical subgenus. The other Naticinae species, *Natica (Naticarius) wasana* Gabb, occurs with

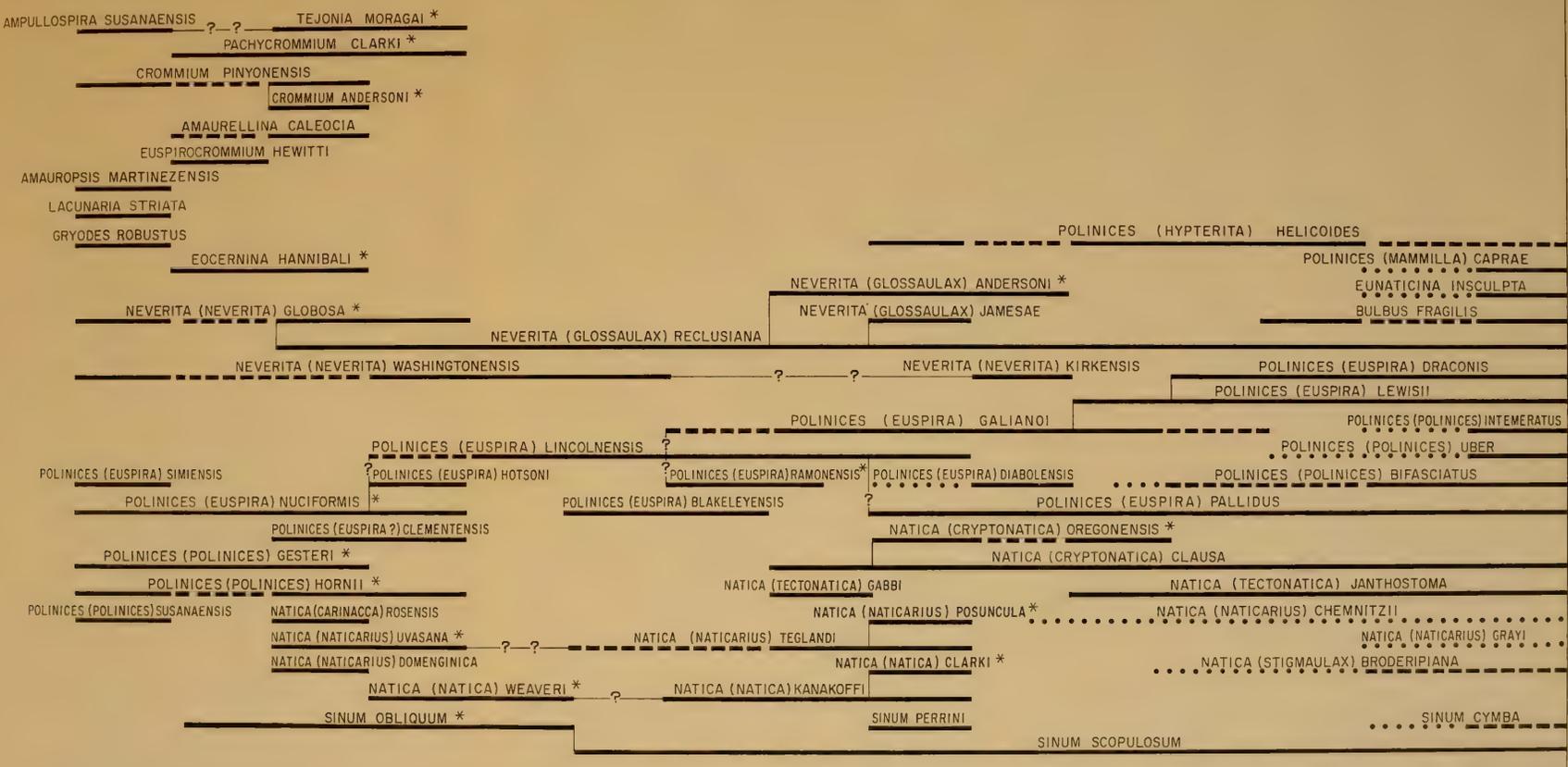
other tropical mollusks in southern California. In the Polinicinae the most significant late Eocene event was the extinction of the tropical species *Polinices (Polinices) gesteri* (Dickerson) which may be another sign of climatic cooling. The significance of two new Polinicinae in the subgenus *Euspira* is less clear because living *Euspiras* occur in warm-temperate to Arctic seas, although they prefer temperate regions.

The greatest extinction among Cenozoic naticids of western North America occurred at the close of the Eocene, when the fauna was reduced from 13 to five species (Text-figs. 5, 6). The last of the Ampullospirinae disappeared and only one Naticinae, one Sininae, and three Polinicinae species survived into the early Oligocene. The only early Oligocene *Natica*, as noted above, anomalously occurred only in distinctly cool-water faunas and three Polinicinae species indicate a climate no warmer than warm-temperate. Early Oligocene naticids in general suggest a distinctly cooler shallow-water hydroclimate than that in the late Eocene, which is in accord with previous inferences (Smith, 1919; Durham, 1950b; Addicott, 1970b), although naticids may have been more strongly affected than other groups. Addicott (1970b) inferred about 10-15 percent tropical molluscan genera in the early Oligocene fauna of the San Joaquin basin of southern California (Text-fig. 5), whereas no characteristically tropical naticids occurred there at the time.

The most significant event among middle Oligocene naticids was the appearance of one *Naticarius* and one *Natica*, *s.s.* species; both subgenera are restricted to the modern tropics. The extant warm-temperate species *Sinum scopulosum* (Conrad) also first appeared at this time. Middle Oligocene naticids of this region had a somewhat warmer water aspect than early Oligocene species, and this was carried through the late Oligocene without major change.

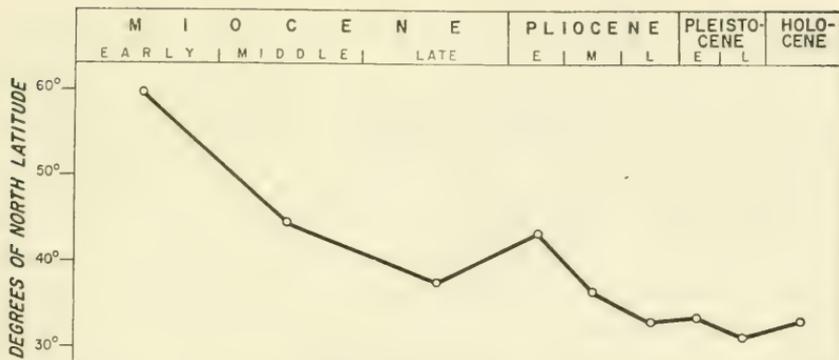
The early Miocene fauna was increased by two species of the Polinicinae subgenus *Glossaulax* which lives mainly in warm-temperate to subtropical climates, and one new *Cryptonatica* and *Tectonatica* among the Naticinae. *Tectonatica* today is reported from the tropics to the Arctic in the North Atlantic, but in the Pacific is reported only from about Kamchatka to Korea. The new *Cryptonatica* is *Natica (Cryptonatica) clausa* Broderip and Sowerby which occurs in many upper Cenozoic deposits of western North America

PALEOCENE		E O C E N E			OLIGOCENE			MIOCENE			PLIOCENE			PLEISTOCENE	
LOWER	UPPER	LOWER	MIDDLE	UPPER	LOWER	MIDDLE	UPPER	LOWER	MIDDLE	UPPER	LOWER	MIDDLE	UPPER	LOWER	UPPER



Text-figure 9. Stratigraphic ranges and inferred phylogenetic relationships of northeastern Pacific Cenozoic naticids. For stratigraphic ranges, heavy solid lines are based on identifiable specimens I have examined, dashed lines on imperfectly preserved specimens or reliable literature records, and dotted lines

on less reliable literature records. Inferred lines of descent are given as thin horizontal and vertical lines, with question marks added where relationships are less certain. Asterisks denote species especially useful as biostratigraphic indicators.



Text-figure 8. Southernmost known occurrence in the northeastern Pacific of the Arctic species *Natica (Cryptonatica) clausa* at intervals from early Miocene to Holocene.

and lives today only in water of Arctic temperature. It was present during the early Miocene only in the Gulf of Alaska, and it is not found in association with warm-water naticids of that age farther south. In the early Miocene climatic cooling was taking place in Alaska that would later extend to lower latitudes, and the first occurrence of *N. (C.) clausa* marks the beginning of this cooling episode. The progressive southward migration of *N. (C.) clausa* in western North America from Alaska to northern Baja California (Text-fig. 8) corroborates the inferred steadily cooling late Cenozoic climate. In summary, except in Alaska the early Miocene naticids indicate a warm-temperate to subtropical climate equivalent to or somewhat warmer than the late Oligocene climate.

Middle Miocene naticids show an influx of tropical genera and subgenera such as occurred in the middle Eocene, although this later warming episode is less pronounced than the earlier one. New species of *Natica*, *s.s.*, *Naticarius*, and *Sinum* agree well with Addicott's (1969, 1970b) evidence for a middle Miocene warm peak in California basins. Two additional *Polinices* species at this time occurred in warm-water faunas of California, and one of them, *Polinices (Euspira) pallidus* (Broderip and Sowerby), has since become restricted to cold water. A new *Cryptonatica* in the middle strata of Washington and Oregon is at odds with a warmer climate, but the species is not common and its apparently anomalous occurrence in warm-water faunas may be a result of inshore upwelling of cold

bottom water, or it may be a manifestation of exaggerated latitudinal temperature gradients.

At the end of the middle Miocene, naticid species were reduced from 15 to nine, and all of the distinctly tropical taxa were eliminated. The surviving Polinicinae subgenera *Glossaulax* and *Euspira* indicate probable warm-temperate conditions. The end of the Miocene saw further reduction of naticid species, and the Pliocene survivors are mostly still living. The living cold-water species *Natica* (*Tectonica*) *janthostoma* Deshayes first appears in lower Pliocene deposits of Oregon and Washington. After the middle Pliocene there were no major changes in the naticid fauna of this region, except for the introduction of *Amauropsis islandica* (Gmelin) from the north Atlantic in the Pleistocene and the migration of *Natica* (*Tectonica*) *janthostoma* Deshayes from the eastern Pacific to the northwestern Pacific at about the same time.

It is clear that the distribution of western North American Cenozoic Naticidae was strongly influenced by climate. Paleoclimatic inferences based solely on the distribution of naticid generic taxa in modern seas agree remarkably well with Cenozoic paleoclimatic trends inferred in broader faunal studies of both megafossils and microfossils. With the demonstrated utility of some naticids as climatic indicators, stratigraphically well-controlled collecting will now permit better resolution of climatic events than was previously possible.

BIOSTRATIGRAPHY AND INFERRED PHYLOGENETIC RELATIONS

The stratigraphic occurrences of northeastern Pacific Cenozoic naticids and their inferred phylogenetic relationships are presented in Text-figure 9. Recording stratigraphic occurrences is seemingly the most straightforward part of a study such as this but in fact relies heavily on subjective appraisals much of the time. The ranges given here as based mainly on specimens I have seen, with the addition of literature citations. Even for examined specimens, however, I must rely on accompanying labels for information on geographic and stratigraphic location which may be vague or incorrect. Many specimens examined for this study were useless for lack of sufficient collecting data. In many cases where I accept literature

citations I have examined the author's original specimens to certify the identity of the species.

A further problem concerns imprecisely known ages of some formations and conflicting age interpretations of a given formation depending on whether one relies on megafossils, benthic foraminifers, or planktonic organisms for age assignment. The Cenozoic time-stratigraphic framework presently used in western North America is being revised in the light of intercontinental correlations based on planktonic microfossils. In most cases the megafossils and benthic foraminifers agree as to provincial age assignments but may be at odds with interprovincial ages based on planktonic microfossils. Planktonic age assignments are still novel and not yet widely accepted by specialists dealing with nonplanktonic organisms, and there is still disagreement even among planktonic specialists as to exact placement of many Cenozoic time boundaries. For this reason, provincial age assignments based on megafossils and benthic foraminifers (Kleinpell, 1938; Weaver, *et al.*, 1944; Addicott, 1972) are used here. Even if age assignments based on planktonic organisms become universally accepted, the relative ages of most formations will remain unchanged. Even where the series/epoch assignment of a naticid species might be changed, its position in an evolutionary (or a stratigraphic) sequence will not be affected. The inferred phylogenetic relationships given here would then remain essentially unaltered. In any case, because of my reliance mainly on locality registers and, at times, on museum labels for stratigraphic data, the occurrence of most Cenozoic naticids cannot be determined more precisely than subepoch (subseries).

AMPULLOSPIRINAE

Cenozoic ampullospirines in western North America are known only from Paleocene and Eocene formations (Text-figs. 7, 9). There was a large ampullospirine fauna during the Cretaceous in this region (Gabb, 1864; Waring, 1917; Packard, 1922; Stewart, 1927; Anderson, 1958; Murphy and Rodda, 1960), with several species similar to those of the Tertiary. Most, if not all, Tertiary ampullospirines of this region probably evolved from indigenous Cretaceous ancestors. But, because Cretaceous naticids of this region have never been comprehensively reviewed, their taxonomic and exact stratigraphic relations are unclear, making it difficult to recognize lineages

that might have continued into the Tertiary. In addition, ampullospirine generic nomenclature worldwide is so confused that there are seemingly as many genera as species, adding to the problem of discerning systematic order. For these reasons, inferred relationships among ampullospirines are less certain than those within other naticid subfamilies.

The earliest known Cenozoic ampullospirines in western North America are five late Paleocene species from California, four of which are not known in younger strata. The most distinctive of these is *Gyrodes robustus* Waring, the only Cenozoic *Gyrodes* known in this region and representative of a genus that had its heyday in the Late Cretaceous. It is most similar to the Late Cretaceous species *G. conradiana* (Gabb) of northern and central California. A second late Paleocene species, *Ampullospira susanaensis* Nelson, looks much like the Late Cretaceous *Amauropsis pseudoalveata* Packard, and both may lie in the ancestry of the middle to late Eocene species *Tejonina moragai* (Stewart). Whatever their relationships to Cretaceous species, most of the late Paleocene ampullospirines do not occur in younger rocks and help to distinguish the limited upper Paleocene deposits in California from other Cenozoic strata.

Of the four known early Eocene ampullospirines, only one also occurred in upper Paleocene rocks. The other three species all have well-developed morphologic characters that indicate no close relationships with any of the Paleocene species. One of the three species, *Eocernina hannibali* (Dickerson), locally occurs in prolific numbers and is similar in form to *Neritoma woodfordi* Allison that is described from middle Cretaceous beds in northwestern Baja California. Although *N. woodfordi* is only about half the size of *E. hannibali* and was described in the family Neritidae, it appears to be a naticid and may lie in the ancestry of *E. hannibali*. *Euspirocrommium hewitti* (Hanna and Hertlein) is the only ampullospirine restricted to lower Eocene deposits, but it does not occur widely or commonly enough to be a useful guide fossil.

With six middle Eocene species, ampullospirines of western North America reached their Cenozoic peak of diversity. Only one species, *Crommium andersoni* (Dickerson), is restricted to middle Eocene deposits, but this species and three others occur commonly from Oregon to southern California. *Crommium andersoni*, which

differs from *C. pinyonensis* (Dickerson) mainly by having a much larger umbilical opening, is almost certainly derived from that species; they occur together in the Domengine Formation in central and southern California as well as separately elsewhere. *Tejonia moragai* may be related to *Ampullospira susanaensis* of the late Paleocene and *Amauropsis pseudoalveata* of the Late Cretaceous, as noted above. All three are similar in form, but there are no known early Eocene specimens linking *T. moragai* with an earlier species. *Pachycrommium clarki* Stewart first occurred in middle Eocene strata and may be locally abundant but is seemingly unrelated to other Eocene or Paleocene species. It may have evolved from a regional Late Cretaceous species unfamiliar to me, or have been introduced from another region.

The extinction of most ampullospirines at the close of the middle Eocene (Text-figs. 7, 9) left only two surviving species, *Tejonia moragai* and *Pachycrommium clarki*, the latter ranging from Washington to southern California. However, these late Eocene species occur commonly only in southern California.

POLINICINAE

Polinicinae, Sininae, and Naticinae have Cenozoic lineages as old as that of Ampullospirinae, and are well represented in Cenozoic strata and in modern seas of this region. *Polinices* is well represented in upper Paleocene strata by five species, three of which are in the tropical subgenus *Polinices*, *s.s.* As there are apparently no species of *Polinices*, *s.s.* in Cretaceous strata of this region, these three species probably migrated into this region from farther south, perhaps from as far away as the Central American Tertiary province. One species, *P. (P.) susanaensis* Nelson, is known only from upper Paleocene rocks of central and southern California. The other two species, *P. (P.) hornii* (Gabb) and *P. (P.) gesteri* (Dickerson), range through the late and middle Eocene, respectively, and are distinctive species useful for recognizing lower Tertiary strata; *P. (P.) hornii* was especially widespread at times during the Eocene (Table 3).

The polinicine subgenus *Euspira* occurs throughout north-eastern Pacific Cenozoic strata and includes several species with restricted stratigraphic ranges. *Polinices (Euspira) nuciformis* (Gabb) is the most common lower Tertiary *Euspira*, occurring con-

sistently in many formations and prolifically in the upper Eocene Cowlitz Formation of Washington. It apparently gave rise to *P. (E.) simiensis* Nelson by elongation of the shell and near closure of the umbilicus. The latter species is known only in upper Paleocene beds but is not common and has been found only in central and southern California. The next *Euspira* to appear in western North America was *P. (E.) clementensis* (Hanna) which is apparently not closely related to the *P. (E.) nuciformis* lineage. Because *P. (E.) clementensis* is abundant only in the bathyal deposits of the Keasey Formation in Oregon, its ancestry may derive from deep-water species not often preserved as fossils. The only certain Eocene offshoot of *P. (E.) nuciformis* is the late Eocene *P. (E.) hotsoni* Weaver and Palmer. This species occurs most abundantly in the Cowlitz Formation, as does *P. (E.) nuciformis*, but is uncommon elsewhere.

At the close of the Eocene, *P. (E.) nuciformis* died out but may have given rise then to *P. (E.) lincolnensis* (Weaver). Although their morphologies are similar, there are no known specimens intermediate between the two species, and their presumed relationship is based on their stratigraphic occurrences. The first appearance of *P. (E.) blakeleyensis* Tegland during the middle or late Oligocene in Washington may have been by introduction from the northwestern Pacific, as there were no similar northeastern Pacific species at that time. It is known from little more than the holotype, so has no utility as a guide fossil.

Near the end of the Oligocene *P. (E.) lincolnensis* may have given rise to *P. (E.) ramonensis* (Clark) and *P. (E.) galianoi* Dall, but these relationships are uncertain because the three shell forms are distinctive and do not intergrade. It is just as likely that the two species had origins in the diverse Japanese Oligocene fauna, especially as the earliest appearance of each is in Alaskan formations and there are several similar middle Tertiary Japanese *Euspiras*. *Polinices (Euspira) ramonensis* is the only Tertiary naticid with a fairly narrow stratigraphic range (Text-fig. 9) that occurs in Alaska as well as in states farther south (Washington and northern California), thereby helping to date deposits in the Gulf of Alaska Tertiary province.

During the Miocene, *P. (E.) lincolnensis* probably gave rise to *P. (E.) pallidus* (Broderip and Sowerby) and *P. (E.) diabloensis*

(Clark). All three are similar in appearance and are found in Miocene deposits of central and southern California. The first two species occurred together in southern California during the middle Miocene, after which *P. (E.) lincolnensis* became extinct and *P. (E.) pallidus* continued to the present. Since the earliest report of *P. (E.) pallidus* in Japan is in lower and middle Pliocene beds (Yokoyama, 1920), it probably did not evolve in the northwestern Pacific. The limited stratigraphic occurrence of *P. (E.) diabloensis* in central and northern California makes it a potential guide fossil, although it is known from only a few specimens.

Whatever the origin of *P. (E.) galianoii*, as noted above, it was a long-lived species that apparently gave rise to *P. (E.) lewisii* (Gould) during the Pliocene. The latter species still lives in temperate waters of this region and may have given rise via trans-Arctic migration to *P. (E.) heros* (Say) of the modern northwestern Atlantic fauna. *Polinices (Euspira) draconis* (Dall) clearly evolved from *P. (E.) lewisii* during the middle Pliocene. These two species are similar in appearance as adults and are often indistinguishable as early juveniles in modern populations.

The polinicine genus *Neverita* is first known regionally in upper Paleocene beds by two species, *Neverita (Neverita) washingtonensis* (Weaver) and *N. (N.) globosa* Gabb. The first species survived through the middle Oligocene, apparently without giving rise to other species. However, *N. (N.) kirkensis* (Clark) of the late Miocene is so nearly indistinguishable from *N. (N.) washingtonensis* that the later species is almost certainly descended from the earlier one, although there are no connecting specimens in upper Oligocene to middle Miocene strata. As a less likely alternative, *N. (N.) kirkensis* may have been introduced from the northwestern Pacific. Its occurrence in upper Miocene rocks throughout northern and central California makes it a useful guide fossil.

The second Paleocene *Neverita*, *N. (N.) globosa*, apparently gave rise to a complex lineage of numerous species that in the middle and late Tertiary populated regions as widely separated as Japan, western South America, the Caribbean area, and the northwestern Atlantic. This species occurs uncommonly in upper Paleocene beds in northern California, more commonly in middle Eocene deposits as far north as Oregon, and abundantly from Washington to southern

California in upper Eocene rocks, before dying out at the end of the Eocene. In the middle Eocene it gave rise to *Neverita* (*Glossaulax*) *reclusiana* (Deshayes) which is the earliest known species assigned to *Glossaulax*. As discussed in the systematics section, *N. (G.) reclusiana*, an extant species, encompasses a broad range of intergrading varieties that have no apparent ecologic, biogeographic or stratigraphic value but have occurred persistently throughout its history. This was the only species of *Glossaulax* during the Oligocene of this region, but at the start of the Miocene it gave rise to *N. (G.) andersoni* (Clark). This species is characteristic of Miocene deposits throughout California and locally occurs in great numbers, making it a reliable marker for the Miocene. In the middle Miocene, *N. (G.) jamesae* Moore emerged as a distinct species from the *N. (G.) reclusiana* complex. It is found only in middle Miocene strata from Washington to southern California, but because it occurs uncommonly it has limited value as a guide fossil.

Among polinicine subgenera, *Hypterita* and *Mammilla* are each known by one living species in the tropical eastern Pacific, and each has a sparse fossil record there. *Polinices (Hypterita) helicoides* (Gray) occurs in middle Miocene to Pliocene beds of Central America (Woodring, 1957) and Pleistocene strata of Ecuador (Hertlein and Strong, 1955b). Its only known relative is *P. (H.) nereidis* Maury from Miocene rocks of the Dominican Republic. The strongly depressed shell and atypical umbilical callus (Pl. 36, figs. 1-4) of this species are distinctive and show no apparent relation to other polinicine taxa; the origin of this subgenus is unknown. *Mammilla* has a fossil record in the northeastern Pacific based on one Pleistocene specimen of *P. (M.) caprae* (Philippi) reported by Hertlein and Strong (1955b) from southwestern Mexico. This subgenus occurs today as several species in the Indo-Pacific region, from where *P. (M.) caprae* migrated during the Pleistocene.

SININAE

Sininae is represented in the Tertiary of western North America by only three species; the earliest is *Sinum obliquum* (Gabb) of the Eocene and early Oligocene. Its origin is unknown and because most living Siniums are found only in the tropics, *S. obliquum* may have been introduced from the south. There are no known Cretaceous

Sinums in the marginal northeastern Pacific. *Sinum obliquum* was the only *Sinum* species in this region until the end of the early Oligocene, when it was replaced by *S. scopulosum* (Conrad). These two species are similar in general shape but have consistent sculptural differences, and there can be little doubt that *S. scopulosum* evolved from *S. obliquum*. The final early Oligocene presence of *S. obliquum* was in Washington, as was the first appearance of *S. scopulosum*. *Sinum scopulosum* has remained a generally uncommon but persistent faunal element to the present. *Sinum perrini* (Arnold) is known by only one specimen from middle Miocene strata in southern California, and its extremely elongate shape clearly distinguishes it from *S. scopulosum*, to which it is not closely related. As was the case with *S. obliquum*, *S. perrini* was likely introduced from the south.

Eunaticina is represented by only one species living in the northeastern Pacific which has a short fossil record. The tropical species *E. insculpta* (Carpenter) is known in Pleistocene deposits of Baja California and western Mexico (Jordan in Hertlein, 1934). Because most living *Eunaticina* species occur in the Indo-Pacific region, *E. insculpta* may be a migrant from there. But as the genus is also known living in the West Indies, this species could have evolved from an ancestor in the Caribbean Tertiary fauna, although *Eunaticina* is not reported from that fauna by Woodring (1957). The consistent presence of spiral sculpture in *Eunaticina* and *Sinum* suggests a close relationship between them, and *Eunaticina* may have been a late Cenozoic offshoot of *Sinum*.

NATICINAE

The Cenozoic history of Naticinae in western North America has included a less diverse and continuous array of species than has that of Polinicinae. Because naticine species are predominantly tropical, they have lived in this region mostly at times when tropical or subtropical hydroclimates prevailed. They first occurred here during the middle Eocene as three clearly distinct species that were certainly introduced from tropical waters to the south. Two of these species are in the subgenus *Naticarius* which is represented in the Caribbean Tertiary province by several species (Olsson, 1922; Woodring, 1957). Two of the three middle Eocene species became extinct at the end of that subepoch (Text-figs. 7, 9), but both are

rare and not useful as guide fossils. The third species, *Natica* (*Naticarius*) *wasana* Gabb, continued to the end of the Eocene in southern California and is found commonly enough that it may be used as a middle and late Eocene marker.

The only naticine species in the early Oligocene was *Natica* (*Natica*) *weaveri* Tegland, which had first appeared during the late Eocene. It belongs in a different subgenus than the three middle Eocene *Naticas* and also likely entered this region as a migrant from the south. It may be used as a guide fossil in Washington and Oregon, where it occurs commonly in some formations. Although it died out at the end of the early Oligocene, it may have given rise to the late Oligocene to middle Miocene *N. (N.) kanakoffi* Marincovich which also occurred fairly commonly in Washington and Oregon. A third Tertiary species of *Natica*, *s.s.*, *N. (N.) clarki* Etherington, lived in Washington and Oregon during the middle Miocene. It may have evolved from *N. (N.) kanakoffi*, but its morphology differs enough from that species that it is more likely to have migrated to these middle latitudes from the south. Miocene species of *Natica*, *s.s.* from the Caribbean Tertiary province are illustrated by Olsson (1922) and Woodring (1957).

In the middle Oligocene, *Naticarius* reappeared in western North America as *N. (N.) teglandae* Hanna and Hertlein, occurring rarely in Washington and southern California. This species either migrated from the south or evolved from the similar *N. (N.) wasana* of the middle and late Eocene, although there are no connecting specimens in the lower Oligocene to link the two. *Natica* (*Naticarius*) *teglandae* persisted through the middle Miocene, when it apparently gave rise to *N. (N.) posuncula* Hanna and Hertlein, which is locally common in middle Miocene beds throughout central and southern California and is a useful guide fossil. The middle Miocene marked the last occurrence of tropical naticine species in western North America due to the onset of climatic cooling.

The first appearance of *Tectonatica* in western North America was *N. (T.) gabbi* Clark during the early Miocene in northern California. As no likely ancestors are known in the northeastern Pacific, *N. gabbi* was probably introduced from the northwestern Pacific. It is known only by its three primary type specimens, so if it was introduced from the Japanese fauna it did not maintain itself in the

northeastern Pacific for long. *Tectonatica* did not reappear in western North America until the early Pliocene, as *N. (T.) janthostoma* Deshayes. This species first occurred in Washington and Oregon and, as discussed in the systematics section, is an offshoot of *N. (T.) janthostomoides* (Kuroda and Habe), which has a Miocene to Holocene history in Japanese seas. Thus, *N. (T.) janthostoma* is certainly a migrant from the northwestern Pacific.

The related subgenus *Cryptonatica* is represented by the early Miocene to Holocene species *N. (C.) clausa* Broderip and Sowerby which is first known in southern Alaska but moved steadily southward during the Cenozoic as far as northern Baja California (Text-fig. 8). Its origin is unknown, and because it has no likely ancestor in the northeastern Pacific, it may have early Tertiary relatives in the northwestern Pacific fauna; *N. (N.) clausa* itself apparently has not been reported as a fossil in Japan. In the middle Miocene in Washington and Oregon this species gave rise to *N. (C.) oregonensis* (Conrad) which survived in Oregon through the early Pliocene. The fortuitous find of three specimens with calcareous opercula in place or nearly so (Pl. 42, fig. 9) confirms the placement of this species in *Cryptonatica* and reinforces its relationship to *N. (C.) clausa*.

Several living tropical naticids in the polinicine subgenus *Polinices*, *s.s.* and the naticine subgenera *Naticarius* and *Stigmaulax* have brief late Cenozoic histories (Text-fig. 9). They are closely related to species of the middle Tertiary to Holocene Caribbean fauna, as discussed in the section on biogeography.

The Tertiary history of naticids in the northeastern Pacific shows most species, especially Polinicinae species, evolving from indigenous ancestors, with the occasional introduction of temperate species from the northwestern Pacific and of tropical species from the south. Species in the modern fauna have histories that began as long ago as middle Eocene [*Neverita (Glossaulax) reclusiana*] or as recently as Pleistocene.

OPERCULAR OBSERVATIONS

Two of the modern tropical species, *Natica (Stigmaulax) broderipiana* Récluz and *N. (S.) elenae* Récluz, show an apparent functional relationship between the sculpture of the operculum and the shape of the umbilical callus and umbilicus. When the animal is extended, the massive central spiral ridge of the operculum fits

exactly into the curved umbilical opening and also seats itself in the notch excavated by the umbilical sulcus in the inner lip (Pl. 40, figs. 6-9). This relationship is also seen in the Caribbean Miocene *N. (S.) guppiana* (Toula) and the modern Caribbean species *N. (S.) cayennensis* Récluz. This interlocking feature maintains a constant relative position between shell and operculum, perhaps to have the operculum in an optimal position for rapid closure, or perhaps to provide better leverage when the animal is extended from the shell and maneuvering in search of prey or manipulating a prey individual. Laboratory observations of *Stigmaulax* species would probably elucidate this apparent functional relationship, not found in any other fossil or living species treated in this study.

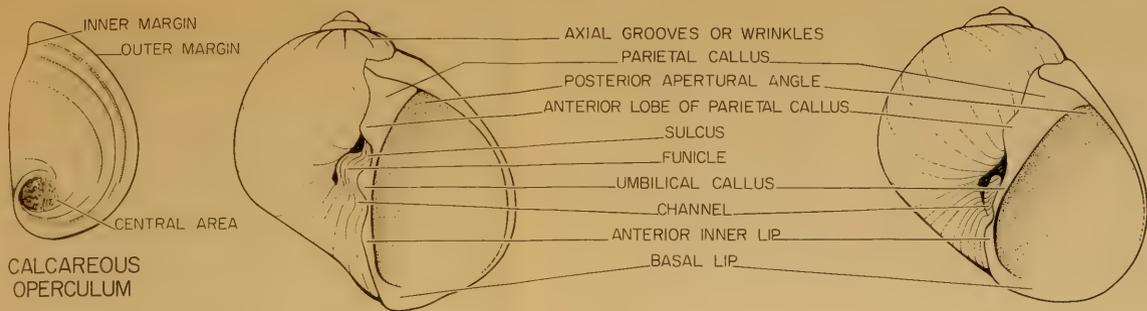
Partially calcified opercula are known in at least two naticid species. Powell (1951) erected *Kerguelenatica* as a subgenus of *Amauropsis* because the operculum of the designated type species, *A. (K.) grisea* (von Martens), is mostly corneous with a thin calcareous coating over the central portion of the outer surface. This feature of *A. (K.) grisea* has been described by Watson (1886) and Clarke (1961). The type species of *Amauropsis*, *A. islandica* (Gmelin), shows no evidence of opercular calcification in hundreds of specimens I have examined. However, one of the tropical species treated here, *Eunaticina insculpta* (Carpenter), has a partially calcified operculum. Whereas the inner surface of the operculum is entirely corneous, most of the outer surface has a thin calcareous coating formed of radial rows of minute, coalesced beads (Pl. 34, fig. 10). The type species of *Eunaticina*, *E. papilla* (Gmelin) of the Indo-Pacific region, is said to have an entirely corneous operculum (Souverbie and Montrouzier, 1874; Oyama, 1969). It would be interesting to know how commonly partially calcified opercula occur in these genera worldwide and to learn whether this is a constant feature through the life of the individual and in all populations.

SYSTEMATIC DESCRIPTIONS

Superfamily **NATICACEA** Forbes, 1838

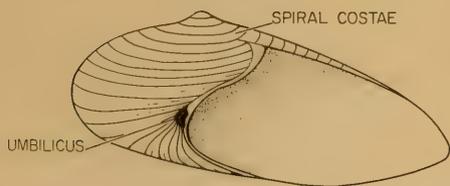
[*Nomen translatum* Thiele, 1929, *ex* Naticidae Forbes, 1838.]

Diagnosis. — Shells globose, ovate-conic or auriform, less commonly elongate; spire usually low to moderately elevated, may be

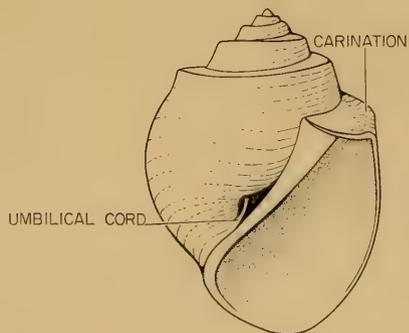


NATICINAE

POLINICINAE



SININAE



AMPULLOSPIRINAE

Text-figure 10. Representative shell forms in the four naticid subfamilies, with morphologic terms used in this report.

strongly elevated; whorls usually smooth but may have axial grooves or spiral costellae; umbilicus open or closed, commonly with a funicle; aperture generally large, oval to semilunar, usually entire; outer lip usually sharp, oblique, columellar lip usually with callus, especially posteriorly; operculum chitinous or calcareous (rarely partly calcified), paucispiral and with eccentric nucleus, rudimentary in some.

Family **NATICIDAE** Forbes, 1838, p. 29

Diagnosis. — With characters of superfamily, in which this is the only family. Morphologic features are shown in Text-figure 10.

Discussion. — Naticids range from Early Jurassic to Holocene (Carriker and Yochelson, 1968; Sohl, 1969a), with at least 300 living species worldwide. A key to the subfamilies follows:

- | | | |
|-----|--|-----------------|
| 1a. | Outer surface of operculum entirely calcareous; shells mostly smooth and umbilicate, with a funicle separated from parietal callus by a sulcus; species with imperforate shells have a semicircular umbilical callus | NATICINAE |
| 1b. | Outer surface of operculum chitinous or with central portion thinly calcareous; shells smooth or with spiral costellae; mostly umbilicate, lacking distinct funicle except rarely | 2 |
| 2a. | Sculpture of bold spiral costellae; shells usually auriform | SININAE |
| 2b. | Shells lacking bold spiral sculpture; shells never auriform | 3 |
| 3a. | Suture often channeled; whorls commonly tabulate; umbilicus often closed or very narrowly open, less commonly broad; umbilical callus usually thin, simple; umbilical area commonly bounded by low basal ridge; operculum chitinous or partly calcareous | AMPULLOSPIRINAE |
| 3b. | Suture rarely channeled; whorls not tabulate; umbilicus usually distinctly open, may be closed; umbilical callus usually thickened posteriorly, may be massive; operculum chitinous | POLINICINAE |

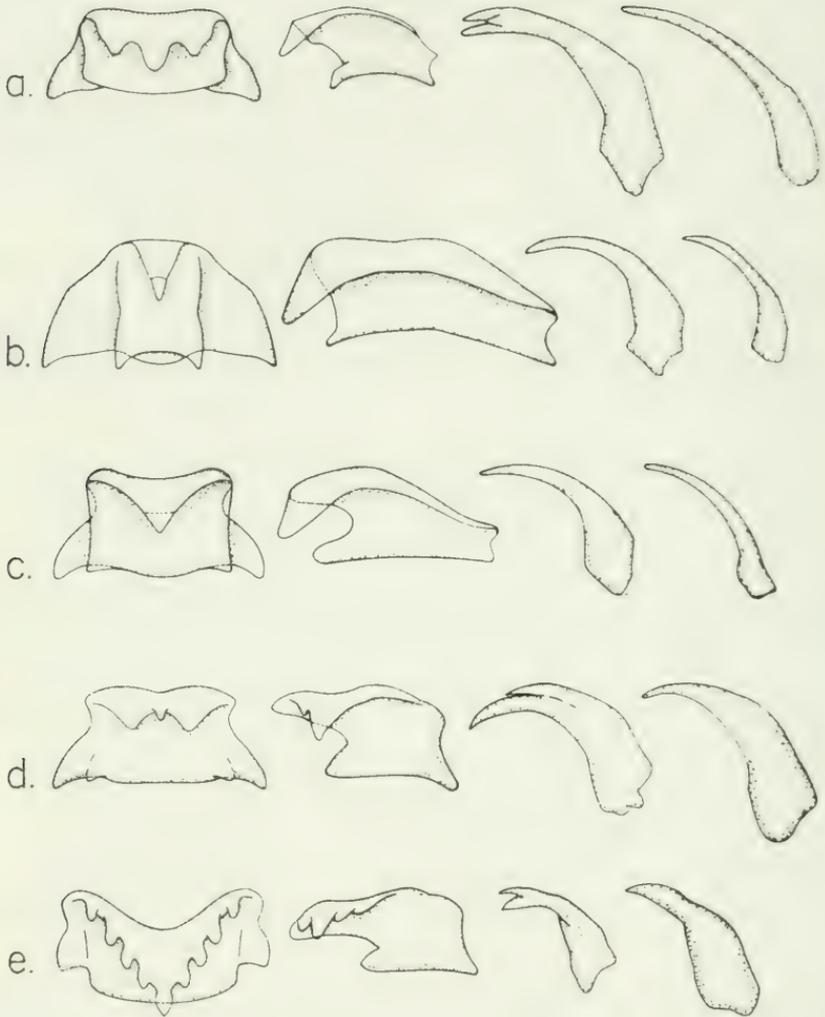
Subfamily **AMPULLOSPIRINAE** Cox, 1930, p. 170

[*Nomen translatum* herein, *ex* Ampullospiridae Cox, 1930.]

[= Euspiridae Cossmann, 1907; Globulariinae and Gyrodinae Wenz, 1941.]

Diagnosis. — Shells globose to elongate, thin- to thick-shelled, spire low to elevated; whorls often tabulate, suture often channeled; whorls smooth or with fine spiral sculpture; umbilicus broadly open to closed, commonly narrow; umbilical callus generally thin and simple, may be thick or absent; umbilical area may be bounded by basal ridge or angulation; operculum entirely chitinous or partly calcareous in living species.

Discussion. — Ampullospirinae is comprised almost entirely of extinct species and was a major worldwide naticid group during the late Mesozoic and early Tertiary. All extinct ampullospirines are associated with tropical or subtropical faunas. However, *Globularia*



Text-figure 11. Varieties of radular dentition found among northeastern Pacific naticids: a, *Neverita (Neverita) lamonae* Marincovich, typical dentition for nearly all Polinicinae and Naticinae in this region, with tricusperate rachidian, one monocuspate lateral tooth, and two simple marginal teeth (the inner of which may have more than one cusp); b, *Choristes carpenteri* Dall, with a monocuspate rachidian, characteristic for the genus; c, *Choristes coani* Marincovich; d, *Sinum cymba* (Menke), showing the small central tooth on a tricusperate rachidian, typical for *Sinum*; e, *Eunaticina insculpta* (Carpenter), with multicusperate rachidian and lateral tooth that are unique among naticids of this region.

fluctuata (Sowerby, 1825) of the Philippine Islands is the only species now living in a marine climate comparable to that of the extinct ampullospirines. The few additional living ampullospirines are *Amauropsis* species restricted to frigid seas and often living at bathyal or greater depths.

The generic systematics and taxonomy of Ampullospirinae are confused and much in need of thorough revision, even in comparison with the poor state of affairs in the other naticid subfamilies. Because ampullospirines are mostly extinct they have received little attention from neontologists, whereas other naticid subfamilies have been studied by both paleontologists and neontologists and are correspondingly better known. Poor preservation of many ampullospirines has further deterred work on them. However, ampullospirines are at least as diverse morphologically as are Naticinae and Polinicinae, and a systematic and taxonomic revision of them would present no greater difficulties than in these other subfamilies. No systematic innovations involving ampullospirine generic taxa are made here, and all generic taxa are treated as full genera, pending a systematic review of the subfamily.

As a group, ampullospirines are distinct from other naticids by their commonly occurring elongate shapes, high spires, channeled sutures, fine spiral sculpture, and unique umbilical features. Genera such as *Amaurellina*, *Tejonia*, *Ampullospira*, and several others have a single slender cord or ridge extending from the anterior inner lip into the umbilicus which is unknown in other naticids. Other ampullospirines have a raised ridge or cord as a basal margin to their umbilical areas, which is absent in the other subfamilies. Umbilical calluses of ampullospirines are generally weakly developed or absent, and no species has a distinct and compact umbilical callus and funicle as in Naticinae.

The order of appearance of ampullospirines in the geologic record relative to the other naticid subfamilies is not yet well documented, but ampullospirines are among the earliest known naticids and are conceivably ancestral to the others. Their generally elongate shapes, tabulate whorls, and channeled sutures may be clues to the ancestral stock from which naticids evolved in the Jurassic.

Ampullospirinae were first segregated as a family-group taxon by Cossmann (1907), who thought they had a different phylo-

genetic origin than Naticidae. He referred to the new family as Euspiridae, following Morris and Lycett's (1851) concept of *Euspira*. However, in their study of English Jurassic mollusks, Morris and Lycett wrongly applied *Euspira*, a polinicine taxon, to ampullospirine shells. In fact, one of their species, *Euspira canaliculata* Morris and Lycett, 1851, has since become type species of *Ampullospira* (Harris, 1897). Euspiridae is thus unavailable as a family-group name for ampullospirines. Many workers after Cossmann (1907) referred to this familial taxon as "Ampullinae," but this combination does not meet accepted criteria for formation of a family-group name (International Code of Zoological Nomenclature, articles 29 and 32c) and was superseded by Ampullospiridae of Cox (1930). Wenz's (1941) Globulariinae and Gyrodinae, proposed as subfamilies of Naticidae, are together equivalent to Cox's Ampullospiridae. Because ampullospirines are treated here as a subfamily of Naticidae, their family-group name is emended to Ampullospirinae.

Genus **AMAUROPSIS** Mörch in Rink, 1857, p. 81

Type species: *Natica helicoides* Johnston, 1835 (= *Nerita islandica* Gmelin, 1791), by subsequent designation (Dall, 1909b, p. 89). Living, circumboreal.

Diagnosis.—Shells small to medium in size, elongate, thin-shelled; whorls laterally compressed to moderately inflated, sculpture of minute spiral costellae; suture distinctly channeled. Umbilicus slitlike. Inner lip slightly thickened, simple, lacking distinct umbilical callus. Parietal callus thin. Operculum chitinous, entirely filling aperture. Radular dentition of tricusgate rachidian, one tricusgate lateral, one bicusgate inner marginal, and one monocusgate outer marginal tooth per half-row.

Discussion.—*Amauropsis* is characterized by its distinctly channeled suture, slitlike umbilicus, fine spiral sculpture, elongate proportions, and thin shell. The channeled suture and elongate shell indicate placement in Ampullospirinae rather than Polinicinae. The radular dentition of the type species diverges from the typical naticid pattern by having a tricusgate rather than a monocusgate lateral tooth. The lateral tooth of the Antarctic *Natica aureolutea* Strebel, 1908, allocated to *Amauropsis* by Powell (1951), is bicuspid. In published illustrations, however, this species appears to lack a channeled suture and might be misplaced in *Amauropsis*.

Powell (1951) proposed *Kerguelenatica* as a subgenus of *Amauropsis*, with the Antarctic type species *Natica grisea* von Martens, 1878. The outer surface of the operculum of this species has a thin calcareous layer over its central portion, with a surrounding chitinous margin which is the diagnostic character of *Kerguelenatica*. However, the two specimens of *N. grisea* figured by Powell (1951) are of globose, rather solid shells lacking channeled sutures which do not appear to belong in *Amauropsis*. *Kerguelenatica* may be more properly treated as a polinicine generic taxon.

In modern seas *Amauropsis* occurs only in northern and southern polar and subpolar regions, although in Tertiary strata it is found in temperate and tropical faunas.

***Amauropsis islandica* (Gmelin, 1791)**

Pl. 17, figs. 1-4;

Pl. 22, fig. 1; Text-fig. 12

Nerita islandica Gmelin, 1791, p. 3675.

Mamma (Amauropsis) islandica (Gmelin), Mörch in Rink, 1857, p. 81.

Natica islandica (Gmelin), Jeffreys, 1867, p. 214; Jeffreys, 1869, p. 215, pl. 78, fig. 1.

Amauropsis islandica (Gmelin), Sars, 1878, p. 156, pl. 21, fig. 17, pl. V, fig. 10, pl. XVIII, fig. 10; Friele & Grieg, 1901, p. iii, 68; Odhner, 1913, pp. 9, 44-46, pl. 4, figs. 29-35; Bousfield, 1960, p. 16, pl. 2, fig. 20; Habe & Ito, 1965, p. 31, pl. 8, fig. 7; MacPherson, 1971, pp. 54-55, pl. 3, fig. 11.

Bulbus (Amauropsis) islandicus (Gmelin), Wenz, 1941, p. 1035, fig. 2965; Kotaka, 1962, p. 134, pl. 33, fig. 16.

Natica helicoides Johnston, 1835, p. 69; Lovén, 1847, p. 149; Middendorff, 1849, pp. 416-419, pl. 7, figs. 8, 9; Forbes & Hanley, 1851, vol. 3, pp. 339-341, vol. 4, pl. 100, fig. 6; not Philippi, 1851, pp. 93-95, pl. 13, figs. 13, 14 [?= *Bulbus*]; Reeve, 1855, pl. 30, fig. 142; Danielssen, 1861, p. 31; Sowerby, 1883, p. 91, pl. 2, fig. 12; Tryon, 1886, p. 53, pl. 22, fig. 31; Gould, 1870, pp. 348-349, fig. 617.

Amauropsis helicoides (Johnston), Dall, 1885, p. 525 [as "Middendorff"].

Natica suturalis Gray, 1839, p. 136, pl. 37, fig. 4; Philippi, 1851, p. 110, pl. 15, fig. 17.

Natica canaliculata Gould, 1839, p. 197; Gould, 1841, pp. 235-236, fig. 161.

Not *Natica canaliculata* Deshayes, 1832, vol. 2, pp. 170-171, Atlas, pl. 21, figs. 9, 10 [fossil, France].

?*Natica gouldii* Philippi, 1845a, pp. 77-78.

Natica gouldii C. B. Adams, 1847, p. 21 [new name for *N. canaliculata* Gould, 1839, not Deshayes, 1832]; Clench & Turner, 1950, p. 288, pl. 41, fig. 12.

Natica cornea Möller, 1842a, p. 80; Möller, 1842b, p. 7.

Natica exulans Gould ex Lovén MS, 1841, p. 235; Jeffreys, 1867, p. 216 [as synonym of *A. islandica*].

Amauropsis purpurea Dall, 1871, p. 124, pl. 15, fig. 16; Dall, 1874, p. 251; Dall, 1885, p. 525; Dall, 1902, p. 551, pl. 38, fig. 9; Dall, 1921, p. 166; Oldroyd, 1927, p. 736; Keen, 1937, p. 29; Burch, 1946, p. 33; MacPherson, 1971, p. 55, pl. 3, fig. 10.

Description. —

Color: Shell exterior and callus white; interior white, sometimes

with pale violet stain. Periostracum thin, medium-yellowish-white to brownish-gray, pale-olive-brown or rust-brown, the colors often axially streaked; earlier whorls often darker.

Size: Average specimen, height 28 mm, diameter 22 mm; largest specimen, height 48.7 mm, diameter 41.9 mm [USNM 11301, Cape Menshikof, Alaska].

Shell form: Shell elongate, spire elevated; body whorl moderately inflated; whorls laterally compressed; shoulder tabulate, rounded; shell thin; whorls about five [apex always eroded!]; suture deeply channeled. Spiral sculpture of minute, low, irregularly spaced costellae and microscopic, wavy, closely spaced lineations; axial sculpture of incremental growth lines. Parietal callus thin, not thickening into posterior apertural angle; lacking anterior lobe. Umbilicus open, extremely narrow and slitlike, usually concealed by periostracum of inner lip margin. Inner lip slightly thickened, simple, lacking umbilical callus. Basal lip thickened.

Operculum: Chitinous, filling aperture.

Specimens examined. — Three hundred sixty-two.

Geographic occurrence and habitat. — Circumboreal. In the eastern Pacific, south to Cape Menshikof, Bristol Bay, Alaska (57°31' N.), apparently unknown in the Aleutians; in the western Pacific, south to the Sea of Okhotsk; in the western Atlantic, south to Chesapeake Bay; in the eastern Atlantic, south to northern England and Ireland. Known on soft bottoms in depths between 9 and 1,267 metres, but primarily in 30 to 60 metres depth; apparently occurs in shallower depths northward, but depth data are few for verified live specimens.

Stratigraphic occurrence. — Reported by Friele and Grieg (1901) "as a fossil in Scandinavia, the British Isles, Canada, Siberia, northern Russia and Spitzbergen," but exact ages of the fossil deposits were not given.

Type localities. —

Nerita islandica — Unknown (Gmelin, 1791).

Natica helicoides — Berwick Bay, Scotland (Johnston, 1835).

Natica suturalis — "North Sea" (Gray, 1839).

Natica canaliculata — Unknown (Gould, 1839).

Natica gouldii — Maine, U.S.A. (Philippi, 1845a).

Natica cornea — Unknown (Möller, 1842a).

Amauropsis purpurea — Saint Michael Sound, Norton Sound, Alaska (Dall, 1871).

Type material. —

Nerita islandica — Unknown, presumably in Linnean Society of London (Dance, 1966).

Natica helicoides — Unknown (Johnston, 1835).

Natica suturalis — Unknown, presumably in BM(NH) (Dance, 1966).

Natica canaliculata — Holotype, MCZ 151080 [inadvertently designated "lectotype" by Clench and Turner, 1950].

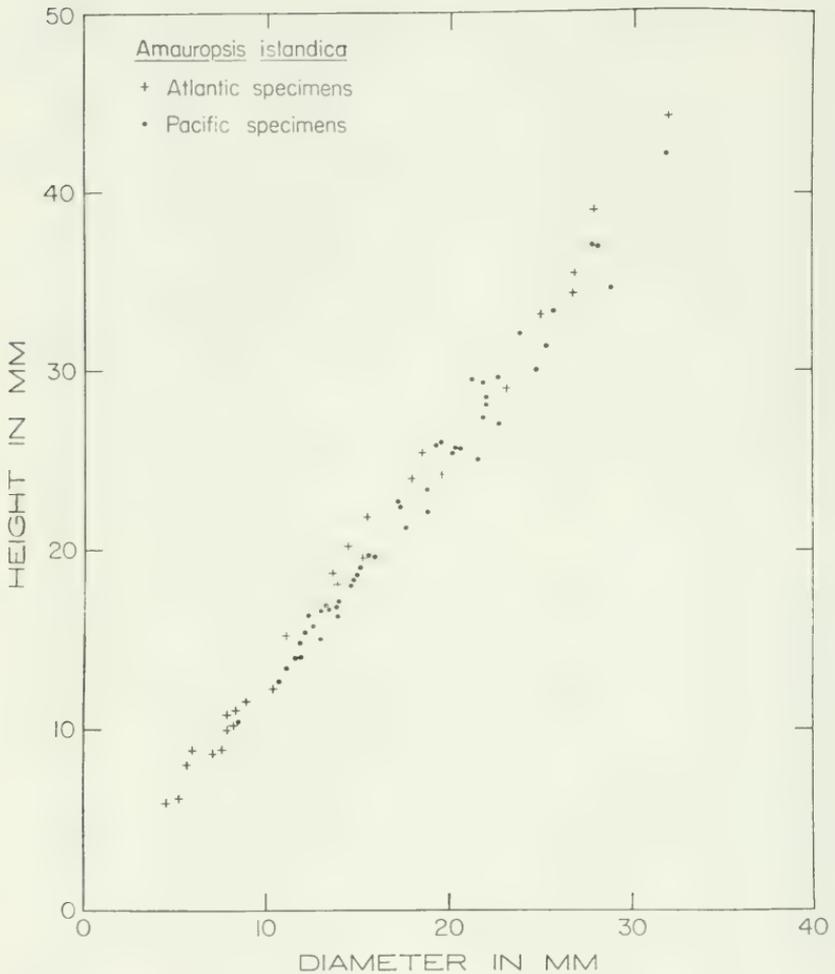
Natica gouldii — Unknown.

Natica cornea — Lectotype, designated herein, and two paralectotypes, Zoological Museum, Copenhagen, Denmark.

Amauropsis purpurea — Holotype, USNM 168988.

Nomenclatural commentary. — The seven nominal taxa included here under *A. islandica* have been considered synonymous in various combinations by earlier workers. Only *A. purpurea* has been consistently regarded as a separate species in recent years, and it is supposed to be darker in color, less elongate, and to have a thicker shell than *A. islandica*. Pacific specimens have been assigned to *A. purpurea* and Atlantic specimens to *A. islandica*. Shell color and thickness vary with specimen size, younger shells having lighter color and a thinner shell than older specimens. Pacific and Atlantic populations show the same range of color and shell thickness. Text-figure 12 shows that the ranges of shell size and height/diameter ratios are the same for Pacific and Atlantic individuals. The height/diameter ratio for Pacific specimens ranges from 1.15 to 1.38, and the same ratio for Atlantic specimens ranges from 1.17 to 1.41. *Amauropsis purpurea* is not separable from *A. islandica* as individuals or populations, on the basis of shell dimensions, color, or shell thickness.

Möller (1842a) did not designate a holotype for the synonymous species *Natica cornea* or state the number of specimens in the type



Text-figure 12. Comparison of height to diameter ratios of Pacific and Atlantic specimens of *Amauropsis islandica* (Gmelin). Based on specimens from several institutions.

lot, although he gave the length of one specimen as seven lines (about 15 mm). The type lot, borrowed from the Zoological Museum, Copenhagen, contains three syntypes. The largest of these (height 7.0 mm, diameter 5.9 mm) is hereby designated lectotype; the two other syntypes thus become paralectotypes.

Discussion. — There is no apparent size gradation with latitude in this species as in *Natica (Cryptonatica) clausa* Broderip and

Sowerby, perhaps because *A. islandica* is not distributed throughout as broad a range of latitudes. The largest known individual of *A. islandica* was found at Cape Menshikof, Alaska, which is also the southern range end-point for the species.

Odhner (1913) reported that the umbilici of some Atlantic specimens may be closed, but I have not seen this. The periostracum is usually thickened within the umbilicus which may conceal the slitlike umbilical opening.

Although the color range of Pacific and Atlantic individuals is identical, more southerly specimens from each ocean tend to be lighter in color.

***Amauropsis martinezensis* Dickerson, 1914**

Pl. 17, figs. 5-10

Amauropsis martinezensis Dickerson, 1914b, p. 142, pl. 13, figs. 4a, b; Dickerson, 1914c, p. 295; Waring, 1917, p. 72, pl. 14, fig. 14; Nelson, 1925, pp. 402, 419, pl. 54, figs. 5, 6; Clark, 1929, pl. 2, fig. 3 [not fig. 16, = *Neptunea cretacea* Gabb, 1869a, Cretaceous, California], Schenck & Keen, 1940, p. 28, pl. 20, fig. 12; Keen & Bentson, 1944, pp. 128, 129.

Description. —

Size: Average specimen, height 23 mm, diameter 16 mm; largest specimen, height 31.2 mm, diameter 23.0 mm [UCR 6900, Martinez Formation, Simi Hills, Ventura County, California, upper Paleocene].

Shell form: Shell elongate globose, spire strongly elevated; body whorl not distinctly inflated; whorls evenly rounded, may be narrowly tabulate; shell thin; whorls about six (apex eroded); suture slightly to moderately impressed, narrowly and shallowly channeled; spiral sculpture of minute, closely spaced costellae separated by much narrower interspaces, the costellae arranged in groups of two or four that are in turn separated by slightly wider interspaces; occasional widely spaced, thin spiral threads may occur distinct from costellae; axial sculpture of closely spaced, incised growth lines that are most distinct on the shoulder and base, where they may form a reticulate pattern with the spiral sculpture. Parietal callus thin, lightly filling posterior apertural angle. Umbilicus slitlike. Umbilical callus absent. Anterior inner lip and basal lip thickened.

Operculum: Unknown.

Specimens examined. — Four hundred nine.

Stratigraphic occurrence. — Upper Paleocene of California. Upper Paleocene: Martinez Fm., Mount Diablo area, Contra Costa

Co., California (Dickerson, 1914b; UCB); Martinez Fm., Simi Hills, Ventura Co., California (Waring, 1917; Nelson, 1925; Zinsmeister, 1974b; SU; CAS; UCR).

Type locality. — One mile south of Stewartville, Contra Costa County, California (Dickerson, 1914b). Martinez Formation, upper Paleocene.

Type material. — Holotype, UCB 11702; paratype, UCB 11703.

Discussion. — This species occurs most abundantly in upper Paleocene strata of the Simi Hills, southern California, where most known specimens have been collected by Zinsmeister (1974b). It apparently occurs rarely in its type area in northern California, although that area has not been collected as extensively as the Simi Hills.

Zinsmeister (1974b) recognized a previously overlooked variant of *A. martinezensis* in the Simi Hills strata. Most specimens from those deposits have evenly rounded whorls, but a few individuals from near the top of the stratigraphic section are narrowly but distinctly tabulate (Pl. 17, figs. 5, 8). Other specimens have whorls intermediate in form between evenly rounded and tabulate, and the development of tabulation in *A. martinezensis* may represent an evolutionary trend with biostratigraphic potential if it can be recognized in other areas with upper Paleocene strata. Tabulate individuals have so far not been found in the region of the type locality of *A. martinezensis* in northern California.

Genus **LACUNARIA** Conrad, 1866, p. 12

Type species: *Natica (Gyrodes) alabamiensis* Whitfield, 1865, by original designation. Paleocene, Alabama.

Diagnosis. — Shell small to medium, thin, subglobose to somewhat elongate, spire moderately elevated, whorls may be weakly tabulate, umbilicus narrowly open to slitlike, umbilical callus absent. Spiral sculpture of minute, closely spaced costellae that may be minutely wavy.

Discussion. — *Lacunaria* is characterized by its relatively elongate shape, narrow umbilicus, and minute spiral sculpture. It is apparently known only by Paleocene species in North America.

Lacunaria striata (Gabb, 1869)

Pl. 17, figs. 11-14; Pl. 18, figs. 1-2

Ampullina striata Gabb, 1869b, p. 161, pl. 27, fig. 40; Dickerson, 1914b, pp. 73, 84, 86, 87, 91, 109, 115; Keen & Bentson, 1944, p. 129.

Lacunaria striata (Gabb), Stewart, 1927, p. 339, pl. 25, fig. 12a; Keen & Bentson, 1944, p. 167; Smith, 1975, p. 469 [as "aff."].

Natica (*Gyrodes*) *lineata* Dickerson, 1914b, pp. 74, 75, 82, 97, 110, 141, pl. 13, figs. 3a, b; Keen & Bentson, 1944, p. 177.

Not *Natica lineata* Lamarck, 1822, vol. 6, pt. 2, p. 201 [living, western Pacific].

Gyrodes insecureis Hanna, 1924, p. 168 [new name for *Natica* (*Gyrodes*) *lineata* Dickerson, 1914b, not *N. lineata* Lamarck, 1822, living, Indo-Pacific]; Nelson, 1925, sp. list.

Sinum dickersoni Waring, 1917, pp. 72, 86-87, pl. 14, fig. 10.

Description. —

Size: Average specimen, height 16 mm, diameter 13 mm; largest specimen, height 19.5 mm (incomplete), diameter 16.8 mm [SU 163, Martinez Fm., Simi Hills, Ventura County, California, upper Paleocene].

Shell form: Shell subglobose to somewhat elongate, spire moderately elevated; body whorl distinctly inflated; whorls fairly evenly rounded, narrowly and weakly tabulate on some specimens, appressed on others; shell thin; nuclear whorls three, adult whorls two; suture slightly impressed on average specimens to strongly impressed on tabulate specimens. Spiral sculpture variable: either of relatively broad, closely spaced riblets separated by much narrower interspaces, or of relatively narrow, closely spaced riblets separated by interspaces about twice as wide, and with one or more minute costellae occupying the interspaces. Parietal callus thin, not thickly filling posterior apertural angle. Umbilicus narrowly open or slitlike. Umbilical callus not distinct from inner lip.

Operculum: Unknown.

Specimens examined. — Sixteen.

Stratigraphic occurrence. — Upper Paleocene of California. Upper Paleocene: Martinez Fm., Contra Costa Co., California (Gabb, 1869b; Dickerson, 1914b; ANSP); Lodo Fm., Panoche Quad., Fresno Co., California (Smith, 1975; SU; UCB); Martinez Fm., Simi Hills, Ventura Co., California (Waring, 1917; Nelson, 1925; Zinsmeister, 1974b; UCR).

Type localities. —

Ampullina striata — Martinez, Contra Costa County, California (Gabb, 1869b). Martinez Formation, upper Paleocene.

Natica (*Gyrodes*) *lineata* — North of Mount Diablo, Contra Costa County, California (Dickerson, 1914b). Martinez Formation, upper Paleocene.

Sinum dickersoni — Simi Hills, Ventura County, California (Waring, 1917). Martinez Formation, upper Paleocene.

Type material. —

Ampullina striata — Lectotype of Stewart (1927), ANSP 4241; three paralectotypes, ANSP 4241.

Natica (Gyrodos) lineata — Holotype missing from UCB collection as of 1940, as noted by Keen and Bentson (1944).

Sinum dickersoni — Holotype, SU 163.

Nomenclatural commentary. — Although this species is distinctive because of its fine spiral sculpture, moderately high spire, and evenly rounded whorls, it has been named three times. Because one of the junior synonyms, *Natica (Gyrodos) lineata*, is also a homonym, it was renamed by Hanna (1927), who thereby created another junior synonym.

Discussion. — Because this species is known from few specimens, its total morphologic range may not be known. However, there is obvious variation in spiral sculpture. Some specimens have broad, closely spaced spiral riblets separated by narrower interspaces, whereas others have narrow, closely spaced riblets separated by wider interspaces; the shells are otherwise identical. This sculptural difference may represent intraspecific variation, sexual dimorphism, or two taxa. Examination of additional well-preserved specimens would be necessary to resolve the problem.

Genus **CROMMIUM** Cossmann, 1888, p. 177

Type species: *Ampullaria willemetii* Deshayes, 1825, by original designation. Eocene, France.

Diagnosis. — Shell medium to large, globose to slightly elongate, spire moderately elevated, often with concave profile, whorls narrowly tabulate to subtabulate, suture may be narrowly channeled, umbilicus narrowly open to slitlike, umbilical callus slender or absent. Shell smooth except for minute costellae on tabulate portion of whorl.

Discussion. — *Crommium* is characterized by its generally globose shape, commonly concave whorl profile, narrowly open umbilicus, and tabulate or subtabulate whorls with faint spiral costellae on the tabulate portion. This genus has often been applied

in a broad sense to numerous species worldwide, ranging in age from Late Cretaceous to Miocene. Its precise geologic and geographic ranges will not be known until the genus is thoroughly reviewed.

Crommium andersoni (Dickerson, 1914) Pl. 18, figs. 3-7

Amauropsis andersoni Dickerson, 1914e, p. 120, pl. 12, figs. 2a, b; Dickerson, 1915, p. 43.

Ampullina andersoni (Dickerson), Anderson & Hanna, 1925, pp. 43, 118.

Ampullina (Crommium) andersoni (Dickerson), Turner, 1938, p. 87, pl. 19, figs. 1, 2, 4, 5; Weaver, 1943, p. 346, pl. 71, figs. 1-4.

Crommium andersoni (Dickerson), Vokes, 1939, pp. 26, 171, pl. 21, figs. 22, 23; Givens, 1974, p. 75, pl. 8, fig. 3.

Amauropsis umpquaensis Dickerson, 1914e, p. 120, pl. 12, figs. 3a, b.

Description. —

Size: Average specimen, height 31 mm, diameter 28 mm; largest specimen, height 40.2 mm, diameter 29.9 mm [CAS 25, Flournoy Fm. of Baldwin and Beaulieu (1973), Glide, Oregon, middle Eocene].

Shell form: Shell globose to moderately elongate, spire low to strongly elevated; body whorl moderately to greatly inflated; whorls evenly rounded but narrowly tabulate; shell thickness average; whorls six; suture deeply impressed, narrowly and shallowly channeled. Shell smooth except for incremental growth lines and extremely faint, minute spiral costellae on tabulate portion of whorls. Parietal callus thin, sometimes moderately filling posterior apertural angle, merges evenly with umbilical callus. Umbilicus narrowly open, lacking a sulcus; channel only gradually tapering anteriorly; lower third of umbilicus bounded by a narrow cordlike angulation on base. Umbilical callus not clearly set off from inner lip. Anterior inner lip and basal lip thickened.

Operculum: Unknown.

Specimens examined. — Two hundred twenty-five.

Stratigraphic occurrence. — Middle Eocene of southwestern Oregon and southern California. Middle Eocene: Flournoy Fm., near Glide, Douglas Co., Oreg. (Dickerson, 1914e; Turner, 1938; Weaver, 1943; CAS; UCB); Domengine Fm., Coalinga area, Fresno Co., Calif. (Vokes, 1939; UCB); Juncal Fm., *Turritella wasana infera* fauna, Mt. Pinos area, Ventura Co., Calif. (Givens, 1974; UCR).

Type localities. —

Amauropsis andersoni — On the east bank of Little River,

at its confluence with the Umpqua River, underneath the bridge at that point, near the center of sec. 19, T. 26 S., R. 3 W., Roseburg quadrangle, Douglas County, Oregon (Dickerson, 1914e). Umpqua [Flournoy] Formation, middle Eocene.

Amauropsis umpquaensis — Same as above (Dickerson, 1914e).

Type material. —

Amauropsis andersoni — Holotype, CAS 244.

Amauropsis umpquaensis — Holotype, CAS 245.

Discussion. — Although the variability of this species is initially confusing, once a large number of specimens have been examined, the range of variability is seen to be consistent. In general, the more globose individuals have lower spires, more inflated body whorls, and more broadly open umbilici. The depth to which the suture is channeled also varies but not consistently with the other features. Most specimens have a slightly elongate shell and narrow umbilicus. Some individuals have umbilici that are open widely enough to appear circular when seen in basal view; the holotype is one of these. In especially globose specimens the spire is composed mainly of juvenile whorls and appears disproportionately small in relation to the body whorl (Pl. 18, fig. 5). Juveniles are often more slender and have more sharply tabulate whorls than full-size specimens.

This species is similar to and almost certainly evolved from *Crommium pinyonensis* (Dickerson, 1914d) which occurs in upper Paleocene to upper Eocene deposits. These are the only two species assigned to *Crommium* in this study; though close in general appearance and size, they differ greatly in detail. Most obviously, the whorls of *C. andersoni* are much more strongly tabulate than those of *C. pinyonensis*, and the suture of the former species is more strongly channeled. At first glance, specimens of *C. pinyonensis* may seem to have normally impressed sutures, but close inspection shows them to be narrowly and shallowly channeled, whereas the suture of *C. andersoni* is always distinctly channeled. The inner lip alongside the umbilicus of *C. pinyonensis* is much thicker than in *C. andersoni*, and the umbilical opening is accordingly smaller. In addition, the umbilical opening of *C. andersoni* is more elongate than in *C. pinyonen-*

sis. A minority of *C. pinyonensis* individuals have closed umbilici which never occurs in *C. andersoni*.

Crommium pinyonensis (Dickerson, 1914) Pl. 18, figs. 8-13

Natica pinyonensis Dickerson, 1914c, p. 295 [*nomen nudum*]; Dickerson, 1914d, p. 302, pl. 29, figs. 5a, b; Keen & Bentson, 1944, p. 177.

Ampullella (Ampullella) schencki Vokes, 1939, pp. 26, 170, pl. 21, figs. 20, 21, 26; Keen & Bentson, 1944, p. 129.

"*Polinices*" sp. cf. "*P.*" *pinyonensis* (Dickerson), Smith, 1975, p. 469, pl. 2, figs. 22, 23.

Description. —

Size: Average specimen, height 25 mm, diameter 22 mm; largest specimen, height 36.7 mm, diameter 31.5 mm (incomplete) [UCB A-9717, Lodo Formation, Panoche quadrangle, Fresno County, California, upper Paleocene].

Shell form: Shell globose, spire low to moderately elevated; body whorl moderately inflated; whorls evenly rounded but slightly flattened (subtabulate) immediately below suture; shell thickness average; whorls $6\frac{1}{2}$; suture moderately impressed, shallowly and narrowly channeled. Shell smooth except for incremental growth lines and extremely faint, minute spiral costellae on subtabulate portion of whorls. Parietal callus thin, lightly to moderately filling posterior apertural angle; anterior lobe weak, slightly overhangs umbilicus. Umbilicus usually open and slitlike, less commonly closed. Umbilical callus narrow, extending the length of the inner lip. Anterior inner lip thickened.

Operculum: Unknown.

Specimens examined. — Sixty-five.

Stratigraphic occurrence. — Upper Paleocene to middle Eocene. Upper Paleocene: Lodo Fm., Panoche Quad., Fresno Co., Calif. (Smith, 1975; SU; UCB); Martinez Fm., Simi Hills, Ventura Co., Calif. (UCR, UCLA); so-called Martinez Fm., Rock Creek, Los Angeles Co., Calif. (Dickerson, 1914c, 1914d; UCB). Middle Eocene: Domengine Fm., Cholame Quad., Kings Co., Calif. (Vokes, 1939; UCB).

Type localities. —

Natica pinyonensis — Pinyon Ridge, one mile southwest of benchmark 3972, at Shoemaker, Rock Creek quadrangle, Los Angeles County, California (Keen & Bentson, 1944). So-called Martinez Formation, upper Paleocene.

Ampullella (Ampullella) schencki — On west side of Big Tar Canyon, where it crosses the Eocene section, Cholame quadrangle, Kings County, California (Vokes, 1939). Domengine Formation, middle Eocene.

Type material. —

Natica pinyonensis — Holotype, UCB 11761; paratype, UCB 11760.

Ampullella (Ampullella) schencki — Holotype, UCB 15856; paratypes, UCB 15857, 15858.

Discussion. — Most specimens of *C. pinyonensis* are from the upper Paleocene part of the Lodo Formation of southern California and are somewhat deformed and eroded, making it difficult to describe the original range of morphologic variation. Almost all individuals, including the holotype, have narrowly open umbilici, but a few specimens have distinctly closed umbilical openings, with only shallow slits to mark the sites of the covered umbilici (Pl. 18, fig. 10). The range in spire height from low to moderately elevated is the only other major variation in this species.

Crommium pinyonensis is inferred to have given rise to the middle Eocene *C. andersoni* (Dickerson, 1914e) because they are so similar in form and lived in the same region. They both occur in the middle Eocene Domengine Formation in southern California. Detailed comparison of the two is made in the discussion of *C. andersoni*.

Genus **EOCERNINA** Gardner & Bowles, 1934, p. 243

Type species: *Natica hannibali* Dickerson, 1914e, by original designation. Lower and middle Eocene of California, Oregon, and Washington.

Diagnosis. — Shell medium to large, thick-shelled, globose to somewhat elongate, spire low to moderately elevated, body whorl large, suture impressed and may become irregularly and narrowly channeled on final whorl, umbilical and parietal calluses massive, merged together, umbilicus closed or nearly so. Shell smooth except for incremental growth lines that may be boldly developed.

Discussion. — *Eocernina* is characterized by its generally globose shape, large body whorl and low spire, closed or nearly closed um-

bilicus with massive callus, and lack of sculpture. It occurs in Eocene strata from Washington, Oregon, and California, to the Isthmus of Tehuantepec, southernmost Mexico, and may occur in the Paris Basin Eocene deposits (Gardner and Bowles, 1934).

Eocernina hannibali (Dickerson, 1914) Pl. 18, fig. 14; Pl. 19, figs. 1-4

"*Amauropsis oviformis* ? Gabb," Arnold, 1910, p. 112, pl. 4, fig. 7 [not *A. oviformis* Gabb, 1864, Cretaceous, northern California]; Arnold & Anderson, 1910, pl. 26, fig. 7 [not *A. oviformis* Gabb, 1864]; Keen & Bentson, 1944, p. 124.

Natica hannibali Dickerson, 1914e, pp. 115, 119, pl. 12, figs. 5a, b; Dickerson, 1915, p. 44; Dickerson, 1916, p. 508, pl. 38, fig. 9a, b; Waring, 1917, p. 90; Keen & Bentson, 1944, p. 176.

Natica (Cryptonatica) hannibali Dickerson, Waring, 1917, p. 122, pl. 15, figs. 21-23; Keen & Bentson, 1944, p. 177.

Ampullina hannibali (Dickerson), Anderson & Hanna, 1925, pp. 43, 118-119; M. Hanna, 1927, p. 306, pl. 48, figs. 1-3, 10 [as "*Ampulina*"]; Keen & Bentson, 1944, p. 129.

Cernina (Eocernina) hannibali (Dickerson), Gardner & Bowles, 1934, p. 246, fig. 4 [as "cf."]; Turner, 1938, pp. 87-88, pl. 19, fig. 3; Vokes, 1939, p. 26, 172, pl. 22, figs. 1, 3; Weaver, 1943, pp. 348-349, pl. 71, figs. 8, 9, 21, 23; Keen & Bentson, 1944, p. 143.

Ampullina (Globularia) hannibali (Dickerson), Clark, 1929, pl. 11, fig. 12; Keen & Bentson, 1944, p. 129.

Eocernina hannibali (Dickerson), Hanna & Hertlein, 1943, p. 170, fig. 62-17.

Globularia (Eocernina) hannibali (Dickerson), Givens, 1974, p. 75, pl. 9, figs. 1, 3.

Description. —

Size: Average specimen, height 45 mm, diameter 43 mm; largest specimen, height 71.4 mm (incomplete), diameter 59.7 mm [UCB 7003, Llajas Formation of McMasters (1933), Santa Susana quadrangle, Ventura County, California, lower and middle Eocene].

Shell form: Shell globose to somewhat elongate, spire low to moderately elevated; body whorl greatly inflated; shell thick; whorls six; suture weakly to strongly impressed in early whorls, becoming increasingly appressed with growth, sometimes irregularly and narrowly channeled on final whorl. Shell smooth except for sinuous incremental growth lines that may be strongly developed, especially just below suture. Parietal callus massive to enormous, heavily filling posterior apertural angle, evenly merging with umbilical callus. Umbilicus closed except in extremely rare instances; umbilical area uncommonly bounded by low cordlike angulation on base. Umbilical callus massive, a continuation of parietal callus. Anterior inner lip and basal lip thickened.

Operculum: Unknown

Specimens examined. — One thousand three.

Stratigraphic occurrence.—Lower and middle Eocene. Lower Eocene: Juncal Fm., *Turritella wasana infera* fauna, Mount Pinos area, Ventura Co., California (Givens, 1974; UCR). Lower and middle Eocene: Crescent Fm., Clallam Co., Wash. (UCB); Avenal Fm., Reef Ridge, Kings Co. (SU, UCLA, UCB), and San Luis Obispo Co. (UCB), Calif.; Llajas Fm. of McMasters (1933), Simi Valley area, Ventura Co., Calif. (Hanna & Hertlein, 1943; LACM; SU; UCR, CAS; UCLA; UCB). Middle Eocene: Flournoy Fm. of Baldwin & Beaulieu (1973), near Glide, Douglas Co., Ore. (Dickerson, 1914e; Turner, 1938; Weaver, 1943; CAS; UCB); Tye Fm., Coos Co., Oreg. (UCB); Domengine Fm., Diablo Quad., Contra Costa Co. (UCB), New Idria Quad. (UCB) and Coalinga Quad. (Dickerson, 1916; Vokes, 1939; UCB), Fresno Co., Garza Peak Quad., Kings Co. (SU; UCB), and Panoche Quad., San Benito Co. (SU), Calif.; Juncal Fm., *Turritella wasana applinae* and *Ectinochilus supraplicatus* faunas, Mt. Pinos area, Ventura Co., Calif. (Givens, 1974; UCR); Ardath Shale, Rose Canyon, San Diego Co., California (M. Hanna, 1927; LACM; UCLA).

Type locality.—On east bank of Little River at its confluence with Umpqua River, near center of sec. 19, T. 26 S., R. 3 W., Roseburg quadrangle, Douglas County, Oregon (Dickerson, 1914e). Umpqua [Flournoy] Formation, middle Eocene.

Type material.—Holotype, CAS 243.

Discussion.—This species is fairly variable yet is among the most easily recognized of lower Tertiary naticids. Variations in shell elongation, spire height and callus development result in a broad range of morphology, but the large size, inflated body whorl and massive callus combine to easily characterize *E. hannibali*. Juveniles and young adults tend to have more elongate shells, whereas large adults tend to be globose. Many specimens have a distinct flattening of the shoulder which may be slightly concave (Pl. 19, figs. 2, 4). Some large specimens have an exceptionally large callus (Pl. 19, fig. 3), and in all the underlying whorl strongly indents the aperture.

A similar species is *E. chiapasensis* (Gardner and Bowles, 1934) from Eocene strata near Salaya, Chiapas, south-central Mexico. This species appears to differ from *E. hannibali* by its smaller size (of the two specimens examined by Gardner and Bowles, the holotype was largest at 36 mm height \times about 38 mm diameter) and the ten-

dency for its umbilicus to be narrowly open. The two species are otherwise identical.

The great majority of *E. hannibali* specimens have been collected from middle Eocene strata of central and southern California, where the species may occur in prolific numbers.

Genus **AMPULLOSPIRA** Harris, 1897, p. 265

Type species: *Euspira canaliculata* Morris and Lycett, 1851, by original designation. Jurassic, England.

Diagnosis.—Shell medium to large, elongate, spire elevated, shoulder narrowly tabulate, suture narrowly channeled, umbilicus slitlike or absent, umbilical callus absent. Sculpture of fine spiral lines that may be punctate.

Discussion.—*Ampullospira* is characterized by its elongate shape, elevated spire, narrowly channeled suture, and fine spiral sculpture that is usually punctate. It has been applied to species ranging in age from Jurassic to Oligocene worldwide, but many species are erroneously assigned here. The related genus *Tejonia* may have evolved from *Ampullospira* during the Eocene in California and is distinct in lacking a channeled suture and having nonpunctate spiral sculpture.

Ampullospira susanaensis Nelson, 1925

Pl. 19, fig. 5

Ampullospira susanaensis Nelson, 1925, pp. 402, 420, pl. 54, fig. 7; Keen & Bentson, 1944, p. 129.

Description.—

Size: Holotype, height 20.9 mm (incomplete), diameter 17.0 mm.

Shell form: Shell moderately elongate, spire strongly elevated; body whorl slightly inflated; juvenile whorls with rounded shoulders, body whorl tabulate, the tabulate surface sloping inward toward suture; shell thin; whorls at least four and one-half (apex of holotype is missing); suture slightly impressed in juvenile whorls to strongly impressed and channeled in body whorl. Spiral sculpture of low, minute, closely and irregularly spaced, flattened costellae that are minutely wavy and separated by shallowly incised interspaces; each costella bears two or more microscopically punctate spiral lines on its flattened surface; axial sculpture of incremental growth lines. Parietal callus thin, lightly filling posterior apertural angle, evenly merging with inner lip. Umbilicus slitlike, lacking

sulcus. Umbilical callus not distinct from inner lip. Anterior inner lip moderately thickened.

Operculum: Unknown.

Specimen examined. — One (holotype).

Stratigraphic occurrence. — Known only from type locality.

Type locality. — South of Simi Valley, Ventura County, California (Nelson, 1925). Martinez Formation, upper Paleocene.

Type material. — Holotype, CAS 985.

Discussion. — This species is known only by the holotype, and recent extensive collecting in the area of the type locality (Zinsmeister, 1974b) has uncovered no additional specimens. It is similar in general shape to the middle to late Eocene *Tejonia moragai* (Stewart, 1927) and may have been ancestral to that species. However, the two differ greatly in detail. Both have tabulate body whorls, but the tabulate surface of *T. moragai* slopes upward to the deeply impressed suture, whereas the tabulate surface of *A. susanaensis* slopes downward to the channeled suture; the spiral costellae of *A. susanaensis* bear microscopically punctate lines on their surfaces, but the costellae of *T. moragai* bear shallowly incised nonpunctate lines. *Tejonia moragai* has a slender cordlike angulation that arises at the anterior inner lip and enters the umbilicus, but hard matrix conceals that portion on the holotype of *A. susanaensis* and cannot be removed without harming the shell. The body whorl of *T. moragai* is more inflated than that of *A. susanaensis*, but additional specimens of the latter species might show some to be more inflated than the holotype.

Genus **TEJONIA** Hanna & Hertlein, 1943, p. 172

Type species: *Natica alveata* Conrad, 1855, not Troschel, 1852, by monotypy. Renamed *Amaurellina moragai* Stewart, 1927. Middle and upper Eocene of California and Oregon.

Diagnosis. — Shell medium in size, subglobose to moderately elongate, spire elevated, shoulder narrowly tabulate, suture not channeled, umbilicus slitlike, umbilical callus absent. A low, slender cord arises at the anterior inner lip and enters the umbilicus. Adult body whorl smooth or with minute, nonpunctate spiral sculpture.

Discussion. — *Tejonia* is characterized by its strongly tabulate whorls with nonchanneled suture, minute nonpunctate spiral sculp-

ture, and by a slender cord entering the umbilicus from the anterior inner lip. It is similar in general form to *Ampullospira* but lacks the channeled suture and usually punctate spiral lines of that genus. The type species is the only one so far assigned to *Tejonia*.

Tejonia moragai (Stewart, 1927)

Pl. 19, figs. 6-12

Natica alveata Conrad, 1855, p. 10; Conrad, 1857, p. 321, pl. 2, figs. 8, 8a; Keen & Bentson, 1944, p. 176.

Amauroopsis alveata (Conrad), Gabb, 1864, p. 110, pl. 19, fig. 59; pl. 21, fig. 111; Arnold, 1910, p. 114, pl. 4, fig. 21; Dickerson, 1914b, pp. 77, 91, 115; Dickerson, 1915, p. 43, pl. 5, fig. 8; Dickerson, 1916, pl. 38, fig. 7; Waring, 1917, p. 90, pl. 15, fig. 25; Anderson & Hanna, 1925, pp. 40, 41, 43, 119-120, pl. 6, fig. 2; pl. 7, fig. 1; pl. 15, fig. 17; Keen & Bentson, 1944, p. 128.

Euspira alveata (Conrad), Gabb, 1869b, p. 160.

Amauroopsis alveatus (Conrad), Arnold, 1907a, p. 540, pl. 39, fig. 8.

Ampullospira alveata (Conrad), M. Hanna, 1927, pp. 258, 259 [as "*Ampullospira*"].

"*Amauroopsis allocata* Gabb," Arnold, 1906, p. 14 [*lapsus calami* for *Natica alveata* Conrad].

"*Amauroopsis allocata* Arnold," Anderson & Hanna, 1925, p. 43 [*lapsus calami* for *Natica alveata* Conrad].

Not *Natica alveata* Troschel, 1852, p. 152, pl. 5, fig. 3 [living, Peru].

Not *Natica* (*Gyrodos*) *alveata* Conrad, 1860, p. 289, pl. 46, fig. 45 [Tertiary, Mississippi; renamed *Gyrodos negligentus* Hanna, 1924, p. 168].

Amaurellina moragai Stewart, 1927, pp. 334-336, pl. 28, fig. 3 [new name for *Natica alveata* Conrad, 1855, not Troschel, 1852]; Clark, 1929, pl. 14, figs. 3, 9; Keen & Bentson, 1944, p. 128; Weaver & Kleinpell, 1963, p. 188, pl. 25, figs. 1, 2.

Tejonia moragai (Stewart), Givens, 1974, p. 74, pl. 8, fig. 8.

Amaurellina moragai lajollaensis Stewart, 1927, p. 336, pl. 28, fig. 2; Keen & Bentson, 1944, p. 128.

Tejonia lajollaensis (Stewart), Hanna & Hertlein, 1943, p. 172, fig. 62-30; Givens, 1974, p. 74, pl. 8, fig. 5.

Amaurellina hendoni Turner, 1938, pp. 86-87, pl. 20, figs. 7, 8, 11; Vokes, 1939, pp. 31, 173, pl. 22, figs. 7, 10; Weaver, 1943, p. 345, pl. 70, figs. 12, 13, 16, 17.

?*Tejonia hendoni* (Turner), Clark & Durham, 1946, pp. 17-18, pl. 15, figs. 9, 12.

Description. —

Size: Average specimen, height 30 mm, diameter 23 mm; largest specimen, height 38.1 mm, diameter 36.2 mm (incomplete) [UCB A971, Tejon Formation, Tejon quadrangle, Kern County, California, upper Eocene].

Shell form: Shell subglobose to moderately elongate, spire strongly elevated; body whorl moderately inflated; juvenile whorls with rounded shoulders, adult whorls sharply tabulate, the tabulate surface usually shallowly concave, sloping upward to the suture, and often bounded by a distinct carination; shell thin; whorls eight;

suture deeply impressed. Spiral sculpture of low, minute, closely and regularly spaced, flattened costellae separated by narrow, sharply incised interspaces; costellae almost always subdivided by faint, shallowly incised spiral lines that may be microscopically wavy; spiral sculpture best developed on lower portion of whorl; axial sculpture of incremental growth lines. Parietal callus thin, lightly filling posterior apertural angle, evenly merging with inner lip. Umbilicus always narrowly open, commonly slitlike, lacking a distinct sulcus; a low, slender cordlike angulation arises at the thickened inner lip and extends into the umbilicus. Umbilical callus not distinct from inner lip. Anterior inner lip greatly thickened and somewhat reflected.

Operculum: Unknown.

Specimens examined. — One thousand sixty-five.

Stratigraphic occurrence. — Middle and upper Eocene. Undifferentiated lower and middle Eocene: Llajas Fm. of McMasters (1933), Aliso Canyon, Ventura Co., Calif. (Hanna & Hertlein, 1943; CAS); Maniobra Fm. of Crowell & Susuki (1959), Orocochia Mountains, Riverside Co., Calif. (UCLA). Middle Eocene: Flournoy Fm., Coos and Douglas Cos., Ore. (Turner, 1938); Weaver, 1943; UCB); Tyee Fm., Coos and Douglas Cos., Ore. (UCB); Domengine Fm., Mount Diablo area, Contra Costa Co., Calif. (UCB); Juncal Fm., *Ectinochilus supraplicatus* and *Turritella wasana applinae* faunas, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR); Ardath Shale, La Jolla Quad., San Diego Co., Calif. (Arnold, 1907a; Stewart, 1927; LACM; CAS; UCLA; UCB). Upper Eocene: Tejon Fm., Tejon Quad., Kern Co., Calif. (Conrad, 1855, 1857; Gabb, 1864; Dickerson, 1915; Anderson & Hanna, 1925; Stewart, 1927; SU; CAS; UCLA; UCB); Matilija Ss., *Ectinochilus canalifer* fauna, Mount Pinos area, Ventura Co. (Givens, 1974; UCR), and western Santa Ynez Mts., Santa Barbara Co. (Weaver & Kleinpell, 1963), Calif.

Type localities. —

Natica alveata — Cañada de las Uvas [Grapevine Canyon], Tejon Quadrangle, Kern County, California (Conrad, 1855). Tejon Formation, upper Eocene.

Amaurellina moragai lajollaensis — Seven to eight miles north of Ladrillo Station, in first canyon east of Rose

Canyon, elevation 259 feet, San Diego County, California (Stewart, 1927). Ardath Shale, middle Eocene.

Amaurellina hendoni — On north bank of North Umpqua River, upstream from the bend a quarter of a mile north of Glide, Douglas County, Oregon (Turner, 1938). Umpqua [Flournoy] Formation, middle Eocene.

Type material. —

Natica alveata — Unknown (see Nomenclatural Commentary below).

Amaurellina moragai lajollaensis — Holotype, UCB 31401.

Amaurellina hendoni — Holotype, UCB 33630; paratype, UCB 33178.

Nomenclatural commentary. — The earliest name proposed for this species, *Natica alveata* Conrad, 1855, is a homonym of *N. alveata* Troschel, 1852, so it was replaced by *Amaurellina moragai* Stewart, 1927. Without indicating that he had searched for Conrad's type specimens, Stewart (1927) erroneously designated a "holotype" for *A. moragai* (UCB 31387, figured here as Pl. 19, fig. 6). If Stewart had searched for Conrad's type material and failed to find it, his "holotype" could be construed as a neotype. Article 75c(2) of the International Code of Zoological Nomenclature states that a neotype designation is valid only when published with "the author's reasons for believing all of the original type-material to be lost or destroyed, and the steps that have been taken to trace it." As Stewart gave no indication that he searched for Conrad's specimens, he did not comply with this rule, and his "holotype" loses all taxonomic status. Conrad's type specimen or specimens may yet reside in the National Museum of Natural History or elsewhere. I did not locate Conrad's specimens in the USNM collections but an exhaustive search was not made.

Discussion. — This species is characterized by its strongly tabulate adult whorls, fine spiral sculpture, and narrowly open umbilicus. The spiral sculpture, however, is present on the body whorls of only about half of the specimens I have seen. Many specimens lacking sculpture are obviously worn and abraded, but many are well preserved and have unworn axial growth lines. On well-preserved specimens, spiral costellae are always present on the earlier whorls but may be missing on the body whorl.

The name *T. moragai lajollaensis* was proposed for specimens that are supposedly more globose than average *T. moragai* and said to have a somewhat more broadly tabulate shoulder lacking a carination. Stewart (1927) reported such specimens from near La Jolla, southern California, and Umpqua, southwestern Oregon. In fact, they may be found at all localities where typical *T. moragai* occurs, although they are more common at La Jolla and Umpqua. The supposed difference in morphology between the two taxa is not consistent, individuals of both kinds occur together widely, and a large proportion of specimens cannot be confidently allocated to one taxon or the other. I consider the two to be conspecific.

Clark and Durham (1946) reported and figured one specimen assigned to this species (as *T. hendoni*) from middle Eocene strata of western Colombia. Examination of their specimen (UCB 34945), however, shows it to be too poorly preserved for positive identification, although it is similar in general form to *T. moragai*. Additional specimens from Colombia would be necessary for confident assignment to *T. moragai* or other species, especially in view of the possible 5,500-kilometer (3,400-mile) range extension of *T. moragai* southward from California.

Vokes (1939) reported specimens of *T. moragai* from the lower Eocene Arroyo Hondo Shale Member of the Lodo Formation, near Coalinga, central California. If correctly identified, these would be the only verified lower Eocene specimens of this species. Examination of these specimens in the UCB collection shows them to be badly worn gastropods for which no generic or specific determination is possible.

This species is closest in general form to the late Paleocene *Ampullospira susanaensis* Nelson, 1925, of southern California, and may have evolved from it. Detailed comparison of the two is made in the discussion of *A. susanaensis*.

Genus **EUSPIROCROMMIUM** Sacco, 1890, p. 42

Type species: *Natica elongata* Michelotti, 1861, not Hoeninghaus, 1829, by subsequent designation of Cossmann, 1892. Renamed *Crommium* (*Euspirocrommium*) *degenensis* Sacco, 1890. Oligocene, Italy.

Diagnosis.—Shell medium to large, elongate, spire strongly

elevated, whorls evenly rounded, not tabulate, suture not channeled, inner lip reflected, umbilicus closed. Shell smooth except for incremental growth lines.

Discussion. — *Euspirocrommium* is characterized by its elongate shape, elevated spire, smooth and nontabulate whorls, and closed umbilicus. The absence of tabulate whorls distinguishes it from *Pachycrommium* Woodring, 1928. According to Woodring (1928), *Euspirocrommium* applies only to European Oligocene species, but Wenz (1941) stated the geologic range as Upper Cretaceous to Oligocene worldwide.

Euspirocrommium hewitti (Hanna & Hertlein, 1949) Pl. 20, figs. 1-3

Ampullella hewitti Hanna & Hertlein, 1949, pp. 393-394, pl. 77, figs. 1, 3;
Givens, 1974, p. 74, pl. 8, fig. 13.

Description. —

Size: Average specimen, height 75 mm, diameter 60 mm; largest specimen, height 94 mm (incomplete), diameter 77 mm (incomplete) [CAS 9430, holotype].

Shell form: Shell globose to moderately elongate, spire strongly elevated; body whorl moderately to greatly inflated; whorls evenly rounded; shell very thick; whorls about six; suture strongly impressed. Shell smooth except for incremental growth lines. Parietal callus thick, heavily filling posterior apertural angle, evenly merges with umbilical callus. Umbilicus closed. Umbilical callus apparently an elongate thickening along inner lip. Anterior inner lip greatly thickened.

Operculum: Unknown.

Specimens examined. — Nine.

Stratigraphic occurrence. — Lower Eocene of southern California. Lower Eocene: Lodo Fm., near Media Agua Creek, Kern Co., Calif. (Hanna & Hertlein, 1949; CAS); Juncal Fm., *Turritella uvasana infera* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR).

Type locality. — Unnamed sandstone member in middle of Lodo Formation, near Media Agua Creek, Kern County, California; on north side of road from Carrizo Plain to Carneros Creek, about 810 feet south and 2,770 feet east of northwest corner of sec. 18, T. 29 S., R. 20 E. (Hanna and Hertlein, 1949). Lodo Formation, lower Eocene.

Type material. — Holotype, CAS 9430; paratypes, CAS 9431, 9432, 9433.

Discussion. — The generally elongate shell, elevated spire, and umbilicus closed by a massive callus characterize this species, along with its large size. It is not similar to any other fossil or living species in this region. The description above is a composite of all individuals I have seen. Specimens are found in coarse, calcareous, porous, pebbly and hard sandstone and are not well preserved. Most are internal molds with attached fragments of recrystallized shell. Umbilical features are not well preserved on any individual I have seen.

This is the largest extinct Cenozoic naticid in western North America. It is exceeded in size in this region only by *Polinices (Euspira) lewisii* (Gould, 1847) which occurs from late Pliocene to Holocene.

Genus **PACHYCROMMIUM** Woodring, 1928, p. 391

Type species: "*Natica phasianelloides* d'Orbigny" of Guppy, 1866 [not of d'Orbigny, 1841]. Renamed *Amaura guppyi* Gabb, 1873. Miocene, Dominican Republic.

Diagnosis. — Shell medium in size, elongate, spire strongly elevated, whorls slightly to distinctly tabulate, suture not channeled, basal part of inner lip broadened and reflected, umbilicus closed. Shell smooth except for incremental growth lines.

Discussion. — *Pachycrommium* is characterized by its elongate shape, elevated spire, smooth tabulate whorls, and closed umbilicus. Woodring (1928) included species that had formerly been placed in *Euspirocrommium* Sacco, 1890, which he considered an appropriate name only for some European Oligocene species. He included in *Pachycrommium* several species from American Eocene and Miocene strata and European Eocene and Oligocene deposits. *Euspirocrommium* differs by having nontabulate whorls and includes some large-sized species.

Pachycrommium clarki (Stewart, 1927)

Pl. 20, figs. 4-10

"*Amauropsis alveata* (Conrad)," [not *Natica alveata* Conrad, 1855, = *Tejonina moragai* (Stewart, 1927), treated herein]; Arnold, 1910, p. 114, pl. 4, fig. 21; Arnold & Anderson, 1910, pp. 71, 286, pl. 26, fig. 21; Dickerson, 1915, p. 86, pl. 5, fig. 9.

Amaurellina (Euspirocrommium) clarki Stewart, 1927, pp. 336-338, pl. 26, figs. 8, 9 [new name for "*Amauropsis alveata* (Conrad)" of Arnold, 1910];

Clark, 1929, pl. 11, fig. 10 [as "*Euspiracromium*"]; Turner, 1938, p. 86, pl. 20, fig. 3; Weaver, 1943, p. 345, pl. 7, figs. 10, 18; Keen & Bentson, 1944, p. 127; Weaver & Kleinpell, 1963, p. 188, pl. 27, fig. 15.

Amaurellina clarki Stewart, Gardner & Bowles, 1934, p. 246, figs. 6, 8; Schenck & Keen, 1940, p. 34, pl. 26, fig. 7; Keen & Bentson, 1944, p. 127.

Pachycrommium (?) *clarki* (Stewart), Vokes, 1939, pp. 26, 175, pl. 22, figs. 11, 30; Givens, 1974, p. 73, pl. 8, figs. 6, 10.

Amaurellina (?) *multiangulata* Vokes, 1939, pp. 26, 174, pl. 22, figs. 2, 8, 13.

Description. —

Size: Average specimen: height 40 mm, diameter 31 mm; largest specimen, height 81.6 mm (incomplete), diameter 59.6 mm (incomplete) [CAS 34611, Cowlitz Formation, Lewis County, Washington, upper Eocene].

Shell form: Shell elongate; spire greatly elevated, often with concave whorl profile; body whorl slightly to moderately inflated; early whorls fairly evenly rounded, shoulder becoming progressively more tabulate in adult whorls, penultimate and body whorls with strong tabulation; shell thick; whorls at least seven (apexes broken in all specimens seen); suture of early whorls strongly to moderately impressed, becoming appressed in later whorls. Shell usually smooth except for incremental growth lines, rarely with weakly developed, widely and irregularly spaced costellae on body whorl. Parietal and umbilical calluses thin to moderately thick, smoothly merging together, becoming massive only on especially large individuals. Umbilicus always closed, rarely with a slitlike pit. Umbilical callus either smoothly merges with anterior inner lip or tapers anteriorly until interrupted by inner lip. Anterior inner lip thickened, sometimes fairly broad and with a raised outer margin.

Operculum: Unknown.

Specimens examined. — Eight hundred seven.

Stratigraphic occurrence. — Lower, middle, and upper Eocene. Lower Eocene: Juncal Fm., *Turritella wasana applinae* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR). Lower and middle Eocene: Crescent Fm., Clallam Co., Wash. (UCB); Llajas Fm. of McMasters (1933), Las Llajas Canyon, Ventura Co., Calif. (Stewart, 1927; SU; CAS; UCLA; UCR; UCB). Middle Eocene: Flournoy Fm. of Baldwin & Beaulieu (1973), near Glide, Douglas Co., Ore. (Turner, 1938; CAS); Avenal Ss., Big Tar Canyon, Fresno Co., Calif. (SU; UCLA; UCB); Domengine Fm., Fresno and San Benito Cos., Calif. (Vokes, 1939; SU; UCB); Juncal Fm., *Ectino-*

chilus supraplicatus fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR); Ardath Shale, San Clemente Canyon and Rose Canyon, San Diego Co., Calif. (LACM; UCLA). Upper Eocene: Cowlitz Fm., near Vader, Lewis Co., Wash. (Weaver, 1943; CAS); Tejon Fm., Tejon Quad., Kern Co., Calif. (Arnold, 1910; Weaver, 1943; CAS; UCLA; UCB); Gaviota, Matilija, Cozy Dell, Sacate and so-called Coldwater Fms., western Santa Ynez Mts., Santa Barbara Co., Calif. (Weaver & Kleinpell, 1963); Matilija Ss., *Ectinochilus canalifer* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR).

Types localities. —

Amaurellina (Euspirocrommium) clarki — Simi Valley, Ventura County, California (Stewart, 1927). Llajas Formation, lower and middle Eocene.

Amaurellina (?) multiangulata — Five feet below top of 2,600-foot hill on southeast side, at edge of southeast 1/4 and northwest 1/4 of sec. 15, T. 17 S., R. 12 E., Priest Valley Quadrangle, San Benito County, California (Vokes, 1939). Domengine Formation, middle Eocene.

Type material. —

Amaurellina (Euspirocrommium) clarki — Holotype, UCB 31385; paratype, UCB 31386.

Amaurellina (?) multiangulata — Holotype, UCB 15866; paratypes, UCB 15867, 15868.

Discussion. — Because of its relatively large size, elongate shape, and high spire, this is one of the most distinctive Cenozoic naticids of western North America. The tabulate shoulder may be either flat or shallowly concave, concave being more common. Individuals with either type of tabulation occur together. The observation by Turner (1938) that specimens from Oregon have convex spire profiles in contrast to the concave spire profiles of California specimens is not supported by specimens I have seen. Both types of spire development occur in local populations, although concave profiles predominate. Juveniles are generally not so relatively elongate as adults (Pl. 20, fig. 5).

Vokes (1939) differentiated *Amaurellina (?) multiangulata* from *P. clarki* by the presence of weakly developed spiral "ridges" on three specimens. Six additional individuals with spiral costellae

were found in collections during this study, some of which are preserved better than the types. These new specimens show the spiral costellae grading from weak to nearly nonexistent. Because *A.* (?) *multiangulata* is gradational with *P. clarki* and has no biostratigraphic utility, I consider it a junior synonym of *P. clarki*.

Genus **AMAURELLINA** Fischer, 1885, p. 766

Type species: *Ampullaria spirata* Lamarck, 1804, by monotypy. Eocene, France.

Diagnosis. — Shell small to medium, moderately elongate, spire elevated, shoulder narrowly tabulate, suture narrowly channeled, umbilicus narrowly to moderately open, umbilical callus absent, inner lip reflected. A slender cord arises on the thickened anterior inner lip and enters the umbilicus. Shell smooth or with fine spiral costellae.

Discussion. — *Amaurellina* is characterized by its elevated spire, tabulate whorls, and channeled suture, and by the slender cord entering the umbilicus from the anterior inner lip. It is reported from lower Upper Cretaceous to Oligocene strata worldwide but, as noted by Sohl (1960), many species probably are incorrectly placed here.

Amaurellina caleocia Vokes, 1939 Pl. 20, figs. 11-13; Pl. 21, figs. 1, 2

Amauroopsis alveata (Conrad), Dickerson, 1916 [in part], p. 508, pl. 38, fig. 7 [not *Natica alveata* Conrad, 1855, = *Tejonia moragai* (Stewart, 1927), treater herein]; Keen & Bentson, 1944, p. 126.

Amaurellina caleocia Vokes, 1939, pp. 26, 31, 172-173, pl. 22, figs. 4-6; Keen & Bentson, 1944, p. 127.

Amaurellina garzaensis Vokes, 1939, pp. 26, 173, pl. 22, figs. 9, 12, 16; Keen & Bentson, 1944, pp. 127-128.

Description. —

Size: Average specimen, height 8.7 mm, diameter 6.8 mm; largest specimen, height 10.6 mm, diameter 8.3 mm [UCB 15864, paratype].

Shell form: Shell subglobose, spire strongly elevated; body whorl moderately inflated, evenly rounded except for slight flattening below suture; shell thickness average; whorls $5\frac{1}{2}$; suture moderately impressed, narrowly and shallowly channeled. Spiral sculpture of minute, closely spaced costellae that vary somewhat in width; axial sculpture of incremental growth lines. Parietal callus thin, lightly filling posterior apertural angle, evenly merging with umbilical callus.

Umbilicus narrowly open. Umbilical callus not clearly set off from inner lip. Anterior inner lip greatly thickened, raised and slightly reflected over base; a slender cord arises at anterior inner lip and is directed posteriorly into umbilicus; basal lip thickened.

Operculum: Unknown.

Specimens examined. — Seven.

Stratigraphic occurrence. — Lower(?) and middle Eocene. Lower and middle Eocene: Llajas Fm., Las Llajas Canyon, Ventura Co., Calif. (UCR); Maniobra Fm. of Crowell & Susuki (1959), Orocoxia Mountains, Riverside Co., Calif. (UCLA). Middle Eocene: Domengine Fm., Coalinga Quad., Fresno Co. (Dickerson, 1916; Vokes, 1939; UCB), and Cholame Quad., San Luis Obispo Co. (Vokes, 1939; UCB), Calif.

Type localities. —

Amaurellina caleocia — Massive sandstone forming southern portion of the crest of Parson's Peak, 45 feet above base of Domengine Formation, north of Coalinga, Coalinga Quadrangle, SE 1/4 NW 1/4 sec. 24, T. 18 S., R. 14 E., Fresno County, California (Vokes, 1939). Domengine Formation, middle Eocene.

Amaurellina garzaensis — Garza Creek, near 2,000-foot elevation, just northwest of center of sec. 10, T. 23 S., R. 16 E., 200 yards west of Reef Ridge Oil Company well number 1, Cholame Quadrangle, Kings County, California (Vokes, 1939). Domengine Formation, middle Eocene.

Type material. —

Amaurellina caleocia — Holotype, UCB 33781; paratype, UCB 15862.

Amaurellina garzaensis — Holotype, UCB 15863; paratypes, UCB 15864, 15865.

Discussion. — This species is characterized by its small size, fine spiral sculpture, and slender cord entering the umbilicus from the anterior inner lip. The width of the spiral costellae is greatest at the periphery of the body whorl and least just below the suture and on the base. The thickened, reflected anterior inner lip is prominent on most specimens and useful for identification. Variations in shell pro-

portions are minor. This is among the smallest of Cenozoic naticids included in this study.

Amaurellina caleocia and *A. garzaensis* were described together by Vokes (1939) and have type localities in separate outcrops of the same formation. Type specimens of the two are identical in form and *A. garzaensis* is arbitrarily considered here to be the junior synonym.

Genus **GYRODES** Conrad, 1860, p. 289

Type species: *Rapa supraplicata* Conrad, 1858, by monotypy. Upper Cretaceous of Mississippi, Tennessee, and Texas.

Diagnosis.—Shell medium to large, subglobose, spire low, whorls narrowly to moderately tabulate, suture may be channeled, umbilicus moderately to broadly open and often bounded by a basal angulation, umbilical callus thin or absent. Shell smooth or with nodes or crenulations immediately below suture and along margin of umbilical area.

Discussion.—*Gyrodes* is characterized by its low spire, tabulate whorls, and usually broadly open umbilicus bounded by a basal angulation. It is a characteristically Upper Cretaceous genus worldwide, occurring less commonly in Lower Cretaceous (Albian) rocks (Sohl, 1960) and rarely in Tertiary strata.

Gyrodes robustus Waring, 1917

Pl. 21, figs. 3-9

Gyrodes robustus Waring, 1917, pp. 72, 84, pl. 13, figs. 11, 12; Keen & Bentson, 1944, p. 165.

Description.—

Size: Average specimen, height 40 mm, diameter 40 mm; largest specimen, height 28.2 mm (incomplete), diameter 54.0 mm (incomplete) [SU 147, lectotype].

Shell form: Shell subglobose, spire low; body whorl strongly inflated; whorls fairly evenly rounded, strongly tabulate, the tabulate surface slightly concave and usually sloping inward; shell thickness average; whorls about five (apexes eroded). Shell smooth except for incremental growth lines. Parietal callus thin, lightly to heavily filling posterior apertural angle. Umbilicus broadly open, the umbilical area continuing as a broad flattened surface tapering evenly to the basal lip and separated from the base by a low, sharp angulation. Umbilical callus absent. Anterior inner lip and basal lip thickened.

Operculum: Unknown.

Specimens examined. — Twenty-six.

Stratigraphic occurrence. — Upper Paleocene of southern California. Upper Paleocene: Martinez Fm., Simi Hills, Ventura Co. (Waring, 1917; Zinsmeister, 1974b; SU; UCR; UCLA), and Santa Monica Mts., Los Angeles Co. (USGS), Calif.

Type locality. — Simi Hills, Ventura County, California (Waring, 1917). Martinez Formation, upper Paleocene.

Type material. — Lectotype designated herein, SU 147; paralectotype, SU 148.

Nomenclatural commentary. — Two syntypes constitute the primary type lot of *G. robustus*. One of the specimens, SU 147 (Pl. 21, figs. 3-5), is herein designated lectotype, and the other specimen, SU 148 (Pl. 21, fig. 6), is designated paralectotype.

Discussion. — This species is known from few specimens, of which only one is well preserved and nearly complete (Pl. 21, figs. 7 to 9). Twenty-two of the 26 known specimens were collected in the Simi Hills of southern California, and the remaining four are from the nearby Santa Monica Mountains some 25 kilometres (15 miles) to the southeast.

Gyrodes is a predominantly Cretaceous genus with numerous species worldwide. The present species is the only Cenozoic *Gyrodes* known from the Pacific Coast of the United States.

Subfamily **POLINICINAE** Finlay & Marwick, 1937, p. 47

Diagnosis. — Shells small to large, sometimes very large; usually globose, less commonly elongate; spire low to moderately elevated; whorls smooth, suture strongly impressed to appressed, rarely channeled. Umbilicus usually open, slitlike to broad; inner lip usually with distinct callus, funicle rudimentary or absent. Parietal callus sometimes thick, may conceal umbilicus. Operculum chitinous, entirely filling aperture. Radular dentition of tricusate (rarely monocusate) rachidian, one monocusate lateral, one mono- or bicusate inner marginal, and one monocusate outer marginal per half row.

Discussion.— This is the largest and most diverse subfamily of northeastern Pacific Naticidae. A key to genera and subgenera used here follows:

- | | | |
|-----|---|-------------------|
| 1a. | Shell thin, umbilicus open, distinct umbilical callus lacking | 2 |
| 1b. | Shell moderately thick, umbilicus open or closed, with a distinct umbilical callus | 3 |
| 2a. | Base distinctly flattened, final whorl greatly inflated; umbilicus not slitlike | CALINATICINA |
| 2b. | Base not flattened, umbilicus slitlike; final whorl not greatly inflated | BULBUS |
| 2c. | Base not flattened, umbilicus distinctly open, not slitlike | CHORISTES |
| 3a. | Umbilicus open | POLINICES, s.l. 4 |
| 3b. | Umbilicus closed, except rarely | NEVERITA, s.l. 6 |
| 4a. | Umbilical callus large to massive, shell ovate | POLINICES, s.s. |
| 4b. | Umbilical callus not large or massive, usually slender; shell globose to depressed | 5 |
| 5a. | Shell elongate pyriform, thin, umbilical callus slender | MAMMILLA |
| 5b. | Shell globose, umbilical callus slender to thickened (especially posteriorly) | EUSPIRA |
| 5c. | Shell strongly depressed; umbilicus broadly open, with umbilical callus as a thin lobe suspended anteriorly from pillarlike funicle | HYPTERITA |
| 6a. | Umbilical callus without a transverse groove | NEVERITA, s.s. |
| 6b. | Umbilical callus with a transverse groove | GLOSSAULAX |

Genus **POLINICES** Montfort, 1810, pp. 223-224, pl. 56

Type species: *Polinices albus* Montfort, 1810, by original designation. Living, West Indies(?).

Diagnosis.— Shells small to large, globose to ovate; whorls inflated to subdued, smooth except for incremental growth lines and microscopic spiral costellae; suture slightly to deeply impressed. Umbilicus narrowly to broadly open, funicle lacking to weak. Umbilical callus slender to broad and massive; parietal callus thin to thick. Operculum chitinous, entirely filling aperture. Radula typically naticid, with tricuspsate rachidian, one multicuspsate lateral, one bicuspsate inner marginal, and one monocuspsate outer marginal tooth per half row.

Discussion.— When typically developed, *Polinices* is characterized by its globose form, chitinous operculum, and open umbilicus.

In the original indication of *Polinices*, Montfort (1810) described the genus as having a solid (*i.e.*, calcareous) operculum (“opercule solide”) like that of “natices canrene” (presumably *Natica canrena* Linnaeus, 1758, a well-known modern Caribbean species). This has apparently been overlooked by other workers and is prob-

ably a result of Montfort never having seen an operculum of *P. albus* and assuming it to be the same as those of other naticids he was familiar with. All subsequent workers have considered species of *Polinices* to have chitinous opercula.

The status of the type species is unsettled. In the original indication for *Polinices*, Montfort (1810) mentioned *Nerita mamilla* Linnaeus, 1758, but it is not clear whether he considered *P. albus*, the type species, and *N. mamilla* to be synonymous or only meant *N. mamilla* as another example of *Polinices*. The identity of *P. albus* is in question, and numerous workers have equated it with *N. mamilla*. Woodring (1957, p. 89) placed *P. albus* with *Natica mamillaris* (Lamarck, 1822) in the synonymy of *Natica brunnea* Link, 1807, a modern Caribbean species. However, Cernohorsky (1971, p. 191) believed *N. brunnea* to be a synonym of *Albula hepatica* Röding, 1798, and in any case to be a tan or orange-brown species, whereas *P. albus* was described (and named) as white. Cernohorsky further believed *P. albus* to be most probably synonymous with *Nerita mamilla*, the second species mentioned by Montfort (1810), although *N. mamilla* may be an earlier name for *P. lacteus* (Gülding, 1834) of the West Indies, or for *P. tumidus* (Swainson, 1840) or *P. pyriformis* (Récluz, 1844) of the Indo-Pacific. Linnaeus' (1758) type locality for *N. mamilla* of "Barbados" places the species in the Caribbean, but still does not identify it.

Subgenus **POLINICES** Montfort, 1810

Diagnosis. — Shell small to medium in size, commonly ovate but may be globose; whorls moderately inflated to subdued; suture slightly impressed; shell thickness average or greater. Umbilical callus nearly always broad and massive, rarely slender, and often nearly closing umbilicus. Parietal callus moderate to heavy.

Discussion. — This subgenus is comprised of a great number of species, including a large proportion of the tropical Polinicinae worldwide.

Polinices (Polinices) uber (Valenciennes, 1832)

Pl. 22, figs. 2-4

Natica uber Valenciennes, 1832, p. 266; d'Orbigny, 1840, vol. 5, p. 401, vol. 9, pl. 55, figs. 12-14 (plate 1835); M. E. Gray, 1850, vol. 4, p. 82; Tröschel, 1852; p. 157; Philippi, 1850, pp. 60-61, pl. 10, fig. 1 (text 1852) [as "Humboldt"]; Reeve, 1855, pl. 13, figs. 54a, b; Carpenter, 1857d, p. 292; Sowerby, 1883, p. 87, pl. 4, fig. 51; Tryon, 1886, p. 48, pl. 17, fig. 61 [not fig. 66, ?=

- P. (P.) panamaensis* (Récluz, 1844), treated herein]; Hanna, 1926, pp. 451-452.
- Polinices uber* (Valenciennes), Carpenter, 1857c, pp. 452-453; Stearns, 1894a, pp. 195-196 [as "*Polynices*"]; Dall, 1909a, p. 235; Jordan, 1924, p. 156; Jordan, 1936, p. 114; Hertlein & Strong, 1955, p. 140; Valentine & Meade, 1961, pp. 25, 28; Parker, 1964, p. 153, pl. 5, fig. 5.
- Polinices uber uber* M. Smith, 1944, p. 12, fig. 123 [*nomen nudum*; as "*Valenciennes*"].
- Polinices (Polinices) uber* (Valenciennes), Grant & Gale, 1931, p. 799, text-fig. 12; Keen, 1958, p. 323, fig. 272 [in part, also *P. (P.) panamaensis* (Récluz, 1844)]; Keen, 1971, p. 480, fig. 882.
- Natica virginica* Récluz, 1850, pp. 388-389, pl. 12, fig. 6.
- Natica ovum* Menke, 1851, pp. 165-166; Carpenter, 1857d, p. 237.
- "*Natica uberina* Orbigny," Récluz, 1844, p. 210 [as "*Valenciennes*"; not *Polinices (Polinices) uberinus* (d'Orbigny, 1842), living, Caribbean]; Philippi, 1851, pp. 142-143, pl. 19, fig. 16 (text 1853) [not *P. (P.) uberinus* (d'Orbigny, 1842)].

Description. —

Color: Shell exterior white, with pale buff to yellow band below suture; first one or two nuclear whorls tinted pale brown; interior white. Periostracum thin, usually pale yellowish white but ranges to medium yellowish brown and may have irregular rust brown stains.

Size: Average specimen, height 20 mm, diameter 16 mm; largest specimen, height 35.7 mm, diameter 31.4 mm [LACM 70-15, Venado Island, Panama].

Shell form: Shell globose to elongate, spire moderately to greatly elevated; body whorl not greatly inflated; whorls range from slightly tabulate in globose forms to slightly concave above the periphery in elongate forms; shell thickness average; nuclear whorls $3\frac{1}{2}$, with closely set spiral costellae separated by narrower interspaces; post-nuclear whorls $3\frac{1}{2}$; suture slightly impressed. Spiral sculpture of microscopic, closely spaced, very weak costellae; axial sculpture of incremental growth lines. Parietal callus heavy, thickly filling posterior apertural angle; anterior lobe weak. Umbilicus narrowly open, often slitlike. Umbilical callus narrowed nearly to a point anteriorly, evenly expands to posterior end of umbilicus where it merges smoothly with parietal callus; shallow groove traverses callus at juncture of umbilical and parietal calluses; anterior inner lip thickened.

Operculum: Chitinous, filling aperture.

Specimens examined. — Two thousand.

Geographic occurrence and habitat. — Cedros Island, western Baja California, Mexico ($28^{\circ}10'$ N.), throughout the Gulf of Cali-

fornia, and south to the Galápagos Islands, Ecuador, and Paita, Peru (5° S.). Found alive on sand bottoms, intertidally and in depths to at least 100 metres.

Stratigraphic occurrence. — Ranges from Pliocene(?) or Pleistocene to Holocene. Pliocene(?) or Pleistocene: Imperial Fm. [in part], Imperial Co., Calif. (Hanna, 1926). Pleistocene: Punta San Telmo (UCB), Islas Coronados (UCB), Magdalena Bay (Jordan, 1926), and Mulege (CAS), Baja California, and Isla María Madre (CAS), Islas Tres Mariás, Mexico. Reported from the upper Miocene Castaic Fm. of Crowell (1954) near Los Angeles, Calif., by Stanton (1966), but I have not located these specimens. This record is doubtful and might be based on specimens of *P. (P.) gesteri* (Dickerson, 1916), the next species treated below.

Type localities. —

Natica uber — “Habitat ad portum Cumanensem” (Valenciennes, 1832) Hertlein & Strong (1955) thought this to be in Venezuela [probably Cumana, $10^{\circ}28'$ N.], and to be an error. Accepting this species as an eastern Pacific one, the type locality is unknown.

Natica virginea — Realejos (Récluz, 1850) [Probably in Nicaragua at 13° N].

Natica ovum — Mazatlán, Mexico (Menke, 1851).

Type material. —

Natica uber — Unknown.

Natica virginea — Muséum d'Histoire naturelle, Geneva, No. 1303/1/1 (*vide* E. Binder); Mus. Nat. Hist. Nat. Paris (*vide* A. M. Testud). Each specimen spoken of as holotype, cannot determine which.

Natica ovum — Unknown, sold to a dealer (Zilch, 1958, p. 53).

Discussion. — The *P. (P.) uber* species-group is one of the more difficult to deal with taxonomically among the living tropical eastern Pacific naticids, and includes *P. (P.) uber*, *P. (P.) intemeratus* (Philippi, 1851), *P. (P.) panamaensis* (Récluz, 1844), and *P. (P.) otis* (Broderip & Sowerby, 1829), in addition to cool-water Chilean and Peruvian species not treated here. These species exhibit overlapping variations in form and umbilical morphology, although they can be identified with confidence in most cases.

These four species range essentially throughout the entire Panamic province, but reach their greatest development in separate parts of the tropics. The largest specimens of *P. (P.) uber* (heights above 20 mm) generally occur in the Gulf of California and southward; the largest specimens of *P. (P.) intemeratus* (heights above 20 mm) between Panama and Peru; the largest individuals of *P. (P.) panamaensis* (heights above 45 mm) also south of Panama. Large specimens of *P. (P.) otis* are not localized in this way. The two most closely related species, *P. (P.) uber* and *P. (P.) panamaensis*, have separate areas of shell-size maxima which reinforces the separation of these species made on shell characters.

When typically developed, the shell of *P. (P.) uber* is elongate and high-spired, with an evenly tapered umbilical callus that reduces the umbilicus nearly to a slit. Large populations occur commonly and consist mostly of smaller, elongate individuals, the large, globose specimens being comparatively rare. The largest specimens of *P. (P.) uber* are globose rather than slender. Individuals with umbilical calluses more slender than usual for most of their anterior lengths are difficult to separate from specimens of *P. (P.) panamaensis*. Individuals of *P. (P.) uber* and *P. (P.) panamaensis* are commonly found together, and there is no difference in habitat, based on museum label data, to account for observed differences in callus morphology. As large specimens of *P. (P.) uber* are not known along the outer coast of Baja California, although the species ranges north to Cedros Island, there might be environmental controls on shell size, and possibly callus form.

The most characteristic feature of *P. (P.) panamaensis* is its umbilical callus which is slender for most of its length then abruptly broadens at its posterior end to match the width of the parietal callus. If the slender portion of this callus is thicker than usual, with a swollen appearance, then the specimen may be mistaken for a *P. (P.) uber*. Such errors are especially likely when specimens are small and have an elevated spire, which is more characteristic of *P. (P.) uber* but occurs in *P. (P.) panamaensis*. Individuals of *P. (P.) uber* have ratios of body whorl height to spire height of about 1.5:1 to 2.0:1, whereas individuals of *P. (P.) panamaensis* have ratios of about 2.5:1 to 9.0:1, so there is a difference in relative elevation of the spires, although the difference may be minor in individual cases.

Some past workers have stressed that *P. (P.) panamaensis* has a strongly shouldered shell with a flattened periphery, giving a distinctly squared appearance. This is not a common condition, however, and seems to be best developed in cool-water populations of the Peruvian zoological province which are not treated here. Such strongly shouldered specimens from the Peruvian province may belong to other species, and a number of names have been used there for shells similar to *P. (P.) panamaensis*. I have seen specimens from as far south as Isla Chiloé, Chile (42°30' S.) that are much like tropical individuals of *P. (P.) panamaensis*. Peruvian and Chilean naticids related to the *P. (P.) uber* species-group need further study to define their relationships with the tropical species.

Polinices (Polinices) intemeratus has the most consistent morphology of any member of the *P. uber* species-group. The shells are always globose, with ratios of body whorl height to spire height of 3:1 to 4:1, and the arcuate umbilical opening and distinct riblet within the umbilical channel are characteristic features. The most common variation is for the parietal callus to be more massive than usual which restricts the umbilical channel to a smaller arc of curvature. This is accompanied by a thickening of the anterior inner lip and a more severe narrowing of the posterior umbilical callus. In some specimens, the median expansion of the umbilical callus is reduced, and the callus assumes the straighter form seen on some *P. (P.) uber* specimens. Here, however, the riblet in the umbilical channel of *P. (P.) intemeratus* is a distinguishing feature. No specimens of *P. (P.) intemeratus* are as elongate as those of *P. (P.) uber* or as large as those of *P. (P.) panamaensis*.

Polinices (Polinices) otis is also relatively easy to identify because of its consistently elongate shape, inflated anterior portion of the body whorl, and commonly occurring brown color in the umbilical area. It is closest to *P. (P.) intemeratus* in form, but distinctive by its more elongate shell with a higher spire, broader umbilicus lacking a sharp riblet, and greater size.

The northern range-limit for this species-group is well established at Cedros Island, Baja California. Museum specimens labeled as *P. (P.) uber* from southern California have proven to be *Polinices (Euspira) pallidus* (Broderip & Sowerby, 1829). The southern range limits of these species, mostly in northern Peru, are less certain. A

relatively small number of cool-water Peruvian and Chilean specimens is available for study; these largely resemble *P. (P.) panamaensis*, although some differ from that species in details of umbilical morphology, shell form and shell thickness.

The earliest geologic occurrence of *P. (P.) uber* needs confirmation. It is possible that this species or related ones existed in western North America during the Miocene, as there are similar species described from Neogene strata of Ecuador and Peru (Hanna & Israelsky, 1925; Olsson, 1932, 1964). Stanton's (1966) report of *P. (P.) uber* from the upper Miocene Castaic Formation of Crowell (1954) near Los Angeles, California, needs confirmation. I have not located the specimens upon which this record is based. Stanton's report might be founded on specimens of *P. (P.) gesteri* (Dickerson, 1916), as noted in the discussion of that species.

Polinices (Polinices) gesteri (Dickerson, 1916) Pl. 21, figs. 10, 11

Natica gesteri Dickerson, 1916, p. 496, pl. 38, fig. 6; Keen & Bentson, 1944, p. 186.

Polinices (Euspira) gesteri (Dickerson), Clark & Woodford, 1927, pp. 120-121, pl. 21, figs. 14, 15; Keen & Bentson, 1944, p. 186.

Polinices (Polinices) gesteri (Dickerson), Vokes, 1939, p. 168, pl. 21, figs. 2, 6; Weaver, 1943, pp. 336-337, pl. 68, fig. 19; Keen & Bentson, 1944, p. 186.

Polinices gesteri (Dickerson), Givens, 1974, p. 75.

Description. —

Size: Average specimen, height 10 mm, diameter 7 mm; largest specimen, height 15.0 mm, diameter 10.0 mm [UCB 11829, holotype].

Shell form: Shell elongate, spire greatly elevated; body whorl somewhat compressed, with slight flattening or concavity on shoulder; shell thickness average; whorls about five; suture slightly impressed. Shell smooth except for incremental growth lines. Parietal callus relatively heavy, thickly filling posterior apertural angle; anterior lobe weak. Umbilicus narrowly open. Umbilical callus narrow, tapering anteriorly, smoothly merging posteriorly with parietal callus; shallow transverse groove or dimple occurs as juncture of umbilical and parietal calluses; anterior inner lip thickened.

Operculum: Unknown.

Specimens examined. — Twelve.

Stratigraphic occurrence. — Upper Paleocene to middle Eocene. Upper Paleocene: Meganos Fm., Mount Diablo area, Contra Costa

Co., Calif. (Clark & Woodford, 1927; UCB). Lower Eocene: Capay Fm., Coalinga Quad., Fresno Co., Calif. (Vokes, 1939; UCB). Middle Eocene: Umpqua Fm. [Flournoy Fm. of Baldwin & Beaulieu (1973)], Douglas Co., Ore. (Weaver, 1943); Domengine Fm., Coalinga Quad., Fresno Co., Calif. (Vokes, 1939; UCB); Juncal Fm., *Turritella wasana applinae* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR).

Type locality. — SE 1/4 NW 1/4 sec. 15, T. 18 S., R. 14 E., on branch of Salt Creek, Coalinga Quad., Fresno Co., Calif. (Dickerson, 1916). Lower part of Cerros Shale Mem. of Lodo Fm., upper Paleocene.

Type material. — Holotype, UCB 11829.

Discussion. — Although this species is rare, its elongate shape makes it one of the most easily identified Cenozoic naticids. It is essentially identical to small specimens of *P. (P.) uber* (Valenciennes), a common species in the modern eastern Pacific tropics. The living species has a somewhat more inflated body whorl and thicker filling of parietal callus in the posterior apertural angle than *P. (P.) gesteri*, but the species are otherwise identical in form.

The report of "*P. uber*" from the upper Miocene Castaic Formation of Crowell (1954) in Los Angeles County (Stanton, 1966) may be based on a specimen of *P. (P.) gesteri*, although this would entail a major stratigraphic range extension. The verified fossil record of *P. (P.) uber* includes only Pleistocene occurrences in Mexico. The specimen on which Stanton's record is based has not been located.

Weaver's (1943) report of this species in middle Eocene strata of Oregon is doubtful. He recorded *P. (P.) gesteri* from UCB locality A-661, but I found no such specimens in that collection.

Polinices (Polinices) panamaensis (Récluz, 1844) Pl. 22, figs. 5-7

Natica panamaensis Récluz, 1844, pp. 208-209; Reeve, 1855, pl. 5, figs. 11a, b. *Natica panamensis* [sic] Récluz, Philippi, 1850, pp. 45-46, pl. 7, fig. 3 (text 1852); Sowerby, 1883, p. 86, pl. 2, fig. 18; Tryon, 1886, p. 48, pl. 17, fig. 60.

Polinices panamensis [sic] (Récluz), M. Smith, 1944, p. 12.

Polinices (Polinices) panamaensis (Récluz), Keen, 1971, pp. 478, 480, fig. 880.

Description. —

Color: Shell exterior and interior white, with pale buff to yellow band below suture. First one or two protoconch whorls medium brown. Periostracum thin, usually pale yellowish white but ranges to medium yellowish brown, may have irregular brown stains.

Size: Average specimen, height 40 mm, diameter 33 mm; largest specimen, height 62.8 mm, diameter 50.0 mm [LACM A.375, Islas de las Trés Marias, Mexico].

Shell form: Shell globose to elongate, spire moderately to strongly elevated; body whorl may be inflated in larger specimens; shoulder slightly flattened, may be slightly concave; shell thickness average; nuclear whorls $3\frac{1}{2}$, apparently smooth; postnuclear whorls four; suture slightly to moderately impressed. Spiral sculpture of microscopic, closely spaced, weak costellae; axial sculpture of incremental growth lines. Parietal callus heavy, thickly filling posterior apertural angle; anterior lobe weak. Umbilicus narrowly to moderately open, rarely slitlike. Umbilical callus comes to a point anteriorly, narrowly expands toward posterior end of umbilicus, where it abruptly broadens to span the width of the umbilicus and merge with the parietal callus; shallow groove traversing callus at juncture of umbilical and parietal calluses is usually absent; anterior inner lip thickened.

Operculum: Chitinous, filling aperture.

Specimens examined. — Seven hundred fifty.

Geographic occurrence and habitat. — Cedros Island, western Baja California, Mexico ($28^{\circ}10'$ N.), throughout the Gulf of California, and south to Bahía Independencia, Peru ($14^{\circ}14'$ S.). Not known in the Galápagos Islands, but it may range farther south into Peru and Chile. Found living on sand bottoms intertidally and to depths of 139 metres.

Type locality. — Panama (Récluz, 1844).

Type material. — BM(NH) (Keen, 1971, fig. 880).

Discussion. — A discussion of this species is included with that of the closely related species *P. (P.) uber* (Valenciennes, 1832).

Polinices (Polinices) intemeratus (Philippi, 1851) Pl. 22, figs. 8, 9

Natica intemerata Philippi, 1851 [1849-53], p. 129, pl. 18, fig. 10 (text 1853); Philippi, 1853, pp. 233-234; Sowerby, 1883, p. 87, pl. 4, fig. 44; Tryon, 1886, p. 46, pl. 18, fig. 83, pl. 19, fig. 93.

Polinices uber var. *intemeratus* (Philippi), Dall, 1908, p. 334 [as *P. u.* var. *intemerata*].

Polinices intemeratus (Philippi), Palmer & Hertlein, 1936, p. 78, pl. 19, fig. 3 [as "*intemerata*"].

Polinices uber intemeratus (Philippi), M. Smith, 1944, p. 12 [as "*intemerata*"].

Polinices (Polinices) intemeratus (Philippi), Keen, 1958, p. 322, fig. 269; Parker, 1964, p. 153, pl. 6, fig. 8 [as "*intemerata*"]; Keen, 1971, p. 478, fig. 877.

Natica alabaster Reeve, 1855, pl. 9, figs. 33a, b; Carpenter, 1857, p. 292.

Natica rapulum Reeve, 1855, pl. 12, figs. 47a, b; Keen, 1971, p. 478.

Description. —

Color: Shell exterior and interior white, with pale buff to yellow band below suture. First one or two protoconch whorls medium brown. Periostracum thin, usually pale yellowish white but ranges to medium yellowish brown, may have irregular rust brown stains.

Size: Average specimen, height 18 mm, diameter 14.5 mm; largest specimen, height 29.5 mm, diameter 24.3 mm [AHF 381-35, Bahía Independencia, Peru].

Shell form: Shell globose to slightly elongate, spire moderately elevated; body whorl not greatly elevated; shoulder slightly flattened, may be slightly concave on final adult whorl; shell thickness average; nuclear whorls three, with short, weakly developed radial wrinkles extending down from suture; postnuclear whorls $3\frac{1}{2}$; suture slightly impressed. Spiral sculpture of microscopic, closely spaced, weak costellae; axial sculpture of incremental growth lines. Parietal callus heavy, thickly filling posterior apertural angle; anterior lobe weak. Umbilicus moderately open, arcuate, never slitlike. Umbilical callus comes to a point anteriorly, expands gradually to its midpoint, then is pinched to form a rounded sulcus before expanding to meet parietal callus. Shallow groove traverses callus where it merges with parietal callus; anterior inner lip thickened. A low, sharp ridge runs along midline of umbilical channel and is expressed on columella as a low fold.

Operculum: Chitinous, filling aperture.

Specimens examined. — Four hundred twenty-nine.

Geographic occurrence and habitat. — Cedros Island, western Baja California, Mexico ($28^{\circ}10'$ N.), throughout the Gulf of California, and south to the Galápagos Islands and Bahía Independencia, Peru ($14^{\circ}14'$ S.). Living on sand bottoms in depths of 9 to 160 metres.

Stratigraphic occurrence. — *Pleistocene*: Carmen Island, Gulf of California, Mexico (CAS).

Type localities. —

Natica intemerata — Gulf of California, Mexico (Philippi, 1851).

Natica alabaster — Mazatlán, Mexico (Reeve, 1855).

Natica rapulum — Paita, Peru (Reeve, 1855).

Type material.—

Natica intemerata — Unknown, presumably in BM(NH) (Dance, 1966).

Natica alabaster — Unknown, presumably in BM(NH), or National Museum of Wales, Cardiff, Wales (Dance, 1966).

Natica rapulum — Same as above.

Discussion.— The discussion of this species is included with that of the closely related *P. (P.) uber* (Valenciennes, 1832).

Polinices (Polinices) otis (Broderip & Sowerby, 1829) Pl. 22, figs. 10, 11

Natica otis Broderip & Sowerby, 1829, p. 372; Gray, 1839, p. 136; Philippi, 1850, p. 57, pl. 9, fig. 4 (text 1852); Tryon, 1886, pp. 43-44, pl. 12, fig. 2, pl. 17, figs. 70-72 [not pl. 19, fig. 91, = "*Natica*" *perspicua* Récluz, 1950, living, Philippines].

Polinices otis (Broderip & Sowerby), Carpenter, 1864, p. 624; Stearns, 1894a, p. 196 [as "*Polynices*"]; Dall, 1909a, p. 235; M. Smith, 1944, p. 12, fig. 134 [as "Broderip" only].

Lunatia otis (Broderip & Sowerby), Stearns, 1894b, p. 409.

Polinices (Polinices) otis (Broderip & Sowerby), Keen, 1958, p. 323, fig. 271; Keen, 1971, p. 478, fig. 879.

Polinices otis var. *fusca* Carpenter, 1864, pp. 523, 624 [*nomen nudum*]; Carpenter, 1872, p. 9, 110; Stearns, 1894a, p. 196 [as "*Polynices*"]; Tryon, 1886, p. 44 [as junior synonym of *P. otis*]; Palmer, 1963, p. 376.

Natica fusca Sowerby ex Carpenter MS, 1883, p. 89, pl. 8, fig. 104 [described].
Ruma subfusca Dall, 1919b, p. 353; Keen, 1958, p. 323 [as junior synonym of *P. otis*].

Polinices subfusca (Dall), M. Smith, 1944, p. 12, fig. 129.

Natica salangonensis Récluz, 1844, p. 211; Adams, 1852, p. 207; Philippi, 1853, pp. 131-132, pl. 18, fig. 13; Tryon, 1886, p. 44 [as junior synonym of *P. otis*].

Natica gallapagosa Récluz, 1844, p. 213; Philippi, 1851, p. 131, pl. 18, fig. 12 (text 1853); Reeve, 1855, pl. 19, figs. 86a, b; Carpenter, 1857d, p. 185; Sowerby, 1883, p. 89, pl. 7, fig. 95; Tryon, 1886, p. 44, pl. 17, fig. 71 [as junior synonym of *P. otis*].

Lunatia galapagosa (Récluz), Carpenter, 1857d, p. 360 [emendation of name]; Stearns, 1894b, p. 406.

Polinices (Polinices) galapagosus (Récluz), Keen, 1971, p. 478, fig. 879 [photo of syntype].

Natica unimaculata Reeve, 1855, pl. 19, figs. 85a, b; Carpenter, 1857d, p. 293; Sowerby, 1883, p. 83, pl. 8, fig. 105; Tryon, 1886, pp. 46-47, pl. 19, fig. 96.

Polinices (Polinices) unimaculatus (Reeve), Keen, 1958, p. 324, fig. 273; Keen, 1971, p. 480, fig. 883.

"*Natica perspicua* Récluz" [not "*Natica perspicua* Récluz, 1850, pp. 379-380, pl. 14, figs. 1, 2, living, Philippines]; Reeve, 1855, pl. 4, fig. 12; Carpenter, 1857d, p. 292; Sowerby, 1883, p. 87, pl. 6, fig. 70.

Not *Natica perspicua* Pictet & Roux, 1849, p. 51, pl. 18, figs. 4a, b [fossil, Switzerland].

Description.—

Color: Shell white with a pale yellow to orange-brown band below suture; umbilicus white, may be partly or completely dark

brown; umbilical callus rarely all white, usually with an anterior spot of medium to dark brown. Interior white to brown. Nuclear whorls light to dark brown. Periostracum thin, medium yellowish white.

Size: Average specimen, height 35 mm, diameter 30 mm; largest specimen, height 44.1 mm, diameter 40.7 mm [USNM 4124, Cabo San Lucas, Baja California, Mexico].

Shell form: Spire moderately elevated, shell elongate; shoulder flattened; shell thick, nuclear whorls $3\frac{1}{2}$, with weak radial wrinkles on shoulder; postnuclear whorls three; suture slightly impressed. Spiral sculpture of minute, weakly developed costellae; axial sculpture of incremental growth lines. Parietal callus massive, thickly filling posterior apertural angle, with a weakly to strongly developed transverse groove; anterior lobe broad, overhangs umbilicus. Umbilicus broadly open, with distinct posterior sulcus; channel broad. Umbilical callus flattened, slender anteriorly, broadens to greatest width at its midpoint, then is abruptly constricted before expanding again to meet parietal callus; funicle broad, distinct.

Operculum: Chitinous, filling aperture.

Specimens examined. — One hundred seventy-two.

Geographic occurrence and habitat. — Gulf of California, Mexico, to Santa Elena, Ecuador ($2^{\circ}11'$ S.). Workers beginning with Tryon (1886) have reported this species from the Galápagos Islands, but I have seen no specimens from there. Such records are probably based on *P. (P.) hacketti* Marinovich, discussed herein. Most specimens of *P. (P.) otis* are from the Gulf of California and Panama, few from elsewhere. Occurs most commonly offshore in depths of 20 to 297 metres, rarely intertidally on mud flats.

Type localities. —

Natica otis — Mazatlán, Mexico (Broderip & Sowerby, 1929).

Natica fusca — Mazatlán, Mexico (Sowerby, 1883).

Ruma subfusca — Panama (Dall, 1919b).

Natica salangonensis — "Salango, West Colombia [Ecuador]; found in sandy mud" (Récluz, 1843).

Natica gallapagosa — Galápagos Islands, Ecuador, "found in coral sand at Albemarle Island" (Récluz, 1844).

Natica unimaculata — Mazatlán, Mexico (Reeve, 1855).

Type material.—

Natica otis — Unknown, presumably in BM(NH) (Dance, 1966).

Natica fusca — Unknown, presumably in BM(NH) (Dance, 1966).

Ruma subfusca — USNM 46544, holotype.

Natica salangonensis — Unknown.

Natica gallapagosa — Unknown.

Natica unimaculata — Unknown, presumably in BM(NH) (Dance, 1966).

Nomenclatural commentary.— Colors of the aperture, callus and umbilicus of *P. (P.) otis* range continuously from brown to white in various combinations, some of which have served as the basis for species names. Two of the more recently used names are *P. galapagosus*, described as having a brown umbilicus and aperture but a white callus, and *P. unimaculatus*, as having a brown spot on the callus and white or brown aperture and umbilicus. As noted above, Mazatlán, Mexico, is the type locality for *P. (P.) otis* and two of its synonymous species.

Polinices otis var. *fusca* Carpenter, 1864, was proposed without description and later workers listed it only as a name until Sowerby (1883) validated it as *Natica fusca*, although he attributed the species to Carpenter. Dall (1919b) proposed *Ruma subfusca* as a substitute for Carpenter's *nomen nudum*, apparently unaware of Sowerby's previous validation of *Natica fusca*.

The syntypes of *P. galapagosus* (figured in Keen, 1971) are considered here to be specimens of *P. (P.) otis*. Because *P. (P.) otis* is not known to occur in the Galápagos, the locality data with the syntypes are probably in error. All literature illustrations of *P. galapagosus* known to me show specimens of *P. (P.) otis*. Galápagos records might be based on specimens of *P. (P.) intemeratus* (Philippi, 1851), as this species is found there and is often misidentified in collections as *P. (P.) otis*.

Discussion.— Among eastern Pacific naticids, *P. (P.) otis* is most similar to *P. (P.) intemeratus*; they have widely overlapping geographic ranges and have often been confused in collections. These species are closely related but do not intergrade, and *P. (P.) otis* is distinguished by its more elongate shell with a higher spire,

broader umbilicus lacking a sharp spiral ridge, and greater size. Specimens of *P. (P.) intemeratus* are also never stained with brown on their calluses.

Except for colored specimens, early juveniles of *P. (P.) otis* are often indistinguishable from those of *P. (P.) intemeratus*, *P. (P.) uber*, and *P. (P.) panamaensis*. The problem of distinguishing these species is discussed further under *P. uber*.

Polinices (Polinices) amiculatus (Philippi, 1849) Pl. 22, figs. 12, 13

Natica amiculata Philippi, 1849, p. 155; Philippi, 1851, p. 98, pl. 14, fig. 4.

Natica ravidus Souleyet, 1852, pp. 576, 582, pl. 35, figs. 12-15 [as "Natica jaune-roux" in plate caption]; Reeve 1855, pl. 16, figs. 68a, b; Sowerby, 1883, pl. 5, fig. 53; Tryon, 1886, p. 43, pl. 15, fig. 38.

Polinices ravidus (Souleyet), Dall, 1909a, p. 235 [as "Eydoux & Souleyet"]; Burch, 1946, p. 26 [as "Eydoux & Souleyet"].

Polinices (Polinices) ravidus (Souleyet), Keen, 1971, p. 480, fig. 881.

Description. —

Color: Shell white; thin periostracum light orange-brown to chocolate brown; callus and interior white.

Size: Average specimen, height 31 mm, diameter 27 mm; largest specimen, height 44.9 mm, diameter 39.6 mm [USNM 538002, Isla Lobos de Tierra, Peru].

Shell form: Spire low to moderately elevated; shell thick, of 2½ nuclear and four postnuclear whorls, clearly set off from each other; suture distinct but not strongly impressed; shoulder flattened, usually slightly concave; spiral sculpture of minute, indistinct costellae; axial sculpture of incremental growth lines. Parietal callus massive, thickly filling posterior apertural angle; margin slightly concave, with a broad anterior lobe that overhangs umbilicus; a weakly impressed groove partly traverses the parietal callus at its growing margin, below center of the callus. Umbilicus broadly open, exposing earlier whorls; inner (central) portion of channel abruptly deepened, indenting inner lip. Umbilical callus narrow anteriorly, broadly expanded posteriorly to meet parietal callus and conceal upper part of umbilicus.

Operculum: Chitinous.

Specimens examined. — Seven.

Geographic occurrence and habitat. — Santa Elena, Ecuador (2°10' S.), to Isla Lobos de Tierra, Peru (5°20' S.). Two of the seven specimens I have examined are from the type locality of Paita,

Peru. No habitat data accompany any of the specimens, but one individual was found dead on the beach at Paita which suggests a nearshore habitat.

Type localities. —

Natica amiculata — Paita, Peru (Philippi, 1849).

Natica ravidus — Paita, Peru (Souleyet, 1852).

Type material. —

Natica amiculata — BM(NH), three syntypes, illustrated by Keen (1971).

Natica ravidus — Unknown, presumably BM(NH) (Dance, 1966).

Nomenclatural commentary. — Philippi's name for this species has been ignored for 125 years, while the species was referred to as *P. (P.) ravidus*. The syntypes of *P. (P.) amiculatus* figured by Keen (1971), however, show that species to be identical to *P. (P.) ravidus*. Both species have the same type locality of Paita, Peru.

Discussion. — This species is characterized by its solid shell and simple, broadly open umbilicus in which earlier whorls are exposed. Comparison with *P. (P.) hacketti* Marinovich, 1975, the most similar species, is made in the discussion of that species.

Polinices (Polinices) bifasciatus (Griffith & Pidgeon, 1834)

Pl. 24, figs. 1, 2

Natica bifasciata Griffith & Pidgeon, 1834, vol. 12, p. 598, pl. 1, fig. 2.

Natica bifasciata "Gray" [error for "Griffith & Pidgeon"], Philippi, 1850, p. 59, pl. 9, fig. 7 (text 1852); Reeve, 1855, pl. 10, figs. 40a, b; Carpenter, 1857d, p. 292; Sowerby, 1883, p. 93, pl. 4, fig. 45; Tryon, 1886, p. 44, pl. 18, fig. 75; Hanna & Hertlein, 1927, pp. 143, 146; M. Smith, 1944, p. 193, pl. 4, fig. 45.

Polinices bifasciata (Griffith & Pidgeon), Stearns, 1894a, p. 195 [as "Gray"].

Polinices bifasciatus (Griffith & Pidgeon), Durham, 1950a, p. 127, pl. 34, fig. 2 [as "Gray"].

Polinices (Polinices) bifasciatus (Griffith & Pidgeon), Grant & Gale, 1931, p. 800 [as "Gray"]; Keen, 1958, p. 322, fig. 266 [as "Gray"]; Keen, 1971, p. 478, fig. 373 [not pl. 14, fig. 4, = *Neverita (Glossaulax) reclusiana* (Deshayes, 1839), treated herein].

Description. —

Color: Shell tan to medium brown, with four narrow, spiral white bands: one at suture, two near middle of whorl, and one low on base; irregular chocolate brown band may occur between suture and uppermost white band; umbilical callus and parietal callus chocolate brown, may be partly white; callus filling at posterior

apertural angle white. Nuclear whorls white or reddish brown. Interior white, with margin of aperture sometimes brown. Periostracum thin, pale yellowish white.

Size: Average specimen, height 35 mm, diameter 29 mm; largest specimen, height 60.7 mm, diameter 46.7 mm [CAS 34874, San Felipe, Baja California, Mexico].

Shell form: Shell elongate, spire moderately elevated; body whorl not strongly inflated; shell thick; nuclear whorls $3\frac{1}{2}$, smooth; postnuclear whorls four; sutures weakly impressed. Spiral sculpture of minute, weakly developed, obscure costellae; axial sculpture of incremental growth lines. Parietal callus massive, heavily filling posterior apertural angle, with a shallow transverse groove at its midpoint; anterior lobe thick, not clearly set off from remainder of callus. Umbilicus open, relatively large to small, depending on callus development; channel broad, sometimes bounded anteriorly by low ridge. Umbilical callus narrow anteriorly, gradually broadens to meet parietal callus and conceal posterior end of umbilicus. Basal lip thickened.

Operculum: Chitinous, filling aperture.

Specimens examined. — Four hundred twenty-seven.

Geographic occurrence and habitat. — Bahía Magdalena, southwestern Baja California, Mexico ($24^{\circ}30'$ N.), throughout the Gulf of California and south to Panama Bay, Panama (8° N.). Not common except in the Gulf of California. This is chiefly an intertidal species but is known rarely in depths to 60 metres.

Stratigraphic occurrence: *Lower Pliocene*(?): San Marcos Formation, San Marcos Island, Gulf of California (Durham, 1950a). *Upper Pliocene:* Carmen Island, Gulf of California (Durham, 1950a). *Pliocene:* Coronado Island, Gulf of California (Hanna & Hertlein, 1927). *Pleistocene:* Santa Elena Bay, eastern Baja California (CAS); Carmen Island, Coronado Island, Santa Inez Bay, and Punta San Telmo, Gulf of California, Mexico (Durham, 1950a).

Type locality. — Unknown (Griffith & Pidgeon, 1834).

Type material. — Unknown, presumably in BM(NH) if included with J. E. Gray collection (Dance, 1966).

Nomenclatural commentary. — Most workers have attributed this species to J. E. Gray, because the original citation in Griffith & Pidgeon (1834) is "*Natica bifasciata*, Gray." However, there is no

other evidence of Gray having described the species, although it may have been a manuscript name of his. Keen (1971) first attributed the species name to Griffith & Pidgeon.

Discussion.—The Pliocene specimens I have seen of *P. (P.) bifasciatus* from the Gulf of California islands are well preserved and may actually be of Pleistocene age.

Polinices (Polinices) hornii (Gabb, 1864)

Pl. 21, figs. 12-14;
Pl. 23, figs. 1, 2

"*Natica acetites* Conrad," Conrad, 1855, p. 7, 10 [as "*N. acetites*?" on p. 10; not *N. acetites* Conrad, 1833, p. 46, Eocene, Alabama]; Conrad, 1857, p. 321, pl. 2, fig. 7 [as "*N. acetites*?"; not *N. acetites* Conrad, 1833].

Lunatia hornii Gabb, 1864, pp. 106-107, pl. 29, fig. 217; Cooper, 1894, p. 62; Stanton, 1896, p. 1044, pl. 66, fig. 4; Arnold, 1910, p. 14, pl. 4, fig. 9; Arnold & Anderson, 1910, pl. 26, fig. 9; Dickerson, 1913, pp. 259, 264, 270; Dickerson, 1914b, p. 151, pl. 13, fig. 5; Dickerson, 1914c, p. 295; Dickerson, 1915, p. 43, pl. 4, fig. 11; Keen & Bentson, 1944, p. 168.

Polynices hornii (Gabb), Waring, 1917, pp. 86, 90, pl. 13, fig. 4; Keen & Bentson, 1944, p. 186.

Natica hornii (Gabb), Clark, 1921, pp. 155, 159; Anderson & Hanna, 1925, pp. 41, 44, 115, pl. 10, fig. 7; M. Hanna, 1927, pp. 259, 305; Keen & Bentson, 1944, p. 177.

Polinices hornii (Gabb), Nelson, 1925, pp. 402, 456, pl. 55, figs. 3-6; Stewart, 1927, p. 324, pl. 30, fig. 15; Turner, 1938, p. 88 pl. 19, figs. 8, 9; Schenck & Keen, 1940, p. 30, pl. 22, figs. 3, 4; Keen & Bentson, 1944, p. 186; Givens, 1974, pp. 75-76, pl. 8, fig. 2.

Polinices (Euspira) hornii (Gabb), Clark & Woodford, 1927, pp. 84, 121, pl. 22, figs. 1-4; Keen & Bentson, 1944, p. 186.

Polinices (Polinices) hornii (Gabb), Weaver, 1943, p. 335, pl. 63, figs. 1-3, pl. 100, fig. 28.

Description.—

Size: Average specimen, height 23 mm, diameter 22 mm; largest specimen, height 31.2 mm, diameter 31.1 mm [UCB A-971, Tejon Formation, Tejon quadrangle, Kern County, California, upper Eocene].

Shell form: Shell globose to somewhat elongate, spire low to moderately elevated; body whorl evenly rounded except for more elongate individuals in which shoulder is slightly flattened; shell thickness average; whorls 5½; suture slightly impressed, strongly appressed such that underlying whorls are almost entirely concealed by body whorl. Shell smooth except for incremental growth lines. Parietal callus heavy, thickly filling posterior apertural angle; anterior lobe weak to indistinct, rarely well developed; merges evenly with umbilical callus. Umbilicus narrowly open in juveniles, becoming progressively closed as growth proceeds, rarely open in adults.

Umbilical callus massive, nearly or entirely filling umbilicus, extending entire length of inner lip and irregularly tapering anteriorly. Anterior inner lip thickened.

Operculum: Unknown.

Specimens examined. — Four hundred one.

Stratigraphic occurrence. — Upper Paleocene to upper Eocene. Upper Paleocene: Meganos Fm., Byron Hot Springs Quad. (UCB) and Diablo Quad. (Clark & Woodford, 1927; SU; UCB), Contra Costa Co., Calif.; Martinez Fm., Simi Hills, Ventura Co., Calif. (Waring, 1917; Nelson, 1925; CAS; UCR). Middle Eocene: Tyece Fm., Douglas and Coos Cos., Ore. (UCB); Juncal Fm., *Ectinochilus supraplicatus* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR); Ardath Shale, La Jolla Quad., San Diego Co., Calif. (M. Hanna, 1927). Upper Eocene: Cowlitz Fm., Cowlitz and Lewis Cos., Wash. (Stewart, 1927; Weaver, 1943; UCB); Coaledo Fm., Coos Co., Ore. (Weaver, 1945; UCB); Markley Fm., Diablo Quad., Contra Costa Co., Calif. (Dickerson, 1914b); Tejon Fm., near Clear Lake, Lake Co. (Stanton, 1896) and Tejon Quad., Kern Co. (Conrad, 1855, 1857; Gabb, 1864; Arnold, 1910; Dickerson, 1915; Anderson & Hanna, 1925; CAS; SU; UCB); Matilija Ss., *Ectinochilus canalifer* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR).

Type locality. — Alizos Creek [Live Oak Canyon], near Fort Tejon, Tejon Quad., Kern Co., Calif. (Gabb, 1864).

Type material. — Lectotype of Stewart (1927), ANSP 4214; eight paralectotypes, ANSP 4214.

Discussion. — The size of the umbilical opening is the most variable feature of this species. All juveniles I have seen are narrowly but distinctly umbilicate. However, the proportion of umbilicate individuals in a population steadily decreases with increasing shell size, so it is rare to see open umbilici on adults more than two-thirds full size. All of the largest specimens I have seen are imperforate.

The massive umbilical-parietal callus is a distinctive feature, so much so that the range in shell proportions from globose to somewhat elongate is not confusing. A few late Paleocene specimens from the Simi Hills of southern California have generally less massive shells and more slender calluses. Because these are among the earliest

known individuals of this species, their more subdued morphology may reflect that of the species, as yet unknown, from which *P. (P.) hornii* evolved.

By the collections I have seen, this species is most abundant in the upper Eocene Tejon Formation of southern California.

Polinices (Polinices) susanaensis Nelson, 1925 Pl. 23, figs. 3-6

Polinices susanaensis Nelson, 1925, p. 421, pl. 55, figs. 2a, b [not figs. 1a, b, = *P. (P.) hornii* (Gabb, 1864), treated herein]; Keen & Bentson, 1944, p. 186; Smith, 1975, p. 469, pl. 2, fig. 21.

Description. —

Size: Average specimen, height 29 mm, diameter 30 mm; largest specimen, height 34.7 mm, diameter 35.5 mm [UCB A-9717, Lodo Fm., Panoche Quad., Fresno Co., Calif., upper Paleocene].

Shell form: Shell subglobose, spire moderately elevated; body whorl inflated, fairly evenly rounded, base obliquely angled; shell thickness average; whorls at least $4\frac{1}{2}$ (apexes of specimens eroded); suture slightly impressed, strongly appressed so that underlying whorls are largely concealed by body whorl. Shell smooth except for incremental growth lines. Parietal callus massive, thickly filling posterior apertural angle; anterior lobe weak, slightly overhangs umbilicus; smoothly merges with umbilical callus. Umbilicus open, umbilical area broadens anteriorly and is bounded by a rounded angulation on base. Umbilical callus simple, tapers anteriorly; anterior end of callus strongly depressed along with inner lip. Anterior inner lip slightly thickened, strongly depressed.

Operculum: Unknown.

Specimens examined. — Twenty-one.

Stratigraphic occurrence. — Upper Paleocene of southern California. Upper Paleocene: Martinez Fm., Simi Hills, Ventura Co., Calif. (Nelson, 1925; Zinsmeister, 1974b; UCB; UCR); Lodo Fm., Panoche Quad., Fresno Co., Calif. (Smith, 1975; SU; UCB).

Type locality. — Center of SE $\frac{1}{4}$ sec. 28, T. 2 N., R. 18 W.; 2,200 feet N. 64° W. of 1,926-foot hill in Simi Hills, on south side of junction of two canyons northeast of 1,926-foot hill; elevation 1,250 feet. Camulos Quadrangle, Simi Hills, Ventura County, California (Nelson, 1925). Martinez Formation, upper Paleocene.

Type material. — Holotype, UCB 30711; paratype UCB 30712 [= *Polinices (Polinices) hornii* (Gabb, 1864); see discussion below].

Discussion.—This species is characterized by its obliquely angled base, rather massive, evenly tapering umbilical callus, and open umbilicus. It is similar and undoubtedly related to *P. (P.) hornii* (Gabb) which lived from the late Paleocene to late Eocene. The nature of the umbilical opening and callus differentiate the two species. All known specimens of *P. (P.) susanaensis* are umbilicate, whereas most adults of *P. (P.) hornii* have closed umbilici and all of the largest individuals are imperforate. In umbilicate specimens of *P. (P.) hornii*, the umbilical opening is much narrower than in *P. (P.) susanaensis*, and the umbilical channel becomes narrower anteriorly, rather than broader as in the latter species. In addition, the umbilical callus of *P. (P.) susanaensis* does not extend relatively as far anteriorly as that of *P. (P.) hornii*. The base of *P. (P.) susanaensis* is obliquely angled in all individuals, whereas this character is rarely seen in *P. (P.) hornii*.

Only one of the two primary type specimens is properly allocated to *P. (P.) susanaensis*. The paratype is the better preserved of the two and is a typically imperforate individual of *P. (P.) hornii*.

Subgenus **EUSPIRA** Agassiz in J. Sowerby, 1838, p. 14

Type species: *Ampullaria sigaretina* Lamarck, 1804, by subsequent designation (Harris, 1897, p. 264). Paleogene of France and England.

Diagnosis.—Shell small to large, globose; whorls moderately to greatly inflated; suture weakly to deeply impressed. Umbilical callus usually slender, may be slightly broad, never closing umbilicus. Parietal callus thin to moderately thick.

Discussion.—*Euspira* is characterized by a globose shell, open umbilicus and slender umbilical callus that becomes thicker posteriorly.

Dall (1908, p. 333) has commonly been cited as designator of the type species, but Harris' (1897) citation is easier. The type species designated by Harris (1897) is one of several fossils included by Agassiz (*in* Sowerby, 1838) in *Euspira*. The subgenus is found primarily in temperate water, but ranges into the Arctic.

Polinices (Euspira) galianoi Dall, 1909

Pl. 23, figs. 7-9

Polinices (Euspira) galianoi Dall, 1909b, pp. 88-89, pl. 5, figs. 12, 13; Etherington, 1931, pp. 94-95, pl. 12, figs. 1, 5, 8, 20; Grant & Gale, 1931, p. 805;

- Clark, 1932, p. 825 [as "cf."]; Weaver, 1943, p. 344, pl. 70, figs. 11, 14; Weaver, 1945, p. 57.
- Polinices galianoi* Dall, Arnold & Hannibal, 1913, pp. 576, 584, 591, 592; Weaver, 1916a, pp. 216, 218 [as "*Polynices*"].
- Natica galianoi* (Dall), Howe, 1922, sp. list.
- Natica (Euspira) galianoi* (Dall), ?Lutz, 1951, pp. 380, 391, pl. 18, fig. 3 [figure unrecognizable].
- Natica (Neverita) orbicularis* Nomland, 1916b, p. 207, pl. 10, figs. 4a, b; Keen & Bentson, 1944, p. 177.
- Natica orbicularis* Nomland, Moody, 1916, p. 44, pl. 2, fig. 6; Nomland, 1917b, pp. 213, 221; Keen & Bentson, 1944, p. 177.
- Polinices (Euspira) orbicularis* (Nomland), Grant & Gale, 1931, p. 805 [as *P. (?E.) orbicularis*]; Soper & Grant, 1932, p. 1063.
- Polinices orbicularis* (Nomland), Adegoke, 1969, p. 166.
- Neverita (Glossaulax)* n. sp.?, Addicott, 1970a, p. 70, pl. 6, figs. 1, 9.
- "*Euspira ramonensis* (Clark, 1918)," Kanno, 1971, p. 110, pl. 13, figs. 1a, 1b.

Description. —

Size: Average specimen, height 43 mm, diameter 42 mm; largest specimen, height 57.4 mm, diameter 53.3 mm (incomplete) [SU NP220, Sylvia Creek, Montesano, Washington, Pliocene?].

Shell form: Shell globose, spire low to moderately elevated, rarely high; body whorl moderately inflated, may be slightly flattened at periphery; shoulder distinctly flattened at suture, may be slightly concave; shell thickness average; nuclear whorls two, sculptured with low, closely spaced axial costellae; postnuclear whorls four; suture moderately to slightly impressed. Shell smooth except for minute incremental growth lines. Parietal callus thin, thickens into posterior apertural angle; anterior lobe moderately developed, merges smoothly with umbilical callus. Umbilicus broadly open, occupied to varying degree by umbilical callus. Umbilical callus confined to posterior half of inner lip, clearly divided into two lobes by sharply incised transverse groove; lobes flattened or rounded with swollen appearance; anterior lobe usually more massive, but posterior lobe may be more elongate; funicle low, inconspicuous. Anterior inner lip and basal lip slightly thickened.

Operculum: Unknown.

Specimens examined. — Two hundred eight.

Stratigraphic occurrence. — Upper Oligocene or lower Miocene to lower or middle Pliocene. Upper Oligocene or lower Miocene: Poul Creek Fm., Yakataga area, Alaska (Clark, 1932; Kanno, 1971; UCB); Sooke Fm., southern Vancouver Island, B.C. (Arnold & Hannibal, 1913). Middle Miocene to middle Pliocene: Yakataga Fm., Yakataga area, Alaska (Clark, 1932). Middle Miocene: Astoria

Fm., northwestern Washington (Arnold & Hannibal, 1913), Montesano (SU), Grays Harbor Co. (UCB), Washington, and Lincoln Co. (UCB), Newport (CAS), and Coos Bay (UCB), Ore.; Monterey Fm., Briones Valley Quad., Calif. (UCB); Sobrante Ss., Pacheco syncline, Calif. (Lutz, 1951); Temblor Fm., Caliente Quad., Calif. (UCB); upper part of Olcese Sand and lower part of Round Mountain Silt, Kern River area, Calif. (Addicott, 1970a; USGS). Upper Miocene to lower Pliocene: Montesano Fm. of Weaver (1912), Montesano (CAS; SU), Grays Harbor Co. (UCB), Wash. Lower Pliocene: Empire Fm., Coos Bay (Weaver, 1945; CAS), and Coos Bay-Cape Blanco area (Arnold & Hannibal, 1913), southwestern Ore. Lower or middle Pliocene: Merced Fm., San Francisco peninsula (Glen, 1959) and Eel River Valley, California (Arnold & Hannibal, 1913); Etchegoin Fm., San Miguel Quad., Monterey Co. (SU), Coalinga area (Nomland, 1916b), Calif.

Type localities. —

Polinices (Euspira) galianoi — Coos Bay, Oregon. Empire Formation, lower Pliocene (Dall, 1909b).

Natica (Neverita) orbicularis — UCB 2679, middle of north line, SE1/4NE1/4 sec. 7, T. 22 S., R. 15 E., Fresno County, California. Jacalitos Formation of former usage, lower Pliocene (Nomland, 1916b; Keen & Bentson, 1944).

Type material. —

Polinices (Euspira) galianoi — Holotype, USNM 153916.

Natica (Neverita) orbicularis — Holotype, UCB 12058.

Nomenclatural commentary. — *Polinices (Euspira) orbicularis* is made a junior synonym of *P. (E.) galianoi* here for the first time, based on a comparison of type specimens. The types of *P. (E.) galianoi* are poorly preserved, but some clearly show remnants of the diagnostic bilobed umbilical callus that is displayed well on the holotype of *P. (E.) orbicularis*.

Although the operculum of this species is unknown, its shell morphology unequivocally allies it with a number of living *Polinicinae* species, such as *P. (E.) lewisii* (Gould, 1847) and *Neverita (Glossaulax) reclusiana* (Deshayes, 1839). The inclusion of this species in the calcareous-operculate genus *Natica* by some past workers is unjustified.

Discussion. — Recognition of this species has been difficult because the type specimens are poorly preserved, with critical umbilical features missing from them. However, unmistakable remnants of the bilobed umbilical callus on some specimens, plus details of shell shape, size, and stratigraphic occurrence, leave no doubt as to the identity of Dall's species.

The umbilical callus varies in prominence and the degree to which it occupies the umbilicus. Juveniles have flattened calluses, with a fairly weak transverse groove, the posterior callus lobe is sometimes small, whereas the umbilical callus of an adult has a deeply incised transverse groove and the lobes have a swollen appearance.

The compact, bilobed umbilical callus is similar to that of *N. (G.) jamesae* (Moore, 1963), an early to middle Miocene species. *N. (G.) jamesae* is easily distinguished by its greatly flattened base, wider umbilicus, lower spire and more inflated body whorl, but the two species occur throughout much the same region. The posterior umbilical callus lobe of *P. (E.) galianoi* is never detached from the underlying whorl as seen in some specimens of *N. (G.) jamesae*.

Individuals with elevated spires are rare, and when they occur with a prominent umbilical callus they resemble the so-called *alta* form of *N. (G.) reclusiana*. The resemblance may be close, but *P. (E.) galianoi* specimens have thinner shells, less elongate posterior lobes of the umbilical callus, and more flattened bases than specimens of *N. (G.) reclusiana*.

Polinices (Euspira) galianoi is similar in form to *P. (E.) lewisii* and is almost certainly ancestral to it. It differs from *P. (E.) lewisii* by its smaller size, lack of a spiral flexure on the shoulder, more abruptly tapered anterior margin of the umbilical callus, and more deeply incised callus groove. The general aspects of shell form and umbilical details are similar.

Polinices (Euspira) diabloensis (Clark, 1915)

Pl. 23, fig. 10

Natica (Euspira) diabloensis Clark, 1915b, pp. 486-487, pl. 68, fig. 7.

Natica diabloensis Clark, Nomland, 1917b, p. 301.

Polinices (Polinices) diabloensis (Clark), Addicott & Vedder, 1963, p. 66.

Euspira diabloensis (Clark), Adegoké, 1969, p. 169.

Description. —

Size: Average specimen, height 45 mm, diameter 37 mm; largest

specimen, height 48.8 mm (incomplete), diameter 50.4 mm (incomplete) [SU 39471, Temblor(?) Formation, Santa Clara County, California, middle Miocene?].

Shell form: Shell elongate, spire elevated; body whorl not greatly inflated; whorls evenly rounded except for slight flattening near suture; shell thickness average; whorls $5\frac{1}{2}$; suture moderately impressed. Shell smooth except for minute incremental growth lines. Parietal callus thick, solidly filling posterior apertural angle; anterior lobe weak, slightly projecting above umbilicus. Umbilicus narrowly open, lacking a distinct sulcus; channel narrow, only slightly tapering anteriorly; umbilicus bounded by a broad cordlike angulation on base. Umbilical callus narrow, not clearly set off from inner lip; funicle indistinct. Anterior inner lip and basal lip thickened.

Operculum: Unknown.

Specimens examined. — Thirteen.

Stratigraphic occurrence. — Ranges from middle(?) to upper Miocene. Middle Miocene(?): Temblor(?) Fm., Calaveras Valley, Santa Clara Co., San Jose Quad., Calif. (SU). Upper Miocene: Santa Margarita Fm., north Coalinga area (Clark, 1915b; Nomland, 1917b), Domengine Ranch Quad. (UCB; Adegoke, 1969), Calif.; upper San Pablo Fm., central Calif. (Clark, 1915b); Neroly Fm., Byron Hot Springs Quad., Calif. (UCB).

Type locality. — Walnut Creek, Diablo Quadrangle, NE1/4 sec. 31, T. 1 N., R. 1 W., Contra Costa County, California (Clark, 1915b). San Pablo Formation, upper Miocene.

Type material. — Holotype, UCB 11595.

Discussion. — The holotype is the best-preserved specimen, and no juveniles are known. *Polinices (Euspira) diabloensis* differs from the upper Eocene to middle Miocene *P. (E.) lincolnensis* (Weaver, 1916) by its large size, more elevated spire, more strongly impressed suture, thinner parietal callus, and thinner inner lip-umbilical callus. It differs from *P. (E.) lewisii* (Gould, 1847) by its smaller size, lack of a shoulder flexure, narrower umbilicus, much weaker anterior lobe of the parietal callus, and lack of a transverse groove on the callus. Similarly, *P. (E.) diabloensis* differs from *P. (E.) galianci* Dall, 1909, the probable ancestor of *P. lewisii*, by its higher spire, narrower umbilicus, and its much narrower and ungrooved umbilical callus. It also resembles the upper Oligocene to lower Miocene *P. (E.)*

ramonensis (Clark, 1918), as noted in the discussion of that species.

The single middle Miocene occurrence of *P. (E.) diabloensis* should be questioned until additional specimens of the same age are found. Until then, it is best to consider this as an exclusively late Miocene species.

Polinices (*Euspira*) *ramonensis* (Clark, 1918) Pl. 23, figs. 11;
Pl. 26, figs. 1-3

Natica (Euspira) ramonensis Clark, 1918, p. 166, pl. 19, fig. 16; Keen & Bentson, 1944, p. 177.

Polinices (Euspira) ramonensis (Clark), Clark, 1932, p. 826, pl. 20, figs. 4, 5, 8, 9.

Euspira ramonensis (Clark), Addicott, *et al.*, 1971, p. 20, figs. 2i, j, n, o, t. Not "*Euspira ramonensis* (Clark)," Kanno, 1971, p. 110, pl. 13, figs. 1a, b [= *P. (E.) galianoii* Dall, 1909b; treated herein].

Description.—

Size: Average specimen, height 14 mm, diameter 11 mm; largest specimen, height 16.0 mm, diameter 12.4 mm [UCB 11257, holotype].

Shell form: Shell elongate globose, spire moderately elevated; body whorl slightly compressed; shell thin; whorls five; suture slightly impressed. Shell smooth except for incremental growth lines. Parietal callus thin, lightly filling posterior apertural angle; anterior lobe weak, slightly overhanging umbilicus. Umbilicus slitlike. Umbilical callus merely a thickened inner lip, without strong features. Anterior inner lip and basal lip thickened.

Operculum: Unknown.

Specimens examined.—Forty.

Stratigraphic occurrence.—Upper Oligocene and lower Miocene. Upper Oligocene: Blakeley Fm. of Weaver (1912), *Echino-phoria apta* zone, Kitsap Co., Wash. (UCB). Upper Oligocene and lower Miocene: Poul Creek Fm., Yakataga District, south-central Alaska (Clark, 1932; UCB); San Ramon Ss., near Walnut Creek, Contra Costa Co., Calif. (Clark, 1918; UCB).

Type locality.—One-half mile southwest of town of Walnut Creek, in creek bed about 100 yards east of Oakland and Antioch bridge, elevation 150 feet, Contra Costa County, California (Clark, 1918). San Ramon Sandstone, upper Oligocene to lower Miocene.

Type material.—Holotype, UCB 11257.

Discussion.—This poorly known species is characterized by its somewhat elongate proportions, slitlike umbilicus and simple umbili-

cal callus. It most closely resembles the middle (?) to late Miocene *P. (E.) diabloensis* (Clark), but the two are not easily confused. *Polinices (Euspira) diabloensis* has an average size more than three times that of *P. (E.) ramonensis*, its umbilicus is narrow but never slitlike, and its parietal callus is relatively thicker than that of the latter species. *Polinices (Euspira) ramonensis* also resembles the middle and upper Oligocene *P. (E.) blakeleyensis* Tegland; and comparison of the two is made in the discussion section of that species.

The precise stratigraphic range of this species is not known, because the formations in which it occurs have not had their faunas studied in detail. Most specimens of *P. (E.) ramonensis* have come from the Blakeley Formation of Washington.

Polinices (Euspira) blakeleyensis Tegland, 1933 Pl. 26, figs. 4,5

Polinices (Euspira) blakeleyensis Tegland, 1933, p. 139, pl. 14, fig. 18.

Amauropsis blakeleyensis Tegland, Weaver, 1943, p. 348, pl. 71, fig. 10; Durham, 1944, pp 123, 160; Armentrout, 1975, p. 28.

Description. —

Size: Dimensions of the only well-preserved specimen, the holotype, are: height 27.5 mm, diameter 22.3 mm.

Shell form: Shell elongate, spire greatly elevated; body whorl moderately inflated, evenly rounded; shell thin; whorls at least four (apexes of all known specimens eroded); suture moderately impressed. Axial sculpture of incremental growth lines that are directed forward just below the suture and intersect the suture at a low angle; spiral sculpture of extremely vague, minute, closely and irregularly spaced costellae. Parietal callus thin, lightly filling posterior apertural angle. Umbilicus closed or nearly so. Umbilical callus narrow, gradually tapering anteriorly. Anterior inner lip not distinctly thickened.

Operculum: Unknown.

Specimens examined. — Three.

Stratigraphic occurrence. — Middle and Upper Oligocene of Washington. Middle Oligocene: Blakeley Fm. of Weaver (1912), *Echinophoria rex* zone, King and Kitsap Cos., Wash. (Durham, 1944; UCB). Upper Oligocene: Twin River Fm., *Echinophoria apta* zone, Port Angeles, Wash. (USGS); Lincoln Creek Fm., southwestern Wash. (Armentrout, 1975).

Type locality.— Restoration Point, Kitsap County, near Seattle, Washington (Tegland, 1933). Blakeley Formation, Oligocene.

Type material.— Holotype, UCB 32216.

Nomenclatural commentary.— Because this species lacks a channeled suture, it cannot be placed in *Amauropsis*, as was done by Weaver (1943) and later workers. None of the known specimens is well enough preserved to permit subgeneric assignment with complete confidence, and *Euspira* seems the best compromise until better specimens are found.

Discussion.— This is one of the most imperfectly known Tertiary naticids of western North America, because no completely intact specimen has been found. The holotype is the best preserved of the three known specimens, but the anterior portion of its umbilical callus is missing and the adjacent section of body whorl is partly decorticated. Thus, the present slitlike umbilicus may be an artifact of preservation.

The species most similar in form to this one is *P. (E.) ramonensis* (Clark) of upper Oligocene and lower Miocene strata in Alaska, Washington, and California. However, *P. (E.) ramonensis* is only about two-thirds the size of *P. (E.) blakeleyensis* and has a less elevated spire. Also, the shell and parietal callus of *P. (E.) ramonensis* are relatively much thicker than on *P. (E.) blakeleyensis*. In addition, the whorls of the latter species are distinctly more inflated than those of the former. Each species has a slitlike umbilicus, although that of *P. (E.) blakeleyensis* may be artificial, as noted above.

As noted in the original description, the incremental growth lines curve in the direction of shell growth just below the suture and intersect the suture at a low angle. This characteristic is uncommon among naticids and helps to identify this species.

Polinices (*Euspira*) lewisii (Gould, 1847)

Pl. 24, figs. 3-5

Natica lewisii Gould, 1847, p. 239; Gould, 1852, pp. 211-212; Gould, 1856, pl. 15, fig. 253; Gould, 1862, pp. 49, 244; Tryon 1886, p. 35, pl. 9, fig. 70, pl. 13, fig. 11 [not pl. 13, fig. 12, = *P. reinianus* (Dunker, 1877), living, Japan]; Martin, 1916, pp. 230, 239, 257 [as "cf."]; Weaver, 1916a, pp. 172, 176 [as "cf."]; Johnson, 1964, p. 101.

Lunatia lewisii (Gould), Carpenter, 1864, p. 661; Keep, 1888, p. 45, fig. 25; Arnold & Anderson, 1907, p. 144, pl. 21, fig. 3, pl. 44, fig. 1; Arnold, 1908a, pp. 353-354; Arnold, 1910, pp. 31, 150, pl. 22, fig. 1; Arnold & Anderson, 1910, pp. 109, 110, 127, 133, pl. 44, fig. 1; Jordan, 1924, p. 150; Woodring, Stewart & Richards, 1940, p. 86, pl. 15, fig. 8, pl. 31, fig. 5; Keen & Bentson,

- 1944, p. 168; Woodring, Bramlette, & Kew, 1946, p. 72; Woodring & Bramlette, 1950, p. 73, pl. 12, fig. 1; Winterer & Durham, 1962, p. 296; Stanton, 1966, p. 23; Adegoke, 1969, pp. 166-167.
- Polinices (Lunatia) lewisii* (Gould), Arnold, 1903, p. 315, pl. 10, fig. 14.
- Polinices (Euspira) lewisii* (Gould), Dall, 1921, p. 165; Oldroyd, 1924, pp. 162-163, pl. 36, fig. 1; Oldroyd, 1927, p. 279; Grant & Gale, 1931, pp. 804-805, figs. 15a, b; Soper & Grant, 1932, p. 1063; Willett, 1937, p. 400; Burch, 1946, p. 29; Glen, 1959, p. 184 [as "cf."]; Faustman, 1964, p. 136.
- Euspira lewisii* (Gould), Clark, 1931, sp. list; Valentine, 1956, p. 200; Valentine, 1957, p. 300 [as "*lewisii*"]; Valentine, 1961, pp. 335, 336, 338 [as "*lewisii*"]; Valentine & Meade, 1961, pp. 17, 19, 23, 27 [as "*lewisii*"]; Valentine, 1962, p. 96.
- Polinices lewisii* (Gould), Packard, 1918, p. 325, pl. 38, fig. 1 [as "*lewisii*"]; Jordan, 1936, p. 246; Arnold & Hannibal, 1913, p. 598; Keen, 1937, p. 44; DeLong, 1941, p. 241; Smith & Gordon, 1948, p. 199; MacGinitie & MacGinitie, 1949, pp. 370, 376, fig. 238; Emerson & Addicott, 1953, p. 440; Addicott & Emerson, 1959, p. 16; Kanakoff & Emerson, 1959, p. 30; Durham & Addicott, 1965, p. 12; McLean, 1969, p. 37, fig. 19.1; Wright, 1972, p. 690.
- Natica herculea* Middendorff, 1849, pp. 424-425, pl. 7, figs. 5-7; Philippi, 1853, pp. 148-149; Gould, 1862, p. 244; Carpenter, 1864, p. 531; Sowerby, 1883, p. 77, pl. 1, fig. 3.
- Natica herculea* forma *normalis* Middendorff, 1849, p. 424.
- Natica herculea* forma *elatior* Middendorff, 1849, p. 424.
- Natica herculea* var. *lewisii* (Gould), Sowerby, 1883, pl. 1, fig. 3.
- Natica algida* Gould, 1848, p. 73; Gould, 1852, p. 214; Gould, 1856, pl. 15, figs. 256, 256a; Gould 1862, pp. 50, 244; Carpenter, 1864, p. 531; Johnson, 1964, pp. 38-39.
- Euspira algida* (Gould), Dall, 1919b, p. 352.
- Polinices (Euspira) algidus* (Gould), Dall, 1921, p. 164 [as "*algida*"]; Oldroyd, 1924, p. 162; Oldroyd, 1927, p. 730; Burch, 1946, p. 29.
- Polinices algidus* (Gould), Keen, 1937, p. 44.

Description. —

Color: Shell exterior white. Periostracum thin, light to medium yellowish brown, commonly stained rust brown, especially on shoulder, becoming thicker, darker and scaly within umbilicus. Interior white or clouded with pale brown; umbilical callus mottled with pale brown and white, parietal callus usually white.

Size: Average specimen, height 90 mm, diameter 75 mm; largest specimen, height 166.0 mm, diameter 131.0 mm [Santa Monica Bay, California; LACM records].

Shell form: Shell globose to elongate, spire moderately to strongly elevated; body whorl inflated; adult whorls with a weakly to strongly concave shoulder profile, sometimes forming a tabulation below suture; shell average or greater in thickness; nuclear whorls $2\frac{1}{2}$, smooth; postnuclear whorls seven. Spiral sculpture of minute, weakly developed, closely spaced costellae, which may be absent; axial sculpture of incremental growth lines that may form irregular rugae below suture and in umbilicus. Parietal callus average to thick,

moderately to heavily filling posterior apertural angle; anterior lobe distinct. Umbilicus open, relatively broad to narrow, not exposing many earlier whorls; sculptured with irregular axial wrinkles and weak spiral costellae; often with broad angulation along basal margin or umbilicus. Umbilical callus narrow, broadens posteriorly, divided into two lobes by weakly to strongly developed transverse groove; posterior lobe may be swollen and partly conceal posterior of umbilicus; funicle lacking; anterior inner lip thickened.

Operculum: Chitinous, filling aperture.

Specimens examined. — Two hundred twenty-five.

Geographic occurrence and habitat. — Northern Vancouver Island, British Columbia, Canada (51° N.), to Isla San Geronimo, western Baja California, Mexico ($29^{\circ}47'$ N.). Living intertidally, especially in embayments, and offshore in depths to a least 200 metres, on sandy bottoms. Willett (1937) reported specimens in southeastern Alaska, without citing a specific locality.

Stratigraphic occurrence. — Ranges from upper Miocene(?) or lower Pliocene to Holocene. Upper Miocene: Castaic Fm. of Crowell (1954), near Castaic, Los Angeles Co., Calif. (Stanton, 1966) [identification questionable]. Lower Pliocene: Empire Fm., Maxfield Creek, southwestern Ore. (SU); Jacalitos Fm., Coalinga area, Calif. (Arnold & Anderson, 1910, as "?"); Pancho Rico Formation, Salinas Valley, Calif. (Durham & Addicott, 1965). Middle Pliocene: Etche-goin Fm., Coalinga area (CAS; Arnold & Anderson, 1910; Martin, 1916; Adegoke, 1969) and Kettleman Hills (SU; Woodring, *et al.*, 1940), California. Middle to upper Pliocene: Rio Del Fm. of Ogle (1953), Scotia Quad., Humboldt Co., Calif. (Faustman, 1964). Middle Pliocene to Pleistocene: Merced Fm., San Francisco South Quad. (UCB; Martin, 1916; Glen, 1959), Bolinas Bay (Martin, 1916), San Mateo Co. (UCB), near Santa Rosa (CAS), and Santa Cruz Quad. (Arnold, 1908a), Calif. Upper Pliocene: Pico Fm., southeastern Ventura basin (Winterer & Durham, 1962), Anaheim Quad. (UCB), and Piru Quad. (UCB), California; Pico Fm., Sand Canyon, Los Angeles Co., Calif. (LACM); San Joaquin Fm., Kettleman Hills (USGS; Woodring, Stewart, & Richards, 1940) and La Cima Quad. (UCB), Calif.; San Diego Fm., San Diego Co., Calif. (LACM); Fernando Fm., central Los Angeles basin (LACM); Soper & Grant, 1932) and Newport Bay (LACM), Calif. Upper

Pliocene to Pleistocene: Saugus Fm., Piru Quad., Calif. (UCB). Pliocene: Purisima Fm., Halfmoon Bay (Martin, 1916), Año Nuevo Quad. (SU), San Juan Bautista Quad. (UCB), Capitola Quad. (UCB), Santa Cruz Quad. (Arnold, 1908a; UCB), and Soquel Quad. (USGS), Calif.; middle part of Wildcat Fm., Humboldt Co., Calif. (Martin, 1916); Foxen Mudstone and Careaga Sandstone, Santa Maria basin, Calif. (Woodring & Bramlette, 1950); Port Orford Fm. of Baldwin (1945), Cape Blanco Quad., southwestern Ore. (USGS); Imperial Fm., southwestern San Diego Co., Calif. (UCB). Lower Pleistocene: San Pedro Fm., Deadman's Island, San Pedro, Calif. (UCB; CAS); so-called San Pedro Sand Mem. (LACM; CAS) and Timms Point Silt Mem. (LACM) of Clark (1931) of San Pedro Fm., San Pedro, Calif.; so-called San Pedro Fm., near Camulos, Ventura Co., Calif. (CAS); Elk River Beds, Cape Blanco Quad. (USGS) and Curry Co. (UCB), Oregon. Upper Pleistocene: Palos Verdes Sand, San Pedro Quad. (LACM; UCB) and Torrance Quad. (UCB), Los Angeles Co., and Newport Bay (UCB), Orange Co., Calif.; Bay Point(?) Fm., San Ysidro Quad., San Diego Co., Calif. (UCB); Bahía San Quintin (UCB; Jordan, 1924) north of Punta Cabras (UCB), and Magdalena Bay (Jordan, 1924), Baja California, Mexico.

Type localities. —

- Natica lewisii* — Puget Sound, Washington (Gould, 1847).
Natica herculea — “Kolonie Ross in Neukalifornien” (Middendorff, 1849).
Natica herculea forma *normalis* — Same as above.
Natica herculea forma *elatio*r — Same as above.
Natica algida — “Rio Negro, Argentina” (Gould, 1848)
 [probably Classet, Oregon, see below].

Type material. —

- Natica lewisii* — Holotype, USNM 3903 (Johnson, 1964).
Natica herculea — Academy of Sciences, Leningrad, U.S.S.R. (Dance, 1966).
Natica herculea forma *normalis* — Same as above.
Natica herculea forma *elatio*r — Same as above.
Natica algida — Unknown (Johnson, 1964).

Nomenclatural commentary. — Tryon (1886) considered the Japanese species *P. (E.) reinianus* (Dunker, 1877) a junior syno-

nym of *P. (E.) lewisii*. As noted and illustrated in Kuroda, Habe, & Oyama (1971, p. 121, pl. 18, fig. 2), *P. (E.) reinianus* is smaller than *P. (E.) lewisii* (height 31.8 mm, diameter 30.0 mm) and has a thicker shell with the umbilical callus abruptly pinched off anteriorly. The two species are distinct, although the range of morphologic variation of *P. (E.) reinianus* has not been described.

Discussion.—*Polinices (Euspira) lewisii* is the largest known living naticid, and nearly equally large fossil specimens are known through the late Pliocene. One specimen from the Pico Formation [UCB 4164] has a height of 63 mm and a diameter of 61 mm, whereas the largest from the Saugus Formation [UCB 7090] is 102 mm \times 80 mm, from the Purisima Formation 90 mm \times 84 mm [UCB 1779], and from the upper Pleistocene of Bahía San Quintin 111 mm \times 97 mm. The probable ancestor of *P. (E.) lewisii* was the Miocene and Pliocene *P. (E.) galianoi* Dall, 1909, of which the largest known specimen has a height of 57.4 mm and a diameter of 53.3 mm (broken).

Bernard (1968) showed that sexual dimorphism in *P. (E.) lewisii* is expressed as a difference in total weight to shell weight ratios. For males, this mean ratio is 0.472, whereas it is 0.401 for females, based on a sample of 1,875 specimens. Probable sexual dimorphism is also expressed in shell differences. There are two easily separable forms, one with a more globose, thinner shell, a narrower umbilical callus and a more open umbilicus (Pl. 24, fig. 3), the other with a more elongate, thicker shell, a broader umbilical callus, and narrower umbilicus (Pl. 24, fig. 4). The more elongate form also has a strong concave flexure at the shoulder, which is never as well developed in the more globose form. The possible correlation of these shell differences with primary sex characters was not investigated in my study.

Polinices (Euspira) lewisii and *P. (E.) draconis* are similar, but *P. (E.) lewisii* is distinguished by its higher spire, nontabulate and less inflated whorls, and thicker shell. *Polinices (Euspira) draconis* apparently evolved as a middle Pliocene offshoot of *P. (E.) lewisii*, and the two species may still be found together, although *P. (E.) draconis* is generally a more offshore form. Small juveniles of the two species are indistinguishable.

As noted above, the type locality originally stated for *Natica*

algida Gould, 1848, of Rio Negro, Argentina, is probably in error. In a citation for *N. algida* in 1852, Gould gave a locality of Classet, Oregon, and apparently never again referred to *N. algida* as a South American species. Dall (1919b, p. 352) noted that U.S. Exploring Expedition material, from which Gould described *N. algida*, often has incorrect locality data.

Polinices (Euspira) draconis (Dall, 1903)

Pl. 24, figs. 6, 7

Lunatia draconis Dall, 1903, pp. 174-175.

Polinices (Euspira) draconis (Dall), Dall, 1921, p. 165, pl. 14, figs. 4, 6; Oldroyd, 1927, pp. 730-731, pl. 99, figs. 3, 6; Burch, 1946, p. 30.

Polinices draconis (Dall), Packard, 1918, pp. 324-325, pl. 38, figs. 2a, b; Oldroyd, 1924, p. 163, pl. 36, figs. 2a, b; Keen, 1937, p. 44; Smith & Gordon, 1948, p. 198; MacGinitie & MacGinitie 1949, pp. 330, 375, figs. 170, 232; Rodda, 1957, p. 2483; Kanakoff & Emerson, 1959, p. 30; McLean, 1969, p. 37, fig. 19.2.

Description. —

Color: Shell exterior white to buff. Periostracum thin, light to medium yellowish brown, becoming thicker, darker and scaly within umbilicus. Inner lip and umbilical callus medium to chocolate brown; filling of posterior apertural angle white; interior cloudy white and pale brown.

Size: Average specimen, height 55 mm, diameter 52 mm; largest specimen, height 78.0 mm, diameter 69.5 mm [USNM, Catalina Island, California].

Shell form: Shell globose, spire low; body whorl inflated; shoulder distinctly tabulate; shell relatively thin; nuclear whorls $2\frac{1}{2}$, smooth; postnuclear whorls $4\frac{1}{2}$; suture deeply impressed. Spiral sculpture of minute, wavy, weakly developed costellae; axial sculpture of incremental growth lines. Parietal callus thin, moderately filling posterior apertural angle; anterior lobe distinct. Umbilicus broadly open, exposing earlier whorls; sculptured with irregular axial wrinkles and weak spiral costellae; with distinct angulation along basal margin of umbilicus. Inner lip thickened, broadens posteriorly, not forming a distinct umbilical callus; basal portion greatly thickened; funicle lacking.

Operculum: Chitinous, filling aperture.

Specimens examined. — Three hundred seventy-five.

Geographic occurrence and habitat. — Redding Rock, California ($41^{\circ}22'$ N.), south to Cedros Island, western Baja California, Mexico ($28^{\circ}10'$ N.). Usually found living on sandy bottoms off-

shore, in depths from 15 to at least 400 metres, also in bays. Dall (1921) reported a northern range limit of Port Althorp, southern Alaska ($58^{\circ}11' N.$), but the specimen upon which this is based, USNM 207378, is a juvenile of *P. (E.) pallidus* (Broderip & Sowerby, 1829).

Stratigraphic occurrence.— Ranges from middle Pliocene to Holocene. Middle Pliocene: Etchegoin Fm., La Cima Quad., central Calif. (UCB). Upper Pliocene: San Diego Fm., San Diego Co., Calif. (LACM). Pliocene: Purisima Fm., Año Nuevo Quad., San Mateo Co., Calif. (SU); formation unknown, Cholame area, central Calif. (USGS). Lower Pleistocene: San Pedro Fm., Deadman's Island, San Pedro, Calif. (UCB); Anchor Silt of Rodda (1957), northwestern Los Angeles basin, Calif. (Rodda, 1957). Upper Pleistocene: Palos Verdes Sand, Newport Bay, Calif. (Kanakoff & Emerson, 1959).

Type locality.— Four localities in California were mentioned by Dall (1903): Drake's Bay, the Farallon Islands, Monterey, and Avalon, Catalina Island. The label with the holotype indicates the type locality as Monterey Bay.

Type material.— Holotype, USNM 172859.

Discussion.— The umbilicus is sometimes partially restricted by the inner lip, so that not all of the earlier whorls are visible within it, which has led people to confuse this species with *P. (E.) lewisii* (Gould, 1847). The combination of low spire, tabulate whorls, and thin shell distinguishes *P. (E.) draconis* from *P. (E.) lewisii* in almost every case. In the few individuals where there is still some doubt about identification, the presence of the shoulder flexure on *P. (E.) lewisii* is a dependable criterion for separating adults of the two species. Small juveniles of the two species are so similar that it is sometimes not possible to identify them with certainty.

The oldest known fossils, from the middle Pliocene Etchegoin Formation, are so poorly preserved that their identification is questionable, whereas the upper Pliocene and later fossils are well preserved. *Polinices (Euspira) draconis* thus apparently evolved in central or southern California during the middle to late Pliocene, and was undoubtedly an offshoot of *P. (E.) lewisii*, which first appeared in the Miocene. From its first appearance in the fossil record, *P. (E.) draconis* has not been so abundant as *P. (E.) lewisii*,

although its thinner shell may have diminished its chances for preservation in fossil assemblages.

Polinices (Euspira) pallidus (Broderip & Sowerby, 1829)

Pl. 25, figs. 1-6, 8

Natica pallida Broderip & Sowerby, 1829, p. 372; Gray, 1839, p. 136, pl. 34, fig. 15; Middendorff, 1849, pp. 421-422; Middendorff, 1851, pp. 210-212; Philippi, 1851, pp. 96-97, pl. 14, fig. 2; Carpenter, 1864, p. 523; Sowerby, 1883, p. 92, pl. 9, fig. 137; Tryon, 1886, p. 37, pl. 9, figs. 76-78, pl. 13, fig. 15, pl. 14, figs. 26-28.

Natica pallida forma *normalis* Middendorff, 1851, p. 210.

Lunatic pallida (Broderip & Sowerby), Carpenter, 1864, p. 661; Dall, 1874, p. 251; Odhner, 1913, pp. 8, 31-40, pl. 3, figs. 15, 19-37, pl. 4, figs. 1-8, pl. 5, figs. 16-18; Thorson, 1951, pp. 22-23; Okutani, 1964, p. 393, pl. 1, fig. 19, pl. 5, fig. 8; Okutani, 1966, p. 16, pl. 2, fig. 6; MacPherson, 1971, pp. 58-59, pl. 3, fig. 8.

Polinices (Euspira) pallidus (Broderip & Sowerby), Dall, 1921, p. 164, pl. 14, fig. 5 [as "*pallida*"]; Oldroyd, 1924, p. 162, pl. 3, fig. 2 [as "*pallida*"]; Oldroyd, 1927, p. 728, pl. 97, fig. 9 [as "*pallida*"]; Burch, 1946, p. 29.

Euspira pallida (Broderip & Sowerby), Kuroda & Habe, 1952, p. 57; Kotaka, 1962, p. 135, pl. 33, figs. 19-20.

Polinices pallidus (Broderip & Sowerby), Pilsbry, 1895, p. 72; Keen, 1937, p. 49; MacGinitie, 1959, p. 91, pl. 12, fig. 10; Clarke, 1963, p. 97.

Eunatica pallida (Broderip & Sowerby), Habe & Ito, 1965, p. 30, pl. 8, fig. 3.

Natica (Lunatic) pallida (Broderip & Sowerby), Friele & Grieg, 1901, p. 69.

Natica groenlandica Möller ex Beck MS, 1842a, p. 80; Möller, 1842b, p. 7; Jeffreys, 1867, p. 216; Jeffreys, 1869, p. 215, pl. 78, fig. 2; Sowerby, 1883, p. 96, pl. 9, fig. 140; Watson, 1886, p. 447.

Lunatic groenlandica (Möller), Gould, 1870, pp. 341-342, fig. 611; Sars, 1878, p. 158, pl. 21, fig. 15, pl. V, fig. 13; Carpenter *in* Dawson, 1872, p. 392; MacNeil, 1957, p. 103, pl. 12, fig. 21 [as "aff."]; Bousfield, 1960, p. 17, pl. 2, fig. 23.

Natica (Lunatic) groenlandica Möller, Friele & Grieg, 1901, p. 69.

Polinices groenlandicus (Möller), Burch, 1946, p. 29 [as "*groenlandica*"]; Smith & Gordon, 1948, p. 198.

Mamma (Lunatic) groenlandica (Möller), Mörch *in* Rink, 1857, p. 80.

Euspira monterona Dall, 1919b, pp. 352-353.

Polinices (Euspira) monterona (Dall), Dall, 1921, p. 164; Oldroyd, 1927, p. 727; Burch, 1946, p. 29.

Polinices monteronus (Dall), Keen, 1937, p. 44 [as "*monterona*"]; MacGinitie, 1959, pp. 91-92, pl. 12, fig. 9.

Natica caurina Gould, 1847, p. 239; Gould, 1852, pp. 212-213; Gould, 1856, pl. 15, fig. 254; Carpenter, 1857d, pp. 209, 213; Gould, 1862, p. 50, 244; Johnson, 1964, p. 53, pl. 16, fig. 13.

Polinices (Euspira) caurinus (Gould), Dall, 1921, p. 164 [as "*caurina*"]; Oldroyd, 1924, p. 162; Oldroyd, 1927, p. 729; Burch, 1946, p. 29.

Polinices caurinus (Gould), Keen, 1937, p. 44; Smith & Gordon, 1948, p. 198.

Lunatic caurina (Gould), Woodring, 1938, p. 22, pl. 5, fig. 19 [as "cf."]; Keen & Bentson, 1944, p. 168 [as "cf."]; Adegoke, 1969, p. 167 [as "cf."].

Euspira canonica Dall, 1919b, p. 353.

Polinices (Euspira) canonicus (Dall), Dall, 1921, p. 165 [as "*canonica*"]; Oldroyd, 1927, p. 727; Keen, 1937, p. 44; Burch, 1946, p. 29.

?*Natica borealis* Gray, 1839, p. 136, pl. 37, fig. 2; Philippi, 1851, pp. 109-110, pl. 15, fig. 16.

Description. —

Color: Shell exterior and interior white. Periostracum thin,

ranging from pale yellowish white to olive brown and rust brown, usually paler on base.

Size: Average specimen, height 25 mm, diameter 20 mm; largest specimen, height 47.6 mm, diameter 41.8 mm [CAS 39460, Bristol Bay, Alaska].

Shell form: Shell somewhat elongate, spire moderately elevated; body whorl not greatly inflated; whorls usually slightly flattened below suture; shell thin; whorls about six (apex eroded). Spiral sculpture of minute, wavy, weak costellae; axial sculpture of incremental growth lines that are heavier just below suture and on base. Parietal callus thin, usually transparent at its center, moderately filling posterior apertural angle; anterior lobe distinct. Umbilicus narrowly open in adults, with a shallow sulcus and narrow channel, may be closed in juveniles. Umbilical callus narrow with a gentle central swelling, expanded posteriorly to bridge umbilicus and meet parietal callus, may plug umbilicus; funicle inconspicuous. Anterior inner lip and basal lip thickened.

Operculum: Chitinous, filling aperture.

Specimens examined. — Fifteen hundred.

Geographic occurrence and habitat. — Circumboreal. In the eastern Pacific, south to the United States-Mexican border ($32^{\circ}32'$ N.); in the western Pacific, south to Japan; in the western Atlantic, south to Cape Hatteras, North Carolina; in the eastern Atlantic, south to the North Sea and Ireland. Not common in the eastern Pacific south of Monterey, California ($36^{\circ}36'$ N.). Found on soft bottoms in depths from 15 to 4,794 metres; reported intertidally alive at San Juan Islands, Washington [UCD, no number], but this needs confirmation.

Stratigraphic occurrence. — Ranges from middle Miocene to Holocene. Middle Miocene: Kern River area, California (CAS). Middle Miocene to Pliocene: Yakataga Fm., Yakataga area, Alaska (UCB). Middle Pliocene: Etchegoin Fm., Coalinga area, Calif. (Adegoke, 1969, as "cf."). Upper Pliocene: Upper part of Rio Dell Fm. of Ogle (1953), Centerville, Humboldt Co., Calif. (CAS). Pliocene: Port Orford Quad., Ore. (UCB); Tugidak Island, Trinity Islands, Ala. (USGS). Pliocene to Pleistocene: Tjörnes sequence, *Serripes* and *Mactra* groups, Iceland (USGS). Lower Pleistocene: Elk River Beds, Cape Blanco Quad. (USGS) and Curry Co. (UCB),

Ore.; Santa Barbara Fm. of Smith (1912), Santa Barbara, Calif. (UCB).

Type localities. —

Natica pallida — Icy Cape [Arctic coast of Alaska] (Broderip & Sowerby, 1829).

Natica pallida forma *normalis* — Southern Sea of Okhotsk and Shantar Island, U.S.S.R. (Middendorff, 1851).

Natica groenlandica — Greenland (Möller, 1842a).

Euspira monterona — USFC station 1199, Captains Bay, Unalaska Island, Alaska, 75 fathoms, mud and gravel (Dall, 1919b).

Natica caurina — Straits of Juan de Fuca, Washington (Gould, 1847).

Euspira canonica — USFC station 2923, off San Diego, California, 822 fathoms, green mud (Dall, 1919b).

Type material. —

Natica pallida — Unknown, presumably in BM(NH) (Dance, 1966).

Natica pallida forma *normalis* — Academy of Sciences, Leningrad, U.S.S.R. (Dance, 1966).

Natica groenlandica — Lectotype, designated herein, and one paralectotype, Zoological Museum, University of Copenhagen.

Euspira monterona — Holotype, USNM 220856.

Natica caurina — Lectotype [inadvertently designated by Johnson, 1964], MCZ 169081.

Euspira canonica — Holotype, USNM 209411.

Nomenclatural commentary. — In his original description of *Natica groenlandica*, Möller (1842a) cited the name as "*N. groenlandica* Bec," and the species was attributed to Beck, a Danish zoologist, by many subsequent authors. However, there seems to be no evidence that Beck authored this species, although he may have used *N. groenlandica* as a manuscript name. Möller did not designate a holotype from among the two syntypes of *Natica groenlandica*. The smaller of these two specimens (height 15.3 mm, diameter 14.0 mm) is hereby designated lectotype. The paralectotype measures 21.7 mm in height and 18.0 mm in diameter.

Discussion. — All adults of *P. (E.) pallidus* have an open um-

bilicus, although it is reduced to a slit in some individuals. Because juveniles have broader umbilical calluses than adults, their umbilici are generally narrower, though usually still open. About a fourth of modern juveniles have a closed umbilicus, and a living population will show all intergradations from closed to open. In juveniles with closed or nearly closed umbilici, broadening of the umbilical callus is accompanied by thickening of the anterior lip and a thicker filling of parietal callus in the posterior apertural angle. The anterior inner lip is often thicker and more elevated than the umbilical callus in both juveniles and adults.

Fossils of *P. (E.) pallidus* are much smaller than living specimens and do not have completely closed umbilici. The largest fossil specimen is 21.3 mm in height and 17.7 mm in diameter [UCB B-7380, Elk River Beds, Cape Blanco, Oregon, lower Pleistocene] and is only slightly larger than average for a Pliocene or Pleistocene specimen. Because no upper Pleistocene fossil *P. (E.) pallidus* are known in the eastern Pacific, it is not known whether the present large size of specimens is a late Pleistocene or modern development. Closure of the umbilicus by the umbilical callus, seen in some living juveniles, is not known among fossils. Thickness of the umbilical callus and its closure of the umbilicus varies among fossils, but to a lesser degree than among modern specimens. Fossil specimens also tend to have thicker parietal calluses and higher spires than living specimens.

The absence of this species in upper Pleistocene deposits is due to circumstances of preservation. Most upper Pleistocene marine deposits in western North American represent shallow-water, rocky shore environments, in which species such as *P. (E.) pallidus* are not likely to have lived. Lower Pleistocene and older deposits of this region preserve a greater variety of marine habitats, including those in which *P. (E.) pallidus* lived.

The occurrence of *P. (E.) pallidus* in CAS collections from Miocene deposits in the Kern River area of southern California needs confirmation, because Addicott (1970b) does not include this species in his comprehensive report of the gastropods of those deposits.

Polinices (Euspira) nuciformis (Gabb, 1864)

Pl. 26, figs. 6-9

Lunatia nuciformis Gabb, 1864, p. 107, pl. 28, fig. 218; Dickerson, 1913, pp. 264, 273; Dickerson, 1914b, p. 97, 110, 151, pl. 13, figs. 6a, b [as "cf."]; Dickerson, 1915, pp. 43, 50; Dickerson, 1916, p. 510, pl. 39, fig. 4.

- Natica nuciformis* (Gabb), Anderson & Hanna, 1925, p. 116, pl. 10, fig. 3; M. A. Hanna, 1927, p. 305; Keen & Bentson, 1944, p. 177.
- Polinices (Euspira) nuciformis* (Gabb), Clark & Woodford, 1927, p. 121, pl. 21, figs. 16, 17; Turner, 1938, p. 88, pl. 20, figs. 4, 5; Clark, 1938, pp. 703-704, pl. 4, figs. 26, 31; Vokes, 1939, p. 168, pl. 21, figs. 12-14; Weaver, 1943, pp. 342-343, pl. 70, figs. 1, 2, pl. 103, fig. 2; Keen & Bentson, 1944, p. 186; Weaver, 1945, p. 45.
- Euspira nuciformis* (Gabb), Stewart, 1927, pp. 323-324, pl. 30, fig. 16; Keen & Bentson, 1944, p. 156; Givens, 1974, p. 77, pl. 7, fig. 14.
- Polinices nuciformis* (Gabb), Smith, 1975, p. 469 [as "cf."].
- Lunatia cowlitzensis* Dickerson, 1915, p. 57, pl. 4, figs. 12a, b.
- Polinices (Euspira) nuciformis* var. *cowlitzensis* (Dickerson), Weaver, 1943, p. 343, pl. 69, figs. 10, 11, 13-19.

Description. —

Color: Many specimens from the upper Eocene Cowlitz Formation have remnants of their original color, consisting of a wide, sharply defined band of purplish black on the base, a wider band on the shoulder, and occasional dark mottlings on the central part of the body whorl.

Size: Average specimen, height 20 mm, diameter 18 mm; largest specimen, height 31.9 mm, diameter 26.7 mm [USGS, Vader, Washington, Cowlitz Formation, upper Eocene].

Shell form: Shell globose to elongate, spire moderately to strongly elevated; body whorl moderately inflated, fairly evenly rounded; shell thickness average to thin; whorls six; suture ranges from slightly to strongly impressed and from strongly appressed to very narrowly and shallowly channeled. Shell smooth except for incremental growth lines. Parietal callus thin to fairly thick, lightly to heavily filling posterior apertural angle; anterior lobe usually well developed, slightly overhanging umbilicus. Umbilicus broadly to narrowly open, may be slitlike. Umbilical callus either absent, slender with a gradual anterior taper, or slender and tapering anteriorly but with a medial swelling. Anterior inner lip and basal lip may be thickened.

Operculum: Unknown.

Specimens examined. — Twenty-five hundred sixty-seven.

Stratigraphic occurrence. — Upper Paleocene to upper Eocene. Upper Paleocene: Meganos Fm., Diablo Quad., Contra Costa Co. (Clark & Woodford, 1927; UCB), and Clear Lake Oaks Quad., Lake Co. (UCB), Calif.; Lodo Fm., Panoche Quad., Fresno Co., Calif. (Smith, 1975; SU; UCB). Lower Eocene: Arroyo Hondo Shale Member of the Lodo Formation, Coalinga area, Fresno Co., Calif. (Vokes, 1939; UCB); Capay Fm., Capay Valley, Yolo Co.,

Calif. (Merriam & Turner, 1937). Middle Eocene: Umpqua Fm. [Flournoy Formation of Baldwin & Beaulieu (1973)], Douglas and Coos Cos., Oreg. (Turner, 1938; UCB); Domengine Fm., Coalinga area, Fresno Co., Calif. (Vokes, 1939; UCB); Juncal Fm., *Turritella wasana applinae* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR); Delmar Fm., La Jolla area, San Diego Co., Calif. (M. A. Hanna, 1927). Upper Eocene: Cowlitz Fm., Lewis Co. (LACM; CAS; UCB) and Cowlitz Co. (Dickerson, 1915; USGS; CAS; UCB; UCLA), Wash.; Spencer Fm., Polk Co., Oreg. (UCB); Keasey Fm., Columbia and Washington Cos., Ore. (USGS); Coaledo Fm., Coos Co., Ore. (Weaver, 1945; UCB); Markley Sandstone Member of the Kreyenhagen Formation, Solano Co., Calif. (Clark, 1938; UCB); Tejon Fm., Tejon Quad., Kern Co., Calif. (Gabb, 1864; Dickerson, 1915; Anderson & Hanna, 1925; CAS; UCR; UCB; UCLA); Matilija and Cozy Dell Fms., *Ectinochilus canalifer* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR).

Type localities. —

Lunatia nuciformis — Alizos Creek [Live Oak Canyon], near Fort Tejon, Kern County, California (Gabb, 1864). Tejon Formation, upper Eocene.

Lunatia cowlitzensis — West bank of the Cowlitz River, immediately south of the eastward bend about 1½ miles east of Vader, Lewis County, Washington (Dickerson, 1915). Cowlitz Formation, upper Eocene.

Type material. —

Lunatia nuciformis — Lectotype (Stewart, 1927), ANSP 4213; two paralectotypes, ANSP 4213.

Lunatia cowlitzensis — Holotype, CAS 281; paratype, CAS 282.

Discussion. — This is one of the most variable naticids included in this study, and it is certainly the most variable *Euspira*. Shell proportions, umbilical features, and sutural character all show such great variability it is surprising that only one junior synonym has been named. Most individuals are globose, with low spires, but some have strongly elevated spires and somewhat compressed whorls. Variations in umbilical morphology are striking. Most specimens have a fairly narrow umbilicus, but it ranges from a slit to a broad

opening that exposes earlier whorls. Individuals with narrow umbilici generally have higher spires and more appressed sutures than those with a broad umbilici. The umbilical callus ranges from absent to distinct but slender. When a callus is present it may taper evenly to the anterior end or it may have a gentle swelling at its midpoint. In either case, the callus restricts the umbilicus enough that earlier whorls are no longer visible within it. The suture varies from appressed to channeled. Most specimens have sutures appressed to some degree, but the whole range of sutural types may occur in any population.

Despite the apparent bewildering variability shown by *P. (E.) nuciformis*, there are two general categories that include all specimens: (a) a somewhat elongate shell with a high spire, appressed sutures, and narrowly open umbilicus, with a distinct umbilical callus, and (b) a globose shell with a low spire, normally abutting or weakly channeled sutures, and a broadly open umbilicus lacking a distinct umbilical callus. The first form generally has a thicker parietal callus than the second, but in all features the two forms intergrade to some extent. The more globose form greatly predominates in all collections I have seen. This species was most abundant during the late Eocene, and individuals with channeled sutures are somewhat more common in the upper Eocene Tejon Formation of southern California than in the coeval Cowlitz Formation of Washington.

This species is closely related to the late Eocene to middle Miocene species *P. (E.) lincolnensis* (Weaver), and the two come close to intergrading in form. Both species are similar in size and general shape, although *P. (E.) lincolnensis* has a slightly thicker shell, especially along the basal lip. The umbilicus of *P. (E.) lincolnensis* is never broad enough to expose earlier whorls to view, and the umbilical callus is almost always heavier than that on the callused form of *P. (E.) nuciformis*. In addition, the former species never has channeled or normally abutting sutures, but they are always strongly appressed. As a peculiarity, the shells of *P. (E.) lincolnensis* are almost invariably decorticated in part, especially on the base and early whorls, whereas the shells of *P. (E.) nuciformis* are rarely found decorticated.

In the late Eocene, *P. (E.) nuciformis* gave rise to the short-

lived *P. (E.) hotsoni* Weaver and Palmer. Both species are most abundant in the Cowlitz Formation of Washington, the comparison of the two is made in the discussion of the latter species.

Polinices (Euspira) hotsoni Weaver & Palmer, 1922 · Pl. 26, figs. 10-13

Polinices hotsoni Weaver & Palmer, 1922, p. 32, pl. 9, figs. 14, 15; Clark & Vokes, 1936, p. 866.

Polinices (Euspira) hotsoni Weaver & Palmer, Clark, 1938, p. 703, pl. 4, figs. 36, 41; Keen & Bentson, 1944, p. 186.

Polinices (Polinices) hotsoni Weaver & Palmer, Weaver, 1943, pp. 338-339, pl. 69, figs. 1, 2.

Description. —

Size: Average specimen, height 16 mm, diameter 13 mm; largest specimen, height 29.5 mm, diameter 27.2 mm [USGS 15282, Keasey Formation, northwestern Oregon, upper Eocene].

Shell form: Shell elongate globose, spire moderately to strongly elevated; body whorl not distinctly inflated, evenly rounded; shell thickness average; whorls about four (apexes of all specimens eroded); suture slightly impressed. Shell smooth except for incremental growth lines. Parietal callus thick, heavily filling posterior apertural angle; anterior lobe well developed, overhanging umbilicus. Umbilicus moderately to broadly open. Umbilical callus slender, merely a thickening of inner lip, abruptly broadening posteriorly to match width of the parietal callus, not tapering anteriorly. Anterior inner lip and basal lip thickened.

Operculum: Unknown.

Specimens examined. — One hundred seventy-seven.

Stratigraphic occurrence. — Upper Eocene only. Upper Eocene: Cowlitz Fm., Cowlitz Co. (Weaver & Palmer, 1922; Clark, 1938; CAS; UCB) and Lewis Co. (USGS; UCB), Wash.; Keasey Fm., Wash. Co., northwestern Ore. (USGS); Markley Sandstone Member of the Kreyenhagen Fm., north of Winters, Yolo Co. (Clark & Vokes, 1936) and near Vacaville, Solano Co. (Clark, 1938; UCB), northern Calif.

Type locality. — Scattagrace Falls, Cowlitz County, Washington, SE1/4 sec. 18, T. 4 N., R. 2 W. (Weaver & Palmer, 1922). Cowlitz Formation, upper Eocene.

Type material. — Holotype, CAS 7830.

Discussion. — This species is closely related to the more openly umbilicate form of *P. (E.) nuciformis* (Gabb), from which it almost

certainly evolved. However, there are distinct differences between the two species and they do not intergrade. First, *P. (E.) hotsoni* always has a thick parietal callus, whereas the callus of openly umbilicate *P. (E.) nuciformis* is always thin. Secondly, when the umbilical callus of *P. (E.) hotsoni* broadens at its posterior end to match the width of the parietal callus, it does so much more abruptly than occurs in *P. (E.) nuciformis*. In addition, *P. (E.) hotsoni* is smaller and slightly more elongate than the latter species. Finally, openly umbilicate specimens of *P. (E.) nuciformis* generally expose earlier whorls to view within their umbilici, but this rarely occurs in *P. (E.) hotsoni*. The most abundant occurrence of each species is in the upper Eocene Cowlitz Formation of Washington, where *P. (E.) nuciformis* is found in the thousands.

Polinices (Euspira) lincolnensis (Weaver, 1916) Pl. 27, figs. 1-6

Natica lincolnensis Weaver, 1916b, pp. 44-45, pl. 5, figs. 71, 72; Van Winkle, 1918, p. 76.

Polinices lincolnensis (Weaver), Tegland, 1933, p. 139, pl. 13, figs. 19, 20 [not fig. 21, = *Neverita (Neverita) washingtonensis* (Weaver, 1916b), treated herein]; Effinger, 1938, p. 377; Durham, 1944, pp. 120, 121, 124, 159.

"*Polinices washingtonensis* (Weaver)," Clark & Anderson, 1938, p. 954, pl. 3, figs. 16, 17.

Polinices (Polinices) washingtonensis var. *lincolnensis* (Weaver), Weaver, 1943, pp. 337-338, pl. 68, fig. 22, pl. 69, figs. 4, 7.

Polinices (Euspira) victoriana Clark & Arnold, 1923, p. 170, pl. 33, figs. 1a, b, 5a, b; Durham, 1944, p. 160 [as "?"].

Polinices (Polinices) victoriana Clark & Arnold, Weaver, 1943, pp. 335-336, pl. 68, figs. 10-12, 14.

Polinices victoriana Clark & Arnold, Addicott, 1970a, p. 67, pl. 5, figs. 17, 18, 21.

Polinices canalis Moore, 1963, p. 28, pl. 2, figs. 18, 22; Moore, 1971, p. 23, pl. 7, figs. 1, 2.

"*Natica (Natica) saxea* Conrad," Etherington, 1931, pl. 12, figs. 2, 3, 7, 14 [not *N. saxea* Conrad, 1849, *nomen dubium*, treated herein].

"*Natica (Tectonatica) saxea* Conrad," Weaver, 1943, pl. 68, fig. 4 [not *N. saxea* Conrad, 1849].

Description. —

Size: Average specimen, height 28 mm, diameter 25 mm; largest specimen, height 38.1 mm, diameter 36.3 mm [UCB 2713, Temblor Formation, Caliente quadrangle, Kern County, California, middle Miocene].

Shell form: Shell globose to somewhat elongate, spire moderately to strongly elevated; body whorl not greatly inflated; shoulder flattened near suture, may be slightly concave; shell thickness average; whorls $4\frac{1}{2}$; suture slightly impressed, strongly appressed.

Shell smooth except for fine incremental growth lines. Parietal callus thick, heavily filling posterior apertural angle; anterior lobe weak to moderate. Umbilicus slitlike to moderately broad; shallow, poorly defined sulcus may be present. Umbilical callus slender, gently tapers anteriorly; may have central swelling set off above by sulcus and below by indentation on umbilical side of inner lip, or swelling may be absent, leaving umbilical margin of callus straight; funicle low, broad, if present. Anterior inner lip and basal lip thickened.

Operculum: Unknown.

Specimens examined. — Six hundred fifty-five.

Stratigraphic occurrence. — Upper Eocene to middle Miocene. Upper Eocene: Lincoln Creek Fm., *Molopophorus stephensoni* Zone, near Galvin, Lewis Co., Wash. (Durham, 1944); Wheatland Fm. of Clark & Anderson (1938), near Wheatland, Yuba Co., Calif. (Clark & Anderson, 1938). Lower Oligocene: Lincoln Creek Fm., type section, *Turritella porterensis* Zone, near Galvin, Lewis Co., Wash. (Durham, 1944; UCB); Quimper Ss. of Durham (1944), *Turritella olympicensis* Zone, Jefferson Co., Wash. (Durham, 1944; UCB). Middle Oligocene: Pittsburg Bluff Fm., Columbia Co., Ore. (UCLA); Blakeley Fm. of Weaver (1912), *Echinophoria rex* Zone, Kitsap Co., Wash. (Durham, 1944; UCB). Upper Oligocene: Lincoln Creek Formation, southwestern Wash. (Armentrout, 1973). Lower Miocene(?): Sooke Fm., Vancouver Island, B.C. (Clark & Arnold, 1923). Lower Miocene: Clallam Fm., Pysht Quad., Clallam Co., Wash. (USGS); basal part of Jewett Sand, Kern River area, Calif. (Addicott, 1970a; USGS). Middle Miocene: middle and upper parts of Olcese Sand and Round Mountain Silt, Kern River area, Kern Co., Calif. (Addicott, 1970a; USGS; UCB); Temblor Fm., Reef Ridge, Coalinga district, Fresno Co. (SU), and Caliente Quad., Kern Co. (UCB), Calif.; Astoria Fm., Skamokawa Quad., southwestern Wash. (Addicott, 1970a), Montesano Quad., Wash. (USGS), and coastal Ore. (Moore, 1963; CAS; UCB).

Type localities. —

Natica lincolnensis — cut in Union Pacific Railway, one mile north of Galvin Station, Lewis County, Washington, sec. 27, T. 15 N., R. 3 W. (Weaver, 1916b, 1943).

Polinices (Euspira) victoriana — in sea cliffs east of the mouth of Kirby Creek, six miles west of Sooke, Van-

couver Island, British Columbia, Canada (Addicott, 1970a). Sooke Formation, lower Miocene(?).

Polinices canalis — in beach cliffs forming first headland south of fill at Spencer Creek, Lincoln County, Oregon (Moore, 1963). Astoria Formation, middle Miocene.

Type material. —

Natica lincolnensis — Lectotype (Weaver, 1943), CAS 463; paralectotypes, CAS 463-A [= *Neverita (Neverita) washingtonensis* (Weaver, 1916b)], 7515, 7515-A.

Polinices (Euspira) victoriana — Holotype, CAS 582.

Polinices canalis — Holotype, USNM 563134 [not 561534 or 56134, as given by previous workers].

Nomenclatural commentary. — Weaver (1916b) described this species without selecting a holotype from among the four syntypes, although he gave the dimensions of one syntype. However, he later (Weaver, 1943) figured one of the syntypes and referred to it as the "holotype," also citing a second figured syntype as a "cotype." The figured "holotype" of Weaver (1943) is also the specimen that most closely matches the dimensions given in his 1916 work. The term lectotype was not current when Weaver wrote his 1943 work, but his citation of a "holotype" effectively amounts to a lectotype designation, and it is so considered here.

Only three of the four primary type specimens are correctly allocated to *P. (E.) lincolnensis*. One of the paralectotypes, CAS 463-A, is an individual of *Neverita (Neverita) washingtonensis* (Weaver, 1916), which was described in the same publication with *P. (E.) lincolnensis*. The former species has a closed umbilicus, whereas the latter has a distinctly open umbilicus. There has been confusion for decades about the correct identities of and distinctions between *P. (E.) lincolnensis* and *N. (N.) washingtonensis*, as is discussed more fully in the nomenclatural commentary of the latter species.

Discussion. — Synonymous names have been applied to *P. (E.) lincolnensis* because of variations in umbilical callus morphology. As noted above, the umbilical margin of the callus may either be straight for its entire length or have a shallow indentation at its posterior end, with every gradation between these extremes. In addition, some specimens from lower and middle Miocene beds of the

Kern River area, southern California, have a shallow indentation on the umbilical side of the inner lip at about the anterior termination of the umbilical callus, and this indentation continues into the umbilicus as a shallow channel, as noted by Addicott (1970a). This condition makes the central portion of the umbilical callus appear as a slight swelling, which continues into the umbilicus as a low funicle. Additional variations occur uncommonly in which an individual has a slitlike umbilicus or is distinctly more elongate than usual.

This species is most abundant in Oligocene strata of Washington and Oregon, and in lower and middle Miocene beds of the Kern River area, southern California. In the latter area it has commonly gone under the name *P. (E.) victorianus* Clark & Arnold, 1923.

Polinices (Euspira) simiensis Nelson, 1925

Pl. 27, fig. 7

Polinices (Euspira) simiensis Nelson, 1925, pp. 420-421, pl. 54, figs. 1a-c.

Description. —

Size: Average specimen, height 20 mm, diameter 17 mm; largest specimen, height 24.8 mm, diameter 22.5 mm [SU 6558, Lodo Formation, Panoche quadrangle, Fresno County, California, upper Paleocene].

Shell form: Shell moderately elongate, spire moderately to strongly elevated; body whorl not greatly inflated; whorls evenly rounded, but flattened or slightly concave immediately below suture; shell thickness average; whorls at least $4\frac{1}{2}$ (apexes of all specimens eroded); suture slightly to moderately impressed, generally appressed. Shell smooth except for incremental growth lines. Parietal callus thin, lightly to moderately filling posterior apertural angle. Umbilicus narrowly open. Umbilical callus narrow, hardly distinct from inner lip. Anterior inner lip slightly thickened.

Operculum: Unknown.

Specimens examined. — Thirty-two.

Stratigraphic occurrence. — Upper Paleocene of southern California. Upper Paleocene: Martinez Fm., Simi Hills, Ventura Co., Calif. (Nelson, 1925; UCB); Lodo Fm., Panoche Quad., Fresno Co., Calif. (SU; UCB).

Type locality. — SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 23, T. 2 N., R. 18 W.; 6,800 feet N. 2° E. of 2,150-foot hill in Simi Hills, in small canyon on east

side of road running through E1/2 sec. 23, T. 2 N., R. 18 W., and one-half mile north of point where stream divides; elevation 1,100 feet. Calabasas quadrangle, Simi Hills, Ventura County, California (Nelson, 1925). Martinez Formation, upper Paleocene.

Type material. — Holotype, UCB 30710.

Discussion. — This species is similar to the late Paleocene to late Eocene *P. (E.) nuciformis*, and the two may have a common ancestry. However, *P. (E.) simiensis* has a relatively higher spire and is consistently more elongate than *P. (E.) nuciformis*. In addition, the whorls of *P. (E.) simiensis* are more distinctly flattened or slightly concave immediately below the suture than those of the other species.

This species is apparently rare in the area of the type locality, as it was not found during extensive collecting in the Simi Hills by Zinsmeister (1974b).

Polinices (Euspira?) clementensis (M. A. Hanna, 1927) Pl. 27, figs. 8-10

Natica clementensis M. A. Hanna, 1927, p. 304, pl. 47, figs. 1-4 [not pl. 44, figs. 8, 10-12, as stated]; Clark, 1929, pl. 10, fig. 6; Vokes, 1939, pp. 26, 168; Keen & Bentson, 1944, pp. 176, 185.

Polinices (Euspira) clementensis (M. A. Hanna), Clark, 1938, pp. 690, 703, pl. 4, figs. 15, 22.

Euspira clementensis (M. Hanna), Givens, 1974, p. 77, pl. 7, figs. 15, 17.

Description. —

Size: Average specimen, height 11.5 mm, diameter 11.0 mm; largest specimen, height 14.5 mm, diameter 13.0 (incomplete) [USGS 15279, Keasey Formation, western Oregon, upper Eocene].

Shell form: Shell somewhat elongate, spire strongly elevated; body whorl somewhat compressed, with distinct flattening on shoulder; shell thickness average; whorls 4; suture deeply impressed, narrowly and shallowly channeled. Shell smooth except for incremental growth lines. Parietal callus moderately thick, usually thickly filling posterior apertural angle, with weak anterior lobe. Umbilicus narrowly open, usually lacking a sulcus but sometimes with the faint suggestion of one; channel not distinct. Umbilical callus narrow, small, growing margin either straight or slightly convex; callus partly conceals posterior end of umbilicus. Anterior inner lip slightly thickened.

Operculum: Unknown.

Specimens examined. — Three hundred eighty-two.

Stratigraphic occurrence. — Middle and upper Eocene of Oregon and California. Middle Eocene: Domengine Fm., Cholame Quad., Kings Co., Calif. (Vokes, 1939; UCB); Juncal Fm., *Turritella wvasana applinae* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR); Ardath Shale, La Jolla Quad., San Diego Co., Calif. (M. Hanna, 1927; UCB). Upper Eocene: Keasey Fm., Washington Co., northwestern Ore. (USGS; UCLA); Markley Ss. Member of the Kreyenhagen Formation, Solano Co., Calif. (Clark, 1938; UCB).

Type locality. — On the east side of the canyon in the bottom of Rose Creek, 0.3 mile east of the "t" of Soledad Mountain, La Jolla quadrangle, San Diego County, California (M. A. Hanna, 1927). Ardath Shale, middle Eocene.

Type material. — Holotype, UCB 31003; paratype, UCB 31004.

Nomenclatural commentary. — The combination of channeled suture, open umbilicus, and simple umbilical features makes generic assignment of this species uncertain. Pending a review of naticid superspecific taxonomy and systematics, assignment of this species to *Euspira* is tentative.

Discussion. — This species is characterized by its small size, elongate shape, channeled suture, and small, triangular umbilical callus. In addition the posterior apertural angle is more thickly filled by the parietal callus than is usual for a species with such a generally thin parietal callus and small umbilical callus. The size of the umbilical opening, from slitlike to fairly broad, is the most variable feature.

Although *P. (E.?) clementensis* occurs through a wide range of latitudes, it is not common at most localities. It is abundant only in the upper Eocene Keasey Formation, where it is associated with a bathyal molluscan fauna. The apex of virtually all specimens are eroded and pitted in the manner peculiar to modern mollusks collected from great depths. This suggests a deep-water habitat for *P. (E.?) clementensis* and supports interpretation of the Keasey Formation of Oregon as a bathyal deposit (Hickman, 1974).

Polinices (*Euspira*) agujanus Dall, 1908

Pl. 25, fig. 7

Polinices (Euspira) agujanus Dall, 1908, p. 334, pl. 9, fig. 2; Dall, 1909a, p. 236; M. Smith, 1944, p. 12, fig. 127.

Polinices (Polinices s.l.) agujanus Dall, Keen, 1971, p. 480, fig. 884.

Description.—

Color: Shell white. Interior and callus white. Periostracum thin, olive brown.

Size: Holotype: height 26.0 mm, diameter 24.0 mm.

Shell form: Shell globose, spire low; body whorl moderately inflated; whorls slightly compressed laterally, weakly and narrowly shouldered; shell thin; whorls about five [type worn]; suture slightly impressed, minutely channeled. Spiral sculpture of minute, weakly developed, obscure lineations; axial sculpture of incremental growth lines. Parietal callus thin, lightly filling posterior apertural angle; anterior lobe weak. Umbilicus open, relatively small. Umbilical callus broken off of holotype, was apparently very slender. Basal lip thickened.

Operculum: Unknown, presumably chitinous.

Specimen examined.—Holotype.

Geographic occurrence and habitat.—Known with certainty only from off of Punta Aguja, northern Peru (type locality), also reported as “probably” *P. (E.) agujanus* from the Gulf of Panama (Dall, 1908).

Type locality.—U.S.S. “Albatross” station 4653, 17 miles N. 61° W. from Punta Aguja, northern Peru (6° S.), on a mud bottom of 981 metres depth, bottom temperature 5.2°C (Dall, 1908).

Type material.—Holotype, USNM 110566.

Discussion.—In addition to the holotype, Dall (1908) referred to a second specimen identified “probably” as this species, from the Gulf of Panama in 3,058 metres depth, which was supposedly dead and worn. I could not locate this specimen in the USNM collections.

Polinices (Euspira) crawfordianus Dall, 1906

Pl. 25, fig. 9

Polinices (Euspira) crawfordianus Dall, 1908, pp. 335-336, pl. 11, fig. 7; M. Smith, 1944, p. 12, fig. 138.

Polinices (Polinices s.l.) crawfordianus Dall, Keen, 1971, p. 480, fig. 885.

Description.—

Color: Shell whitish. Periostracum thin, pale yellowish brown.

Size: Ranges from height 6.5 mm, diameter 5.8 mm [USNM 123051] to height 15.0 mm, diameter 13.5 mm [USNM 110650], based on three specimens.

Shell form: Shell elongate, spire moderately elevated; whorls evenly rounded; shell thin; whorls four or more, apex eroded; suture

moderately impressed. Whorls smooth, with only incremental axial growth lines. Parietal callus thin, lightly filling posterior apertural angle; anterior lobe weak. Umbilicus open, slitlike, inconspicuous. Umbilical callus not distinct from inner lip, slightly conceals part of umbilicus. Inner lip and basal lip thickened; outer lip smooth.

Operculum: Chitinous, filling aperture.

Specimens examined.— Holotype and two paratypes.

Geographic occurrence and habitat.— Mazatlán, Mexico (23° N.), to Punta Aguja, Peru (5°40' S.), and the Galápagos Islands. In depths of 996 to 1,895 metres, from substrates of mud and "ooze," and with prevailing bottom-water temperatures of 2.8°C to 5°C (37°F to 40.1°F).

Type locality.— Gulf of Panama, 996 metres depth, U.S.S. "Albatross" station 3356 (Dall, 1908).

Type material.— Holotype, USNM 123044; paratype, USNM 102586.

Discussion.— Dall mentioned five specimens in his description of *P. (E.) crawfordianus*, of which four are considered here to be correctly assigned. The fifth specimen is from off southern Chile at about 50° S. latitude and is 32 mm in height and 28 mm in diameter. It is characterized by a greatly thickened inner lip, slightly swollen umbilical callus, and imperforate umbilicus. I did not locate this specimen in the USNM collection, but I did find a similar specimen, USNM 102586, labeled "*Polinices (Euspira) crawfordianus* Dall. Cotype. Patagonia. Dr. Crawford." This specimen is 30.8 mm in height and 28.6 mm in diameter and was apparently considered by Dall when he proposed the species, although he did not mention it. This specimen and the one noted by Dall (1908) from off southern Chile are considered here to be distinct from *P. (E.) crawfordianus* and are not assignable to any species within my study area.

***Polinices (Euspira) litorinus* Dall, 1908**

Pl. 25, fig. 10

Polinices (Euspira) litorinus Dall, 1908, p. 337.

Polinices litorinus Dall, Keen, 1971, p. 480.

Description.—

Color: Shell white. Periostracum thin, pale yellowish white.

Size: Height 9 mm, diameter 8.5 mm (holotype).

Shell form: Shell globose, spire low; shoulder flattened, whorls

evenly rounded; shell thickness average; whorls about $3\frac{1}{2}$, apex eroded; suture very slightly impressed. Spiral sculpture of indistinct, minute striations; axial sculpture of minute incremental growth lines; shell smooth. Parietal callus of average thickness, moderately filling posterior apertural angle; anterior lobe weak. Umbilicus narrowly open, slitlike. Umbilical callus an indistinct swelling. Inner lip and basal lip slightly thickened.

Operculum: Chitinous, filling aperture.

Specimens examined. — Holotype.

Geographic occurrence and habitat. — Known only from type locality, in 1,485 metres on a bottom of "ooze," with temperature of 3.5°C (38.4°F).

Type locality. — Near Galápagos Islands, U.S.S. "Albatross" station 2807, 1,845 metres (Dall, 1908).

Type material. — Holotype, USNM 96481.

Discussion. — Because it is known from a single specimen, this species is difficult to evaluate as a member of a family whose species are often similar and show wide intraspecific variation. If it occurred in shallow water it might be mistaken for a juvenile *Polinices* (*Polinices*) *intemeratus* (Philippi).

***Polinices* (*Euspira*) *pardoanus* Dall, 1908**

Pl. 25, fig. 11

Polinices (*Euspira*) *pardoanus* Dall, 1908, p. 336.

Polinices (*Polinices* s.l.) *pardoanus* Dall, Keen, 1971, p. 480, fig. 887.

Description. —

Color: Shell white. Periostracum thin, pale yellowish brown.

Size: Ranges from height 5.9 mm, diameter 7.0 mm [USNM 123050] to height 13 mm (broken), diameter 14 mm (broken) [USNM 123046], based on three specimens.

Shell form: Shell globose, spire low to moderately elevated; whorls evenly rounded; shell thickness average; whorls about four; suture moderately impressed. Spiral sculpture of occasional, indistinct, minute striations; axial sculpture of incremental growth lines. Parietal callus thin, moderately filling posterior apertural angle; anterior lobe weak, not overhanging umbilicus. Umbilicus open, narrow. Umbilical callus a simple thickening of inner lip, partly reflected over umbilicus. Inner and basal lip thickened.

Operculum: Chitinous, filling aperture.

Specimens examined. — Holotype and two paratypes.

Geographic occurrence and habitat. — Gulf of Panama and near the Galápagos Islands. In depths of 1,915 metres and 2,690 metres in the Gulf of Panama and 1,620 metres near the Galápagos, on "ooze" substrates, with water temperatures of 2.3°C to 2.9°C (36.2°F to 37°F).

Type locality. — Gulf of Panama, 2,690 metres depth, U.S.S. "Albatross" station 3361 (Dall, 1908).

Type material. — Holotype, USNM 123046.

Discussion. — This species is known only from the three specimens described by Dall. Its shape is like that of some juvenile *P. (E.) pallidus* (Broderip & Sowerby) but has a lower spire and more open umbilicus.

Polinices sookensis Clark & Arnold, 1923

Pl. 25, fig. 12

Polinices (Ampullina?) sookensis Clark & Arnold, 1923, p. 170, pl. 33, figs. 4a, b.
Ampullina sookensis (Clark & Arnold), Weaver, 1943, p. 347, pl. 7, figs. 5, 6.

Description (from Clark & Arnold, 1923). —

Shell medium in size, subglobose; whorls five in number; spire about one-third height of shell. Suture slightly appressed. Whorls gently convex, greatest convexity near base of whorl. Aperture broadly subovate. Inner lip reflexed anteriorly and nearly covering the closed to subperforate umbilicus; posteriorly there is a thin wash of callus on body whorl. Dimensions of type: Height, 15 mm; greatest width of body whorl, 12 mm; height of body whorl, 10.5 mm.

Specimens examined. — "Holotype" only.

Stratigraphic occurrence. — Known only from type locality.

Type locality. — SU NP129, sea cliffs between mouths of Muir and Kirby creeks, west of Otter Point, Sooke, Vancouver Island, British Columbia, Canada. Sooke Formation, lower Miocene(?) (Clark & Arnold, 1923).

Type material. — Unknown, apparently lost. See discussion below.

Discussion. — The labeled "holotype" of *P. sookensis* in the Stanford University collection is not the specimen figured as the type by Clark and Arnold (1923) or by Weaver (1943). The Stanford specimen has the same lot number (30205) and locality number (NP 129) inked on it as were given for the holotype; the number 245 has been more recently inked on the Stanford specimen. The correct identity of the Stanford "holotype" is *Natica (Tectonatica)*

gabbi Clark, 1938 which occurs in lower Miocene strata of northern California and Oregon.

The present Stanford specimen is nearly the same size as the figured holotype, with a height of 14.4 mm, diameter of 12.5 mm, and body whorl height of 10.0 mm, but it differs from the figured holotype by having an open umbilicus. The umbilicus of the figured type is described as "closed to subperforate" (Clark & Arnold, 1923, p. 347) and is clearly shown as closed and represented by a shallow depression. This is unquestionably different from the narrow but clearly open umbilicus of the Stanford specimen. In addition, the figured holotype has more acutely tabulate whorls, the sutural area of its body whorl is not so badly decorticated, and it bears a different pattern of minor fractures and breaks than the Stanford specimen. The Stanford specimen is thus clearly not the holotype of Clark and Arnold (1923), which appears to be lost. I examined the Sooke Formation collection made by Clark and Arnold at Stanford, but no specimen similar to their figured holotype was found. I have done no preparation work on the Stanford specimen.

Subgenus **HYPTERITA** Woodring, 1957, p. 92

Type species: *Natica helicoides* Gray, 1825, by original designation. Miocene to Holocene, eastern Pacific. Figured herein.

Diagnosis.—Shell thin, greatly depressed. Umbilicus broadly open, with gently sloping wall. Umbilical callus a thin lobe suspended anteriorly from the pillar-like funicle. Parietal callus thin.

Discussion.—*Hypterita* is characterized by its flattened shell and peculiar umbilical callus. The type species is the only known living representative of this subgenus, with a Caribbean Miocene species also placed here by Woodring (1957).

Polinices (Hypterita) helicoides (Gray, 1825)

Pl. 36, figs. 1-4

Natica patula G. B. Sowerby I, 1824, p. 60, pl. 5, fig. 6; Carpenter, 1864, p. 522.

Not *Natica patula* J. Sowerby, 1822, vol. 4, p. 99 [= Tertiary, England].

Not *Natica patula* Wood, 1828, p. 45 [= *Nerita*].

Not *Natica patula* Deshayes, 1832, p. 16 [= *Ampullaria*, s.l., Tertiary, France].

Natica helicoides Gray ex Barnes MS, 1825, p. 511 [new name for *N. patula* G. B. Sowerby I, 1824, not J. Sowerby, 1822].

Polinices helicoides (Gray), Hertlein & Strong, 1955, pp. 287-288.

Polinices (Polinices) helicoides (Gray), Keen, 1958, p. 322, fig. 268; Keen, 1971, p. 478, fig. 876.

Neverita (Hypterita) helicoides (Gray), Woodring, 1957, pp. 92-93, pl. 18, figs. 15, 16.

Not *Natica helicoides* Johnston, 1835, p. 69 [= *Amauropsis islandica* (Gmelin, 1791), living, circumboreal].

Natica glauca Lesson, 1830, p. 369, pl. 11, fig. 1.

Natica glauca "Humboldt," d'Orbigny, 1840, p. 403; Menke, 1851, p. 165; Philippi, 1849, p. 42, pl. 6, fig. 3 (text 1852); Troschel, 1852, p. 161; Reeve, 1855, pl. 2, figs. 5a, b; G. B. Sowerby II, 1883, p. 76, pl. 1, fig. 5; Tryon, 1886, p. 34, pl. 11, figs. 97-98.

Polinices (Neverita) glauca (Lesson), Dall, 1909a, p. 236 [as "Humboldt"].

Polinices glauca (Lesson), M. Smith, 1944, p. 12, figs. 125, 130 [as "Humboldt"].

Natica bonplandi Valenciennes, 1832, pp. 264-265, pl. 57, figs. 3a, b [new name for *N. patula* G. B. Sowerby I, 1824, not J. Sowerby, 1822]; Carpenter, 1864, p. 521.

Description. —

Color: Nuclear whorls light brown; early adult whorls grey brown with prominent white band at suture; later whorls pinkish gray or brown, usually lighter near suture, with a diffuse white band below periphery; callus and inner lip dark orange brown; interior chestnut brown, with white band at suture and below periphery.

Size: Average specimen, height 27 mm, diameter 50 mm; largest specimen, height 34.4 mm, diameter 62.2 mm [SU 1377, Acapulco, Mexico].

Shell form: Shell low, spire depressed; shoulder tabulate, and tabulate surface may be slightly concave; base flattened; shell thin; nuclear whorls $1\frac{1}{2}$, smooth, postnuclear whorls $3\frac{1}{2}$; suture moderately impressed. Spiral sculpture of microscopic, closely spaced striations; axial sculpture of incremental growth lines that strongly disrupt the spiral striations and are heaviest near the suture. Parietal callus thin, transparent, lightly filling posterior apertural angle; anterior lobe weak. Umbilicus widely open, with gently sloping walls. Umbilical callus a thin lobe concealing posterior part of umbilicus, suspended anteriorly from the pillarlike funicle, tapering anteriorly; funicle strongly developed, nearly circular in section. Inner lip and basal lip not thickened; outer lip smooth.

Operculum: Chitinous, filling aperture.

Specimens examined. — Eighty-one.

Geographic occurrence and habitat. — Bahía Magdalena, southwestern Baja California, Mexico ($24^{\circ}30'$ N.) to Paita, Peru (5° S.). Most common throughout the Gulf of California, rare south of Acapulco, Mexico (17° N.). Sparse habitat data indicate a depth range of 9 to 46 metres, and Keen (1971) suggests intertidal occurrence. Earlier workers beginning with Tryon (1886) extend the

southern range limit to Callao, Peru (12° S.), but it is unlikely that this tropical species ranges below Paita into the cool waters of the Peruvian zoological province.

Stratigraphic occurrence. — Ranges from middle Miocene to Holocene. Middle Miocene: lower and middle parts of Gatun Formation, Panama (Woodring, 1957); ?Banana River area, eastern Costa Rica (Woodring, 1957). Pliocene: western Costa Rica (Woodring, 1957). Pleistocene: Ecuador (Hertlein & Strong, 1955).

Type localities. —

Natica patula — Unknown (Sowerby, 1824).

Natica glauca — Colan, near Paita, Peru (Lesson, 1830).

Type material. —

Natica patula — Unknown, probably in BM(NH) (Dance, 1966).

Natica glauca — Unknown.

Nomenclatural commentary. — The earliest proposed name for this species, *Natica patula* G. B. Sowerby I, 1824, was preoccupied by *N. patula* J. Sowerby, 1822. Gray proposed the replacement name *N. helicoides* in 1825 and Valenciennes proposed another replacement, *N. bonplandi*, in 1832. Gray cited *N. helicoides* as "Mr. Barnes's MS name" (Barnes, 1824), but it is still available as of Gray's (1825) mention of it.

Natica helicoides Gray, 1825, has a junior primary homonym of *Natica helicoides* Johnston, 1835, which normally would require renaming. However, the latter species is also a junior synonym of *Amauropsis islandica* (Gmelin, 1791), treated herein, and thus ceases to be a significant taxonomic problem.

Discussion. — Because of its shell form and umbilical features, this is the most distinct of all living eastern Pacific naticids. It is related to *P. (H.) nereidis* Maury, 1917a (Miocene, Dominican Republic) which differs by being smaller (diameter 34 mm) and having a broader funicle. *Natica euryomphala* Philippi, 1887 (Tertiary, Chile) was considered somewhat similar to *P. (H.) helicoides* by Hertlein & Strong (1955), but Philippi's original description is not diagnostic, making comparisons with other species difficult. The record of *P. (H.) helicoides* from the Miocene of Costa Rica is based on Woodring's (1957) doubtful identification of a fragment earlier identified by Olsson (1942) as *P. (H.) nereidis*.

Subgenus **MAMMILLA** Schumacher, 1817, p. 58

Type species: *Mammilla fasciata* Schumacher, 1817 (= *Albula mammata* Röding, 1798), by monotypy. Living, western Pacific.

Diagnosis. — Shell small to medium in size, elongate pyriform, thin; suture slightly impressed. Umbilical callus slender, elongate. Parietal callus thin.

Discussion. — This subgenus is characterized by its elongate pyriform shape and thin shell. *Mammilla* is a distinctly tropical group, confined largely to the Indo-Pacific region, with only a single species in the eastern Pacific.

Polinices (Mammilla) caprae (Philippi, 1850) Pl. 25, figs. 13-14

Natica caprae Philippi, 1850, p. 56, pl. 9, fig. 2 (text 1852).

Polinices caprae (Philippi), Hertlein & Strong, 1955, p. 139; Shasky & Campbell, 1964, p. 115.

Polinices (Polinices) caprae (Philippi), Keen, 1958, p. 322, fig. 267; Keen, 1971, p. 478, fig. 874.

Polinices crickmayi Palmer & Hertlein, 1936, pp. 77-78, pl. 19, figs. 12, 14.

Polinices (Mammilla) clarki M. Smith, 1950, pp. 60-61, pl. 4, figs. 7, 7a.

Description. —

Color: Shell pale greyish white to tan, with a wide band of mottled dark brown on the shoulder and a narrower band on the base; color bands may be poorly developed, reduced to series of irregular blotches; entire adult shell may be covered by series of closely spaced spiral lines consisting of minute orange-brown dots; umbilicus and anterior half of callus dark brown; interior light to dark brown, reflecting exterior color pattern. Nuclear whorls buff. Periostracum thin, pale yellowish white.

Size: Average specimen, height 25 mm, diameter 22 mm; largest specimen, height 32.1 mm, diameter 25.5 mm [MCZ, no number, Pearl Islands, Panama].

Shell form: Shell elongate, spire moderately elevated; body whorl greatly inflated anteriorly; shoulder steeply sloping; shell thin; nuclear whorls $2\frac{1}{2}$, smooth; postnuclear whorls three; suture slightly impressed. Spiral sculpture of minute, poorly defined, wavy costellae; axial sculpture of incremental growth lines. Parietal callus thin, moderately filling posterior apertural angle; anterior lobe weak. Umbilicus open, elongate, with broad channel. Umbilical callus narrow, occupying posterior half of inner lip; broadest near anterior end, where an abrupt swelling is dimpled by a short transverse groove;

funicle broad, with a more abrupt posterior face. Anterior inner lip thickened, basal lip not thickened.

Operculum: Unknown, presumably chitinous. Indo-Pacific species of *Mammilla* have chitinous opercula.

Specimens examined. — Fifty-nine.

Geographic occurrence and habitat. — Cabo San Lucas, southernmost Baja California, Mexico ($22^{\circ}45'$ N.), throughout the southern end of the Gulf of California, and south to Paita, Peru (5° S.), and the Galápagos Islands, Ecuador. Based on limited collecting data, it is found in depths of 45 to 65 metres, and Keen (1971) reports it intertidally.

Stratigraphic occurrence. — Reported in Pleistocene deposits along the "coast of Oaxaca," southern Mexico (Palmer & Hertlein, 1936; CAS).

Type localities. —

Natica caprae — Mazatlán, Mexico (Philippi, 1850).

Polinices crickmayi — Coast of Oaxaca, southern Mexico, Pleistocene (Palmer & Hertlein, 1936).

Polinices clarki — Panama (Smith, 1950).

Type material. —

Natica caprae — Museo Nacional de Historia Natural, Santiago, Chile, 61.567, two syntypes (N. Bahamondo, written commun.).

Polinices crickmayi — Holotype, CAS 5615.

Polinices clarki — Holotype, ANSP 189043.

Discussion. — The anteriorly inflated whorls of *P. (M.) caprae* distinguish it from other eastern Pacific naticids, to which it is not closely related. However, *P. (M.) caprae* is close to several Indo-Pacific species of similar form, including *P. (M.) maurus* (Lamarck, 1816), *P. (M.) melanostomus* (Gmelin, 1791), and *P. (M.) melanostomoides* (Quoy & Gaimard, 1833), among others (figured in Cernohorsky, 1971). Because this general shell shape seems to be confined to Indo-Pacific naticids, *P. (M.) caprae* is apparently a Pleistocene migrant from the western Pacific. No similar species is known as a fossil in the northeastern Pacific.

Genus **NEVERITA** Risso, 1826, p. 149

Type species: *Neverita josephina* Risso, 1826, by monotypy.

Eocene to Holocene, Europe. Figured in Wenz (1941, p. 1031, fig. 2952).

Diagnosis. — Shell small to large, globose to ovate; whorls not greatly inflated, smooth except for incremental growth lines and microscopic spiral costellae; suture slightly to moderately impressed; shell thickness average or greater. Umbilicus closed, except for a few species or variations within a given species. Umbilical callus broad and massive, either entire or divided into two lobes by a transverse groove. Parietal callus moderately thick to heavy. Operculum chitinous, entirely filling aperture.

Discussion. — This genus is characterized by its closed or nearly closed umbilicus and generally massive umbilical callus. *Neverita* is considered to be of full generic rank because of the degree of closure of the umbilicus which is of major importance in a subfamily composed of otherwise generally similar species. Umbilical closure is thus deemed more significant in the Polinicinae than in the Naticinae, where there are more morphologic features to aid in evaluating generic taxa.

The concept of *Neverita* employed here, which embraces both solid, low-spined shells and more fragile, high-spined shells, is broader than that used by other workers. This procedure is one of expedience to facilitate treatment of both fossil and living species such as *N. (N.) nana* (Möller, 1842), *N. (N.) kirkensis* (Clark, 1915), *N. (N.) lamonae* Marinovich, 1975, and others. The subgeneric placement of these species is uncertain at present and will remain so until a review of worldwide naticid generic taxa is undertaken.

This genus is worldwide in distribution, and as defined here it ranges in the northeastern Pacific from the Arctic to the tropics.

Subgenus **NEVERITA** Risso, 1826

Diagnosis. — Umbilical callus entirely covering umbilicus, not divided into two lobes by transverse groove.

Discussion. — This subgenus is characterized by its massive, smooth umbilical callus. It occurs living in temperate and Arctic waters of the eastern Pacific and elsewhere and is found in upper Paleocene and younger deposits of western America.

Neverita (Neverita) nana Möller, 1842)

Pl. 27, figs. 11, 12

Natica nana Möller, 1842a, p. 80; Möller, 1842b, p. 7; Philippi, 1851, p. 108, pl. 15, fig. 13.

Lunatia nana (Möller), Sars, 1878, p. 159, pl. 21, figs. 16a, b, pl. V, fig. 14; Verrill, 1882, p. 516, pl. 42, fig. 9; Odhner, 1913, pp. 8, 30, pl. 4, figs. 22-25; Okutani, 1964, p. 394, pl. 1, fig. 20, pl. 5, fig. 6; Okutani, 1966, p. 16, pl. 2, fig. 7 [as Müller].

Lunatia (Mamma) nana (Möller), Dall, 1885, p. 182.

Mamma nana (Möller), Dall, 1878, p. 12.

Natica (Lunatia) nana (Möller), Friele & Grieg, 1901, p. 69.

Polinices (Polinices) nanus (Möller), Dall, 1921, p. 165; Oldroyd, 1927, p. 732; Keen, 1937, p. 44; Burch, 1946, p. 32.

Not *Natica nana* Tenison-Woods, 1875, p. 149 [living, Tasmania].

Description. —

Color: Shell off-white, with a brighter white subsutural band. Periostracum very thin, inconspicuous, pale yellowish white or yellowish brown.

Size: Average specimen, height 9 mm, diameter 7 mm; largest specimen, height 17.3 mm, diameter 14.8 mm [USNM 267170, Santa Barbara, California].

Shell form: Shell elongate, somewhat translucent, spire low to moderately elevated; shoulder flattened, slightly concave; thickness average; nuclear whorls $1\frac{1}{2}$, smooth except for minute radial grooves extending short way from the suture; postnuclear whorls three; suture slightly impressed. Spiral sculpture of obscure microscopic striations. Axial sculpture of minute incremental growth lines. Parietal callus thin at its center but thickens toward posterior apertural angle and umbilicus; anterior lobe well developed, merges smoothly with umbilical callus. Umbilicus closed. Umbilical callus broad, semicircular, flat, depressed anteriorly, with its margin smoothy blending into underlying whorl. Inner lip and basal lip thickened.

Operculum: Chitinous, filling aperture.

Specimens examined. — Four hundred seventy-seven.

Geographic occurrence and habitat. — From Point Belcher, Arctic coast of Alaska ($70^{\circ}48' N.$, $159^{\circ}39' W.$), and Atka Island in the Aleutians, south to Cabo San Quintín, western Baja California, Mexico ($30^{\circ}20' N.$), and from Labrador south to Newport, Rhode Island ($41^{\circ}25' N.$), and Georges Bank ($41^{\circ}23' N.$, $68^{\circ}46' W.$). Also known on Greenland, Spitzbergen ($77^{\circ} N.$), and in the Minch area of Scotland ($58^{\circ} N.$), Vadsö, Norway ($70^{\circ}08' N.$) and in the White Sea, Russia. In Japan, at Sagami Bay and nearby islands (Okutani, 1964, 1966). Odhner (1913) reported specimens from Iceland and south in the western Atlantic to Cape Hatteras, North Carolina

(35° N.). The distribution is discontinuous, as there are no known specimens from Arctic Canada (MacPherson, 1971), none from between the southeastern Alaska Peninsula and Monterey, California (36°39' N.), and few from the Aleutian Islands. Most specimens I have seen are from Alaska. The total depth range for this species is 11 to 1,710 metres, but its presence at a given locality is apparently a function of water temperature, for it lives at progressively greater depths southward. Typical depth occurrences in the eastern Pacific are: Point Belcher, Arctic Alaska, 16 metres; Bering Sea and Bristol Bay, Alaska, 43 to 91 metres; western Aleutian Islands, 27 to 30 metres; Monterey, California, 1,065 metres; southern California islands, 976 to 1,281 metres; San Diego, California, 658 to 1,506 metres; San Quintín, Baja California, Mexico, 658 metres. Okutani (1964, 1966) gave depths of 620 to 1,350 metres for Sagami Bay, Japan. Eastern Pacific specimens from several localities between Alaska and San Diego were collected at water temperatures of 3.9°C to 5.4°C (39°F to 41.8°F), in sand and mud substrates.

Type locality. — Greenland (Möller, 1842a).

Type material. — Lectotype, designated herein, and three paralectotypes, Zoological Museum, Copenhagen, Denmark.

Nomenclatural commentary. — It is remarkable for such a widely distributed species, especially a naticid, to be free of synonymous names, but this seems to be the case. Tryon (1886) considered *N. (N.) nana* a junior synonym of *Natica immaculata* Totten, 1835, but the latter has an open umbilicus. Mörch (*in* Rink, 1857) and Sars (1878) thought *N. (N.) nana* synonymous with *N. borealis* Gray, 1839, but that narrowly umbilicate species is a junior synonym of *Polinices (Euspira) pallidus* (Broderip & Sowerby, 1829).

Möller (1842a) did not designate a holotype for this species or state the number of specimens in the type lot, although he gave the length of one specimen as three lines (about 6 mm). The type lot, borrowed from the Zoological Museum, University of Copenhagen, contains four syntypes. The largest of these (height 6.2 mm, diameter 5.9 mm) closely matches the length of the specimen in Möller's description and is hereby designated lectotype, the other three syntypes thereby becoming paralectotypes. The smallest specimen among the paralectotypes is 5.2 mm in height and 4.5 mm in diameter.

Discussion. — All of the eastern Pacific adult specimens I have examined have moderately elevated spires, but Odhner (1913) illustrated some Atlantic specimens that have low spires.

This species is commonly confused with juveniles of *Natica* (*Cryptonatica*) *clausa* Broderip and Sowerby in collections, understandably so considering their similar basic shapes. Living specimens are easily distinguished because *N. (C.) clausa* has a calcareous operculum, and shells of *N. (N.) nana* are translucent, whereas those of *N. (C.) clausa* are not. Shell form must be used to distinguish dead specimens, however; shells of *N. (N.) nana* are more elongate, with higher spires and more steeply sloping shoulders. In addition, the umbilical and parietal calluses of *N. (N.) nana* merge together more smoothly than do those of *N. (C.) clausa*, the filling of the posterior apertural angle of *N. (N.) nana* is thicker and sticks out farther ahead of the aperture than in *N. clausa*.

The cool-water habitat of *N. (N.) nana* prevents its being found commonly in areas that have warm-temperate surface waters. However, it would have lived in shallower depths during the cool-water intervals of the Pleistocene, and its occurrence in the abundant marine Pleistocene deposits of southern California is not unlikely, although it has not yet been found there.

This species is also similar to *N. (N.) lamonae* Marincovich, 1975, which lives in bathyal depths off of Oregon. Comparison of the two species is made in the discussion of the latter.

Neverita (Neverita) lamonae Marincovich, 1975

Pl. 27, figs. 13, 14;
Text-fig. 11a

Neverita (Neverita) lamonae Marincovich, 1975, pp. 168-169, figs. 1, 4, 5.

Description. —

Color: Shell exterior white, with narrow dark brown or white band just below suture; interior, parietal callus and umbilical callus white. Periostracum thin, light grayish brown.

Size: Average specimen, height 19 mm, diameter 17 mm; largest specimen, height 19.8 mm, diameter 17.6 mm [AMNH 181738, off of central Oregon, paratype].

Shell form: Shell elongate, spire elevated, body whorl noticeably inflated, with a distinct, narrow, shallowly incised groove a short way below suture; shell thin; whorls $4\frac{1}{2}$, nuclear whorls not clearly differentiated, earliest nuclear whorl sunk into following whorl;

suture moderately impressed. Spiral sculpture of minute, wavy, closely spaced costellae, absent from base and earliest $1\frac{1}{2}$ whorls; axial sculpture of incremental growth lines. Parietal callus thick, moderately to heavily filling posterior apertural angle; anterior lobe weak but generally distinct. Umbilicus usually closed, may be narrowly open along entire margin. Umbilical callus elongate, with greatest width near or at posterior end, smoothly merging with parietal callus; tapers anteriorly nearly to a point; callus evenly thins toward growing margin or more abruptly ends at an elongate marginal depression that may be deepest posteriorly. Umbilical area bounded anteriorly by low, sometimes indistinct rib on body whorl. Anterior inner lip thickened.

Operculum: Chitinous.

Specimens examined. — Six.

Geographic occurrence and habitat. — West Moresby Island, Queen Charlotte Islands, British Columbia, Canada ($52^{\circ}2.5' N.$, $133^{\circ}11.0' W.$), to off central Oregon ($44^{\circ}34.8' N.$, $125^{\circ}33.6' W.$), in depths of 1,198 to 2,860 metres.

Type locality. — Off central Oregon at $44^{\circ}34.8' N.$, $125^{\circ}33.6' W.$, 2,816 metres depth (Marincovich, 1975).

Type material. — Holotype, USNM 741012; 1 paratype, USNM 741013; 1 paratype, LACM 1732; 1 paratype, CAS 55391; 1 paratype, AMNH 181738.

Discussion. — This species is characterized by its elongate shape, thin shell, elongate umbilical callus, and shallow groove just below the suture. It most closely resembles the living circumboreal species *N. (N.) nana* (Möller, 1842). The latter species is smaller (average size: height 9 mm, diameter 7 mm) than *N. (N.) lamonae*, and has a thinner parietal callus, more weakly impressed suture, less inflated body whorl, relatively thicker shell, and lacks a narrow groove below the suture and a depressed first protoconch whorl. In addition, the umbilicus of *N. (N.) nana* is always completely closed.

As noted in the type description, the holotype and all but one paratype were collected alive. All living specimens but one have a dark-brown band just below the suture. The lone exception has a white band instead of a brown one, which is still distinct by being more brightly white than the rest of the shell. One paratype has a narrowly open umbilicus along the entire growing margin of the um-

bilical callus. This feature is apparently atypical, because all other specimens have closed umbilici.

The radular dentition of *N. (N.) lamonae* (Text-fig. 11a) does not bear taxonomically useful characters.

Neverita (Neverita) kirkensis (Clark, 1915) Pl. 28, figs. 1, 2

Natica (Euspira) kirkensis Clark, 1915b, p. 487, pl. 69, figs. 4, 9.

Natica kirkensis Clark, Trask, 1922, p. 143.

Polinices (Euspira) kirkensis (Clark), Clark, 1929, pl. 34, fig. 20.

Natica (Neverita) arnoldi Clark, 1915b, p. 488, pl. 68, figs. 13, 15.

Natica arnoldi Clark, Trask, 1922, p. 143.

Neverita arnoldi (Clark), Adegoke, 1969, pp. 168-169.

Description. —

Size: Average specimen, height 25 mm, diameter 20 mm; largest specimen, height 43.5 mm, diameter 33.7 mm [UCB 1227, San Pablo Group, Concord quadrangle, California, Miocene].

Shell form: Shell usually elongate, rarely globose, spire moderately to greatly elevated; body whorl not greatly inflated; whorls evenly rounded except for flattening below suture; shell thickness average; whorls $5\frac{1}{2}$; suture slightly impressed, rarely moderately impressed. Shell surface smooth except for fine incremental growth lines. Parietal callus thick, heavily filling posterior apertural angle; anterior lobe inconspicuous. Umbilicus closed. Umbilical callus relatively narrow, evenly tapers anteriorly, smoothly merges with parietal callus; occasionally depressed at anterior end. Anterior inner lip greatly thickened, elevated; basal lip slightly thickened.

Operculum: Unknown.

Specimens examined. — One hundred fifty-two.

Stratigraphic occurrence. — Known only from upper Miocene strata. Upper Miocene: Cierbo Ss., Diablo Quad., Calif. (UCB); San Pablo Group, Contra Costa Co. (Clark, 1915b), Concord Quad. (UCB), California; Neroly Fm., Mount Diablo Quad. (UCB), Byron Hot Springs Quad. (UCB), Calif.; Briones Ss., Concord Quad., Calif. (UCB); Santa Margarita Fm., Coalinga area, Calif. (Adegoke, 1969).

Type localities. —

Natica (Euspira) kirkensis — UCB 467, southeast of Oyster Point, NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 28, T. 1 S., R. 1 E., Contra Costa County, California. Lower part of San Pablo Group, upper Miocene (Clark, 1915b; Keen & Bentson, 1944).

Natica (Neverita) arnoldi — UCB 505, a little west of center of SE1/4 NE1/4 sec. 9, T. 1 S., R. 2 W., Concord quadrangle, Contra Costa County, California. Upper part of San Pablo Group, upper Miocene (Clark, 1915b; Keen & Bentson, 1944).

Type material. —

Natica (Euspira) kirkensis — Holotype, UCB 11591.

Natica (Neverita) arnoldi — Holotype, UCB 11594.

Nomenclatural commentary. — *Neverita (Neverita) kirkensis* and *N. (N.) arnoldi* are synonymized here for the first time. The holotype of *N. (N.) kirkensis* is more globose than the more typically elongate holotype of *N. (N.) arnoldi*, but the specimens are otherwise identical. Both species were described by Clark (1915b) in the same publication, and *N. (N.) kirkensis* is chosen arbitrarily as the senior synonym.

Discussion. — The most noticeable variation in this species is in shell proportions. The great majority of specimens are distinctly elongate, but individuals occasionally occur that are fairly globose. Juveniles are slightly less slender than adults. The width and taper of the umbilical callus also varies noticeably and some specimens, especially juveniles, have a nearly imperceptible anterior taper to the callus. When this occurs, individuals may resemble *Polinices (Euspira) pallidus* (Broderip & Sowerby, 1829), although most living specimens and all fossils of *P. (E.) pallidus* have a narrowly open umbilicus. Living individuals of *P. (E.) pallidus* with closed umbilici are distinguished from *N. (N.) kirkensis* by their centrally swollen umbilical calluses and more strongly impressed sutures. *Polinices (Euspira) pallidus* is known from the middle Pliocene to Holocene of western North America, and is not considered here to be closely related to *N. (N.) kirkensis*.

This species is similar in form to and probably descended from the upper Paleocene to middle Oligocene *N. (N.) washingtonensis*. Comparison of the two species is made in the discussion of the latter.

***Neverita (Neverita) washingtonensis* (Weaver, 1916) Pl. 28, figs. 3-9**

Natica washingtonensis Weaver, 1916b, p. 44, pl. 5, figs. 73, 74, 76 [not fig. 75, = *Polinices (Euspira) lincolnsis* (Weaver, 1916b), treated herein]; Van Winkle, 1918, p. 76.

- Polinices washingtonensis* (Weaver), Durham, 1944, pp. 118, 119, 121, 160; Keen & Bentson, 1944, p. 186; DeLise, 1967, pp. 16, 46; Hickman, 1969, pp. 84-85 [in part; not pl. 11, figs. 12-19, = *Polinices (Euspira) lincolnensis* (Weaver, 1916b), treated herein]; not Clark & Anderson, 1938, p. 954, pl. 3, figs. 16, 17 [= *P. (E.) lincolnensis* (Weaver, 1916b)].
- Polinices (Polinices) washingtonensis* (Weaver), Weaver, 1943, p. 337 [not pl. 68, figs. 18, 23, = *P. (E.) lincolnensis* (Weaver, 1916b), treated herein].
- Polinices (Euspira) rectus* Tegland, 1933, pp. 139-140, pl. 14, fig. 22; Durham, 1944, pp. 124, 160.
- Polinices (Polinices) rectus* Tegland, Weaver, 1943, p. 336, pl. 68, figs. 15, 20.
- Polinices rectus* Tegland, Smith, 1975, p. 469 [as "aff."].
- Cryptonatica pittsburgensis* Moore, 1976, p. 31, pl. 1, figs. 9, 12, 13, 15, 16, 18, 19, 23.

Description.—

Size: Average specimen, height 11.5 mm, diameter 10.0 mm; largest specimen, height 24.7 mm (incomplete), diameter 21.8 mm [UCLA 4621, Pittsburg Bluff Formation, Columbia County, Oregon, middle Oligocene].

Shell form: Shell elongate globose, spire strongly elevated; body whorl not greatly inflated, usually slightly but distinctly flattened above periphery; shell thickness average; whorls at least $4\frac{1}{2}$ (apexes of all known specimens eroded); suture slightly to moderately impressed, generally strongly appressed. Shell smooth except for incremental growth lines. Parietal callus thick, heavily filling posterior apertural angle; anterior lobe weak to inconspicuous, may slightly overhang umbilicus. Umbilicus always closed, rarely as a minute shallow slit. Umbilical callus narrow, broadest posteriorly where it merges smoothly with parietal callus and tapering anteriorly. Anterior inner lip thickened.

Operculum: Unknown.

Specimens examined.— Two hundred thirty-nine.

Stratigraphic occurrence.— Upper Paleocene to middle Oligocene. Upper Paleocene and lower Eocene: Lodo Fm., Panoche Quad., Fresno Co., Calif. (SU; UCB). Upper Eocene: Keasey Fm., Washington Co., northwestern Oreg. (USGS). Upper Eocene and Oligocene: Lincoln Creek Fm., Lewis, Thurston, and Grays Harbor Cos., Wash. (USGS; SU; UCLA). Lower Oligocene: type Porter Fm. of Weaver (1912), Porter, Grays Harbor Co., Wash. (UCLA). Middle Oligocene: type Pittsburg Bluff Fm., Vernonia Quad., Columbia Co., Oreg. (Moore, 1976; CAS; UCLA); Blakeley Fm., *Echinophoria rex* zone, Bainbridge Island, Kitsap Co., Wash. (Tegland, 1933; UCB).

Type localities. —

Natica washingtonensis — Cut along Union Pacific Railway, one mile north of Galvin Station, Lewis County, Washington; sec. 27, T. 15 N., R. 3 W. (Weaver, 1916b, 1943). Lincoln Creek Formation, *Molopophorus lincolnensis* zone, lower Oligocene.

Polinices (Euspira) rectus — Restoration Point, Bainbridge Island, Kitsap County, near Seattle, Washington (Tegland, 1933). Blakeley Formation of Weaver (1912), middle Oligocene.

Cryptonatica pittsburgensis — First large roadcut on west side of Scappoose-Vernonia Road, south of cutoff to Wilark, Columbia County, Oregon (Moore, 1976). Pittsburg Bluff Formation, middle Oligocene.

Type material. —

Natica washingtonensis — Lectotype designated herein, CAS 462-C; paralectotypes, CAS 462, 462-A [= *Polinices (Euspira) lincolnensis* (Weaver, 1916b)], 7516 [= *P. (E.) lincolnensis*], and 462-B [mistakenly numbered "262-B," = *Natica (Natica) weaveri* Tegland, 1933].

Polinices (Euspira) rectus — Holotype, UCB 32191.

Cryptonatica pittsburgensis — Holotype, USNM 213951.

Nomenclatural commentary. — Five syntypes make up the type lot of Weaver (1916b), including two specimens of *N. (N.) washingtonensis*, two of *Polinices (Euspira) lincolnensis* (Weaver, 1916b), and one of *Natica (Natica) weaveri* Tegland, 1933. The original description was accompanied by four figures, one of *N. (N.) washingtonensis*, one of *P. (E.) lincolnensis* (both syntypes), and two of another specimen of *P. (E.) lincolnensis* that is not a syntype. Understandably, there was much confusion as to the identity of these two species. Confusion was compounded when Weaver unfortunately illustrated his account of *N. (N.) washingtonensis* with figures of *P. (E.) lincolnensis* in a frequently consulted work (Weaver, 1943). In desperation, most workers, beginning with Clark and Anderson (1938), decided that only one variable species was represented by *N. (N.) washingtonensis* and *P. (E.) lincolnensis* and referred to all specimens under one name or the other, depending on personal preference. Ironically, the orig-

inal description of *N. (N.) washingtonensis* clearly stated that the umbilicus was entirely closed, and the original description of *P. (E.) lincolnensis* noted with equal clarity the large umbilical opening of that species. Confusion regarding the identity of these species resulted from reliance on illustrations rather than written descriptions.

A holotype was not designated by Weaver (1916b) for *N. (N.) washingtonensis*, although he gave dimensions for one of the five syntypes (the specimen shown in his plate 5, figure 76). He later (Weaver, 1943) designated one specimen as "holotype" and another as "paratype," apparently inadvertently. Unfortunately, the specimen referred to as "holotype" (CAS 7516) is an individual of *P. (E.) lincolnensis* that is one of the original syntypes. The "paratype" is one of the original syntypes and also is *P. (E.) lincolnensis*, but Weaver (1943) incorrectly referred to this specimen as CAS 7516-A. No such number is now associated with this specimen, which now has "462-A" inked on it.

In his discussion of *N. (N.) washingtonensis*, Weaver (1943) repeated the original description that stated "the umbilical opening is entirely absent," and added the comment that the umbilicus is "closed by a moderately heavy callus." It, therefore, seems unlikely that he intended to designate as primary types specimens that obviously have open umbilici, as he did in his 1943 work. His designations of "holotype" and "paratype" are, therefore, considered to have been inadvertent.

As noted above, Weaver (1943) gave the dimensions of one of the five syntypes and also figured this specimen (Weaver, 1916b, pl. 5, fig. 76). This individual has a completely closed umbilicus which matches the original description (Weaver, 1916b) and later comments by Weaver (1943). This specimen, CAS 462-C, is herein designated lectotype, and the remaining four syntypes (CAS 462, 462-A, 462-B [mistakenly written as "262-B" on the specimen], and 7516) are designated paralectotypes.

Discussion. — Although shells of *N. (N.) washingtonensis* are imperforate, many shells falsely appear to have an umbilicus. Particularly, the body whorl near the umbilical callus is more easily dissolved than the callus itself, and the result is a false "umbilicus" formed along the growing margin of the callus. This deceptive condition is usually revealed on close inspection by remnants of the orig-

inal shell surface in the umbilical area. Uncommonly, the umbilical callus is not fully developed, leaving a shallow depression along the growing margin of the callus that may be mistaken for an umbilical opening. Close examination of such specimens shows them to be imperforate.

Because some past workers have speculated that *N. (N.) washingtonensis* and *P. (E.) lincolnensis* constitute one species, I considered the possibility that the imperforate and relatively small *N. (N.) washingtonensis* was the juvenile of the larger and umbilicate *P. (E.) lincolnensis*. To test this idea, I selected 20 adults of *P. (E.) lincolnensis* that had umbilical openings ranging from slitlike to moderately broad, then by small increments removed the whorls from each specimen back to the protoconch. In every specimen, the umbilicus was fully open along the whole length of the coiled shell. A similar examination of *N. (N.) washingtonensis* specimens showed the umbilicus to have been closed for the entire life of each individual. The fact that the two species have widely different stratigraphic ranges also dispels the idea that only one species is represented by both umbilicate and imperforate specimens: *N. (N.) washingtonensis* ranges from late Paleocene to middle Oligocene, whereas *P. (E.) lincolnensis* ranges from late Eocene to middle Miocene. The two species do occur together in many formations, as noted by several past workers, but clearly do not do so everywhere.

This species is most similar to the late Miocene *N. (N.) kirkensis* (Clark, 1915). The most obvious difference is in size, for *N. (N.) kirkensis* averages more than twice the size of *N. (N.) washingtonensis*. Shells of *N. (N.) kirkensis* are, with few exceptions, distinctly more elongate than those of *N. (N.) washingtonensis*, and the sutures are proportionately more appressed. The umbilical calluses of the two species are similar, but the callus of *N. (N.) kirkensis* has a more regular and distinct anterior taper and tapers to a relatively finer point. In addition, the anterior inner lip of *N. (N.) kirkensis* is relatively thicker than in the other species; the contrast between this thick anterior inner lip and the slender anterior end of the umbilical callus is greater than in *N. (N.) washingtonensis*.

Neverita (Neverita) politiana (Dall, 1919)

Pl. 36, fig. 5

Euspira politiana Dall, 1919b, p. 353.

Polinices (Euspira) politianus (Dall), Dall, 1921, p. 164 [as "politiana"]; Oldroyd, 1927, p. 727; Burch, 1946, p. 29.

Polinices politianus (Dall), Keen, 1937, p. 44; Burch, 1946, p. 29.

Description. —

Color: Shell white. Periostracum thin, pale yellowish brown.

Size: Height 16 mm, diameter 13 mm (holotype).

Shell form: Shell globose, spire low; whorls evenly rounded; shell thin; whorls about four; suture slightly impressed and narrowly channeled. Spiral sculpture lacking; axial sculpture of incremental growth lines and sharply incised grooves radiating from the suture part way to the periphery. Parietal callus thin, but thickens to moderately fill posterior apertural angle; anterior lobe indistinct. Umbilicus closed. Umbilical callus small, low, with a small dimple at its growing margin. Inner lip slightly thickened, basal lip thin.

Operculum: Chitinous, filling aperture.

Specimens examined. — Holotype only.

Geographic occurrence and habitat. — Known only from the type locality in the Bering Sea, at a depth of 1,098 metres, on sand and pebbles.

Type locality. — Petrel Bank, Bering Sea [about 52°08' N., 179°48' E.], in 1,098 metres, U.S.S. "Albatross" station 4779 (Dall, 1919b).

Type material. — Holotype, USNM 205653.

Neverita (Neverita) globosa Gabb, 1869

Pl. 28, figs. 10-15;
Pl. 29, figs. 1-3

Neverita globosa Gabb, 1869b, p. 161, pl. 27, fig. 39; Cooper, 1894, p. 62; Dickerson, 1914b, p. 95; Dickerson, 1916, pp. 392, 408, 442, 451, pl. 39, figs. 5a, b; Stewart, 1927, pp. 326-327, pl. 28, fig. 6; Clark & Woodford, 1927, pp. 121-122, pl. 22, figs. 5-10; Merriam & Turner, 1937, p. 100; Turner, 1938, p. 89, pl. 19, figs. 6, 7, 13-15; Vokes, 1939, p. 169, pl. 21, figs. 9, 15-19; Schenck & Keen, 1940, p. 32, pl. 24, figs. 2-5; Keen & Bentson, 1944, pp. 179-180.

Polinices globosa (Gabb), Arnold & Hannibal, 1913, p. 572.

Polinices (Neverita) globosa (Gabb), Weaver, 1943, p. 339, pl. 68, figs. 21, 24, pl. 69, figs. 5, 6, pl. 100, fig. 29; Keen & Bentson, 1944, p. 186; Weaver, 1945, p. 45.

Neverita (Neverita) globosa Gabb, Givens, 1974, p. 76.

Natica fiasco Hanna, 1924, pp. 173-174 [new name; see nomenclatural commentary]; Anderson & Hanna, 1925, pp. 117-118; Keen & Bentson, 1944, p. 176.

Neverita globosa reefensis Vokes, 1939, p. 169, pl. 21, figs. 24, 25; Keen & Bentson, 1944, p. 180.

Neverita weaveri Dickerson, 1915, p. 57, pl. 4, figs. 10a, b.

Polinices weaveri (Dickerson), Turner, 1938, p. 86, pl. 20, figs. 14, 16.

Polinices (Neverita) weaveri (Dickerson), Weaver, 1943, p. 340, pl. 68, figs. 16, 17, pl. 69, fig. 3; Weaver, 1945, p. 45.

- Neverita nomlandi* Dickerson, 1917, pp. 173-174, pl. 30, figs. 2a, b; Van Winkle, 1918, p. 76; Effinger, 1938, p. 377; Durham, 1944, pp. 118, 160.
- Polinices (Neverita) nomlandi* (Dickerson), Weaver, 1943, p. 340, pl. 69, figs. 8, 9, 12.
- "*Polinices (Neverita) recluzianus* (Deshayes)," Clark & Anderson, 1938, p. 954 [as "aff."].

Description. —

Color: Several specimens from the upper Eocene Cowlitz Formation retain vestiges of their original color pattern. These are now mostly whitish, with a dark-gray or brown band high on the shoulder that is separated from the suture by a narrow white band. The umbilical and parietal calluses are white and the base is white with a dark band.

Size: Average specimen, height 14 mm, diameter 14 mm; largest specimen, height 21.4 mm, diameter 23.0 mm (incomplete) [USGS, no number, type Cowlitz Formation, Lewis County, Washington, upper Eocene].

Shell form: Shell subglobose, spire low to moderately elevated; body whorl not greatly inflated; shoulder rounded to slightly flattened, slightly concave immediately below suture on higher spired individuals; shell thickness average; whorls about six (apexes of specimens eroded); suture impressed slightly or not at all, strongly appressed. Spiral sculpture of minute, weakly developed, closely spaced, minutely wavy costellae (eroded on most specimens); axial sculpture of incremental growth lines. Parietal callus heavy, thickly filling posterior apertural angle; anterior lobe weak to indistinct. Umbilicus narrowly open to closed. Umbilical callus massive (bulbous on individuals with partly open umbilici), largely or entirely filling umbilicus. Anterior inner lip slightly thickened.

Operculum: Unknown.

Specimens examined. — Two hundred ninety.

Stratigraphic occurrence. — Upper Paleocene to upper Eocene. Upper Paleocene: Meganos Fm., Byron Hot Springs Quad., Contra Costa Co., Calif. (Clark & Woodford, 1927; UCB). Middle Eocene: Crescent (?) Fm., Olympic Peninsula, Wash. (Arnold & Hannibal, 1913); Umpqua Fm. [Flournoy Formation of Baldwin & Beaulieu (1973)], Douglas Co., Ore. (Turner, 1938; UCB); Domengine Fm., Coalinga Quad., Fresno Co., and Cholame Quad., San Luis Obispo Co., Calif. (Vokes, 1939; UCB); Domengine (?) Fm., near New

Idria, San Benito Co., Calif. (Gabb, 1869b); Juncal Fm., *Ectinochilus supraplicatus* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR); Ardath (?) Shale, Rose Canyon, La Jolla Quad., San Diego Co., Calif. (Cooper, 1894). Upper Eocene: Quimper Ss. of Durham (1944), *Molopophorus stephensoni* zone, Jefferson Co., Wash. (Durham, 1944; UCB); type Cowlitz Fm., Lewis Co., Wash. (Dickerson, 1915, USGS: CAS; UCB); Lincoln Creek Fm., Gries Ranch section, Lewis Co., Wash. (Dickerson, 1917; Van Winkle, 1918; Effinger, 1938); Coaledo Fm., Coos Co., Ore. (Weaver, 1945; UCB); Wheatland Fm. of Clark & Anderson (1938), near Wheatland, Yuba Co., Calif. (Clark & Anderson, 1938); Tejon Fm., Tejon Quad., Kern Co., Calif. (USGS).

Type localities. —

Neverita globosa — Ten miles west of Griswold's, on the road from San Juan to New Idria, and southeast of the "Sheep Well"; T. 15 S., R. 9 E., Priest Valley quadrangle, San Benito County, California (Gabb, 1869b; Keen & Bentson, 1944). Domengine(?) Formation, middle Eocene.

Neverita globosa reefensis — Lowest reef bed on side of hill just east of and above first saddle south of Big Tar Canyon, north half sec. 20, T. 23 S., R. 17 E., Cholame quadrangle, Kings County, California (Vokes, 1939). Domengine Formation, middle Eocene.

Neverita weaveri — On the west bank of the Cowlitz River, about 1-3/4 miles southeast of Vader, Lewis County, Washington (Dickerson, 1915). Cowlitz Formation, upper Eocene.

Neverita nomlandi — On east bank of the Cowlitz River, just back of the Gries ranch house, about 4 miles east of Vader, Lewis County, Washington (Dickerson, 1917). Lincoln Creek Formation, upper Eocene.

Type material. —

Neverita globosa — Holotype, MCZ 27859.

Neverita globosa reefensis — Holotype, UCB 15855.

Neverita weaveri — Holotype, CAS 278; paratypes, CAS 279, 279-A.

Neverita nomlandi — Holotype, CAS 411.

Nomenclatural commentary. — Five species were named *Natica globosa*, beginning with *N. globosa* Grateloup, 1827 [Tertiary, France], before Gabb (1869b) described *Neverita globosa*. Hanna (1924) mistakenly placed *Neverita globosa* in *Natica* and considered it a junior homonym of *Natica globosa* King, 1832 [living, Straits of Magellan], apparently overlooking the earlier name of Grateloup. The interests of nomenclatural stability would clearly favor retention of the often-used specific name *Neverita globosa*, despite Hanna's (1924) action. The new version of the ICZN Code, not yet available in official book form, makes retention of the earlier name far clearer than the previous version (ICZN article 59(b)i). Although a petition to the Commission would seem to be required by the new version of the Code, this has not generally been the practice and should await the finalization of the wording of the changes recently made in the Code.

Discussion. — This species has been named more than once because of variability in its shell proportions, shoulder profile, and umbilical callus size. The shell is most often nearly globose, with evenly rounded whorls and a low spire, but some individuals have more elongate shells with higher spires; accompanying this is a somewhat compressed body whorl and flattened shoulder. Such variants have a broad angulation midway up the shoulder when seen in profile. There is continuous gradation between typically subglobose individuals and the more elongate variety.

The great majority of specimens have their umbilici closed by relatively massive calluses, leaving no trace of the umbilical openings. Some individuals, however, have a shallow pit at the site of the concealed umbilicus. In addition, a few specimens, ranging from juveniles to adults, have a narrowly but distinctly open umbilicus as a curved opening along the leading edge of the umbilical callus. These rare umbilical openings are never as broad as seen in extreme variants of *Neverita (Glossaulax) reclusiana* (Deshayes), in which whorls earlier than the final one may be seen.

This species is placed in *Neverita*, *s.s.* for lack of the transverse callus groove that characterizes *Glossaulax*. However, a few individuals of *N. (N.) globosa* show a faint transverse callus groove when examined in strong oblique light. I have seen such faint grooves in juveniles and small adult specimens, but never in larger

individuals. Because this groove is so poorly developed, is seen only in smaller specimens, and occurs rarely, it is not sufficient to place *N. (N.) globosa* in *Glossaulax*. It does suggest, however, that *N. (N.) globosa* lies close phylogenetically to the point at which *Glossaulax* evolved from *Neverita s.s.*

The earliest known species of *Glossaulax* are *N. (G.) reclusiana* of the northeastern Pacific and *N. (G.) bolivarensis* Clark (in Clark & Durham, 1946) of Colombia. The former species ranges from the middle Eocene to Holocene in California and adjacent areas, and the latter is known from beds of middle and late Eocene age in western Colombia. The occurrence of pre-middle Eocene species of *Glossaulax* or *Neverita, s.s.* in Colombia or adjacent regions is not known. Because of the close geographic and stratigraphic relationships of *N. (N.) globosa* and *N. (G.) reclusiana*, plus the existence of faintly grooved individuals of *N. (N.) globosa* inferred to be transitional with *N. (G.) reclusiana*, the latter species is considered to be the earliest manifestation of the *Glossaulax* morphology. Because the tropics extended at least as far north as Washington during the middle Eocene, *N. (G.) reclusiana* presumably could have rapidly extended its range from California to the Caribbean region and western South America and given rise to *N. (G.) bolivarensis* and other closely related Tertiary species.

At most places where it has been collected, *N. (N.) globosa* does not occur in large numbers. It is abundant only in upper Eocene deposits of the Cowlitz Formation in Washington.

Subgenus **GLOSSAULAX** Pilsbry, 1929, p. 113

Type species: *Natica reclusiana* Deshayes, 1839, by original designation. Middle Eocene to Holocene, eastern Pacific. Figured herein.

Diagnosis. — Umbilical callus entirely covering umbilicus, divided into anterior and posterior lobes by narrow transverse groove.

Discussion. — *Glossaulax* is characterized by its massive grooved callus. Some species, including the type species, show occasional variations with the umbilicus open, although the callus groove always remains distinct. In the eastern Pacific, this subgenus occurs mainly in temperate waters, but ranges into the tropical

Panamic province. In western North America it is found in deposits as old as middle Eocene.

Neverita (Glossaulax) reclusiana (Deshayes, 1839) Pl. 29, figs. 4-12;
Pl. 30, figs. 1-4; Text-fig. 13

Natica reclusiana Deshayes, 1839, p. 361; Deshayes, 1841, pl. 37; Menke, 1851, p. 165 [as "*recluziana*"]; Philippi, 1852, pp. 38-39, pl. 5, fig. 5 [plate 1849]; Reeve, 1855, pl. 1, fig. 3 [as "*recluziana*"]; Sowerby, 1883, p. 76, pl. 1, fig. 6 [as "*recluziana*"].

Neverita reclusiana (Deshayes), H. & A. Adams, 1853, vol. 1, p. 208; Keep, 1888, p. 46, fig. 26 [as "*recluziana* Petit"]; Arnold, 1907a, p. 544, pl. 48, fig. 6 [as "*recluziana* Petit"]; Arnold, 1907b, pl. 38, fig. 6 [as "*recluziana* Petit"]; Arnold & Anderson, 1907, p. 144, pl. 21, figs. 14a, b, 15 [as "*recluziana* Petit"]; Arnold, 1910, pp. 31, 146, pl. 20, fig. 2 [as "*recluziana* Petit"]; Pilsbry, 1929, p. 109, pl. 6, fig. 1; Woodring, Stewart, & Richards, 1940, p. 86 [in part], pl. 20, figs. 1, 3, 5 [not pl. 15, figs. 19, 20; pl. 20, figs. 2, 4, = *N. (G.) andersoni* (Clark, 1918), treated herein]; Durham, 1950a, p. 127, pl. 34, fig. 8; Woodring & Bramlette, 1950, p. 73, pl. 20, fig. 4.

Natica (Neverita) reclusiana (Deshayes), Tryon, 1886, p. 34, pl. 2, fig. 1 [as "*recluziana*"]; Clark, 1918, pp. 167-168.

Polinices (Neverita) reclusianus (Deshayes), Stearns, 1894a, p. 196 [as "*Polynices*"]; Arnold, 1903, pp. 314-315, pl. 10, fig. 12 [as "*Polynices (Neverita) reclusiana* Petit"]; Grant & Gale, 1931, pp. 800-801, figs. 13a-c; Keen, 1958, p. 324, fig. 274; Keen, 1971, p. 482, fig. 888, pl. 14, fig. 4 [not *Polinices (Polinices) bifasciatus* (Griffith & Pidgeon, 1834), as stated in plate caption].

Polinices (Neverita) reclusianus reclusianus Grant & Gale, 1931, pp. 801-802.

Polinices reclusianus (Deshayes), Jordan, 1924, pp. 150-152 [as "*recluzianus*"]; MacGinitie & MacGinitie, 1949, pp. 330, 355, figs. 170, 202 [as "*recluziana*"]; McLean, 1969, p. 37, fig. 19.3.

Neverita callosa Gabb, 1866, pp. 10-11, pl. 2, figs. 17, 17a, b [plate, 1869]; Arnold, 1907a, p. 542, pl. 44, figs. 4, 4a; Arnold 1907b, p. 234, figs. 4, 4a; Adegoke, 1969, p. 167.

Polinices callosus (Gabb), Arnold & Hannibal, 1913, p. 576 [as "*callosa*"].

Polinices (Neverita) reclusianus callosus (Gabb), Grant & Gale, 1931, p. 803, text-fig. 14.

Neverita reclusiana alta Dall, 1878, p. 12 [as "*recluziana* var. *alta*"; *nomen nudum*]; Arnold, 1910, pp. 32, 146, pl. 20, figs. 5, 5a [as "*recluziana* var. *alta* Dall"]; Arnold & Anderson, 1910, pp. 130, 133, pl. 45, figs. 5, 5a [as "*recluziana* var. *alta* Dall"]; Adegoke, 1969, p. 168.

Polinices (Neverita) reclusianus altus Arnold ex Dall MS, 1903, p. 315 [as "*Polynices (Neverita) recluziana* var. *alta* Dall"]; Dall, 1909b, p. 88 [as "*recluziana* var. *alta* Dall"]; Dall, 1921, p. 165 [as "*recluziana alta* Dall"]; Grant & Gale, 1931, pp. 801-802.

Natica reclusiana alta (Arnold), Nomland, 1917a, p. 221 [as "*recluziana alta* Dall"].

Neverita alta (Arnold), Pilsbry, 1929, pp. 110-111, pl. 6, figs. 5-9 [as "*alta* 'Dall' Arnold"].

Polinices altus Arnold, Keen, 1937, p. 44; Kanakoff & Emerson, 1959, p. 30; McLean, 1969, pp. 37-38, fig. 19.4 [as "*altus* Pilsbry"].

Polinices (Neverita) altus Arnold, Willett, 1937, p. 400 [as "*altus* Dall"]; Burch, 1946, p. 31.

Polinices reclusianus altus Arnold, Smith & Gordon, 1948, p. 199 [as of "Dall"]. *Neverita (Glossaulax) alta* (Arnold), Addicott, 1970a, p. 69, pl. 5, figs. 19, 25. *Polinices (Neverita) reclusianus imperforatus* Dall ex Stearns MS, 1909b, p. 88.

- [as "*recluziana* var. *imperfurata* Stearns"]; Dall, 1921, p. 165 [as "*recluziana imperfurata*"]; Burch, 1946, p. 30-31 [as "*recluziana imperfuratus*"].
- Neverita recluziana imperfurata* (Dall), Pilsbry, 1929, pp. 111-112, pl. 6, figs. 2-4; Valentine, 1961, pp. 361, 376.
- Polinices imperfuratus* Dall, Keen, 1937, p. 44.
- Not *Natica imperfurata* Jay, 1836, pl. 4 [living, Philippines].
- Not *Natica imperfurata* Gray, 1839, p. 135, pl. 37, fig. 1 [living, Cape of Good Hope].
- Neverita secta* Gabb, 1864, pp. 108-109, pl. 29, figs. 220, 220a; Dickerson, 1914b, p. 115; Dickerson, 1915, pl. 4, fig. 9; Dickerson, 1916, pl. 39, fig. 6; Stewart, 1927, pp. 325-326, pl. 30, fig. 17.
- Natica secta* (Gabb), Anderson & Hanna, 1925, p. 117, pl. 10, fig. 4.
- Polinices (Neverita) secta* (Gabb), Weaver, 1943, p. 341, pl. 70, figs. 3, 4, 7, 8, pl. 100, fig. 30; Weaver & Kleinpell, 1963, p. 138, pl. 24, fig. 15.
- Neverita (Glossaulax) secta* Gabb, Givens, 1974, p. 76.
- Neverita secta hemisecta* Clark, 1938, pp. 702-703, pl. 3, figs. 26, 27, pl. 4, figs. 29, 30, 32, 33.
- Polinices (Neverita) recluzianus vancouverensis* Clark & Arnold, 1923, p. 169, pl. 33, figs. 2a, b, 3 [as "*recluziana vancouverensis*"].
- Neverita (Glossaulax) thomsonae* Hickman, 1969, p. 84, pl. 11, figs. 20-23.
- Neverita thomsonae* Hickman, Addicott, 1972, p. 7, pl. 1, fig. 10.

Description.—

Color: Shell buff to pale gray, with a darker band high on the shoulder and a narrower white band usually at the suture; base white or at least paler than rest of whorl; umbilical callus white to medium brown, may be white centrally with a brown margin; parietal callus white, may be brown on its anterior half; interior clouded with white and light to dark brown, white on base; nuclear whorls dark brown. Periostracum thin, whitish on base, pale grayish brown to chocolate and rust brown above base, often with irregular rusty staining. Dorsal part of shell, not covered by mantle in life, may be darker than remainder of shell.

Size: Average specimen, height 40 mm, diameter 38 mm; largest specimen, height 90.5 mm, diameter 82.0 mm [CAS 1937, San Diego, California, modern].

Shell form: Shell low and subglobose to elongate, spire moderately to greatly elevated; body whorl not greatly inflated; shoulder slightly to distinctly flattened, often slightly concave, especially in high-spired forms; shell thick to average; nuclear whorls 2½, smooth; postnuclear whorls four, suture slightly impressed. Spiral sculpture of minute, weakly developed, closely spaced, minutely wavy costellae; axial sculpture of incremental growth lines that are heaviest on base. Parietal callus heavy, thickly filling posterior apertural angle; anterior lobe weak to indistinct, merges with umbilical

callus. Umbilicus broadly open to closed, with all intermediate gradations; broadly open umbilicus, if present, shows weakly developed spiral costellae in channel. Umbilical callus divided into two lobes by strong transverse groove; groove may be simple or terminate as a deep pit at inner lip margin; posterior callus lobe always larger than anterior lobe, may be confined to posterior end of umbilicus or may be elongate anteriorly to plug or nearly plug umbilical opening. Anterior inner lip and basal lip thickened.

Operculum: Chitinous.

Specimens examined. — Thirty-five hundred thirty-two.

Geographic occurrence and habitat. — Crescent City, California ($41^{\circ}46'$ N.), south to the Gulf of California, throughout which it occurs, and to just south of Mazatlán ($23^{\circ}14'$ N.), and at Islas las Tres Marías ($21^{\circ}30'$ N., $106^{\circ}40'$ W.), Mexico. Uncommon north of Mugu Lagoon, California ($34^{\circ}05'$ N.) and south of the Gulf of California. Living on sandy and muddy bottoms intertidally and in depths to 50 metres, common in embayments.

Stratigraphic occurrence. — Middle Eocene to Holocene. Middle Eocene: Domengine Fm., Coalinga area, Fresno Co., Calif. (Vokes, 1939; UCB); Ardath Shale, San Clemente Canyon, San Diego Co., Calif. (LACM). Upper Eocene: Quimper Ss. of Durham (1944), Port Ludlow Quad., Jefferson Co., Wash. (USGS); Cowlitz Fm., Lewis Co., Wash., (Dickerson, 1915; Weaver, 1943; USGS; UCB); Coaledo Fm., Coos Bay, Coos Co., Oreg. (Weaver, 1945); Markley Ss. Member of the Kreyenhagen Formation, near Vacaville, Solano Co., Calif. (Clark, 1938; UCB); Wheatland Fm. of Clark & Anderson (1938), near Wheatland, Yuba Co., Calif. (Clark & Anderson, 1938); Tejon Fm., Tejon Quad., Kern Co., Calif. (Gabb, 1864; Dickerson, 1915; Anderson & Hanna, 1925; SU; CAS; UCB); Matilija Ss., *Ectinochilus canalifer* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR). Upper Eocene and Oligocene: Lincoln Creek Fm., Grays Harbor and Skamokawa Quads., Grays Harbor Co., Wash. (USGS); San Lorenzo Fm., Mount Diablo area, Contra Costa Co., Calif. (Clark, 1918; UCB). Lower Oligocene: Wygal Ss. Member of the Temblor Fm., Temblor Range, southern Calif. (Addicott, 1972; USGS); Gaviota Fm. of Effinger (1935), upper Refugian stage, Santa Ynez Mts., Santa Barbara Co., Calif. (Weaver & Kleinpell, 1963). Lower and middle Oligocene: Eugene

Fm., west-central Ore. (Hickman, 1969; USGS). Middle Oligocene: Pittsburg Bluff Formation, Columbia Co., Ore. (Hickman, 1969; USGS; CAS; UCLA). Upper Oligocene: Blakeley Fm. of Weaver (1912), *Echinophoria apta* zone, King Co., Wash. (Durham, 1944; UCB). Upper Oligocene or lower Miocene: Sooke Fm., Vancouver Island, B.C., Canada (Clark & Arnold, 1923; SU; USGS). Lower Miocene: Clallam Fm., northwestern Wash. (Reagan, 1909, 1910); Vaqueros Fm., Trabuco Canyon, Los Angeles Co., Calif. (LACM); Vaqueros Fm., San Miguel Island, southern Calif. (Bremner, 1933). Middle Miocene: Astoria Fm., Montesano Quad., Wash. (USGS); Temblor Fm. and McLure Shale Member of Monterey Shale, Reef Ridge, Coalinga area, Calif. (Stewart, 1946; USGS); Temblor Fm., Coalinga area (Adegoke, 1969; UCB), Wilson Corner Quad. (USGS), and Panoche Valley Quad. (USGS), Calif.; lower and upper parts of the Olcese Sand and Jewett Sand, Kern River area, Calif. (Addicott, 1970a; USGS); Topanga Fm., Topanga Canyon, Los Angeles Co., Calif. (USC; LACM; UCLA). Upper Miocene: Santa Margarita and San Pablo Fms., central Calif. (Nomland, 1917b); Santa Margarita Fm., Coalinga area (Nomland, 1917b; UCB) and La Panza Quad. (USGS), Calif. Miocene or Pliocene: "Imperial Fm. (in part)", Carrizo Creek, San Diego Co., Calif. (UCB); Towsley Fm., southeastern Ventura Basin, southern Calif. (Winterer & Durham, 1962). Lower Pliocene: Jacalitos Fm. of former usage, Coalinga area (Arnold & Anderson, 1910), and Priest Valley Quad. (UCB), Calif.; Panorama Hills Fm. of Dibblee (1962), Temblor Range, southern Calif. (Addicott, 1972; USGS); Empire Fm., Coos Bay, Coos Co., Ore. (UCB); Pancho Rico Fm., Hames Valley Quad. (USGS) and Salinas Valley (Durham & Addicott, 1965; USGS), Calif.; Repetto Fm. of former usage, San Fernando Quad., Los Angeles Co., Calif. (CAS; UCB); upper Sisquoc Fm., Lompoc Quad., Santa Barbara Co., Calif. (UCB). Middle Pliocene: Etchegoin Fm., Coalinga area (Martin, 1916; Nomland, 1917a; Arnold, 1910; UCB), and Palvadero Gap Quad. (UCB), Calif.; Carmen Island, Gulf of California, Mexico (Durham, 1950a). Upper Pliocene: Pico Fm., San Fernando Quad. (UCB), southeastern Ventura basin (Winterer & Durham, 1962), Piru Quad. (UCB), Triunfo Quad. (UCB), Val Verde Quad. (UCB), and Elsmere Canyon (Arnold, 1907a), Calif.; San Joaquin Fm., *Pecten* and *Trachy-*

cardium zones, *Neverita* zone, *Acila* zone [as "cf."], Cascajo Conglomerate Mem. [as "?"], Kettleman Hills, Calif. (Woodring, Stewart, & Richards, 1940); San Joaquin Fm., Los Viejos Quad. (UCB) and Reef Ridge Quad. (UCB), Fresno Co., Calif.; Fernando Fm., central Los Angeles basin, Calif. (LACM); San Diego Fm., San Ysidro Quad. (UCB), Pacific Beach (LACM; CAS), Balboa Park (CAS), and U.S.-Mexican border (CAS), San Diego Co., Calif. Undifferentiated Pliocene: Purisima Fm., Año Nuevo Quad., San Mateo Co., Calif. (SU); Falor Fm. of Manning & Ogle (1950), Trinidad Head, Humboldt Co., Calif. (UCB); "Merced Formation," Healdsburg Quad. (UCB) and Sargent oil field (Martin, 1916), Santa Clara Co., Calif.; formation unknown, Newhall Canyon, Los Angeles Co., Calif. (CAS). Upper Pliocene to Pleistocene: Saugus Fm., Ventura and Piru Quads., Calif. (UCB). Lower Pleistocene: Santa Barbara Fm. of Smith (1912), Santa Barbara, Calif. (LACM; UCB); so-called San Pedro Fm., Ventura Co., Calif. (CAS); unnamed sand member of San Pedro Fm., San Pedro, Los Angeles Co., Calif. (Arnold, 1903; Oldroyd, 1924; Woodring, Bramlette, & Kew, 1946; LACM; CAS; UCB); Lomita Marl Member (Woodring, Bramlette & Kew, 1946; LACM) and Timms Point Silt Mem. (Woodring *et al.*, 1946; Clark, 1931; LACM) of San Pedro Fm., San Pedro, Los Angeles Co., Calif. Upper Pleistocene: Palos Verdes Sand, Palos Verdes Hills and San Pedro area (Arnold, 1903; Woodring, Bramlette, & Kew, 1946; Valentine, 1961; LACM; UCLA), Playa del Rey (Willett, 1937; LACM; CAS), Newport Bay (Kanakoff & Emerson, 1959; LACM; CAS), and Potrero Canyon, Pacific Palisades (Valentine, 1956), Calif.; terrace deposits, Pacific Beach (Valentine, 1961) and southwestern San Diego Co. (Emerson & Addicott, 1953; Valentine, 1961), Calif.; terrace deposits, San Clemente, Orange Co., Calif. (Valentine, 1961); terrace deposits, Summerland and El Capitan Beach, Santa Barbara Co., Calif. (Valentine, 1961).

Type localities.—

Natica reclusiana — "Mers de California" (Deshayes, 1839). Holocene.

Neverita callosa — Walnut Creek, Contra Costa County, California (Gabb, 1866). Formation unknown, Miocene.

Polynices (Neverita) reclusianus var. *alta* — Intersection

of Pacific and Oliver streets, San Pedro, Los Angeles County, California (Pilsbry, 1929). Palos Verdes Sand, upper Pleistocene.

Polinices (Neverita) recluziana var. *imperforata* — Noted by Dall (1909b) as “living in the vicinity of San Diego and in the Pleistocene of the upper San Pedro [Palos Verdes Sand, upper Pleistocene] at Deadman Island [San Pedro, Los Angeles County, California].” The lectotype is a modern specimen and its label reads “probably San Diego,” so I accept San Diego, California, as type locality.

Neverita secta — “Alizos Creek” [Live Oak Canyon], near Fort Tejon, Kern County, California (Gabb, 1864). Tejon Formation, upper Eocene.

Neverita secta hemisecta — “Along Pleasant Creek between one and two miles south of junction with Putah Creek. This locality embraces four separate localities within a stratigraphic thickness of 300 feet.” Solano County, California (Clark, 1938). Markley Formation, upper Eocene.

Polinices (Neverita) recluziana vancouverensis — Sea cliffs between mouths of Muir and Kirby creeks, west of Otter Point, Sooke, Vancouver Island, British Columbia, Canada (Clark & Arnold, 1923). Sooke Formation, upper Oligocene or lower Miocene.

Neverita (Glossaulax) thomsonae — East bank of Nehalem River, along Oregon State Highway 47, north of Pittsburg, NE1/4 sec. 23, T. 5 N., R. 4 W., Vernonia 15' quadrangle, Columbia County, Oregon (Hickman, written commun.). Pittsburg Bluff Formation, middle Oligocene.

Type material. —

Natica recluziana — Unknown, presumably in École des Mines, Paris (Dance, 1966).

Natica callosa — Unknown, as first noted by Stewart (1927).

Polynices (Neverita) recluzianus var. *alta* — Neotype (Pilsbry, 1929), ANSP 147585.

Polinices (Neverita) reclusiana var. *imperfurata* — Lectotype designated herein, USNM 36633; two paralectotypes, USNM 710768. Pilsbry (1929) mistakenly designated a "neotype" as ANSP 147436. See nomenclatural commentary below.

Neverita secta — Holotype, ANSP 4212; two paratypes, ANSP 4212.

Neverita secta hemisecta — Holotype, UCB 12482; paratypes, UCB 12481 and 30488.

Polinices (Neverita) reclusiana vancouverensis — Holotype located at SU but bears number UCB 30204; paratype, CAS 684.

Neverita (Glossaulax) thomsonae — Holotype, University of Oregon (Eugene) 27366; paratypes, University of Oregon (Eugene) 27367 to 27372.

Nomenclatural commentary. — The authorship of *N. (G.) reclusiana* was for many years mistakenly attributed to S. Petit by some authors. Petit was merely editor of the journal in which Deshayes (1839) published the original description of the species and had nothing to do with naming the species. A more common mistake, which has persisted until recently, has been to misspell "*reclusiana*" as "*recluziana*." Although the species was named by Deshayes in honor of C. M. Récluz, the species name was spelled with an "s" in the original description, and the rules of zoological nomenclature do not allow alteration of the name by substituting a "z" in place of the "s" (ICZN Rules, Article 32a).

Authorship of the synonymous species *N. (G.) alta* has been variously attributed to Arnold (1903), Dall (1909b), and Pilsbry (1929). The earliest mention of the name was by Dall (1878) as a *nomen nudum*. Arnold (1903, p. 315) noted that "Dr. Dall has described a variety [of *N. (G.) reclusiana*] with an elevated spire which he calls var. *alta*." Because this is sufficient description to differentiate the taxon, authorship is correctly attributed to Arnold. In a discussion of *N. (G.) reclusiana*, Dall (1909b, p. 88) later stated that "There is a variety *alta* Dall, with small narrow shell and exceptionally elevated spire," which would have been enough to validate the taxon if Arnold has not already done so. None of the specimens examined by Dall or Arnold when considering this species are

known to exist. Discounting the brief descriptions of Arnold (1903) and Dall (1909b), Pilsbry (1929) thoroughly redescribed the species as *Neverita alta* and designated a neotype. Most later workers have used Pilsbry's concept of the taxon, although its authorship still belongs to Arnold (1903).

There was early misunderstanding about authorship of the so-called *imperforata* form of *N. (G.) reclusiana*, which Dall (1909b) first cited as "*Polinices (Neverita) reclusiana* var. *imperforata* Stearns." However, Stearns never published this name, so Dall probably borrowed it from a Stearns manuscript or from a specimen label. Dall (1909b) is, therefore, the correct author of the taxon. In a later review of *N. (G.) reclusiana* and allied species, Pilsbry (1929) mistakenly designated a "neotype" for *N. (G.) reclusiana imperforata*, apparently overlooking Dall's lot of three syntypes in the USNM. The ICZN Rules [Article 75c(3)] state that a neotype designation is valid only if its author states his "reasons for believing all of the original type-material to be lost or destroyed, and the steps that have been taken to trace it." As Pilsbry gave no indication that he searched for Dall's syntypes, his neotype designation is invalid. To rectify this situation, I have designated a lectotype and two paralectotypes from Dall's syntypes, with specifics as noted above in the section on type material.

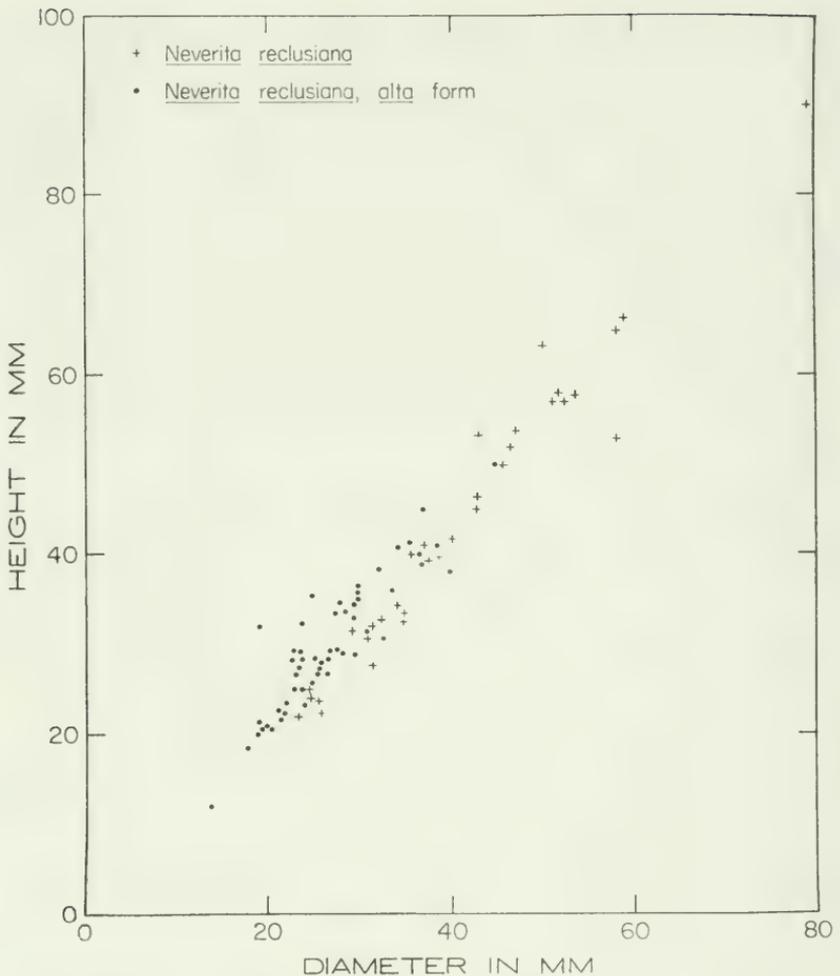
Discussion.—The many synonyms of *N. (G.) reclusiana* plus the varied allocation of given trivial names to the subspecific, specific, or varietal level by previous workers indicate the instability of its morphologic features. Shell proportions, umbilical morphology, and color vary so widely that it has been unpopular to assign all of the observed features to a single species, as is done here. The trivial names have been used in the past to account for portions of the whole range of morphology and color exhibited by the species. I believe that the synonymous names given here do not represent discrete morphological or color entities, perhaps not even consistent ecotypic forms. Further detailed collecting and observation of living individuals may show that some or all of the variations are related to local environmental factors.

This species is the most morphologically variable one included in this study. As noted above, the umbilical callus is divided into an anterior and posterior lobe by a transverse groove, and the um-

bilical variations largely depend on the degree to which this callus conceals the umbilicus, plus relative sizes of the callus lobes. Completely imperforate specimens have been called *N. imperforata*, moderately umbilicate specimens *N. (G.) reclusiana*, and widely umbilicate specimens *N. alta*. *Neverita imperforata* is the taxon most easily dispensed with. Its closed umbilicus is known only among relatively low-spired shells of the otherwise "typical" *N. (G.) reclusiana* kind. A single population of *N. imperforata* includes shells with every degree of umbilical closure from imperforate to narrowly perforate to the moderately perforate shells of "typical" *N. (G.) reclusiana*. Specimens of *N. imperforata* are usually present in fossil and modern populations of *N. (G.) reclusiana* in various proportions, and there is no way to consistently segregate them as a discrete species-level taxon.

The principal criterion for recognition of the so-called *alta* form has been its elongate proportions, even though Woodring, Bramlette, and Kew (1946, p. 71) noted that both *N. (G.) reclusiana* and its *alta* form have spires of variable height. Text-figure 13 compares "typical" *N. (G.) reclusiana* (low spire, narrow or closed umbilicus, white callus) and so-called "typical" *alta* (high spire, distinctly open umbilicus, brown callus), based on ratios of shell height to diameter, using specimens from a variety of LACM Holocene localities. This graph shows that "typical" *alta* specimens tend to have a slightly more elongate shape than "typical" *N. (G.) reclusiana*, but that the two completely intergrade. The measured specimens of *alta* also have a smaller average size than those of *N. (G.) reclusiana*, which confirms my observation that all of the large specimens I have seen have "typical" *N. (G.) reclusiana* features.

The *alta* form is supposed to have a brown umbilical callus that is smaller than the white callus of *N. (G.) reclusiana*, but callus size and color show a broad and nearly continuous range of variation between these two extremes. Entirely brown calluses are common among both the small-callused and large-callused forms, although more common among the former. I have not seen a brown callus on an imperforate specimen, although some nearly imperforate specimens, including some of the largest individuals known, have calluses partly pale-brown. Many specimens of both callus types have mostly white calluses with brown margins. Individuals showing



Text-figure 13. Comparison of height to diameter ratios of "typical" *Neverita (Glossaulax) reclusiana* (Deshayes) and its so-called *alta* form. Based on LACM Holocene specimens from throughout the geographic range of the species.

all manner of callus coloration may be found together, although one color type will usually predominate in a local population. Except in fortuitous cases, colors of fossil specimens are not preserved. Diet is known to affect the coloration of some gastropods, including naticids. Turner (1958) showed that individuals of *Neverita (Neverita) duplicata* (Say, 1822), the northwestern Atlantic analogue of *N. (G.) reclusiana*, may have brown or white umbilical

calluses, depending on diet. Those snails that feed upon the clam *Mya arenaria* Linnaeus, 1758, develop a white callus with a faintly pink margin, whereas those that feed on other clams develop a dark-brown callus. Turner (1958) found that specimens with dark calluses developed white ones when fed a steady diet of *M. arenaria*.

Despite supposed differences in umbilical coverage by the callus between *N. (G.) reclusiana* and its *alta* form, there is little difference between most specimens of the two types. In "typical" *N. (G.) reclusiana*, the two callus lobes are about equally elongate, whatever the absolute shell size or coverage of the callus. In "typical" *alta* the posterior lobe is distinctly more elongate and covers most of the umbilicus. As with shell height and callus color, there is a continuous gradation in relative sizes of the umbilical callus lobes, with no clear distinctions between the two forms. More elevated shells tend to have elongate posterior callus lobes, but a large percentage do not, and many low-spined shells have elongate posterior lobes. Local fossil and modern accumulations are predominantly of one type, but more extensive collecting shows a patchwork of such populations with intergrading umbilical features.

As noted above, specimens of *N. (G.) reclusiana* and the forms *imperfurata* and *alta* are found together in both fossil and modern populations. This is shown especially well in prolific fossil assemblages such as those of the upper Pleistocene beds at San Pedro, California, where hundreds of specimens may be collected in a short time. All of the morphologic varieties of *N. (G.) reclusiana* may be found together in these deposits.

The present study has not confirmed the observations of McLean (1969) that individuals of *N. (G.) reclusiana* are more likely to live in shallow bays and lagoons, whereas those of *alta* are more characteristic of offshore sandy bottoms. Although the *alta* form may predominate in local populations, such populations are as commonly found in embayments as in offshore habitats. For example, abundant specimens of *alta* have been collected in Morro Bay, Mugu Lagoon, San Pedro Bay, Anaheim Bay, Newport Bay, Bahía Magdalena, and Bahía Adair, whereas populations of *N. (G.) reclusiana* occur at numerous open-shore localities throughout its geographic range. There is no known consistent distinction in habitats between the two.

Individuals of the *alta* form with a mostly brown callus range from Point Conception, California (Berry collection 18895), to Islas las Tres Marías, Mexico (USNM 46535), whereas specimens of *N. (G.) reclusiana* range from Crescent City, California (USNM 104130), to Islas las Tres Marías (USNM 46535). Their known northern range limits are thus slightly different, which might relate to prey species available at different latitudes, because diet may affect callus color in naticids, as noted above.

Neverita (Glossaulax) reclusiana apparently evolved in the middle Eocene from the late Paleocene to late Eocene species *Neverita (Neverita) globosa* Gabb, 1869 (Text-fig. 9). Still living in the northeastern Pacific, it has the longest geologic history of any naticid in this region. The similar species *N. (G.) bolivarensis* Clark in Clark and Durham, 1946, occurs in middle and upper Eocene strata in northwestern Colombia. These two are the earliest known *Glossaulax* species. However, as noted in the discussion of *N. (N.) globosa*, *N. (G.) reclusiana* is thought to be the earliest evolved species of *Glossaulax*, from which *N. (G.) bolivarensis* and several other extinct and living species evolved in the eastern and northwestern Pacific, northwestern Atlantic, and Caribbean areas. *Glossaulax* last appeared in the Caribbean-northwestern Atlantic region in the late Miocene (Woodring, 1957) and is living only in the northeastern and northwestern Pacific.

During the Miocene, *N. (G.) reclusiana* gave rise to *N. (G.) andersoni* (Clark, 1918) and *N. (G.) jamesae* Moore, 1963, in California and adjacent areas. These species are discussed separately.

Neverita (Glossaulax) andersoni (Clark, 1918) Pl. 30, figs. 5-8

Natica reclusiana andersoni Nomland, 1917b, p. 301 [*nomen nudum*: as "*N. reclusiana andersoni* Clark (MS)"].

Natica (Neverita) reclusiana andersoni Clark, 1918, pp. 168-169, pl. 20, figs. 3, 10-12 [as "*N. (N.) reclusiana andersoni*, n. var."].

Natica andersoni (Clark), Hanna, 1924, p. 173.

Polinices (Neverita) reclusianus andersoni (Clark), Grant & Gale, 1931, p. 802 [as "*reclusianus* variety *andersoni*"]; Loel & Corey, 1932, p. 270, pl. 65, figs. 4a, b [as "*reclusianus andersoni*"], [not figs. 5a, b, = *Neverita (Glossaulax) reclusiana* (Deshayes, 1839), treated herein].

Polinices reclusianus andersoni (Clark), Lutz, 1951, pp. 380, 391, pl. 18, fig. 4 [as "*var. andersoni*"].

Neverita andersoni (Clark), Keen, 1943, p. 37; Stanton, 1966, p. 33.

Neverita reclusiana andersoni (Clark), Adegoke, 1969, p. 168.

Neverita (Glossaulax) andersoni (Clark), Addicott, 1965, p. 108, pl. 4, fig. d; Addicott, 1970b, pp. 67-69, pl. 5, figs. 22-24.

Natica (Neverita) pabloensis Clark, 1915b, pp. 488-489, pl. 68, figs. 12, 14.

Natica pabloensis (Clark), Trask, 1922, pp. 143-145.

Polinices reclusianus pabloensis (Clark), Clark, 1929, pl. 34, fig. 12; Grant & Gale, 1931, pp. 802-803 [as "variety *pabloensis*"].

Not *Natica andersoni* Strebel, 1906, pp. 142-143, pl. 11, figs. 67, 67a, b [living, Magellanic region].

Description.—

Color: Addicott (1970a) described cream-colored subsutural and basal color bands for middle Miocene specimens of *Neverita alta* [= *N. (G.) reclusiana*] from the Round Mountain Silt of the Kern River area, California, and noted similar banding on specimens of *N. andersoni*. I have seen one specimen from the middle Miocene Topanga Formation of southern California with a dark-brown parietal and umbilical callus.

Size: Average specimen, height 32 mm, diameter 29 mm; largest specimen, height 62.0 mm, diameter 58.3 mm [CAS 69, Pyramid Hill, Kern County, California, Miocene].

Shell form: Shell relatively low to elongate, spire usually low, may be elevated; body whorl not greatly inflated; sides of body whorl flattened, narrowly tabulate; shell thickness average; whorls about 5½; suture slightly impressed. Spiral sculpture of minute, weakly developed, closely spaced, minutely wavy costellae, usually not preserved; axial sculpture of incremental growth lines that are heaviest on base. Parietal callus heavy, thickly filling posterior apertural angle; anterior lobe weak to indistinct, merges with umbilical callus. Umbilicus usually closed, may be partly open, especially in juveniles. Umbilical callus massive, divided into two lobes by weak transverse groove; posterior callus lobe always larger, is elongate anteriorly to plug or nearly plug umbilicus; callus thick, generally with swollen appearance. Anterior inner lip thickened.

Operculum: Unknown, presumably chitinous.

Specimens examined.—Fifteen hundred eleven.

Stratigraphic occurrence.—Ranges from lower to upper Miocene. Lower Miocene(?): San Ramon Fm., Contra Costa Co., Calif. (Clark, 1918; UCB). Lower Miocene: Vaqueros Fm., Santa Cruz Mts., northern Gabilan Range, Santa Lucia Range, La Panza Range, San Emigdia Mts., western Santa Ynez Range, Ventura basin, Channel Islands, western Santa Monica Mts., San Joaquin Hills, Santa Ana Mts. (Loel & Corey, 1932), Mount Pinos Quad., Junipero Serra Quad., Coalinga Quad. (UCB), New Idria Quad. (USGS).

and Caliente Range (Eaton, Grant & Allen, 1941), Calif.; Painted Rock Ss., La Panza Quad. (USGS) and Pozo Quad. (USGS); Jewett Sand, Kern River area, Calif. (Addicott, 1970a; USGS). Middle Miocene: Astoria(?) Fm., Clatskanie, Ore. (CAS); Sobrante Ss., Pacheco-Walnut Creek area, Calif. (Lutz, 1951); Monterey Fm., Saltos Shale Mem., Caliente Range, Chimineas Quad., Calif. (USGS); Gould Shale Mem., Temblor Range, Calif. (USGS); Oursan Ss., Pleasanton area, Calif. (Hall, 1958); Oursan(?) Ss., Tesla Quad., Calif. (Clark *in* Huey, 1948); McLure Shale Mem., Reef Ridge Quad., Calif. (USGS); Temblor Fm., Coalinga area, La Panza Range (Loel & Corey, 1932), Caliente Range (Eaton, Grant & Allen, 1941), Calabajas Quad., San Joaquin Rocks Quad., Priest Valley Quad., Dominguez Ranch Quad. (UCB), Panoche Valley (USGS), Calif.; Topanga Fm., Santa Monica Mts. (LACM; USC; USGS; Woodring *in* Hoots, 1931, "cf."; Loel & Corey, 1932) Santa Ana Mts. (Loel & Corey, 1932), Calif. Round Mountain Silt, and lower and upper parts of Olcese Sand, Kern River area, Calif. (USGS; UCB; Addicott, 1970b). Upper Miocene: Neroly Fm., Byron Hot Springs Quad., Calif. (UCB); lower and upper parts of San Pablo Group, central Calif. (Clark, 1915b); Santa Margarita Fm., Coalinga area (Nomland, 1917b; Clark, 1918; UCB), Stockdale Mountain Quad., Cholame Hills (USGS), Priest Valley Quad. (USGS), Pozo Quad., San Luis Obispo Quad. (USGS), Calif.

Type localities. —

Natica (Neverita) recluziana andersoni — UCB 1131, in creekbed half a mile southwest of Walnut Creek about 100 yards east of Oakland and Antioch bridge, altitude 150 feet, Contra Costa County, California. San Ramon Sandstone, upper Oligocene or lower Miocene (Clark, 1918; Addicott, 1970b).

Natica (Neverita) pabloensis — UCB 1227, just west of center of SE¼, NE¼, section 9, T. 1 S., R. 2 W., Concord Quadrangle, Contra Costa County, California. Upper part of San Pablo Group, upper Miocene (Clark, 1915b; Keen & Bentson, 1944).

Type material. —

Natica (Neverita) recluziana andersoni — Holotype, UCB 11212.

Natica (Neverita) pabloensis — Holotype, UCB 11592.

Discussion. — *Neverita (Glossaulax) andersoni* is closely related to *N. (G.) reclusiana* (Deshayes, 1839), and some specimens are difficult to assign to one species or the other. When typically developed, as are the great majority of specimens, *N. (G.) andersoni* is characterized by a body whorl with flattened sides and tabulate shoulder, massive callus thickly filling the umbilicus, and low spire. The most common variation is for a deep pit to form at the anterior margin of the umbilical callus, at the site of the closed umbilicus, or, less commonly, for the umbilicus to be slightly open. An open umbilicus is not common but is most often seen on immature specimens, although a closed umbilicus still predominates among these younger individuals. Adult or juvenile specimens with an open umbilicus are always high-spired and look somewhat like the so-called *alta* form of *N. (G.) reclusiana*, although the posterior callus lobe is never as elongate as in the latter. The *alta* form also never has the flat-sided whorls of *N. (G.) andersoni*.

Some specimens have more elongate body whorls than usual, although they retain their low spires. Specimens occur rarely with greatly elevated spires, but retain other specific features such as flattened, slightly tabulate shoulders, and massive callus closing the umbilicus.

Neverita (Glossaulax) andersoni is most similar to the so-called *imperfurata* form of *N. (G.) reclusiana* which is known from Pleistocene and modern assemblages. The main differences between the two are that the *imperfurata* form has a less elongate shell, has its outer apertural lip attached lower on the preceding whorl, and has more gently sloping margins to its umbilical callus. The *imperfurata* form often has an evenly rounded shoulder profile, but some living and fossil specimens have whorls nearly as flattened as typical *N. (G.) andersoni*. The margins of the umbilical callus of *N. (G.) andersoni* are invariably steep, especially anteriorly, whether the callus is complete or not, unlike most *N. (G.) reclusiana*. The transverse groove of *N. (G.) andersoni* is less strongly impressed than on any variety of *N. (G.) reclusiana* except the so-called *imperfurata* form.

N. (G.) andersoni is the most common naticid in Miocene deposits of California. It is sometimes found in huge numbers that

show consistent morphology not intergrading with that of other species. Specimens of the related *N. (G.) reclusiana* and *N. (G.) jamesae* (Moore, 1963) are relatively uncommon, whether or not they are found along with *N. (G.) andersoni*. *N. (G.) andersoni* is known from a single occurrence north of California, in probable beds of the Astoria Formation at Clatskanie, Oregon. It is replaced as the common Miocene naticid in the Pacific Northwest by *P. (E.) galiano* Dall, 1909, which was apparently adapted to cooler conditions.

This species undoubtedly evolved from the middle Eocene to Holocene *Neverita (Glossaulax) reclusiana* (Deshayes, 1839) at about the beginning of the Miocene, and the two species are similar in form.

Neverita (Glossaulax) jamesae Moore, 1963 Pl. 30, fig. 9; Pl. 31, figs. 1, 2
Neverita (Glossaulax) jamesae Moore, 1963, pp. 28-29, pl. 2, figs. 5, 15, 19;
 Addicott, 1970a, p. 70, pl. 6, figs. 8, 10; Moore, 1971, p. 23, pl. 7, figs. 3-5.

Description. —

Size: Average specimen, height 21 mm, diameter 24 mm; largest specimen, height 22.6 mm, diameter 28.6 mm [CAS 2064, Kern River area, California, middle Miocene].

Shell form: Shell relatively elongate, spire moderately elevated; body whorl inflated; shoulder usually evenly rounded, may be flattened near suture; base distinctly flattened; shell thin; whorls five; suture slightly impressed. Shell smooth except for fine incremental growth lines that are heaviest on base. Parietal callus thin, lightly filling posterior apertural angle; anterior lobe weak. Umbilicus broadly open but not revealing earlier whorls, with its posterior portion occupied by funicle. Umbilical callus small, confined to posterior half of inner lip, clearly divided into two lobes by sharply incised transverse groove; both lobes rounded, with swollen appearance; lobes equally elongate or posterior lobe slightly longer; posterior margin of callus rarely detached from underlying whorl; funicle occupies posterior half of umbilicus. Anterior inner lip and basal lip not thickened.

Operculum: Unknown, presumably chitinous.

Specimens examined. — Twenty-five.

Stratigraphic occurrence. — Known only from middle Miocene strata. Middle Miocene: Astoria Fm., coastal Ore. and Wash.

(Moore, 1963); Temblor Fm., Caliente Quad., Calif. (UCB); upper part of Olcese Sand, lower part of Round Mountain Silt (as "cf."), Olcese Sand or Round Mountain Silt, Kern River area, Calif. (Addicott, 1970a); Round Mountain Silt, Caliente Quad., Calif. (UCB). Middle Miocene(?): Near mouth of Fall Creek, where it enters Scappoose Creek, Ore. (USGS).

Type locality. — About 17 feet above base of section exposed in big headland in beach cliff about 600 yards north of Spencer Creek, Lincoln County, Oregon. Astoria Formation, middle Miocene (Moore, 1963).

Type material. — Holotype, USNM 563129.

Discussion. — *N. (G.) jamesae* belongs to the complex of species and forms associated with *N. (G.) reclusiana* (Deshayes, 1839), among which it is one of the more distinct taxa. It is characterized by a flattened base, by a relatively small, swollen umbilical callus that is bisected by a sharply incised groove, and by a thin parietal callus. The spire always remains moderately elevated, but the body whorls of some specimens are more elongate than average. Juvenile specimens may be difficult to differentiate from *N. (G.) reclusiana*. There are no living forms of *N. (G.) reclusiana* similar to *N. (G.) jamesae*.

Genus **CALINATICINA** Burch & Campbell, 1963, p. 221

Type species: *Sigaretus oldroydii* Dall, 1897, by original designation. Living, northeastern Pacific. Figured herein.

Diagnosis. — Shells medium to large in size, globose, thin, base distinctly flattened; whorls inflated, shoulder flattened, slightly concave below suture; sculpture of minute, closely spaced spiral costellae; suture slightly impressed. Umbilicus broadly open, simple. Inner lip thickened, lacking distinct umbilical callus, reflected to partly conceal umbilicus. Parietal callus thin. Operculum chitinous, not entirely filling aperture. Radula typically naticid, with tricusate rachidian, one multicusate lateral, one bicusate inner marginal, and one monocusate outer marginal tooth per half row.

Discussion. — *Calinaticina* is characterized by its thin shell, flattened base with widely open umbilicus, inflated whorls, and lack of an umbilical callus. As noted by Dall (1899, p. 85), the type species seems intermediate in shell form between *Sinum*, *Euspira*, and *Eunaticina*. The genus is monotypic.

Calinaticina oldroydii (Dall, 1897)

Pl. 31, fig. 3

Sigaretus oldroydii Dall, 1897, p. 85; Dall, 1899, p. 85.*Eunaticina oldroydii* (Dall), Packard, 1918, pp. 325-326, pl. 35, figs. 10a, b; Dall, 1921, p. 165, pl. 14, figs. 1, 3; Oldroyd, 1927, p. 734, pl. 92, figs. 11, 11a; Keen, 1937, p. 36; Burch, 1946, p. 32; Smith & Gordon, 1948, p. 199.*Calinaticina oldroydii* (Dall). Burch & Campbell, 1963, pp. 221-223, pl. 34, figs. 4-7, text fig. 2.*Description.* —

Color: Shell pale grayish brown, often slightly pinkish, with a narrow band of yellowish orange at the suture; base white. Interior white and medium brown, axially streaked, white at base; umbilical callus usually blotched with brown and white. Periostracum thin, pale yellowish white.

Size: Average specimen, height 42 mm, diameter 40 mm; largest specimen, height 81.4 mm, diameter 71.5 mm [SU 27053, Monterey Bay, California].

Shell form: Shell globose, spire moderately elevated; body whorl greatly inflated; shoulder flattened, slightly concave just below suture; shell thin; whorls about seven (apex always eroded); suture slightly impressed. Spiral sculpture of minute, wavy, closely and irregularly spaced costellae that are best developed above the periphery; axial sculpture of incremental growth lines. Parietal callus thin, lightly filling posterior apertural angle, anterior lobe weak but distinct. Umbilicus broadly open, partly concealed by reflected inner lip. Inner lip thickened, lacking a distinct umbilical callus, with a shallow but distinct notch at its posterior end, where it meets the parietal callus. Basal lip not thickened.

Operculum: Chitinous, thin, not filling aperture.

Specimens examined. — Seventy-three.

Geographic occurrence and habitat. — Eureka (40°45' N.) to San Diego (32°43' N.) and Catalina Island, California. Found in sandy mud substrates in depths of 73 to 365 metres, most common in depths of 73 to 110 metres.

Type locality. — Catalina Island, California, in "deep water" (Dall, 1897).

Type material. — Holotype, SU 6447.

Discussion. — The adult animal is too large to retract completely into its shell, as seen in numerous preserved specimens. However, one dried juvenile [USNM 111307; height 12.8 mm, diameter

14.5 mm] has its operculum tightly fitting the aperture, sealing the desiccated animal within the shell. From this one example, it may be that juveniles can fully retract their soft parts into the shell, whereas adults, being less susceptible to predators, are unable to do so.

Genus **BULBUS** Brown in J. Smith, 1839, p. 104

[Not Humphrey, 1797, p. 31 non-binomial]

Type species: *Bulbus smithii* Brown in J. Smith, 1839 (= *Natica fragilis* Leach, 1819), by monotypy. Late Cenozoic, circum-boreal. Figured herein.

Diagnosis. — Shells small to medium in size, globose to slightly elongate, thin; whorls evenly rounded to slightly flattened at suture, sculptured with minute, weak spiral costellae. Umbilicus closed to narrowly open or slitlike. Umbilical callus thin, slender. Parietal callus thin. Operculum chitinous, thin, entirely filling aperture. Radula with monocuspate rachidian, one monocuspate lateral tooth and outer marginal tooth, and one bicuspate inner marginal tooth per half row.

Discussion. — *Bulbus* is characterized by its extremely thin shell, rounded base, and slitlike umbilicus. It lacks the deeply channeled suture and more elongate proportions of *Amauropsis*, and the more widely open umbilicus of *Choristes*. *Bulbus* is known living only in polar or subpolar regions.

Among northeastern Pacific naticids, only *B. fragilis* (Leach) and the two *Choristes* species have monocuspate rachidians.

Bulbus fragilis (Leach, 1819)

Pl. 31, figs. 4-7

Natica fragilis Leach, 1819, App. 2, p. 62; Philippi, 1853, p. 151.

Not *Natica fragilis* Conrad, 1830, p. 222, pl. 9, fig. 3 [= *Sinum fragile* (Conrad), Miocene, Maryland and Virginia].

?*Natica fragilis* J. Smith, 1841, p. 156 [Pleistocene, Ardincaple, Scotland].

Natica flava Gould, 1839, p. 196; Gould, 1841, pp. 239-240, fig. 162; Middendorff, 1849, pp. 422-424; Philippi, 1851, pp. 114-115, pl. 16, fig. 5; Sowerby, 1883, p. 79, pl. 8, fig. 175.

Bulbus flavus (Gould), Gould, 1870, pp. 347-348, fig. 616; Habe & Ito, 1965, p. 31, pl. 8, fig. 9.

Lunatia (Bulbus) flavus (Gould), Dall, 1885, p. 182.

Amaura (Acrybia) flava (Gould), Pilsbry, 1895, p. 72.

Acrybia flava (Gould), Odhner, 1913, pp. 9, 46-47, pl. 4, figs. 26-28.

Bulbus flava elongatus Habe & Ito, 1965, p. 31, pl. 8, fig. 8.

Bulbus smithii Brown in J. Smith, 1839, p. 104, pl. 1, fig. 18.

Natica smithii (Brown), Jeffreys, 1867, vol. 4, p. 230.

Ampullina smithii (Brown), Sars, 1878, pp. 155-156, pl. 12, figs. 2a, b, pl. 21, fig. 18, pl. V, fig. 9, pl. XVIII, fig. 9; Friele & Grieg, 1901, p. iii, 68.

- Acrybia smithii* (Brown), Harmer, 1921, pp. 699-700, pl. 55, fig. 9.
Natica aperta Lovén, 1847, p. 149; Middendorff, 1849, p. 419; Middendorff, 1851, p. 206, pl. 11, figs. 1-3; Philippi, 1853, p. 146; Danielssen, 1861, p. 31.
Bulbus apertus (Lovén), Keen, 1937, p. 31; Burch, 1946, p. 33.
 Not *Natica aperta* Lea, 1843, p. 164 [*nomen nudum*]; Lea, 1846, p. 254, pl. 36, fig. 51 [described] [= *Sinum fragile* (Conrad, 1830), Miocene, Maryland and Virginia].
 ?*Natica* (*Polinices*) *tenuicula* Sowerby, 1915, p. 166, pl. 10, fig. 3 [living, Japan].
 ?*Natica glacialis* Danielssen, 1861, p. 31 [living, Vadsö, Norway; not *Bulbus glacialis* (Thorson, 1951)].

Description. —

Color: Shell exterior and interior white. Periostracum thin, resistant, colors range from light yellowish brown and gray to dark olive brown; colors often axially streaked; rust-brown staining common on upper parts of whorls; base paler.

Size: Average specimen, height 23 mm, diameter 18 mm; largest specimen, height 51.0 mm, diameter 39.0 mm [CAS 39460, Bristol Bay, Alaska].

Shell form: Shell globose to somewhat elongate, spire low to moderately elevated; body whorl inflated; shoulder flattened; shell thin; whorls about five (apex always eroded); suture slightly impressed. Spiral sculpture of minute, closely and irregularly spaced costellae that are strongest above periphery; axial sculpture of incremental growth lines. Parietal callus thin, often transparent and nearly imperceptible; anterior lobe indistinct. Umbilicus open as a narrow slit at base of umbilical callus, rarely closed; more widely open in younger shells but never conspicuously open. Umbilical callus thin, narrow, applied as a narrow semicircle upon underlying whorl, scarcely broader than inner lip in young individuals. Basal lip thin.

Operculum: Chitinous, thin, filling aperture.

Specimens examined. — Sixty.

Geographic occurrence and habitat. — Circumboreal. In the eastern Pacific, south to Atka and Unalaska Islands in the Aleutians and the Shumagin Islands (55°10' N., 160° W.); in the western Pacific, south to Iwate Prefecture, Japan; in the western Atlantic, south to Massachusetts Bay; in the eastern Atlantic, south to the Lofoten Islands, Norway. Known on sand and mud bottoms in depths of 37 to 317 metres in the eastern Pacific, and in depths to 600 metres in the northern Atlantic (Odhner, 1913).

Stratigraphic occurrence. — Upper Pliocene to Holocene. Upper Pliocene: Deposits of Beringian marine transgression, Kivalina, western Alaska (USGS). Upper Pleistocene: Deposits of Kotzebuan marine transgression, type section, Baldwin Peninsula, Kotzebue Sound, Alaska (USGS). Undifferentiated Pleistocene: Ardincaple, Scotland (Smith, 1841, as *Natica fragilis* Smith), Iceland (Harmer, 1921), and "England and northern Russia" (Friele & Grieg, 1901).

Type localities. —

Natica fragilis — Baffin Bay, Between Greenland and Canada (Leach, 1819).

Natica flava — "stomachs of fishes" (Gould, 1839).

Bulbus flavus elongatus — Nemuro, Hokkaido, Japan (Habe & Ito, 1965).

Bulbus smithii — Ardincaple, near Helensburgh, southwestern Scotland (Brown in J. Smith, 1839).

Natica aperta — Finmark, Norway (Lovén, 1847).

Type material. —

Natica fragilis — Unknown, presumably in BM(NH) (Dance, 1966).

Natica flava — Unknown, presumably lost (Johnson, 1964).

Bulbus flavus elongatus — Holotype, National Science Museum, Tokyo (Habe & Ito, 1965).

Bulbus smithii — Unknown, presumably in Manchester Museum, Manchester, England, (Dance, 1966).

Nomenclatural commentary. — There is an array of northern Atlantic species that may or may not be identical with *B. smithii*. These species generally have poor literature descriptions, are rare or absent in American collections, and have type specimens unavailable to me. Included as possible synonyms are *Natica tenuicula* G. B. Sowerby III, *N. glacialis* Danielssen, and perhaps *N. tenuistriata* Dautzenberg and Fischer. Settling of their taxonomic relationships must await study of type specimens in European collections.

Discussion. — Variations in the relative height and thickness of shells have resulted in the naming of species that are distinct only when considered alone. The range in morphology is from an elongate, higher-spined form with a thin shell, to a more globose, lower-spined form with a thicker shell. The lower-spined form has a slight flat-

tening of the shoulder and a stronger deflection of the inner lip by the penultimate whorl. These two extremes intergrade, with no apparent geographic separation, and known collecting data are not precise enough to demonstrate ecological distinctions.

I have not made a radular preparation for lack of suitable material, but Odhner (1913), referring to *B. fragilis*, stated that it has a monocuspate rachidian. If true, this would distinguish *B. fragilis*, and presumably all *Bulbus* species, from most other naticids. In the eastern Pacific, only the two *Choristes* species have monocuspate rachidians. Thorson (1951) figured a monocuspate rachidian and lateral teeth in the original description of *B. glacialis*, so the monocuspate rachidian may be a general feature of *Bulbus*.

It is not clear from Brown's (in J. Smith, 1839) original description whether the type of *B. smithii* is a Pleistocene or Holocene shell. Harmer (1921) seemed to indicate that it is a fossil.

Genus **CHORISTES** Carpenter, 1872, p. 392

Type species: *Choristes elegans* Carpenter in Dawson, 1872, by monotypy. Pleistocene, Montreal, Canada. Figured by Carpenter in Dawson (1872, pl. 7, figs. 13, 13a).

Diagnosis.— Shells small to medium in size, globose, thin; whorls moderately inflated, sculptured with weak spiral costellae; suture narrowly channeled. Umbilicus narrow to relatively broad, simple. Inner lip slightly thickened, simple, lacking umbilical callus. Parietal callus thin to average. Operculum chitinous, entirely filling aperture. Radula with monocuspate rachidian, one monocuspate lateral tooth, and two monocuspate marginal teeth per half row.

Discussion.— *Choristes* is characterized by its thin shell, channeled suture, rounded base, distinctly open rather than slitlike umbilicus, and by the lack of a distinct umbilical callus. It has been reported living in bathyal and abyssal depths in the northwestern Atlantic (one species), Japan (two species), and the northeastern Pacific (two species).

The radulae of the two northeastern Pacific *Choristes* treated here are similar to each other and differ from the usual naticid dentition by having monocuspate rachidians and monocuspate inner marginals. Most living naticids included in this study have tricuspate rachidians and bicuspate inner marginals. The dentition of these two

species differs markedly from that attributed to *C. tenera* Verrill, 1882, from Massachusetts. The dentition of *C. tenera* given by Verrill and reproduced by Abbott (1974) shows a modified taenioglossate radula with a small rachidian, one monocuspate inner lateral, one bicuspate inner lateral, two monocuspate marginals, and a third, small, quadrate marginal. The shell morphology of *C. tenera* supports placement in *Choristes* and is close to that of two northeastern Pacific species. Another radular mount of *C. tenera* should be made to confirm the radular dentition reported by Verrill (1882). The type species of *Choristes*, *C. elegans* Carpenter in Dawson, 1872, is a Pleistocene fossil from Montreal whose radular dentition is unknown.

Verrill (1882) reported that *C. tenera* was found in an empty skate egg case, and Abbott (1974) noted that one of the two Japanese species is parasitic on shark egg capsules. If true, this mode of feeding differs from the predatory carnivorous habits of all other known naticids. Feeding preferences of the two northeastern Pacific *Choristes* are not known, but none of the specimens I have examined have the circular parabolic holes characteristic of naticid borings.

Choristes has not previously been placed in Naticidae. Carpenter in Dawson (1872) did not place *Choristes* in any family when he proposed the genus, but Verrill (1882) later erected the family Choristidae to include *C. elegans* and *C. tenera*. Thiele (1929) questioned the necessity for the family name but still used it to include *Choristes* and *Choristella* Bush (1897). The figured radular dentition of *Choristella leptalea* Bush, 1897, is identical in general plan to that of *Choristes tenera* Verrill and may be the only reliable character differentiating *Choristella* from *Choristes*, since the shell forms of these genera are identical. Thiele (1929) placed Choristidae near Rissoellidae, whereas Keen (1971) and Abbott (1974) placed it near Vitrinellidae. Marincovich in Keen & Coan (1975) transferred *Choristes* to the naticid subfamily Polinicinae, as is followed here. The shell form of all known *Choristes* species, plus the radular dentition of the two northeastern Pacific species I have examined, substantiate this systematic placement.

Choristes carpenteri Dall, 1896

Pl. 31, figs. 8, 9; Text-fig. 11b

Choristes carpenteri Dall, 1896, pp. 10-11; Dall, 1908, pp. 328-329, pl. 3, fig. 4; Keen, 1971, p. 388, fig. 424; Marinovich, 1975, figs. 8, 9.

Description. —

Color: Shell whitish. Periostracum thin, pale greenish brown.

Size: Average specimen, height 20 mm, diameter 20 mm; largest specimen (holotype), height 20.5 mm, diameter 20.4 mm.

Shell form: Shell somewhat elongate, spire moderately elevated; body whorl not greatly inflated; suture channeled; shell thin; whorls more than $3\frac{1}{2}$ (apices eroded on all specimens). Spiral sculpture of minute, weakly developed, obscure costellae; axial sculpture of incremental growth lines. Parietal callus thin, not thickening into posterior apertural angle; anterior lobe lacking. Umbilicus open, narrow to relatively broad. Inner lip slightly thickened, simple, lacking umbilical callus. Basal lip not thickened.

Operculum: Chitinous, filling aperture; margin of penultimate whorl extends beyond inner edge of operculum.

Radula: Each row of teeth with a rachidian flanked on each side by one lateral and two marginals (Text-fig. 11b). Rachidian with a single anterior cusp and prominent basal processes. Lateral tooth elongate, with one strong anterior cusp and two short and narrow basal processes. Inner and outer marginal teeth simple, evenly curving, lacking denticles.

Specimens examined. — Sixty-five.

Geographic occurrence and habitat. — Known from the Gulf of Panama (about 13° N.), from off southernmost Mexico ($14^{\circ}46'$ N.), and from off central Oregon ($44^{\circ}41'$ N., $125^{\circ}37'$ W.). The Oregon record (LACM) is based on two recently collected specimens, one alive. Reported in depths of 2,693 metres (live) and 3,291 metres (dead) in the Gulf of Panama, 3,436 metres (dead) off southern Mexico, and 2,500 to 2,800 metres off central Oregon (live), on substrates of mud and "ooze."

Type locality. — Gulf of Panama, 2,693 metres depth, mud (Dall, 1896).

Type material. — Holotype, USNM 123039.

Discussion. — The combination of relatively high spire, thin shell, open umbilicus, and channeled suture characterizes this

species. A detailed comparison with *C. coani* Marincovich, 1975, is given in the discussion of that species.

Choristes coani Marincovich, 1975

Pl. 31, figs. 10-12; Text-fig. 11c

Choristes coani Marincovich, 1975, pp. 169-171, figs. 2, 6, 7.

Description. —

Color: Shell exterior and interior whitish, periostracum pale yellow to brownish white.

Size: Average specimen, height 12.8 mm, diameter 13.1 mm; largest specimen, height 17.1 mm, diameter 15.7 mm [LACM 1733, paratype].

Shell form: Shell globose, spire moderately elevated; body whorl not greatly inflated, narrowly flattened to slightly concave just below suture; shell thickness average; whorls $4\frac{1}{2}$, nuclear whorls not clearly differentiated; earliest nuclear whorl sunken into succeeding whorl; microscopic radial wrinkles occur discontinuously below suture on nuclear whorls; suture slightly impressed. Spiral sculpture of faint, minute, irregularly spaced costellae, slightly stronger near suture; axial sculpture of incremental growth lines. Parietal callus of average thickness, moderately filling posterior apertural angle; anterior lobe weak. Umbilicus open, small. Inner lip thickened, lacking distinct umbilical projection, and expanded posteriorly to match width of parietal callus. Anterior inner lip and basal lip slightly thickened.

Operculum: Chitinous, filling aperture.

Radula: Each row of teeth with a rachidian flanked on each side by one lateral and two marginals (Text-fig. 11c). Rachidian with a single anterior cusp and prominent basal processes. Lateral tooth elongate, with one strong anterior cusp and smaller basal process on inner end. Inner and outer marginal teeth simple, evenly curving, lacking denticles.

Specimens examined. — One hundred thirty-seven.

Geographic occurrence and habitat. — Known only from the type locality and other nearby dredge hauls, in depths of 1,540 to 3,860 metres, on mud substrate.

Type locality. — Off central Oregon at 2,830 metres depth, from dredge haul that extended from $44^{\circ}35.3' N.$, $125^{\circ}34.5' W.$ to $44^{\circ}37.0' N.$, $125^{\circ}36.4' W.$ (Marincovich, 1975).

Type material. — Holotype, USNM 741014; two paratypes,

USNM 741015 [not 741014 as published earlier]; two paratypes, LACM 1733; two paratypes, SDNHM, nos. SDSNH 63705 and 63706; two paratypes, CAS 55392 and 55393; two paratypes, AMNH 181739a, b; two paratypes, MCZ 272885; 2 paratypes, ANSP 335460 and 339992 [not 335460 only, as published earlier].

Discussion. — This species is characterized by its low to moderately elevated spire, narrowly and shallowly channeled suture, and faint spiral sculpture best developed below the suture. Compared to *C. carpenteri* Dall, 1896, the only other known *Choristes* in the eastern Pacific, *C. coani* has a generally lower spire, a more narrowly and shallowly channeled suture, more distinct spiral sculpture (especially near the suture), a thicker shell, and often a heavier filling of parietal callus in the posterior apertural angle. Examination of the whorl profile immediately below the suture is the quickest way of distinguishing the two species: *C. coani* has a flat or slightly concave shoulder, whereas *C. carpenteri* has a convex shoulder owing to its more broadly channeled suture. The radulae of these species also differ, as shown in Text-figures 11b and 11c. Both species occur together in bathyal depths off of Oregon.

Some juveniles of *C. coani* may have closed or nearly closed umbilici, making them similar to juveniles of *Polinices* (*Euspira*) *pallidus* (Broderip & Sowerby, 1829), but the latter species never has a channeled suture.

Subfamily **SININAE** Wenz, 1941, p. 1037

Diagnosis. — Usually thin-shelled, auriform to nearly globose, rarely elongate; final whorl greatly enlarged; ornamented with spiral costellae; animal too large to retract into shell; operculum chitinous, rarely partly calcareous.

Discussion. — This subfamily is almost exclusively a tropical group, with only a few species ranging into temperate waters. A key to the two genera used here follows:

- 1a. Shells auriform, extremely depressed to moderately elevated, rarely elevated greatly, umbilicus slitlike to closed, umbilical callus lacking
SINUM
- 1b. Shells ovate, not auriform, umbilicus distinctly open, umbilical callus slender EUNATICINA

Genus **SINUM** Röding, 1798, p. 14
[*Sigaretus* Lamarck, 1799, p. 77]

Type species: *Helix haliotoidea* Linnaeus, 1758, by subsequent designation (Dall, 1915, p. 109). Living, West Africa.

Diagnosis.— Shells small to large; whorls typically depressed, may be globose, rarely elongate; sculptured with distinct, closely spaced spiral costellae. Umbilicus extremely narrow and slitlike or closed. Outer lip may be weakly crenulated. Operculum chitinous, much smaller than aperture. Radula with tricuspsate rachidian in which central tooth is often very small, one multicuspsate lateral tooth, one bicuspsate inner marginal tooth, and one monocuspsate outer marginal tooth per half row.

Discussion.— *Sinum* is characterized in most cases by an extremely depressed, auriform shell with a slitlike or closed umbilicus. A few species have relatively elevated, nearly globose shells. Only the middle Miocene species treated here, *Sinum perrini* (Arnold, 1907), has an extremely elongate shell.

***Sinum cymba* (Menke, 1828)**

Pl. 32, figs. 1-6; Text-fig. 11d

Sigaretus cymba Menke, 1828, p. 88; Menke, 1830, p. 87; Orbigny, 1837, p. 403, pl. 57, figs. 3-6 (text 1840); Troscchel, 1852, p. 161; Hupé, 1854, pp. 225-226; Philippi, 1860, p. 186; Weinkauff, 1883, pp. 10-12, pl. A, figs. 1, 2, 3, pl. 1, figs. 10-12.

Sigaretus cymba var. *alba* Weinkauff, 1883, pl. 3, figs. 4, 5.

Sinum cymbum (Menke), Bosworth, 1922, p. 78, pl. 26, fig. 18.

Sinum cymba (Menke), Keen, 1971, p. 482, fig. 889.

Sigaretus maximus Philippi, 1844, vol. 1, p. 143, *Sigaretus*, pl. 1, fig. 1; Philippi, 1860, p. 186 [as synonym of *S. cymba*].

"*Sigaretus concavus* Lamarck" [not *S. concavus* Lamarck, 1822, living, West Africa]; Reeve, 1864, pl. 1, figs. 3a, b; Sowerby, 1882, p. 39-40, pl. 1, figs. 8-11, pl. 2, figs. 18, 19; Tryon, 1886, p. 55, pl. 23, figs. 36, 37 [not pl. 22, fig. 34, = *S. haliotoides* Linnaeus, 1758, ? = *S. concavus* Lamarck, 1822, living, West Africa]; Dall, 1909a, p. 236; Dall, 1909b, p. 175; Burch & Burch, 1964, p. 109, pl. 5, figs. 2, 4.

"*Sinum concavum* (Lamarck)" [not *S. concavum* (Lamarck, 1822)]; Oldroyd, 1917, p. 13.

Description.—

Color: Protoconch pale yellowish brown; early adult whorls dark brownish gray; last one to two whorls pale yellowish brown to purplish brown; base white. Narrow white band occurs below suture of postnuclear whorls. Periostracum thin, pale yellow, thickening toward growing margin of large adults. Interior chestnut brown; internal peripheral ridge chocolate brown; callus and margin of aperture white.

Size: Average specimen, height 35 mm, diameter 40 mm; largest specimen, height 50.8 mm, diameter 59.4 mm [AMNH 155878, Caldera, Chile].

Shell form: Spire moderately elevated, shell high for the genus;

shoulder slightly flattened; shell thick for the genus; nuclear whorls $2\frac{1}{2}$, with indistinct spiral costellae; postnuclear whorls three; suture slightly impressed and narrowly but distinctly channeled. Interior with low ridge along periphery. Spiral sculpture of flat-topped costae separated by much narrower interspaces, both of which may bear minute costellae; axial sculpture of incremental growth lines that disrupt the spiral costae and give them a wavy appearance. Parietal callus thin, transparent in young specimens, lightly filling posterior apertural angle; anterior lobe indistinct. Umbilicus open, inconspicuous, slitlike. Umbilical callus narrow, flattened, conceals umbilicus. Inner lip evenly rounded; basal lip not thickened; outer lip weakly crenulate.

Operculum: Chitinous, much smaller than aperture.

Specimens examined. — Three hundred fifty-one.

Geographic occurrence and habitat. — Galápagos Islands and Manta, Ecuador (1° S.) to Caldera, Chile (27° S.), and possibly farther south. Single adult specimens are present in collections from Nicaragua, and from Acapulco, Sinaloa, and Baja California, Mexico, but these localities are probably in error. The southern range-limit is even less certain. Two MCZ specimens are reportedly from the Magellanic region at "Port Gallant" and "Possession Bay," but I have not been able to locate these. Hupé's (1854) record from Valparaíso (33° S.) has not been confirmed by modern collecting. Based on sparse collecting data, this species occurs alive in 24 to 100 metres depth and has been found abundantly in 91 to 100 metres off of northern Peru (LACM collection). It is not reported in shallow water from southern Chile by Dell (1971) or from northern Chile by Marinovich (1973a). Because this species is fairly well represented in collections, its habitat probably ranges into shallow water but apparently not into the intertidal zone.

Stratigraphic occurrence. — Reported from presumed Cenozoic beds on Seymour Island, Galápagos, by Dall and Ochsner (1928), and represented in CAS collections by one specimen from the so-called Pliocene of Indefatigable Island, Galápagos. It is not reported from the Pliocene or Pleistocene of northern or central Chile by Herm (1969) but is figured from the Pleistocene of northwestern Peru by Bosworth (1922).

Type localities. —

Sigaretus cymba — “In oceano peruviana” (Menke, 1828).

Sigaretus cymba var. *alba* — Unknown (Weinkauff, 1883).

Sigaretus maximus — Peru (Philippi, 1844).

Type material. —

Sigaretus cymba — Unknown, presumably sold to a dealer and lost (Zilch, 1958, p. 53).

Sigaretus cymba var. *alba* — Unknown.

Sigaretus maximus — Museo Nacional de Historia Natural, Santiago, Chile, number 60.181, 2 syntypes (N. Bahamonde, written commun.).

Nomenclatural commentary. — The West African species *S. concavum* is similar to *S. cymba* and has been widely confused with it until recently. There are at least four-named species in West Africa that are similar to *S. concavum* and that have been considered synonymous in various combinations by earlier workers.

Discussion. — This species has the largest and most solid shell of the eastern Pacific Sinums and is also the most colorful. It is most similar to *S. scopulosum* (Conrad, 1849), from which it is distinguished by its darker color, thicker shell, narrower spiral interspaces, higher spire with more steeply sloping whorl profile, and more broadly rounded inner lip. The spiral costae of *S. cymba* maintain their integrity better than do those of *S. scopulosum*, tending less to become subdivided into costellae. Some specimens of *S. cymba* may appear close to *S. grayi* (Deshayes, 1843), but the latter differs by being smaller and having lighter colored early whorls, a proportionately higher and thicker shell, angulate inner lip, wider spiral interspaces, and usually a brown margin within the aperture.

Sinum cymba and *S. concavum* of West Africa are closely related. Individuals of each species are similar in size and whorl profile. The principal differences are that *S. concavum* has lighter colored early whorls and completely lacks a white band below the suture, has a paler brown interior, narrower and wavier spiral costae, and has interspaces equal to or greater in width to the costae. It would be interesting to compare fossils of each species to see if the differences are less than those between living shells.

Sinum grayi (Deshayes, 1843)

Pl. 32, figs. 7-10

Sigaretus grayi Deshayes in Lamarck, 1843, vol. 9, p. 12; Troschel, 1852, p. 161 [as synonym of *S. cymba* Menke, 1828].

Sinum grayi (Deshayes), Shasky, 1961, p. 23, pl. 4, figs. 13, 14; Keen, 1971, p. 482, fig. 891.

Sinum cortezi Burch & Burch, 1964, pp. 109-110, pl. 5, figs. 1, 3.

Description. —

Color: Shell tan to medium brown, with a narrow white band just below the suture; vague axial banding of lighter and darker colors may occur; base white; interior and callus white, usually with light brown margin to outer lip. Periostracum thin, pale yellowish brown.

Size: Average specimen, height 25 mm, diameter 27 mm; largest specimen, height 36.6 mm, diameter 34.8 mm [LACM, no number, off northern Peru].

Shell form: Shell globose, spire low to moderately elevated, shell high for the genus; whorls evenly rounded; shell moderately thick; nuclear whorls $2\frac{1}{2}$, with microscopic spiral costellae; post-nuclear whorls three; suture slightly impressed. Spiral sculpture of flat-topped costae separated by interspaces of about equal or greater width; interspaces usually with one or more well-developed costellae; axial sculpture of incremental growth lines that may disrupt the spiral costae and give them a slightly wavy appearance. Parietal callus thin, transparent in young specimens, moderately filling posterior apertural angle; anterior lobe indistinct. Umbilicus open, inconspicuous, slitlike. Umbilical callus narrow, flattened, conceals umbilicus. Inner lip slightly angulate, not evenly rounded; basal lip thickened; outer lip weakly crenulate.

Operculum: Chitinous, much smaller than aperture.

Specimens examined. — Three hundred fifty.

Geographic occurrence and habitat. — Guaymas, Mexico (28° N.), to near Lambayeque, Peru ($6^{\circ}27'$ S.). Other than at the range end-points, reported only from Panama Bay (Keen, 1971) and the Golfo de Fonseca, El Salvador (Shasky, 1961). Found in depths of 25 to 160 metres. Rare throughout its range except off northern Peru, where about 300 LACM specimens were collected in 160 metres depth.

Type localities. —

Sigaretus grayi — Unknown.

Sinum cortezi — "Shrimp trawlers working between Mazatlán and Altata [Sinaloa, west Mexico] in 15 fathoms" (Burch & Burch, 1964).

Type material.—

Sigaretus grayi — Unknown, presumably in BM(NH) or
École de Mines, Paris (Dance, 1966).

Sinum cortezi — Holotype, CAS 12601.

Discussion.—*Sinum grayi* has the most globose and proportionately high shell of the living eastern Pacific Sinums. Its shape, thickened basal lip and light interior coloration distinguish it in most cases from *S. cymba*, and other differences are noted in the discussion of the latter species. *Sinum cymba* may range into shallower depths than *S. grayi*, although the habitats of these species are imprecisely known.

Sinum obliquum (Gabb, 1864)

Pl. 33, figs. 1-12

Naticina obliqua Gabb, 1864, p. 109, pl. 21, fig. 112; Dickerson, 1914b, p. 95; Dickerson, 1915, pp. 44, 48, pl. 5, figs. 5a, b.

Eunaticina cf. *obliqua* (Gabb), Nelson, 1925, p. 402.

Sinum obliquum (Gabb), Waring, 1917, p. 99; Stewart, 1927, p. 327, pl. 30, fig. 7a; Clark, 1938, pp. 690, 704, pl. 3, figs. 32, 37; Vokes, 1939, pp. 26, 31, 170; Durham, 1944, pp. 118, 121, 161; Weaver, 1945, p. 45; Hickman, 1969, pp. 85, 88, pl. 11, figs. 9, 10; Givens, 1974, p. 76.

Sinum occidentis Weaver & Palmer, 1922, pp. 32-33, pl. 11, figs. 8, 26; Weaver, 1943, p. 351, pl. 71, fig. 15.

Sinum corylifforme Anderson & Hanna, 1925, p. 120, pl. 9, fig. 10, pl. 10, fig. 15, pl. 15, fig. 8; M. Hanna, 1927, pp. 259, 304.

Description.—

Size: Average specimen, height 10 mm, diameter 13 mm; largest specimen, height 18.3 mm, diameter 21.0 mm [UCB 3991, Ardath Shale, San Diego County, California, middle Eocene].

Shell form: Shell low to moderately elongate, spire low to distinctly elevated; body whorl inflated, shoulder usually broadly convex but sometimes slightly flattened, base flattened; shell thin; whorls about four (apexes eroded); suture slightly impressed. Spiral sculpture of low, flat-topped or rounded costae separated by interspaces of equal or lesser width; interspaces with one minute costella each, uncommonly with two; axial sculpture of incremental growth lines. Parietal callus thin, lightly filling posterior apertural angle; anterior lobe indistinct. Umbilicus broadly open, rarely slit-like. Umbilical callus indistinct from inner lip, reflected over umbilicus (especially at posterior end). Anterior inner lip slightly thickened; outer lip smooth to weakly crenulate.

Operculum: Unknown.

Specimens examined.— Eighty-two.

Stratigraphic occurrence.—Lower Eocene to lower Oligocene of Washington, Oregon, and California. Nelson (1925) reported this species in upper Paleocene rocks of the Simi Hills in southern California, but I have found no specimens in his collection to substantiate this. Lower Eocene: Lower part of Arroyo Hondo Shale Member of Lodo Fm., Coalinga area, Fresno Co., Calif. (Vokes, 1939; UCB); Juncal Fm., *Turritella wasana infera* and *T. wasana applinae* faunas, Pine Mountain area, Ventura Co., Calif. (Givens, 1974; UCR). Middle Eocene: Domengine Fm., Coalinga area, Fresno Co., Calif. (Vokes, 1939; UCB); Juncal Fm., *Turritella wasana applinae* and *Ectinochilus supraplicatus* faunas, Pine Mountain area, Ventura Co., Calif. (Givens, 1974; UCR); Ardath Shale, near La Jolla, San Diego Co., Calif. (M. Hanna, 1927; UCB). Upper Eocene: Cowlitz Fm., Lewis Co., Wash. (Dickerson, 1915; Weaver, 1943; UCB); Quimper Ss. of Durham (1944), *Molopophorus stephensoni* Zone, Jefferson Co., Wash. (Durham, 1944; UCB); Coaledo Fm., Coos Bay, Coos Co., Ore. (Weaver, 1945); Markley Ss. Member of Kreyenhagen Fm., near Vacaville, Solano Co., Calif. (Clark, 1938); UCB); Tejon Fm., type area, Kern Co. (Dickerson, 1915; Anderson and Hanna, 1925; CAS; UCB; UCLA), and Lower Lake, Lake Co. (Dickerson, 1914b), Calif.; Matilija Ss., *Ectinochilus canalifer* fauna, Pine Mountain area, Ventura Co., Calif. (Givens, 1969; UCR). Lower Oligocene: Marrowstone Shale of Durham (1944), *Turritella porterensis* Zone, Jefferson Co., Wash. (Durham, 1944; UCB); Eugene Fm., type area, Eugene, Lane Co., Oreg. (Hickman, 1969).

Type localities.—

Naticina obliqua — Fort Tejon, Kern County, California.

Tejon Formation, upper Eocene (Gabb, 1864; Stewart, 1927).

Sinum corylifforme — CAS 244, Live Oak Canyon, Kern County, California. Type section of Tejon Formation, upper Eocene (Anderson & Hanna, 1925).

Sinum occidentis — University of Washington locality 319, McClarety Ranch, on south bank of Stillwater Creek, one mile west of Vader, Lewis County, Washington, sec. 30, T. 11 N., R. 2 W. Cowlitz Formation, upper Eocene (Weaver & Palmer, 1922).

Type material. —

Naticina obliqua — Lectotype of Stewart (1927), ANSP 4215; seven paralectotypes, ANSP 4215.

Sinum corylifforme — Holotype, CAS 851; paratypes, CAS 852, 853, 971.

Sinum occidentis — Holotype, CAS 7509.

Discussion. — This species is most variable in the relative height of its shell. An average shell has a height equal to about 0.8 of its diameter, whereas several individuals have heights equal to about 1.1 times their diameters. There is complete gradation between the more elevated and more depressed shells, and they may be collected together at the same localities. As in most *Sinums*, the sculpture of *S. obliquum* shows minor variations. The interspaces between spiral costae are usually equal in width to the costae but may be somewhat narrower; in rare cases the interspaces are slightly wider than the costae. In some instances the spiral sculpture on an individual breaks up immediately below the suture such that the interspaces broaden to as much as five times wider than the spiral costae and there may be two minute costellae per interspace instead of one. It is not uncommon for the spiral sculpture to be minutely wavy, which results from interference with the weak axial growth lines.

Sinum obliquum is similar to the middle Oligocene to Holocene species *S. scopulosum* (Conrad, 1849) and was almost certainly ancestral to it, although the two are not known to intergrade. The spiral interspaces of *S. obliquum* invariably bear one, uncommonly two, well-developed costellae, whereas the interspaces of *S. scopulosum* usually lack costellae; an individual of *S. scopulosum* may have costellae in some interspaces but never in all of them as does *S. obliquum*. The spiral costae of *S. obliquum* are less consistently flat-topped than those of *S. scopulosum* and never bear costellae as in the latter species. The umbilicus of typical *S. obliquum* is broadly open for the genus, so that it appears as a circular perforation in basal view, whereas the umbilicus of *S. scopulosum* is always inconspicuous and slitlike. In uncommon instances the umbilicus of *S. obliquum* is slitlike, and this occurs in some of the more elongate individuals.

Fifty of the 82 specimens of *S. obliquum* I have examined have come from the upper Eocene Tejon Formation of southern Cali-

ifornia, with the next greatest abundance in collections from the upper Eocene Cowlitz Formation of Washington.

Sinum scopulosum (Conrad, 1849) Pl. 33, figs. 13, 14; Pl. 34, figs. 1-5

Sigaretus scopulosus Conrad, 1849, appendix p. 727, pl. 19, figs. 6, 6a [not figs. 6b, c, = *Natica (Cryptonatica) oregonensis* (Conrad, 1849), treated herein; not fig. 6d, = not identifiable]; Meek, 1864, p. 31; Dall, 1892, p. 380; Dall in Diller, 1896, p. 474; Anderson, 1905, pp. 188, 203, pl. 16, figs. 72, 73; Arnold, 1906, pp. 17, 19; Arnold, 1908a, p. 350; Dall, 1909b, p. 125; Reagan, 1909, pp. 194-195, pl. 3, fig. 30; Reagen, 1910, p. 648; Arnold, 1910, p. 154, pl. 24, fig. 1; Arnold & Anderson, 1910, p. 127, pl. 46, fig. 1; Anderson, 1911, p. 100; J. P. Smith, 1912, pp. 167, 176; Anderson & Martin, 1914, p. 43; Keen & Bentson, 1944, p. 192.

Catinus scopulosus (Conrad), Meek, 1864, p. 31; Conrad, 1865, p. 151.

Stomatia scopulosa (Conrad), Meek, 1864, p. 31.

Sinum scopulosum (Conrad), Meek, 1864, p. 31; Merriam, 1896, pp. 103, 106; Dall, 1909b, pp. 12, 18, 91-92, pl. 4, fig. 10, pl. 5, fig. 8; Arnold & Hannibal, 1913, pp. 584, 588; English, 1914, p. 211; Clark, 1915, p. 15; Weaver, 1916a, pp. 172, 176, 216, 218; Nomland, 1917a, pp. 213, 221; Nomland, 1917b, p. 301; Clark, 1918, pp. 169-170, pl. 22, fig. 8; Trask, 1922, pp. 153-154; Stewart, 1927, pp. 327-328, pl. 32, fig. 4; Grant & Gale, 1931, p. 806; Etherington, 1931, pp. 95-96, pl. 12, fig. 13; Loel & Corey, 1932, p. 270, pl. 63, figs. 1a, b, 3a, b; Tegland, 1933, p. 140, pl. 14, fig. 23; Keen, 1937, p. 45; Willett, 1937, p. 400; Schenck & Keen, 1940, p. 43, pl. 35, fig. 3; Weaver, 1943, pp. 349-350, pl. 71, figs. 12, 14, 17, 18; Keen, 1943, p. 37; Durham, 1944, p. 161; Weaver, 1945, p. 57; Burch, 1946, p. 32; Stewart, 1946, p. 100 [as "cf."]; Smith & Gordon, 1948, p. 199; Woodring & Bramlette, 1950, p. 73, pl. 12, fig. 5; Morris, 1952, p. 95, pl. 24, fig. 17; Valentine, 1956, p. 201; Kanakoff & Emerson, 1959, p. 30; Winterer & Durham, 1962, p. 296; Moore, 1963, pp. 29-30, pl. 1, figs. 2, 3, pl. 2, figs. 20, 21; Durham & Addicott, 1965, p. 12; Morris, 1966, p. 79, pl. 35, fig. 9; Stanton, 1966, p. 23; Moore, 1968, p. 34; McLean, 1969, p. 38, fig. 19.5; Adegoke, 1969, pp. 169-170; Addicott, 1970a, pp. 70-72, pl. 6, figs. 5-7, 11; Moore, 1971, pp. 23, 28, pl. 7, figs. 6, 7.

Sinum planicostum Gabb, 1869a, pp. 49-50, 78, pl. 14, fig. 6; Dall, 1909b, pp. 91-92 [as junior synonym of *S. scopulosum*].

Sigaretus planicostum (Gabb), Cooper in Watts, 1896, p. 81; Anderson, 1905, p. 204.

Sinum californicum I. S. Oldroyd, 1917, p. 13; Dall, 1921, p. 165; I. S. Oldroyd, 1924, p. 19; I. S. Oldroyd, 1927, p. 732, pl. 92, figs. 13-14; Stewart, 1927, p. 327 [as junior synonym of *S. scopulosum*].

Sinum keratium Dall, 1919b, p. 354; Dall, 1921, p. 165; I. S. Oldroyd, 1927, p. 733; Keen, 1937, p. 45; Burch, 1946, p. 32.

Sinum (Sigaretus) trigenarium Trask, 1922, pp. 153-154, pl. 7, figs. 2a, b; Stewart, 1927, p. 327 [as junior synonym of *S. scopulosum*].

"*Sigaretus debilis* Gould" [not *S. debile* Gould, 1853, treated herein], Keep, 1888, p. 47; Arnold, 1903, p. 316; Arnold, 1906, pp. 28, 36; Arnold, 1908b, p. 423.

"*Sinum debile* (Gould)" [not *S. debile* Gould, 1853], Valentine, 1956, p. 200.

Description.—

Color: Shell exterior and interior white. Periostracum thin, pale yellowish white, may have dark rust-brown staining above base; base white.

Size: Average specimen, height 21 mm, diameter 26 mm; largest living specimen, height 31.2 mm, diameter 38.2 mm [CAS, no number, Newport Bay, California]; largest fossil specimen: height 33.0 mm, diameter 35.0 mm [CAS 1, Empire Formation, Coos Bay, Oregon, lower Pliocene].

Shell form: Shell high, spire moderately elevated; body whorl inflated and laterally expanded; shoulder broadly convex, base flattened; shell thin; nuclear whorls $2\frac{1}{2}$, smooth, postnuclear whorls two; suture slightly impressed. Spiral sculpture of low, flat-topped costae separated by interspaces of equal or lesser width; costae usually bear up to five weak to well-developed costellae; interspaces usually lack costellae, may bear one weak one; axial sculpture of incremental growth lines. Parietal callus thin, transparent, lightly filling posterior apertural angle; anterior lobe indistinct. Umbilicus open, inconspicuous, slitlike. Umbilical callus narrow, flattened, conceals umbilicus. Inner lip angulate, thickened; basal lip not thickened; outer lip smooth to weakly crenulate.

Operculum: Chitinous, much smaller than aperture.

Specimens examined.— Four hundred twenty-seven.

Geographic occurrence and habitat.— Monterey, California ($36^{\circ}30'$ N.) to Bahía Tortolo, western Baja California, Mexico ($27^{\circ}39'$ N.), including the southern California islands. Principally living in undisturbed sandy and muddy substrates nearshore, in depth of 15 to 171 metres, and in shallow embayments; occasionally found at low water in bays (McLean, 1969). Its shallowest known occurrence at the southern limit of its range (which is also the southern limit of the Californian molluscan province) is 48 to 60 metres, indicating its aversion to warm southern surface water.

Stratigraphic occurrence.— Middle Oligocene to Holocene. Middle Oligocene: Twin River Fm., *Echinophoria rex* zone, northern Olympic Peninsula, Wash. (Durham, 1944; UCB). Upper Oligocene: type Blakeley Fm. of Weaver (1912), Puget Sound, Wash. (Tegland, 1933; UCB). Lower Miocene(?): San Ramon Ss., Contra Costa Co., Calif. (Clark, 1918; Weaver, 1953). Lower Miocene: Vaqueros Fm., northern Santa Lucia Range, La Panza Range, western Santa Ynez Range, Ventura basin (Loel & Corey, 1932); Caliente Range (Eaton, Grant & Allan, 1941); Jewett Sand, Kern River area, Calif. (Addicott, 1970a). Middle Miocene: Clallam Fm.,

northern Olympic Peninsula, Wash. (Reagan, 1909, 1910; Arnold & Hannibal, 1913; Durham, 1944); Astoria Fm., southwestern Wash. (Etherington, 1931), coastal Oreg. (Conrad, 1849; Moore, 1963); Monterey Shale, Carneros Creek, Napa Co., Calif. (Weaver, 1949); Monterey Group, western Contra Costa Co. (Weaver, 1949); Tumbler Fm., Vallecitos area (Schenck & Keen, 1940), Reef Ridge (Stewart, 1946, cf.), La Panza Range (Loel & Corey, 1932); Salton Shale Member of the Monterey Shale of Hill, Carlson, and Dibblee (1958), Caliente Range (J. G. Vedder, *vide* Addicott, 1970a); Topanga Fm., Santa Monica Mountains (Susuki, 1951), Santa Ana Mts. (Vedder & Woodring, unpub., *vide* Addicott, 1970a); upper part of Olcese Sand and lower part of Round Mountain Silt, Kern River area, Calif. (Addicott, 1970a). Upper Miocene: Montesano Fm. of Weaver (1912), southwestern Wash. (Weaver, 1916a; Etherington, 1931); Santa Margarita Fm., Coalinga area (Nomland, 1917a), Comanche Point (Addicott, 1970a); Briones Ss., Solano Co., Calif. (Trask, 1922); Castaic Fm. of Crowell (1954), eastern Ventura basin (Stanton, 1966, 1967). Lower Pliocene: Empire Fm., southwestern Ore. (Dall, 1909b; Weaver, 1943, 1945; CAS); Pancho Rico Fm., Salinas Valley (Durham & Addicott, 1965; USGS). Lower and middle Pliocene: Etchegoin Fm., Coalinga area (Nomland, 1917b; Adegoke, 1969). Upper Pliocene: Careaga Ss., Santa Maria basin (Woodring & Bramlette, 1950); Pico Fm., eastern Ventura basin (Gabb, 1869a; Kew, 1924; Grant & Gale, 1931; Woodring and others *in* Winterer & Durham, 1962), central Los Angeles Co. (LACM); Fernando Fm., Puente Hills (Vedder *in* Durham & Yerkes, 1964, cf.). Lower Pleistocene: San Pedro Fm., San Pedro, Calif. (Oldroyd, 1925). Upper Pleistocene: Palos Verdes Sand, Palos Verdes Hills, terrace 12 (Marincovich, 1970), Playa del Rey (Willett, 1937), Potrero Canyon (Valentine, 1956), Newport Bay area (Kanakoff & Emerson, 1959), southern California.

Type localities. —

Sigaretus scopulosus — Astoria, Oregon (Conrad, 1849) [presumably from the Astoria Formation, middle Miocene].

Sinum planicostum — Pliocene of San Fernanco (Gabb, 1869a); Pico Formation, Ventura basin, California, Pliocene (Addicott, 1970a).

Sinum californicum — San Pedro, California (Oldroyd, 1917).

Sinum keratium — Catalina Island, California (Dall, 1919b).

Sinum (Sigaretus) trigenarium — UCB locality 3576, Mare Island Quadrangle, near San Pablo Bay, Solano County, California, Briones Sandstone, upper Miocene (Trask, 1922; Keen & Bentson, 1944).

Type material. —

Sigaretus scopulosus — Lectotype of Moore (1963), USNM 3553.

Sinum planicostum — Lectotype of Stewart (1927), ANSP 4326.

Sinum californicum — Holotype, SU 6446.

Sinum keratium — Holotype, USNM 206152.

Sinum (Sigaretus) trigenarium — Holotype, UCB 12386.

Nomenclatural commentary. — The lectotype of *S. planicostum* is badly worn, with only vestiges of shell material showing spiral sculpture identical to that of *S. scopulosum*. *Sinum californicum* was compared in its type description to *S. debile* (Gould) and "*S. concavum*" [= *S. cymba* (Menke, 1828), not *S. concavum* (Lamarck, 1822)], but not to *S. scopulosum*, which even then was well known at the type locality of *S. californicum*. The holotype of *S. keratium* is a juvenile *S. scopulosum*, with the sculpture and juvenile proportions of this species. The holotype of *S. trigenarium* is a cast without shell material and has been abraded and deformed. Deformation has altered the proportions of the shell, to make the base appear more flattened than usual for the genus. Spacing of the spiral costae is the same as on *S. scopulosum*, but costellae are not preserved. Trask (1922) stated that *S. trigenarium* has 30 spiral costae on its body whorl, compared to 45 for *S. scopulosum*. The poorly preserved spiral costae of Trask's holotype are difficult to accurately count, but at least 30 are present, with others apparently missing, whereas living and Neogene individuals of *S. scopulosum* have 35 to 50 costae on their body whorls. Trask's species is not separable from *S. scopulosum*.

Discussion. — Individuals of *S. scopulosum* vary noticeable in inflation of the body whorl, proportionate height of the shell, and the

degree to which the body whorl is angled downward to give the shell an "oblique" look. These variations have been partly responsible for the naming of synonymous species. Relatively flattened shells from southern California Pleistocene deposits have sometimes been referred erroneously to *S. debile* (Gould), but I have seen no specimens of that species in the several extensive Pleistocene collections that are in West Coast institutions.

Neogene specimens show the same range of variation in shell characters as do modern ones. Some Miocene specimens have thickened shells but are otherwise typical. The largest known fossils are about the same size as the largest living specimens but have slightly higher shells (see "Size" heading above).

***Sinum debile* (Gould, 1853)**

Pl. 34, figs. 6-8

Sigaretus debilis Gould, 1853, pp. 379-380, pl. 14, fig. 17; Carpenter, 1857a, p. 207; Tryon, 1886, p. 57, pl. 24, fig. 65; Keep, 1888, p. 47; Stearns, 1894a, p. 196; not Arnold, 1903, p. 316 [= *S. scopulosum* (Conrad, 1849)]; Johnson, 1964, p. 66.

Sinum debile (Gould), Dall, 1921, p. 65; Oldroyd, 1927, p. 733, pl. 92, figs. 3, 7; Grant & Gale, 1931, pp. 806-807; M. Smith, 1944, p. 13, fig. 136; Keen, 1958, p. 324, fig. 275; Parker, 1964, p. 153, pl. 4, fig. 6; Keen, 1971, p. 482, fig. 890.

Sinum pazianum Dall, 1919b, p. 354; Dall, 1921, p. 165; Oldroyd, 1927, p. 734, pl. 92, fig. 10; Keen, 1937, p. 45; M. Smith, 1944, p. 13; Burch, 1946, p. 32; Keen, 1958, p. 325, fig. 277.

Description. —

Color: Shell white, covered with thin yellowish-white periostracum; callus and interior white.

Size: Average specimen, height 9 mm, diameter 20 mm; largest specimen, height 12.0 mm, diameter 29.0 mm [USNM 46554, Gulf of California, Mexico].

Shell form: Apex strongly depressed, shell outline low; shell thin; nuclear whorls two with microscopic spiral costellae; post-nuclear whorls 2½; suture slightly impressed. Spiral sculpture of flat-topped costae separated by sharply incised interspaces of equal or greater width; inconspicuous costellae may be present in interspaces; axial sculpture of incremental growth lines that often disrupt the spiral costae and give them a wavy appearance. Parietal callus extremely thin, transparent, only slightly filling posterior apertural angle; anterior lobe broad. Umbilicus open, inconspicuous, slitlike. Umbilical callus narrow, flattened, conceals umbilicus. Interior of outer lip weakly crenulated.

Operculum: Chitinous, much smaller than aperture.

Specimens examined. — Sixty-two.

Geographic occurrence and habitat. — La Paz, Baja California, Mexico (24° N.), to Panama Bay, Panama (8° N.); most common throughout the Gulf of California, rare elsewhere. Dall (1919b) and some later workers listed *S. debile* from Catalina Island, California (33° N.), but specimens so named from that locality are actually *S. scopulosum* (Conrad). One specimen from Salinas, Ecuador [CAS, no number], is close to *S. debile* but too worn to identify with certainty. Living intertidally on sand and mud, dead shells found to 73 metres.

Stratigraphic occurrence. — Reported from upper Pleistocene deposits at San Pedro and Long Beach, California (Arnold, 1903), and from the Pliocene in a well at San Diego, California (Cooper, *vide* Arnold, 1903), but these records are based on specimens of *S. scopulosum* (Conrad).

Type localities. —

Sigaretus debilis — La Paz, Baja California, Mexico (Gould, 1853).

Sinum pazianum — Off La Paz, Baja California, Mexico, USFC station 2823, 26½ fathoms (Dall, 1919b).

Type material. —

Sigaretus debilis — Holotype, MCZ 169117.

Sinum pazianum — Holotype, USNM 211406.

Discussion. — This species has the most flattened proportions among the eastern Pacific *Sinums*. A few specimens have shells that are much thicker than average for the genus. Although faint costellae may occur in the spiral interspaces, they are absent on most specimens. *Sinum sanctijohannis* (Pilsbry & Lowe) is similar to this species, but has a higher shell, occasional rust-colored stains on the periostracum, and more frequent and stronger costellae in its spiral interspaces. The morphology of the Caribbean species *S. perspectivum* (Say, 1831) is similar to that of *S. debile*, although the former attains a greater maximum size (to a diameter of at least 36 mm).

***Sinum noyesii* Dall, 1903**

Pl. 35, figs. 2-4

Sinum noyesii Dall, 1903, p. 37; M. Smith, 1944, p. 13; Keen, 1958, p. 324, fig. 276; Keen, 1971, p. 482, fig. 892.

Description. —

Color: Earliest part of protoconch dark brown, otherwise white; early postnuclear whorls white with two spiral rows of pale brown spots above periphery, which become darker and spread to color entire upper half of final adult whorl mahogany brown; interior repeats exterior color pattern through semitransparent shell; callus white. Periostracum thin, pale yellowish brown.

Size: Average specimen, height 13 mm, diameter 32 mm; largest specimen, height 21.7 mm, diameter 42.1 mm [USNM 622799, Isla Tortola, Panama Bay, Panama].

Shell form: Shell flattened, spire low; shoulder flat or slightly convex; shell thin; nuclear whorls two, with microscopic spiral costellae; postnuclear whorls $2\frac{1}{2}$; suture concealed by periostracum, lies within narrow channel of uneven depth formed by overlapping of earlier whorl by later whorl. Spiral sculpture of low, narrow, weak costae separated by interspaces of lesser to much greater (to about six times) width; interspaces with several indistinct costellae; axial sculpture of incremental growth lines that disrupt the spiral sculpture and give it a minutely wavy appearance. Parietal callus thin, transparent, lightly filling posterior apertural angle; anterior lobe indistinct. Umbilicus closed. Umbilical callus not distinct, reduced to an anterior extension of parietal callus. Inner lip and basal lip slightly thickened, evenly rounded; outer lip may be weakly crenulate in juveniles, not in adults.

Opriculum: Chitinous, much smaller than aperture.

Specimens examined. — Twenty.

Geographic occurrence and habitat. — Isla San Benito, outer coast of Baja California, Mexico ($28^{\circ}20'$ N., $115^{\circ}30'$ W.), to Isla Gorgona, Colombia (3° N., $78^{\circ}19'$ W.). Between these range endpoints, specimens have been collected only at Isla Espíritu Santo, Gulf of California, Mexico ($24^{\circ}30'$ N., $110^{\circ}20'$ W.), at San Juan del Sur, Nicaragua ($11^{\circ}15'$ N.), and in the Gulf of Panama. Reported living intertidally at San Juan del Sur (Lowe, 1932) in a substrate of small stones and sandy mud, and found elsewhere living in depths to 89 metres.

Type locality. — Isla Gorgona, Colombia [3° N. lat. $78^{\circ}19'$ W. long] (Dall, 1903).

Type material. — Holotype, USNM 170298.

Discussion.—*Sinum noyesii* is easily distinguished from other eastern Pacific *Sinums* by its closed umbilicus. The other two extremely flattened species, *S. debile* (Gould) and *S. sanctijohannis* (Pilsbry & Lowe), also lack the dark-brown color of *S. noyesii*. *Sinum noyesii* and *S. debile* have been found living together in the Bay of Panama.

Sinum sanctijohannis (Pilsbry & Lowe, 1932)

Pl. 35, figs. 5-7

Sigaretus sanctijohannis Pilsbry & Lowe, 1932, p. 84, pl. 9, fig. 7.

Sinum sanctijohannis (Pilsbry & Lowe), M. Smith, 1944, p. 13, fig. 135; Keen, 1958, p. 325, fig. 278; Keen, 1971, p. 482, fig. 893.

Description.—

Color: Shell exterior and interior white. Periostracum thin, pale yellowish white, rust-brown staining at periphery and above.

Size: Average specimen, height 11 mm, diameter 21 mm; largest specimen, height 15.1 mm, diameter 25.9 mm [LACM, no number, 160 metres depth off northern Peru].

Shell form: Shell flattened, spire low; shoulder slightly concave just below suture, otherwise broadly convex; shell thin; nuclear whorls three, with closely spaced microscopic spiral lines, postnuclear whorls two; suture slightly impressed. Spiral sculpture of low, flat-topped costae separated by interspaces of equal or greater width; interspaces usually with one costella, may have four or more; axial sculpture of incremental growth lines that disrupt the spiral sculpture and give it minutely wavy appearance. Parietal callus thin, transparent, lightly filling posterior apertural angle; anterior lobe indistinct. Umbilicus open, inconspicuous, slitlike. Umbilical callus narrow, flattened, conceals umbilicus. Inner lip evenly rounded, basal lip very slightly thickened; outer lip smooth to weakly crenulate.

Operculum: Chitinous, much smaller than aperture.

Specimens examined.—Twenty.

Geographic occurrence and habitat.—Isla San Benito [AHF 1250-41], outer coast of Baja California, Mexico (28°20' N., 115°30' W.), to off northern Peru (6°27' S., 80°56' W.). Found most commonly throughout the Gulf of California and off northern Peru, rarely between these two places. In depths of 18 to 165 metres in the Gulf of California, 27 to 73 metres off of southern Mexico, and

118 to 160 metres off northern Peru (where it has been found with *S. cymba*).

Type locality. — San Juan del Sur, Nicaragua (Pilsbry & Lowe, 1932).

Type material. — Holotype, ANSP 155436.

Discussion. — This species is most similar to *S. debile* (Gould) which differs by having a more flattened shell, broader and more persistent spiral costae, inconspicuous costellae in its interspaces, and a periostracum lacking rust-brown stains. The spiral costae of *S. sanctijohannis* may be so narrow that they are not distinct from the costellae, but this never happens in *S. debile*.

***Sinum perrini* (Arnold, 1907)**

Pl. 35, fig. 8

Sigaretus perrini Arnold, 1907a, p. 532, pl. 51, fig. 5; Arnold, 1907b, p. 228, pl. 28, fig. 5; Eldridge & Arnold, 1907, p. 147; Grant & Gale, 1931, p. 807.

Description. —

Size: Height 19.9 mm, diameter 10.1 mm (holotype).

Shell form: Shell extremely high, spire greatly elevated; body whorl axially elongate, anteriorly inflated; shoulder broadly convex, sloping steeply from suture; shell thin; 2½ whorls preserved, apex missing; suture strongly impressed for the genus, overhung by preceding whorl. Spiral sculpture of low, narrow and rounded costae separated by interspaces that are twice as wide; interspaces of each bear one well-developed costella; axial sculpture of incremental growth lines. Parietal callus thin, poorly exposed on holotype. Umbilicus concealed by matrix.

Specimens examined. — Holotype.

Stratigraphic occurrence. — Middle Miocene: Topanga Fm., Topanga Canyon, Los Angeles, Calif. (Arnold, 1907a; USNM).

Type locality. — Head of Topanga Canyon, 3 miles south of Calabasas, western Los Angeles County, California (Arnold, 1907a). Camulos Quadrangle, south ½ section 33, T. 1 N., R. 17 W. (Keen & Bentson, 1944). Topanga Formation, middle Miocene.

Type material. — Holotype, USNM 164979.

Discussion. — This species has a more elevated shell than any other *Sinum* species known to me. It is known only from the holotype, even though its type locality has been heavily collected by professional and amateur paleontologists.

Genus **EUNATICINA** Fischer, 1885, p. 768

Type species: *Nerita papilla* Gmelin, 1791, by original designa-

tion. Living, western Pacific. Figured by Cernohorsky (1971, pp. 201-202, fig. 69).

Diagnosis. — Shells small to medium in size, globose to elongate, thin to average thickness; whorls moderately inflated, sculptured with spiral costae and sharply incised grooves; shoulder slightly flattened; suture narrowly and weakly channeled. Umbilicus broadly open. Umbilical callus slender, may be indistinct from inner lip; funicle low to indistinct. Parietal callus thin. Operculum partly calcified in some species, may possibly be entirely chitinous or entirely calcareous in other species. Radula with multicuspedate rachidian, one multicuspedate lateral tooth, one mono- or bicuspedate inner marginal tooth, and one monocuspedate outer marginal tooth per half row.

Discussion. — *Eunaticina* is characterized by its ovate shape, broadly open umbilicus with slender callus, and sharply incised spiral grooves over the shell surface. It never has the depressed auriform shape of most *Sinums*.

This genus is entirely tropical in distribution and has only a few species, perhaps as few as five or six.

Eunaticina insculpta (Carpenter, 1865) Pl. 34, figs. 9, 10; Pl. 35, fig. 1; Text-fig. 11e

Narica insculpta Carpenter, 1865a, p. 280; Carpenter, 1872, p. 273; Palmer, 1963, p. 296 (pp. 301, 343 as *Vanikoro*).

Eunaticina heimi Jordan in Hertlein, 1934, p. 68, pl. 21, fig. 4; Jordan, 1936, p. 161, pl. 19, fig. 6; Keen, 1958, p. 322, fig. 265; Keen, 1971, p. 477, fig. 872.

Description. —

Color: Shell exterior and interior white; nuclear whorls medium brown. Periostracum thin, pale yellowish white.

Size: Average specimen, height 13 mm, diameter 11.5 mm; largest specimen: height 14.3 mm, diameter 12.9 mm [AHF 1725-49, Cabeza Ballena, Baja California, Mexico].

Shell form: Shell globose, spire moderately elevated; body whorl inflated; shoulder slightly flattened; shell thickness average, shell with solid appearance; nuclear whorls $2\frac{1}{2}$, smooth; postnuclear whorls three; suture narrowly channeled; inner lip may be weakly crenulated. Spiral sculpture of flat-topped costae separated by much narrower, sharply incised grooves; spiral costae are narrower near suture and on base, are sometimes subdivided into poorly defined costellae; bottoms of the grooves are irregular, sometimes with

closely spaced shallow pits. Axial sculpture of incremental growth lines. Parietal callus thin, transparent, lightly filling posterior apertural angle; anterior lobe weak. Umbilicus widely open, exposing earlier whorls. Inner lip thickened, with a low forward projection at its midpoint, not forming a distinct umbilical callus; funicle low, narrow, sometimes indistinct. Basal lip not thickened.

Operculum: Inner surface chitinous; outer surface partially calcified, white, formed of radial rows of minute, coalesced beads, with occasional open interstices; outer calcareous layer thickest at inner part of final whorl, thinning and disappearing toward the upward-curved outer margin.

Specimens examined. — Eleven.

Geographic occurrence and habitat. — Cabeza Ballena, southernmost Baja California, Mexico ($22^{\circ}54'$ N.), in the southern Gulf of California, and south to Corinto, Nicaragua ($12^{\circ}30'$ N.), and the Galápagos Islands, Ecuador. Only one live collected specimen with depth data is known, from Bahía de la Concepción, eastern Baja California, in 22 metres.

Stratigraphic occurrence. — *Pleistocene*: Magdalena Bay, southwestern Baja California, and Isla Maria Madre, Islas Tres Marias, west Mexico (Jordan in Hertlein, 1934; CAS).

Type localities. —

Narica insculpta — Acapulco, Mexico (Carpenter, 1865a).

Eunaticina heimi — Magdalena Bay, western Baja California; Pleistocene (Jordan in Hertlein, 1934).

Type material. —

Narica insculpta — Holotype, USNM 11841.

Eunaticina heimi — Holotype, CAS 5557.

Nomenclatural commentary. — I fortuitously found the holotype of *Narica insculpta* in the USNM general collection, where it had lain undetected since 1865. This specimen is a young adult that is 6.0 mm in height and 6.3 mm in diameter, and is identical in form to the type of *E. heimi*.

Discussion. — The radular dentition of *E. insculpta* (Text-fig. 11e) differs from that of every other eastern Pacific naticid by having a multicuspate rather than a tricuspate or monocuspate rachidian. In this respect, the dentition of *E. insculpta* resembles that of the western Pacific species *E. papilla* Gmelin, 1791, the type

species of *Eunaticina*. The radular dentition of *E. papilla* (Azuma, 1961, pl. 13, fig. 5; Oyama, 1969, text-fig. 7) has a prominent central cusp and downturned basal processes on the rachidian to distinguish it from that of *E. insculpta*. Although clearly different, the dentitions of these two species are similar and distinct from most other naticid dentitions by having multicusped rachidians. The radular drawings by Azuma (1961) and Oyama (1969) of *E. papilla* differ in details of the lateral and marginal teeth, making these hard to compare with *E. insculpta*. However, both workers show the inner marginal teeth with a single apical termination, whereas the corresponding teeth of *E. insculpta* have double terminations.

The operculum differs from most other naticid opercula known to me by being only partially calcified. I have seen only two opercula of *E. insculpta*, but both lack calcification along the outer margin, with the thickest calcareous deposits along the inner margin and inner part of the final whorl. The operculum of the type species, *E. papilla*, is apparently entirely chitinous (Souverbie & Montrouzier, 1874, pl. 7, fig. 8; Oyama, 1969, text-fig. 6), without the outer calcareous layer of *E. insculpta*. It is not possible to say whether the primitive opercular condition of *Eunaticina* is chitinous or calcareous; no opercula are known from the Pleistocene specimens of *E. insculpta*.

Subfamily **NATICINAE** Forbes, 1838, p. 29

[*Nomen translatum* Wenz, 1941, ex Naticidae Forbes, 1838, p. 29.]

Diagnosis. — Usually globose, mostly smooth; spire low to moderately elevated; umbilicate, with funicle separated from parietal callus by a sulcus; if imperforate, umbilical callus is a semicircular plug; external calcareous layer on operculum is usually thick and ornamented.

Discussion. — This subfamily is characterized by its entirely calcareous operculum and by the presence of a funicle within the umbilicus of most species. It is principally a tropical group and the species are commonly brightly colored and patterned, and it is the naticid subfamily most highly developed in opercular sculpture and umbilical morphology.

Genus **NATICA** Scopoli, 1777, p. 392

Type species: *Nerita vitellus* Linnaeus, 1758, by subsequent

designation (Anton, 1839). Living, Indo-Pacific. Figured in Wenz (1941, p. 1039, fig. 2974).

Diagnosis. — Shells small to medium in size, globose, with low to moderately elevated spires; outer surface often brightly colored and patterned, smooth or with incised axial and spiral lines or spiral lines. Umbilicus usually narrowly to broadly open, sometimes closed; umbilical callus and funicle robust to weak, callus located just below middle of inner lip. Parietal callus thin to moderately thick. Operculum calcareous, usually with one to many spiral ribs on outer face, sometimes smooth. Radula typically naticid, with a tricuspsate rachidian, one multicuspsate lateral, one bicuspsate inner marginal, and one monocuspsate outer marginal tooth per half row.

Discussion. — *Natica* is characterized by its calcareous operculum and, in most cases, by its open umbilicus with distinct funicle.

In his original description of *Natica*, Scopoli (1777) referred to "*Natica*, Adanson," meaning Adanson (1757, p. 172), a pre-Linnaean description of the genus. Anton (1839, p. 31) subsequently designated *Nerita vitellus* Linnaeus, 1758, as type species of *Natica* but referred to *Natica* Lamarck, 1799, not Scopoli, 1777. Anton (1839, p. vi) clearly stated that specific names printed in capitals in his work were type species of their genera. He listed six species under *Natica*, and none of them is capitalized, although *N. mammillaris* is listed first and printed in ordinary letters and the other five species are in italics. However, under *N. vitellus* he listed several synonymous species, including "VITELLUS Lam. — *Nerita vitellus* L.," which thereby designated *N. vitellus* as type species of *Natica*. Even though Anton designated the type species for *Natica* Lamarck, 1799, not Scopoli, 1777, his designation also applies to Scopoli's genus (International Code of Zoological Nomenclature, rule 67g). A much later designation of *N. vitellus* as type species of *Natica* (Harris, 1897) is, therefore, redundant.

A key to the subgenera of *Natica*, *s. l.*, used here follows:

- | | |
|---|---------------------|
| 1a. Shells smooth, lacking sculpture | 2 |
| 1b. Shells sculptured, usually with axial grooves | 3 |
| 2a. Shells umbilicate, umbilical callus slender | NATICA, <i>s.s.</i> |
| 2b. Shells umbilicate, umbilical callus semicircular, not slender | TECTONATICA |
| 2c. Shells imperforate | CRYPTONATICA |
| 3a. Axial grooves extend from suture to base | STIGMAULAX |

ington, 1931), Montesano Quad. (USGS), and Grays Harbor Co. (CAS), Wash., and Cape Foulweather Quad. (Addicott, 1966a; USGS) and Astoria (Moore, 1963), Oreg.

Type localities. —

Natica (Natica) clarki — Seam of fossils in bed of Rock Creek, about $\frac{1}{4}$ mile downstream from the falls and just below the old dam site, sec. 7, T. 16 N., R. 5 W., Grays Harbor County, Washington (Etherington, 1931). Astoria Formation, middle Miocene.

Natica (Natica) vokesi — Outcrop in the intertidal zone at western edge of point due east of Gull Rock, 550 feet south, 4,150 feet west of northeast corner sec. 32, T. 9 S., R. 11 W., Cape Foulweather quadrangle, Oregon (Addicott, 1966a). Astoria Formation, middle Miocene.

Type material. —

Natica (Natica) clarki — Holotype, UCB 31996.

Natica (Natica) vokesi — Holotype, USNM 649130.

Discussion. — Among the few known specimens of *N. (N.) clarki*, the greatest morphologic variation is in the form of the umbilical callus. The holotype has a slender callus that does not greatly restrict the umbilicus, but other specimens have a more swollen callus whose increased width reduces the umbilical channel to a groove.

This species differs from *N. (N.) kanakoffi* Marinovich, 1975, by having a more elongate umbilical callus and an inner lip that is oblique to the axis of the shell rather than parallel to it, and by being much smaller. *Natica (Natica) clarki* differs from *Natica (Naticarius) posuncula* Hanna & Hertlein, 1938, and *Natica (Naticarius) teglandae* Hanna & Hertlein, 1938, by having a much more slender umbilical callus, a more distinct funicle, and a less distinct umbilical sulcus. It also lacks the axial wrinkles below the suture on juveniles of the other two species that place them in *Naticarius*.

The figure in Weaver (1943) is mistakenly referred to as the holotype of *N. (N.) clarki* but differs from the holotype in shell form and umbilical morphology. His figure appears to be *Polinices (Euspira) lincolnensis* (Weaver, 1916).

Natica (Natica) kanakoffi Marinovich, 1975

Pl. 38, figs. 4-6

"*Natica (Natica) saxea* Conrad," Etherington, 1931, p. 93, pl. 12, figs. 2, 3, 7, 14 [see *N. saxea* in Rejected and Indeterminate Taxa section].

Natica (Naticarius) teglandi Hanna & Hertlein, Durham, 1944, p. 159 [in part; as "*Natica (Natica) teglandae*"].

Natica (Natica) kanakoffi Marincovich, 1975, pp. 172-173, figs. 12-15.

Description.—

Size: Average specimen, height 19.5 mm, diameter 20.0 mm; largest specimen, height 44.1 mm, diameter 43.4 mm [UCB 31997, Astoria Formation, middle Miocene, southwestern Washington].

Shell form: Shell globose, spire moderately elevated; body whorl moderately inflated, evenly rounded; shell thickness average; whorls about $3\frac{1}{2}$ (apexes of all known specimens eroded); suture moderately impressed. Shell essentially smooth but with minute, weak, closely and irregularly spaced costellae and axial incremental growth lines that coarsen in the umbilical area. Parietal callus thick, heavily filling posterior apertural angle; anterior lobe weak, slightly overhanging umbilicus. Umbilicus broadly open, exposing earlier whorls; sulcus usually a broadly curved, shallow arc, less commonly a deeply excavated, angular indentation, with the apex of the angle at the midpoint of the sulcus; channel broad, not tapering toward inner lip. Umbilical callus small, funicle low but distinct. Anterior inner lip and basal lip thickened.

Operculum: Unknown.

Specimens examined.—Ninety-eight.

Stratigraphic occurrence.—Upper Oligocene to middle Miocene. Upper Oligocene: Blakeley Fm. of Weaver (1912), *Echinophoria apta* zone, Kitsap Co., Wash. (Durham, 1944; UCB). Lower Miocene: Clallam Fm., Pysht Quad., Clallam Co., Wash. (USGS); Scappoose Fm., near Scappoose, Columbia Co., Oreg. (USGS; CAS). Middle Miocene: Astoria Fm., Montesano Quad., Grays Harbor Co., Wash. (USGS), and Astoria, Clatsop Co., Oreg. (UCB).

Type locality.—CAS locality 168, about 16 km northwest of Scappoose, northeast corner sec. 36, T. 4 N., R. 3 W., Willamette Base, Columbia County, Oregon. Scappoose Formation, lower Miocene (Marincovich, 1975).

Type material.—Holotype, CAS 55794; paratypes, CAS 55795, USNM 219433 and 219434, UCB 14213 and 14214, LACM 5044 and 5045.

Discussion.—The shape of the umbilical sulcus is the most variable feature of this species. The sulcus of the holotype (Pl. 38,

fig. 4) and that of most specimens is a smooth arc that shallowly indents the inner lip and forms the posterior limit of the umbilical calus. However, a few specimens have the sulcus more deeply excavated and instead of being a smooth arc the sulcus is an angular indentation with the apex of the angle at the midpoint of the sulcus (Pl. 38, figs. 5, 6). An angular sulcus may be seen on individuals of all sizes, but is best developed on large specimens.

Natica (Natica) kanakoffi is similar in general form to four lower and middle Tertiary species of western North America: *Natica (Naticarius) teglandae* Hanna & Hertlein, 1938 (Pl. 39, figs. 2 to 4), *Natica (Naticarius) posuncula* Hanna & Hertlein, 1938 (Pl. 38, fig. 13, Pl. 39, fig. 1), *Natica (Naticarius) wasana* Gabb, 1864 (Pl. 39, figs. 5 to 8), and *Natica (Natica) weaveri* Tegland, 1933 (Pl. 38, figs. 7 to 12). It differs from the first three by lacking the axial wrinkles immediately below the suture that places these species in *Naticarius*. It further differs by having an umbilicus so broadly open that most earlier whorls are visible within it; only *N. (N.) teglandae* approaches this condition, and never to the extent seen in *N. (N.) kanakoffi*. Whereas the umbilical sulcus of *N. (N.) kanakoffi* is a smooth arc or an angulation, the sulci of the other three species form essentially straight lines along the posterior inner lips. The umbilical calluses of these species are also much more robust than that of *N. (N.) kanakoffi*, with the exception that some specimens of *N. (N.) teglandae* have calluses as subdued as that of *N. (N.) kanakoffi*. Finally, the parietal callus of *N. (N.) kanakoffi* is much thicker than on any of the other species, and more heavily fills the posterior apertural angle.

Natica (Natica) kanakoffi is more closely related to *Natica (Natica) weaveri* than to the above three species, but these two are easily distinguished. Although both occur in Washington and Oregon, *N. (N.) weaveri* is known only in upper Eocene and lower Oligocene strata, thus preceding *N. (N.) kanakoffi* in the Tertiary and perhaps being ancestral to it (Text-fig. 9). The largest known specimen of *N. (N.) weaveri* is 19.2 mm high and 18.8 mm in diameter, which is less than half the size of the largest known *N. (N.) kanakoffi*, and the latter species also has a greater average size. The umbilicus of *N. (N.) weaveri* is never broadly open, and its sulcus is shallow and has a nearly straight margin, in contrast to the much more open

umbilicus and more deeply excavated sulcus of *N. (N.) kanakoffi*. In general, the umbilical callus of *N. (N.) kanakoffi* is more strongly developed than in the other species, and the funicle is always more robust. The parietal callus of *N. (N.) kanakoffi* is always much thicker than on an individual of *N. (N.) weaveri* of equal size.

Durham's (1944) unfigured hypotype (UCB 35284) attributed to *Natica (Naticarius) teglandae* is an individual of *N. (N.) kanakoffi*, thus extending the occurrence of the latter species into the late Oligocene.

***Natica (Natica) weaveri* Tegland, 1933**

Pl. 38, figs. 7-12

Natica (Natica) weaveri Tegland, 1933, pp. 138-139, pl. 14, figs. 13-17; Effinger, 1938, pp. 365, 377 [as "cf."]; Durham, 1944, pp. 121, 159.

Natica (Tectonatica) weaveri Tegland, Weaver, 1943, pp. 333-334, pl. 68, figs. 8, 9, 13.

Description.—

Color: Many specimens have remnants of their original color, consisting of one vaguely defined broad spiral band of pale to dark brown immediately below the suture and on the base.

Size: Average specimen, height 16 mm, diameter 15 mm; largest specimen, height 19.2 mm, diameter 18.8 mm [UCB 32185, Lincoln Creek Formation, Lincoln Creek, Washington, Oligocene; paratype].

Shell form: Shell globose, spire moderately elevated; body whorl moderately inflated, evenly rounded but with a slight flattening just below suture; shell thin; whorls about four (apexes eroded on all known specimens); suture slightly to moderately impressed. Shell smooth except for incremental growth lines. Parietal callus thin to slightly thickened, lightly to moderately filling posterior apertural angle; anterior lobe weak. Umbilicus narrowly to moderately open; sulcus shallow, narrowly to broadly curved or with nearly straight margin along inner lip; channel tapering to a point anteriorly along inner lip. Umbilical callus with a narrow central swelling that continues into the umbilicus as a low funicle; callus continues anteriorly as a thickened inner lip. Basal lip slightly thickened.

Operculum: One unattached calcareous operculum is among the type specimens (UCB 32184) and was attributed to this species in the original description. Most of the outer edge is missing, but the remaining two-thirds of the operculum is well preserved. The

outer surface is smooth except for irregular calcareous deposits over the nuclear portion; two low, closely spaced riblets run along the remaining outer margin. Tegland (1933) noted that the inner edge of the operculum was minutely denticulate, but this is not so.

Specimens examined. — Two hundred forty-one.

Stratigraphic occurrence. — Upper Eocene and lower Oligocene of Washington and Oregon. Upper Eocene: Lincoln Creek Fm., *Molopophorus stephensoni* zone, near Galvin (Durham, 1944; UCB), and at Gries Ranch, Vader (Effinger, 1938, as "cf."), southwestern Wash.; Keasey Fm., western Wash. and Ore. (USGS). Lower Oligocene: Lincoln Creek Fm., *Turritella porterensis* zone, near Galvin, Wash. (Durham, 1944; UCB; UCLA).

Type locality. — Cut on Union Pacific Railway one mile north of Galvin Station, Lewis County, Washington, sec. 27, T. 15 N., R. 5 W. (Weaver, 1943). Lincoln Creek Formation, Oligocene.

Type material. — Holotype, UCB 32183; operculum attributed to holotype, UCB 32184; paratypes, UCB 32185 and 32186.

Discussion. — This species shows a broad range of variation in its umbilical morphology that may be related to its inferred bathymetric range. Most individuals (including the holotype) have distinctly open umbilici and umbilical calluses that are not well differentiated from the inner lip (Pl. 38, figs. 7, 9, 10), but some specimens are more tightly coiled (resulting in higher spires and smaller umbilici) and have broader umbilical calluses that are more distinct from the inner lips (Pl. 38, figs. 11, 12). The latter specimens are also smaller than more typical ones, averaging 10 mm in height and 9 mm in diameter; they also have four uneroded whorls per specimen, showing that they are stunted adults rather than juveniles. These smaller specimens show a wide range in relative size of the umbilical opening and of the umbilical callus, but only the more broadly umbilicate among them resemble the majority of typical specimens. Such atypical specimens have been found only in the upper Eocene Keasey Formation of western Oregon which is interpreted as a bathyal deposit (Hickman, 1974), whereas only typical individuals of *N. (N.) weaveri* come from neritic deposits. The smaller specimens are interpreted here as individuals that were stunted by living at great depths.

Bathymetric stunting is well documented in *Natica* (*Crypto-*

natica) *clausa* Broderip & Sowerby, 1829, which has occurred from the early Miocene to Holocene of the northeastern Pacific and lives in modern circumboreal faunas. Stunting in this species was first observed and documented by Odhner (1913) and has been confirmed in the present study, as noted in the discussion section on *N. (G.) clausa*.

In general, living deep-water (bathyal and deeper) naticids have smaller umbilici than shallow-water species. This is best seen in the polinicine subgenus *Euspira*, which includes most deep-water naticids worldwide. So far as is known, deep-water *Euspiras* all have small or imperforate umbilici, whereas neritic *Euspiras* have umbilici moderately to broadly open. The difference in umbilical openings between shallow- and deep-water *N. (N.) weaveri* is regarded as a related trend.

The presence of *N. (N.) weaveri* in the deep- and cool-water fauna of the Keasey Formation is anomalous for a species of *Natica*, *s.s.* In modern seas and in other Cenozoic deposits, this subgenus is known only in tropical or subtropical, shallow-water deposits. As shell and opercular morphology allow confident allocation of this species to *Natica*, *s.s.*, its presence in the Keasey deposits is atypical and perhaps unique for the subgenus.

This species was the earliest Tertiary representative of *Natica*, *s.s.* in the western United States, but two other species occur in Miocene strata: *N. (N.) clarki* Etherington and *N. (N.) kanakoffi* Marinovich. *Natica (Natica) clarki* is known by only five specimens and is similar to *N. (N.) weaveri*. However, it differs by having a somewhat higher spire and a more slender umbilical callus than *N. (N.) weaveri*. Even the atypically slender calluses of *N. (N.) weaveri* from the Keasey Formation are not as slender as those seen on *N. (N.) clarki*.

Natica (Natica) kanakoffi differs more strongly from *N. (N.) weaveri* than does *N. (N.) clarki*. Compared to *N. (N.) weaveri*, *N. (N.) kanakoffi* (Pl. 38, figs. 4-6) has a larger and thicker shell, much thicker parietal callus, far more broadly open umbilicus, and generally more distinct umbilical callus. The widely open umbilicus of *N. (N.) kanakoffi* exposes earlier whorls to view, compared to the narrowly open umbilicus of *N. (N.) weaveri*. The difference in umbilical opening alone serves to distinguish the two species.

Natica (Natica) inexpectans Olsson, 1971

Pl. 36, figs. 6, 7

Natica inexpectans Olsson, 1971, pp. 69-71, figs. 31a, b, 32; Keen, 1971, p. 475, fig. 864a.

Description. —

Color: Shell with axial stripes of white and dark brown extending from suture to base, sometimes with zigzag pattern on shoulder; callus white; base white. Nuclear whorls white, translucent. Periostracum thin, pale yellowish brown.

Size: Average specimen, height 17.7 mm, diameter 18.8 mm; largest specimen, height 23.1 mm, diameter 22.6 mm (holotype).

Shell form: Shell globose, spire low; whorls evenly rounded; shell thick; whorls five, nuclear whorls not clearly set off; suture slightly impressed. Whorls smooth except for incremental growth lines. Parietal callus thin, but thickens to moderately fill posterior apertural angle; anterior lobe distinct. Umbilicus open, narrow; channel narrow, tapers anteriorly. Umbilical callus narrow, tapers gently anteriorly, expands posteriorly to parietal callus; funicle broad, low. Inner lip and basal lip slightly thickened.

Operculum: Calcareous, white, mostly smooth, with four smooth, flat-topped ribs along the outer margin and separated by narrow interspaces; nucleus slightly swollen.

Specimens examined. — Holotype and three paratypes.

Geographic occurrence and habitat. — Known only from the Gulf of Panama, northeast of Cabo Mala, Panama (about 7°39' N., 79°40' W.), in 117 to 119 metres depth.

Type material. — Holotype, USNM 701161.

Discussion. — The color pattern is unique among eastern Pacific species.

Natica (Natica) sigillata McLean, 1970

Pl. 36, figs. 8, 9

Natica sigillata McLean, 1970, pp. 313-314, pl. 46, figs. 11, 12.

Natica (Natica) sigillata McLean, Keen, 1971, p. 475, fig. 867.

Description. —

Color: Shell chestnut brown with closely spaced triangular white markings; callus and umbilical area white; interior white with brown outer lip. Nuclear whorls yellowish brown. Periostracum thin, yellowish white.

Size: Average specimen, height 10 mm, diameter 10.5 mm;

largest specimen, height 19.5 mm, diameter 19.2 mm [SU 49428, Carmen Island, Gulf of California, Mexico].

Shell form: Shell globose, spire moderately elevated to low; body whorl inflated; whorls evenly rounded; shell thickness average; nuclear whorls two, smooth, postnuclear whorls $2\frac{1}{2}$; suture moderately impressed. Spiral sculpture of minute, poorly developed, obscure costellae; axial sculpture of incremental growth lines that are best developed near the suture. Parietal callus thin, lightly fills posterior apertural angle; anterior lobe weak. Umbilicus open, narrow; sulcus weak; channel tapers gently, not to a sharp point. Umbilical callus narrow, little more than thickened inner lip, then broadens more abruptly to bridge posterior end of umbilicus; funicle essentially lacking. Basal lip thickened.

Operculum: Calcareous, white, darker centrally from incorporated sediment grains. Outer surface smooth except for four flat-topped ribs near outer margin, the inner two broader than the others.

Specimens examined. — Holotype and three paratypes.

Geographic occurrence and habitat. — Near Carmen Island, Gulf of California, Mexico (26° N.), and the Galápagos Islands, Ecuador (0° lat), unknown in intervening area. Found at 37 to 82 metres depth near Carmen Island and at 91 metres depth in the Galápagos.

Type locality. — Tagus Cove, Isabella Island, Galápagos Islands, Ecuador, lat $0^{\circ}16'$ S., long $91^{\circ}22'$ W., 91 metres (McLean, 1970).

Type material. — Holotype, LACM 1284.

Discussion. — This is the only eastern Pacific species with triangular color markings on its shell.

Subgenus **NATICARIUS** Duméril, 1806, p. 164

Type species: *Nerita canrena* Linnaeus, 1758, by monotypy. Living, West Indies and southeastern U.S.A. Figured in Abbott (1974, text-fig. 1715, pl. 4, fig. 1715).

Diagnosis. — Shell small to medium in size, globose to somewhat elongate, body whorl distinctly inflated. Axial sculpture of sharply incised grooves that extend from suture part way to periphery. Umbilicus usually narrow, rarely broad, with moderately to deeply excavated sulcus. Umbilical callus slender; funicle ranges from robust to low and indistinct. Parietal callus thin to slightly thickened.

Operculum with one or two ribs at outer margin or several ribs over outer portion.

Discussion. — This is a worldwide group, largely confined to the tropics and is among the larger naticid subgenera in number of species. *Naticarius* is characterized by its distinct radial grooves above the periphery, slender umbilical callus, and an operculum usually with several spiral ribs.

***Natica (Naticarius) chemnitzii* Pfeiffer, 1840, nomen inquirendum**
Pl. 36, figs. 10-12

Natica chemnitzii Pfeiffer, 1840, p. viii; Stearns, 1894a, p. 195.

Natica (Natica) chemnitzii Pfeiffer, Keen, 1958, p. 320, fig. 258; Keen, 1971, pp. 473, 475, fig. 861.

Not *Natica chemnitzii* "Récluz," Reeve, 1855, pl. 2, figs. 7a, b [? = *Polinices* sp.].

"*Natica marochiensis* Gmelin" [not *N. marochiensis* Gmelin, 1791; living, Caribbean and Mediterranean], Carpenter, 1857d, pp. 261, 274; Sowerby, 1883, p. 82, pl. 5, fig. 62, pl. 8, figs. 108, 109, pl. 9, fig. 151; M. Smith, 1944, p. 12, fig. 131.

Natica marochiensis var. *chemnitzii* Pfeiffer, Tryon, 1886, p. 24, pl. 5, figs. 94-96.

"*Natica maroccana* Chemnitz" [= *Nerita maroccanae* Chemnitz, 1781, non-binomial], Koch, 1844, p. 152, 155; Philippi, 1850, pp. 78-80, pl. 12, figs. 1-5 (text 1851); Carpenter, 1857c, pp. 448-450; Carpenter, 1864, p. 624; Stearns, 1894b, p. 446; Menke, 1847, p. 179 [as "Koch"]; Menke, 1851, p. 165 [as "Koch"].

Natica? *maroccana* var. *californica* Carpenter, 1857b, p. 227; Palmer, 1958, p. 46.

Natica pritchardi Forbes, 1852, p. 272, pl. 11, figs. 2a-c; Stearns, 1894a, p. 195.

"*Natica lurida* Philippi" [not *N. lurida* Philippi, 1852, = *N. gaultheriana* Récluz, 1844; living, Indo-Pacific], Carpenter, 1857d, p. 261.

Natica undata Philippi, 1852, p. 74, pl. 11, fig. 12 (plates 1850); Troschel, 1852, p. 161; Dall, 1909a, p. 235.

?*Natica undata* Sassi, 1827, p. 478 [not seen].

Not *Natica undata* Philippi, 1844, vol. 2, p. 141 [= fossil, Sicily].

?*Natica undata* Meuschen, 1767 [not seen].

Description. —

Color: Shell with axial zigzag pattern of maroon brown and grayish yellow or grayish white, with bolder pattern on shoulder; pattern best developed on juveniles, commonly cloudy on adults; adults often with whitish blotches on shoulder that may coalesce into a solid band; narrow whitish band is just below suture; base and callus area white. Nuclear whorls dark maroon brown. Interior medium to dark brown, often axially streaked, with white band at shoulder and base. Periostracum, light to medium yellowish brown.

Size: Average specimen, height 28 mm, diameter 25 mm; largest specimen, height 39.1 mm, diameter 37.4 mm [LACM H-527, near San Felipe, Baja California, Mexico].

Shell form: Shell elongate, spire elevated; body whorl not greatly inflated; whorls evenly rounded; shell moderately thick, with solid appearance; nuclear whorls $2\frac{1}{2}$, smooth; postnuclear whorls $3\frac{1}{2}$; suture moderately to deeply impressed. Spiral sculpture of minute, poorly developed costellae; axial sculpture of closely spaced retractive grooves extending from suture halfway to periphery on early adult whorls, becoming indistinguishable from growth lines on final adult whorl. Parietal callus thin, moderately filling posterior apertural angle; anterior lobe weak. Umbilicus open, narrow, sulcus well developed, channel slightly tapered anteriorly. Umbilical callus narrow, with evenly rounded margin raised into a ridge where it meets funicle; funicle low, broad. Basal lip thickened.

Operculum: Calcareous, white, darker on central area from incorporated sediment grains; thickest centrally, tapers toward outer margin; smooth except for one low, rounded rib at outer margin.

Specimens examined. — Eight-hundred sixty-seven.

Geographic occurrence and habitat. — Bahía Magdalena, western Baja California, Mexico ($23^{\circ}30'$ N.), throughout the Gulf of California, and south to Bahía de Sechura, Peru ($5^{\circ}40'$ S.). Found mostly on sand and mud flats intertidally but known to 18 metres depth.

Stratigraphic occurrence. — May occur in Miocene, Pliocene, or Pleistocene strata. Miocene or Pliocene: Bahía Magdalena, western Baja California, Mexico (Hanna, 1926). Pleistocene: Imperial Co., Calif. (Hanna, 1926).

Type localities. —

Natica chemnitzii — Mexico (Pfeiffer, 1840).

Natica? maroccana var. *californica* — Hawaiian Islands (Palmer, 1958), not California as stated by Carpenter (1857b).

Natica pritchardi — Mazatlán, Mexico (Forbes, 1852).

Natica undata — Panama (Philippi, 1852).

Type material. —

Natica chemnitzii — Unknown, either destroyed with Pfeiffer collection in Stettin Museum during Second World War, or in Cuming collection in BM(NH) (Dance, 1966).

Natica? maroccana var. *californica* — Unknown. Twelve

specimens, Redpath Mus., McGill. Uncertain as to types (Condé).

Natica pritchardi — BM(NH) (Dance, 1966).

Natica undata — Unknown, presumably in BM(NH) (Dance, 1966).

Nomenclatural commentary. — When Pfeiffer (1840) described *N. (N.) chemnitzii*, he cited as examples figures 1905-6 of Chemnitz's (1781) six figures (1905-10) of the non-binomial *Neritae maroccanae*. Chemnitz had recorded *Neritae maroccanae* from Africa, in particular Morocco, and the Antilles. Gmelin (1791) described *Nerita marochiensis*, basing his species on Chemnitz's six figures and locality data, and Dillwyn (1817) renamed the species *Nerita maroccana*, citing all six of Chemnitz's figures and recording the species from the West Indies, Africa, and the Bay of Naples. Quoy and Gaimard (1833) were the first to report *N. marochiensis* from the central Pacific and were followed by many later workers. In a review of the taxonomic history of *N. marochiensis*, Cernohorsky (1971) concluded that the name may be correctly applied only to Mediterranean and Caribbean specimens.

The status of *N. (N.) chemnitzii* is uncertain. If the name *N. (N.) marochiensis* applies only to Mediterranean and Caribbean specimens, as is indicated in the original description, then *N. (N.) chemnitzii* is a junior synonym of *N. (N.) marochiensis*, because it is based on two of the six original figures of *N. (N.) marochiensis*. If examination of the types of *N. (N.) marochiensis* (whose location is unknown) shows the specimens given as Chemnitz's figures 1905-6 to be from the eastern Pacific, then Pfeiffer's *N. (N.) chemnitzii* is available; this seems unlikely. Deciding on the availability of *N. (N.) chemnitzii* would still leave the question of whether eastern Pacific specimens are separable from those of the Caribbean and Mediterranean. Specimens from the two regions are not clearly different, but I have not seen enough of the Caribbean and Mediterranean examples to be sure they show the same range of variation in color and shell form as the Pacific specimens. Because it is possible that *N. (N.) chemnitzii* is a junior synonym of *N. marochiensis*, and that specimens from the Pacific and Atlantic represent one species, *N. (N.) chemnitzii* is cited here as a *nomen inquirendum* (name under inquiry).

Discussion.—Among eastern Pacific species, *N. (N.) chemnitzii* is most similar to *N. (N.) unifasciata* Lamarck. The distinctions between these species are given in the discussion of *N. (N.) unifasciata*.

***Natica (Naticarius) unifasciata* Lamarck, 1822** Pl. 35, figs. 9, 10

Natica unifasciata Lamarck, 1822, vol. 6, pt. 2, p. 201; Troschel, 1852, p. 160; Reeve, 1855, pl. 12, fig. 49b; Dall, 1909a, p. 235; Jordan, 1924, p. 156; Hanna, 1926, p. 451; M. Smith, 1944, p. 12.

Natica marochiensis var. *unifasciata* Lamarck, Tryon, 1886, pp. 23-24, pl. 5, fig. 93.

Natica (Natica) unifasciata Lamarck, Grant & Gale, 1931, p. 797, text-fig. 10; Keen, 1971, pp. 475, 477, fig. 868.

Natica (Natica) chemnitzii Pfeiffer [in part], Keen, 1958, p. 320.

Description.—

Color: Shell light grayish brown to dark purple and nearly black, with a narrow band of dull yellow on the shoulder; colors often axially streaked, may become abruptly lighter below periphery; base white; nuclear whorls dark purplish brown. Interior streaked with gray and brown. Periostracum thin, light to medium yellowish brown.

Size: Average specimen, height 35 mm, diameter 31 mm; largest specimen, height 44.0 mm, diameter 37.8 mm [LACM A.2777, Corinto, Nicaragua].

Shell form: Shell elongate, spire elevated; body whorl inflated; whorls evenly rounded; shell moderately thick, with solid appearance; nuclear whorls $2\frac{1}{2}$, smooth; postnuclear whorls $3\frac{1}{2}$; suture moderately to deeply impressed. Spiral sculpture of minute, poorly developed, obscure costellae; axial sculpture of closely spaced retractive grooves extending from suture halfway to periphery on early adult whorls, becoming indistinguishable from growth lines on final adult whorl. Parietal callus thin, moderately filling posterior apertural angle; anterior lobe weak. Umbilicus open, narrow, sulcus well developed, channel only slightly tapered anteriorly. Umbilical callus relatively narrow, with evenly rounded margin; funicle low, broad. Basal lip thickened.

Operculum: Calcareous, white, darker on central area from incorporated sediment grains; thickest centrally, tapers toward outer margin; smooth except for one low, rounded rib at outer margin.

Specimens examined.—Three hundred eighty-six.

Geographic occurrence and habitat.—La Unión, El Salvador

(13°20' N.), south to Golfo de Guayaquil, Ecuador (3° S.). Specimens with questionable locality data are from the Golfo de Tehuantepec, Mexico (16° N.), "Peru," and the Galápagos Islands. Collected alive intertidally on mud flats.

Stratigraphic occurrence. — Hanna (1926) reported this species from the Pliocene? of Coyote Mountain, Imperial County, California, but CAS and UCB specimens from that area, labeled as *N. unifasciata*, are too poorly preserved to identify.

Type locality. — Unknown (Lamarck, 1822).

Type material. — Holotype No. 1094/67, Muséum d'Histoire Naturelle, Geneva, Switzerland (E. Binder).

Nomenclatural commentary. — As noted by Keen (1971), *N. unifasciata* is not recognizable from Lamarck's original description, but a figure by Delessert (1841) of a specimen from Lamarck's collection shows this to be an eastern Pacific species. Photo of holotype from Muséum confirmed the identity.

Discussion. — *Natica (Naticarius) unifasciata* is most similar to *N. (N.) chemnitzii* Pfeiffer, 1840, which ranges from Baja California, Mexico, to Peru. The most obvious difference between the species is in color patterns, *N. (N.) chemnitzii* having a series of yellowish blotches on its shoulder instead of a solid yellowish band, and a zigzag pattern of yellow and purple or brown over the rest of the shell, instead of a solid dark shell as in *N. (N.) unifasciata*. The zigzag pattern of *N. (N.) chemnitzii* is best developed on juveniles, whereas older specimens may have a mottled dark-brown or purple shell similar to paler specimens of *N. (N.) unifasciata*. Older individuals of *N. (N.) chemnitzii* may also have their yellowish shoulder mottlings coalesced into a clouded band that is wider than the similar band in *N. (N.) unifasciata*. The early whorls of *N. (N.) chemnitzii* always show their characteristic zigzag pattern, whereas juveniles of *N. (N.) unifasciata* never do. Development of the umbilical callus is also different, the callus of *N. (N.) unifasciata* being wider and more swollen, filling in the umbilicus more completely. As a result, the umbilical channel of *N. (N.) chemnitzii* is broadly open to its termination at the inner lip, whereas the channel of *N. (N.) unifasciata* is reduced to a narrow groove for most of its length. The junction of the callus surface and funicle surface in *N. (N.) chemnitzii* forms a sharp ridge along the free margin of the callus, unlike

the broadly rounded callus surface of *N. (N.) unifasciata* that conceals most of the funicle. Although these differences are remarkably consistent, occasional specimens seem to have characteristics of both species. These usually have the solid color pattern of *N. (N.) unifasciata* and the more open umbilicus of *N. (N.) chemnitzii*. Such specimens are either individuals of *N. (N.) chemnitzii* that duplicate the color of *N. (N.) unifasciata* as a gerontic feature, or are unusually large specimens of *N. (N.) unifasciata*, which develop a more open umbilicus as they attain great size.

The geographic range difference between *N. (N.) unifasciata* and *N. (N.) chemnitzii* reinforces the distinction made on the basis of umbilical morphology and color pattern. *N. (N.) unifasciata* occurs only in the inner tropics, from El Salvador to Ecuador, whereas *N. (N.) chemnitzii* ranges from southwestern Baja California, Mexico, to Bahía de Sechura, Peru, at the northern and southern limits of the eastern Pacific tropics.

Natica (Naticarius) othello Dall, 1908 Pl. 35, fig. 11; Pl. 37, figs. 1, 2

Natica (Cochlis) othello Dall, 1908, pp. 332-333; M. Smith, 1944, p. 12.

Natica (Natica) othello Dall, Keen, 1958, p. 321; Keen, 1971, p. 475, fig. 865.

Description. —

Color: Shell medium to dark brown, often grayish, with a narrow white band at the suture and a white base; shoulder with a narrow band of alternating white and dark-brown spots; a narrow white band is just below periphery, with a row of dark-brown spots along the upper margin of the band, sometimes with an additional row of smaller spots along the lower margin. Nuclear whorls orange brown, becoming whitish at shoulder. Periostracum thin, pale yellowish white.

Size: Average specimen, height 20 mm, diameter 18 mm: largest specimen, height 24.8 mm, diameter 22.8 mm [USNM 96992, Panama Bay, Panama].

Shell form: Shell elongate, spire elevated, body whorl inflated; whorls evenly rounded; shell thin; nuclear whorls three, with spiral sculpture of microscopic, closely spaced costellae on early whorls, and of retractive axial grooves below the suture on third whorl, the two types overlapping; postnuclear whorls three; suture moderately impressed. Axial sculpture of retractive grooves that extend from suture one-third of the way to periphery, better developed on early adult

whorls; spiral sculpture of minute, poorly developed, obscure costellae. Parietal callus thin, transparent, lightly to moderately filling posterior apertural angle, with weak to moderate anterior lobe overhanging umbilicus. Umbilicus open, narrow, typically with deep sulcus that indents posterior margin of umbilical callus; channel narrow, tapering anteriorly, but not to a point. Umbilical callus relatively narrow, gently tapering anteriorly but abruptly truncated and notched posteriorly by umbilical sulcus; funicle robust, filling anterior half of umbilicus. Anterior inner lip thickened, basal lip thin.

Operculum: Calcareous, white, thickened centrally and thin along outer margin; sculptured with two outer marginal ribs separated by a narrow groove, the outer rib rounded and minutely pustulate, the inner rib sharply raised and more weakly pustulate.

Specimens examined. — Four hundred sixty-seven.

Geographic occurrence and habitat. — Isla San Benito, western Baja California, Mexico ($28^{\circ}17' N.$), throughout the Gulf of California, and south to Bahía Santa Elena ($2^{\circ}10' S.$) and the Galápagos Islands, Ecuador; rare north of the Gulf of California. Collected alive in depths of 4 to 265 metres, most common in 18 to 45 metres depth on a variety of soft substrates.

Type locality. — Bay of Panama, Panama (Dall, 1908).

Type material. — Holotype, USNM 46446.

Discussion. — The deep sulcal notch at the posterior margin of the umbilical callus is the easiest means of identifying this species, but it is not always well developed. Some individuals entirely lack this notch and have a relatively gentle posterior taper to the callus.

Two specimens among those examined differ from typical *N. (N.) othello* specimens in color and form, and may be considered a new subspecies or species when more specimens are available for study. These specimens [AHF 1703-49, Cedros Island, Baja California, Mexico, and USNM 210762, Gulf of California], differ from ordinary *N. (N.) othello* by having a lower spire and more globose whorls. In addition they have four distinct spiral bands of alternating white and brown, instead of the three in *N. (N.) othello*: prominent ones on the shoulder and base, and two much narrower ones at the periphery. Also, the two ribs along the outer margin of the operculum are more widely spaced, and the inner rib not as

sharply crested, as in typical *N. (N.) othello*. The color pattern is nearly identical to that of *N. (N.) grayi* Philippi, 1850, although that species has a fifth brown and white band near its suture. More specimens than the present two would be needed to erect a subspecies of *N. (N.) othello* or a new species for this variant.

Natica (Naticarius) caneloensis Hertlein & Strong, 1955 Pl. 37, figs. 3, 4

Natica caneloensis Hertlein & Strong, 1955, p. 287, pl. 2, figs. 13, 18.

Natica (Natica) caneloensis Hertlein & Strong, Keen, 1958, p. 320, fig. 257; Parker, 1964, p. 153; Keen, 1971, p. 473, fig. 860.

Description. —

Color: Shell pale greyish brown, with three rows of quadrate chestnut-brown spots: rows of large spots on the shoulder and periphery, and a row of smaller spots (which may be lacking) on the base; narrow band of tan or dull yellow occurs just below suture. Nuclear whorls medium orange brown, becoming white. Interior pale violet. Periostracum thin, pale to medium yellowish brown.

Size: Average specimen, height 28 mm, diameter 26 mm; largest specimen, height 29.8 mm, diameter 28.0 [LACM, no number, off northern Peru].

Shell form: Shell globose, spire moderately elevated, body whorl inflated; whorls evenly rounded; shell thin; nuclear whorls three, smooth; postnuclear whorls $3\frac{1}{4}$; suture moderately impressed. Axial sculpture of fine, retractive grooves that extend from the suture less than halfway to the periphery, and become indistinct on the final adult whorl; spiral sculpture of minute, poorly developed, obscure costellae. Parietal callus extremely thin, transparent, lightly filling posterior apertural angle; anterior lobe well-developed. Umbilicus open, relatively narrow; sulcus narrow and shallow; channel tapers to a point anteriorly. Umbilical callus narrow, gently tapered anteriorly and posteriorly. Basal lip not thickened.

Operculum: Calcareous, white, central area dark from incorporated sediment grains; outer margin with two raised ribs undercut by adjacent deep grooves; inward from marginal ribs are four to seven lower and flatter ribs separated by very narrow and shallow grooves; outermost margin with one minute, weakly pustulate costella.

Specimens examined. — One hundred fifty.

Geographic occurrence and habitat. — Cabo San Lucas, south-

ernmost Baja California ($22^{\circ}45'$ N.), and Mazatlán ($23^{\circ}14'$ N.), Mexico, south to Paita, Peru (5° S.). Found alive in depths of 118 to 133 metres, with empty shells known in as shallow as 24 metres.

Type locality. — Port Parker, Costa Rica (Hertlein & Strong, 1955).

Type material. — Holotype, CAS 9891.

Discussion. — Hertlein & Strong (1955) stated that *N. (N.) caneloensis* may have four distinct spiral bands of brown spots per whorl, although their holotype shows only two such bands. Most specimens of *N. (N.) caneloensis* have two such bands, at the shoulder and periphery, and some individuals have a third band of smaller spots on the base, but I have seen no more than three bands per whorl.

Hertlein and Strong (1955) described four ribs and five grooves on the operculum of their holotype, without noting variations among other specimens. In a larger sample, the number of ribs is seen to vary as described above, with a total of four to seven flattened inner ribs and two stronger outer ribs.

Natica (Naticarius) caneloensis differs clearly from *N. (N.) brunneolinea* McLean, 1970, and *N. (N.) scethra* Dall, 1908, in shell color and opercular sculpture but is close to these species in shell form. *Natica (Naticarius) caneloensis* differs from *N. (N.) brunneolinea* by lacking a low ridge or angulation along the anterior margin of its umbilical channel, by having a more sharply attenuated umbilical channel, and by having a thinner parietal callus without a distinct growing margin. *Natica (Naticarius) caneloensis* differs from *N. (N.) scethra* by having its umbilical callus more attenuated posteriorly, a deeper and narrower umbilical sulcus, more inflated whorls, and by lacking a low ridge or angulation along the anterior margin of its umbilical channel.

Natica (Naticarius) colima Strong & Hertlein, 1937 Pl. 37, figs. 5, 6

Natica colima Strong & Hertlein, 1937, p. 174, pl. 35, figs. 12, 13, 16.

Natica (Natica) colima Hertlein & Strong, Keen, 1958, p. 32, fig. 259; Parker, 1964, p. 153; Keen, 1971, p. 475, fig. 862.

Description. —

Color: Shell with irregular axial stripes of alternating medium brown and white, interrupted below suture and at periphery by narrow spiral bands of white; wider pale-brown bands usually occur

on shoulder and between base and periphery; base white; nuclear whorls medium orange brown; early adult whorls often grayish; callus white; interior streaked with violet and white, with white band at suture and base. Periostracum thin, pale yellowish brown.

Size: Average specimen, height 18 mm, diameter 15 mm; largest specimen, height 22.5 mm, diameter 19.9 mm [LACM 67-20, Mazatlán, Mexico].

Shell form: Shell somewhat elongate, spire moderately elevated, body whorl inflated; whorls evenly rounded, shoulder slightly flattened; shell thin; nuclear whorls three, with weak, closely spaced, microscopic spiral costellae; postnuclear whorls three; suture moderately impressed. Adult whorls smooth except for closely spaced retractive axial grooves extending from suture halfway to periphery on first two adult whorls, becoming indistinguishable from growth lines on final adult whorl. Parietal callus thin, transparent at its center, lightly filling posterior apertural angle; anterior lobe weak, extending over umbilicus. Umbilicus open; sulcus broad, shallow; channel narrows anteriorly nearly to a groove. Umbilical callus narrow, with gentle anterior taper, more abrupt posterior taper; slightly concave anteriorly; funicle low, broad. Inner lip thickened, basal lip thin.

Operculum: Calcareous, white, central area often brown from incorporated sediment grains; central area shallowly concave. Outer surface typically sculptured with eight sharply incised spiral grooves (may have seven to ten), separated by seven flat-topped to slightly concave ribs, with a rounded outermost rib. Inner margin with fine irregular wrinkles along its posterior half, and microscopic longitudinal wrinkles along its anterior half. Outer margin with one to three (usually two) microscopic riblets, indistinctly beaded.

Specimens examined. — Fifty-nine.

Geographic occurrence and habitat. — Cedros Island, western Baja California, Mexico (28° N.), throughout the Gulf of California, and south to Golfo de Nicoya, Costa Rica (10°09' N.). Found alive in depths of 32 to 130 metres, most commonly in 45 to 65 metres.

Type locality. — CAS locality 27574, lat 18°33' N., long 103°45' W., Punta San Juan de Lima, about 47 miles southwest of Manzanillo, Colima, Mexico; 52 fathoms (Strong & Hertlein, 1937).

Type material. — Holotype, CAS 6996.

Discussion.—The color pattern is often poorly developed, so that specimens may mostly be pale brown. The final one-third of a large adult is usually axially streaked with light and medium brown, lacking spiral color patterns entirely, no matter how strong the spiral pattern may have been on earlier whorls. Variation in the number of spiral ribs on the operculum, from 7 to 10, is seen in a single population and has no obvious significance.

Natica (Naticarius) scethra Dall, 1908

Pl. 37, figs. 7, 8

Natica (Cochlis) scethra Dall, 1908, p. 333, pl. 11, fig. 5; M. Smith, 1944, p. 12, fig. 132.

Natica (Natica) scethra Dall, Keen, 1971, p. 475, fig. 866.

Description.—

Color: Shell light to medium yellowish brown, usually axially streaked, commonly but not predominately with narrow pale bands at the suture, on the shoulder, and below the periphery; base and callus white. Nuclear whorls light to medium brown, becoming white on last half-whorl. Periostracum thin, pale yellowish brown.

Size: Average specimen, height 24 mm, diameter 21 mm; largest specimen, height 29.3 mm, diameter 26.1 mm [LACM, uncataloged, off northern Peru in 160 metres].

Shell form: Shell somewhat elongate, spire moderately elevated; body whorl inflated, whorls evenly rounded; shell thin; nuclear whorls three, smooth; postnuclear whorls three; suture moderately impressed. Spiral sculpture of minute, poorly developed, obscure costellae; axial sculpture of fine, retractive grooves that extend from suture halfway to periphery, better developed on early adult whorls. Parietal callus thin, transparent, lightly filling posterior apertural angle, with weak to moderate anterior lobe overhanging umbilicus. Umbilicus open, narrow, with a shallow sulcus and a channel that tapers anteriorly but not to a point; a low cord or angulation bounds the anterior side of the channel near the inner lip. Umbilical callus narrow, gently tapered anteriorly, more abruptly tapered posteriorly, slightly concave anteriorly. Basal lip not thickened.

Operculum: Calcareous, white, central area often dark from incorporated sediment grains; outer surface smooth except for two deep, sharply incised grooves near outer margin that form two undercut ribs, one between the grooves and one along the outer opercular

margin. Outermost margin with one minute, weakly pustulate costella.

Specimens examined.—Two hundred ninety-two.

Geographic occurrence.—Off La Paz, southeastern Baja California, Mexico ($24^{\circ}15'$ N.), south to near Islas Lobos de Tierra, northern Peru ($6^{\circ}23'$ S., $80^{\circ}56'$ W.). Rare throughout nearly its whole range, and not known in the Gulf of California north of La Paz. All but about 40 of the specimens I examined came from two dredge hauls in the Gulf of Tehuantepec, southernmost Mexico (16° N.), and one off of northern Peru. Found alive in depths of 37 to 281 metres, most abundantly in depths of 160 metres off northern Peru, in muddy substrates.

Type locality.—Gulf of Panama, in 153 fathoms; U.S.S. "Albatross" station 3391 (Dall, 1908).

Type material.—Holotype, USNM 123048.

Discussion.—*Natica (Naticarius) scethra* differs from *N. (N.) othello* Dall, 1908, by having a lower, more globose form, an umbilicus of more uniform width, and a smaller umbilical sulcus. *Natica (Naticarius) scethra* has two grooves near the opercular outer margin, whereas *N. (N.) othello* has two ribs.

Natica (Naticarius) colima Strong & Hertlein, 1937, differs from *N. (N.) scethra* by its color pattern, prominent umbilical sulcus, and more abruptly tapered umbilical channel, plus having a multigrooved operculum.

The principal differences between *N. (N.) scethra* and *N. (N.) caneloensis* Hertlein & Strong, 1955, are shell color and opercular sculpture. *Natica (Naticarius) caneloensis* has three spiral rows of brown spots on each whorl, and the operculum has six to nine ribs. However, these two species are essentially indistinguishable in shell form. *Natica (Naticarius) caneloensis* has a more globose shell, with a lower spire, and an umbilical callus that is slightly wider and has a slightly more abrupt posterior taper than seen in *N. (N.) scethra*. These species probably could not be distinguished if they were preserved as fossils lacking color and opercula.

Possible remnants of microscopic spiral sculpture are present on some nuclear whorls of specimens at hand, but none is preserved well enough to show the sculpture clearly, if it exists.

Natica (Naticarius) brunneolinea McLean, 1970

Pl. 37, figs. 9-11

Natica brunneolinea McLean, 1970, p. 313, pl. 46, figs. 9, 10.

Natica (Natica) brunneolinea McLean, Keen, 1971, p. 473, fig. 859.

Description. —

Color: Shell marked with narrow, alternating axial stripes of medium brown and yellowish white, from middle of shoulder to point just below periphery; color becomes paler and fades out toward suture, with narrow band of orange or yellowish white at suture; base and umbilical area white; interior whitish, showing exterior color pattern. Nuclear whorls dark brown, becoming whitish. Periostracum thin, pale yellowish white.

Size: Average specimen, height 22 mm, diameter 21 mm; largest specimen, height 45.8 mm, diameter 42.3 mm [LACM type No. 1283, Isla Santa Cruz, Galápagos Islands].

Shell form: Shell globose, spire moderately elevated, body whorl inflated; whorls evenly rounded, slightly concave below suture; shell thin; nuclear whorls three, slightly tabulate, with minute retractive axial grooves extending a short way from the suture; postnuclear whorls three; suture slightly impressed. Axial sculpture of retractive grooves that extend from suture less than halfway to periphery, more sharply incised on early whorls; spiral sculpture of minute, poorly developed, obscure costellae. Parietal callus thin, transparent, lightly filling posterior apertural angle; anterior lobe well developed. Umbilicus open, relatively narrow; sulcus distinct but broad and shallow, rounded; channel tapers anteriorly, but remains broadly open to inner lip; a low cord or angulation bounds the anterior side of channel near the inner lip. Umbilical callus narrow, very gently tapered anteriorly, more abruptly tapered posteriorly. Basal lip not thickened.

Operculum: Calcareous, white, central area often dark from incorporated sediment grains; outer surface smooth except for two deep, sharply incised grooves near outer margin that form two undercut ribs, one between the grooves and one along the outer opercular margin. Outermost margin with one minute, weakly pustulate costella.

Specimens examined. — Fourteen.

Geographic occurrence and habitat. — The Galápagos Islands, Ecuador (0°10' S., 87°45' W.), dredged in 37 to 292 metres depth.

Type locality. — Academy Bay, Isla Santa Cruz, Galápagos Islands, Ecuador, 0°45' S., 90°20' W., 50-100 fathoms (McLean, 1970).

Type material. — Holotype, LACM 1282.

Discussion. — This species is most similar to *N. (N.) scethra* Dall, 1908, and the opercula of the two species are indistinguishable. The most obvious difference is in the color patterns, the strong axial banding of *N. (N.) brunneolinea* contrasting to the more evenly brown color of *N. (N.) scethra*. In shell form, *N. (N.) brunneolinea* differs from the other species by its lower shell and more inflated body whorl, with more weakly impressed sutures, slightly broader umbilical callus, and more arcuate umbilical channel. Although the two species are not known to occur together, they are closely related and probably derived from a common ancestor.

Natica (Naticarius) grayi Philippi, 1850 Pl. 37, fig. 12; Pl. 40, fig. 1

Natica depressa Gray, 1839, p. 136, pl. 36, fig. 2.

Not *Natica depressa* Sowerby, 1812, vol. 1, p. 21, pl. 5, lower figs. [fossil, England].

Not *Natica glaucinoides* var. *B depressa* Grateloup, 1847, Atlas, *Natica*, pl. 5, figs. 11, 12 [fossil, France].

Natica grayi Philippi, 1850, pp. 74-75, pl. 11, fig. 13 (text 1851) [replacement name for *N. depressa* Gray, 1839, not Sowerby, 1812]; Hertlein & Strong, 1955, pp. 286-287, pl. 2, fig. 14.

Natica (Natica) grayi Philippi, Keen, 1958, p. 320, fig. 260; Parker, 1964, p. 153; Keen, 1971, p. 475, fig. 863.

Natica catenata Philippi, 1851, p. 130, pl. 18, fig. 11 (text 1853); Philippi, 1853, p. 233; Reeve, 1855, pl. 21, fig. 92a, not 92b, c; Sowerby, 1883, p. 82, pl. 8, fig. 106, not 107; Tryon, 1886, p. 22, pl. 4, figs. 71-73; Stearns, 1894a, p. 195; Pilsbry & Lowe, 1932, p. 126 [as "*catenatus*"]; Palmer & Hertlein, 1936, pp. 78-79, pl. 19, figs. 2, 11; M. Smith, 1944, p. 12 [not fig. 124 = *N. (N.) chemnitzii* Pfeiffer, 1840, treated herein].

Description. —

Color: Shell light to medium brown, commonly grayish, with five narrow spiral white bands marked with dark-brown spots; uppermost band near suture is most distinct on early whorls, another band is on shoulder, one at periphery, and two on base; lowermost band is along border of white base; there is narrow white band between suture and uppermost brown-spotted band; callus white; interior white, sometimes showing pale violet, showing exterior color pattern. Nuclear whorls medium brown. Periostracum thin, pale yellowish white.

Size: Average specimen, height 14 mm, diameter 14 mm; largest

specimen, height 20.4 mm, diameter 20.3 mm [LACM HH-112, Venado Island, Panama Bay, Panama].

Shell form: Shell somewhat elongate, spire moderately elevated, body whorl inflated; shoulder slightly flattened, with weak tabulation near the suture; shell thin; nuclear whorls three, with microscopic retractive grooves on shoulder; postnuclear whorls two; suture slightly to moderately impressed. Spiral sculpture of inconspicuous, irregularly spaced lineations. Axial sculpture of closely spaced and sharply incised retractive grooves that extend from suture halfway to the periphery; additional axial sculpture of incremental growth lines only. Parietal callus thin, transparent, lightly filling posterior apertural angle; anterior lobe weak, extends over umbilicus. Umbilicus open, sulcus broad and deep; channel narrows anteriorly, but not to a point or groove. Umbilical callus concave, strongly depressed anteriorly; anterior end gently tapered, posterior end abruptly terminated, greatest width at posterior margin; funicle robust. Basal lip slightly thickened.

Operculum: Calcareous, white, with depressed central area and slightly thickened nucleus; smooth except for two sharp, closely set ribs along outer margin; outer side of outermost rib is wrinkled, appears almost beaded.

Specimens examined. — Four hundred eighty.

Geographic occurrence and habitat. — Cabo San Lucas, southernmost Baja California, Mexico ($22^{\circ}45'$ N.), the southern end of the Gulf of California, and south to Paita, Peru (5° S.), and the Galápagos Islands. Hertlein & Strong (1955) indicated a northern range limit on the outer coast of Baja California at Magdalena Bay ($24^{\circ}30'$ N.). The Galápagos Islands occurrence is based on a single dead specimen. Live specimens are found in 2 to 58 metres depth, most commonly in 5 to 15 metres, and empty shells have been found intertidally. Specimens have been found on substrates of mud, sand, and shell debris.

Stratigraphic occurrence. — *Pleistocene* — Oaxaca, Mexico (Palmer & Hertlein, 1936).

Type localities. —

Natica depressa — Unknown (Gray, 1839).

Natica catenata — Unknown (Philippi, 1851).

Type material. —

Natica depressa — BM(NH) (Dance, 1966).

Natica catenata — Unknown, presumably in BM(NH) (Dance, 1966).

Nomenclatural commentary. — This species, as *N. catenata*, was reported from Sicily by Reeve (1855) and Sowerby (1883) who, according to Tryon (1886), confused it with *N. marochiensis* Gmelin, 1791. Figures 92b and 92c of Reeve (1855) and figure 107 of Sowerby (1883) are clearly not of *N. (N.) grayi*, whereas the other figures they give are of this species. The figure given for *N. grayi* by Smith (1944) is of *N. (N.) chemnitzii* Pfeiffer, 1840, which is similar in form and color to *N. marochiensis*.

Discussion. — Five spiral bands of white and dark brown are invariably present, although the uppermost band is sometimes obvious only on early adult whorls. Some workers beginning with Hertlein and Strong (1955) reported only four such bands on the shells.

Natica (Naticarius) posuncula Hanna & Hertlein, 1938 Pl. 38, fig. 13;
Pl. 39, fig. 1

Natica posuncula Hanna & Hertlein, 1938, pp. 107-108, pl. 21, fig. 6; Keen, 1943, p. 37; Stewart, 1946, table 2.

Natica (Naticarius?) posuncula Hanna & Hertlein, Addicott, 1970a, pp. 66-67, pl. 5, figs. 3, 4.

Natica (Naticarius) posuncula Hanna & Hertlein, Marinovich, 1975, p. 172, figs. 18, 19.

Description. —

Size: Average specimen, height 21 mm, diameter 19 mm; largest specimen, height 28.1 mm, diameter (incomplete) 24.6 mm [UCB 2713, Temblor Formation, Caliente quadrangle, Kern River area, California, middle Miocene].

Shell form: Shell somewhat elongate to globose; spire moderately elevated; body whorl greatly inflated, slightly concave near suture; shell thin; whorls about five; suture slightly impressed. Shell smooth except for minute incremental growth lines and low, irregular, closely spaced axial wrinkles that extend a short way from suture of some specimens, especially on early adult whorls. Parietal callus thin to average, lightly to moderately filling posterior apertural angle; anterior lobe weak to inconspicuous, slightly overhangs umbilical sulcus. Umbilicus open; sulcus broad but shallow; channel

broad posteriorly, narrowing nearly to a groove anteriorly. Umbilical callus relatively small, with evenly rounded and slightly elevated margin; funicle strong, relatively narrow. Anterior inner lip thickened; basal lip thickened and raised into a low forward projection.

Operculum: Unknown.

Specimens examined. — One hundred seventy-four.

Stratigraphic occurrence. — Known only from middle Miocene strata. Middle Miocene: Temblor Fm., lower member (*Vertipecten* zone) at Reef Ridge, Coalinga area (Stewart, 1946), Caliente Quad. (Hanna & Hertlein, 1938; UCB), Calif.; upper part of Olcese Sand and lower part of Round Mountain Silt, Kern River area, Calif. (Addicott, 1970a; USGS; UCB); Saltos Shale Member of Monterey Shale of Hill, Carlson, and Dibblee (1958), Caliente Range, Calif. (Vedder, in Addicott, 1970a).

Type locality. — CAS locality 65, hills just north of Kern River and northeast of Barker's ranch house, Kern County, California (Hanna & Hertlein, 1938). Temblor Formation, middle Miocene.

Type material. — Holotype, CAS 7084.

Nomenclatural commentary. — This species is assigned to the subgenus *Naticarius* because some well-preserved specimens have axial wrinkles that extend from the suture part way to the periphery, even though most specimens are too worn to show this. Addicott (1970a) noted one specimen with faint spiral rows of light-brown spots, similar to the color pattern of the living Caribbean species *N. (N.) canrena* Linnaeus, 1758, the type species of *Naticarius*.

Discussion. — *Natica (Naticarius) posuncula* is most similar to *N. (N.) teglandae* Hanna & Hertlein, 1938, but differs by having a broader umbilical callus with a more strongly curved margin, and a much more robust funicle. The umbilicus of *N. (N.) posuncula* is thus filled by the callus and funicle to a greater extent than in *N. (N.) teglandae*, and the umbilical channel is correspondingly more narrow.

Natica (Naticarius) teglandae Hanna & Hertlein, 1938 Pl. 39, figs. 2-4

Natica (Natica) dalli Tegland, 1933, p. 138, pl. 14, figs. 8-12.

Not *Tectonatica dalli* Cossmann, 1925, p. 121 [= *Natica (Tectonatica)*].

Natica teglandi Hanna & Hertlein, 1938, p. 108 [new name for *N. dalli* Tegland, 1933].

Natica (Tectonatica) teglandae Hanna & Hertlein, Weaver, 1943, p. 333, pl. 68, figs. 5-7.

Natica (Natica) teglandae Hanna & Hertlein, Durham, 1944, p. 150; Addicott, 1970a, pp. 65-66, pl. 5, figs. 1, 2, 20.

Natica (Naticarius) teglandi Hanna & Hertlein, Marincovich, 1975, p. 172, figs. 16, 17.

Description. —

Size: Average specimen, (based on few specimens): height 20 mm, diameter 18 mm; largest specimen, height 26.0 mm, diameter (incomplete) 25.3 mm [UCB 32215, type Blakeley Formation, northwestern Washington, Oligocene; holotype].

Shell form: Shell subglobose to somewhat elongate, spire moderately elevated; body whorl moderately inflated, flattened to slightly concave near suture; shell thin; whorls about five, protoconch sculptured with minute, closely spaced spiral costellae; suture moderately impressed. Shell smooth except for incremental growth lines and weak, irregularly spaced axial wrinkles on some specimens. Parietal callus thin to average, lightly to moderately filling posterior apertural angle; anterior lobe weak to inconspicuous, slightly overhanging umbilical sulcus. Umbilicus open; sulcus broad but shallow; channel broad throughout its length, not narrowing much anteriorly. Umbilical callus small, with evenly rounded and slightly elevated margin; funicle strong, relatively narrow. Anterior inner lip thickened; basal lip thickened and raised into a low forward projection.

Operculum: Unknown.

Specimens examined. — Fifteen.

Stratigraphic occurrence. — Middle Oligocene to middle Miocene. Middle Oligocene: Blakeley Fm. of Weaver (1912), *Echinophoria rex* zone, Kitsap Co., Wash. (Durham, 1944). Upper Oligocene: Blakeley Fm. of Weaver (1912), *Echinophoria apta* zone, Kitsap Co., Wash. (Durham, 1944); Blakeley Fm. of Weaver (1912), Puget Sound area, Wash. (Tegland, 1933; Weaver, 1943). Lower Miocene: Clallam Fm., Pysht Quad., Clallam Co., Olympic Peninsula, Wash. (USGS); Nye Mudstone, Yaquina Quad., Lincoln Co., Ore. (USGS). Middle Miocene: upper part of Olcese Sand and lower part of Round Mountain Silt, Kern River area, Calif. (Addicott, 1970a; USGS).

Type locality. — UCB locality 681, Restoration Point, Kitsap County, Washington, Blakeley Formation of Weaver (1912) (Addicott, 1970a).

Type material. — Holotype, UCB 32215.

Nomenclatural commentary. — The specific name of *N. (N.) teglandi* was proposed by Hanna and Hertlein (1938) to replace that of *Natica (Natica) dalli* Tegland, 1933, which is preoccupied by *Natica (Tectonatica) dalli* (Cossmann, 1925). Unfortunately, *N. (N.) teglandi* was erroneously latinized with a masculine ending, even though it was named in honor of Nellie May Tegland. The emendation of the ending to the feminine gender was made by Weaver (1943) and a second time Durham (1944).

Discussion. — This species is similar to *Natica (Naticarius) posuncula* Hanna & Hertlein, 1938, from which it differs by having a narrower umbilical callus with a more gently curved margin, a less distinct funicle, and a broader umbilical channel. It is also generally similar in form to *Natica (Natica) kanakoffi* Marincovich, 1975, as noted in the discussion of that species.

***Natica (Naticarius) uvasana* Gabb, 1864**

Pl. 39, figs. 5-8

Natica uvasana Gabb, 1864, p. 212, pl. 32, fig. 277; Dickerson, 1915, p. 44; Dickerson, 1916, p. 508, pl. 38, fig. 8; Anderson & Hanna, 1925, pp. 116-117, pl. 9, figs. 3, 4; Stewart, 1927, p. 332, pl. 30, fig. 14; M. Hanna, 1927, p. 259, 305; Keen & Bentson, 1944, p. 178.

Natica (Natica) uvasana Gabb, Weaver & Kleinpell, 1963, p. 101, 187, pl. 24, figs. 12, 13; Givens, 1974, p. 77, pl. 7, fig. 18, pl. 8, fig. 1.

Natica (Naticarius) uvasana Gabb, Marincovich, 1975, p. 172, figs. 20-22.

Description. —

Size: Average specimen: height 10 mm, diameter 10 mm; largest specimen, height 15.5 mm, diameter 15.2 mm [UCR 4721/24, Matilija Sandstone, Ventura County, California, upper Eocene].

Shell form: Shell globose, spire moderately elevated; body whorl moderately inflated, evenly rounded except for slight flattening or concavity immediately below suture; shell thickness average; whorls 4; suture slightly to moderately impressed. Shell smooth except for incremental growth lines and weak, irregularly spaced axial wrinkles immediately below suture. Parietal callus thin, lightly filling posterior apertural angle; anterior lobe weak, slightly overhanging umbilicus. Umbilicus open, sulcus relatively broad but shallow, with nearly straight margin; channel tapering to a point anteriorly along inner lip. Umbilical callus small but robust, rather abruptly trun-

cated posteriorly and more gradually tapering anteriorly; funicle sharply raised. Anterior inner lip and basal lip slightly thickened.

Operculum: Unknown.

Specimens examined. — Forty-nine.

Stratigraphic occurrence. — Middle and upper Eocene of southern California. Middle Eocene: upper part of La Jolla Group, La Jolla Quad., San Diego Co., Calif. (M. Hanna, 1927); Juncal Fm., *Ectinochilus supraplicatus* fauna, Mt. Pinos area, Ventura Co., Calif. (Givens, 1974; UCR). Upper Eocene: Tejon Fm., near Fort Tejon, Kern Co., Calif. (Gabb, 1864; Dickerson, 1915, 1916; Anderson & Hanna, 1925; Stewart, 1927; ANSP, UCB; CAS; UCR); Matilija Ss., *Ectinochilus canalifer* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR); Gaviota Fm., Point Conception Quad., Santa Barbara Co., Calif. (Weaver & Kleinpell, 1963).

Type locality. — Near Fort Tejon, Kern County, California (Gabb, 1864). Tejon Formation, upper Eocene.

Type material. — Lectotype of Stewart (1927), ANSP 4233; two paralectotypes, ANSP 4233.

Nomenclatural commentary. — This species is placed in *Naticarius* because it has weak but distinct axial wrinkles or grooves that extend from the suture a short distance across the upper portion of each adult whorl. The wrinkles are often missing due to poor preservation but are clearly present on the lectotype and several other specimens.

Discussion. — This species and the middle Eocene *Natica* (*Naticarius*) *domenginica* Vokes, 1939, are the earliest Cenozoic representatives of Naticinae along the Pacific coast of the United States. The latter species is small and known only by its two type specimens, which may be juveniles of *N. (N.) wasana*. However, *N. (N.) wasana* consistently has a more robust umbilical callus and funicle than *N. (N.) domenginica*, but further collecting of the latter is necessary to clarify relationships between the two.

Natica (*Naticarius*) *wasana* is also similar to two middle Tertiary *Naticarius* species: *N. (N.) teglandae* Hanna & Hertlein, 1938, of the middle Oligocene to middle Miocene, and *N. (N.) posuncula* Hanna & Hertlein, 1938, of the middle Miocene. These two species average about twice the size of *N. (N.) wasana* and have more strongly inflated whorls. In addition, the umbilical callus of *N. (N.)*

wasana is abruptly truncated posteriorly, whereas calluses of the other two are gently tapered posteriorly, giving the umbilical callus and funicle of *N. (N.) wasana* a relatively robust look. The umbilical sulcus of *N. (N.) wasana* is excavated somewhat more deeply into the inner lip than is seen in the other two species.

Natica (Naticarius) domenginica Vokes, 1939

Pl. 36, fig. 9

Natica domenginica Vokes, 1939, pp. 167-168, pl. 21, figs. 5, 8.

Description. —

Size: Height 6.4 mm, diameter 6.0 mm (holotype); height 3.2 mm, diameter 3.4 mm (paratype).

Shell form: Shell globose, spire moderately elevated; body whorl slightly flattened to concave immediately below suture; shell thin, whorls four; suture moderately impressed. Shell smooth except for weak, irregularly spaced axial wrinkles immediately below suture. Parietal callus thin, lightly filling posterior apertural angle; anterior lobe weak, slightly overhanging umbilicus. Umbilicus open, sulcus broad but shallow, channel fairly broad throughout its length, not sharply narrowing anteriorly. Umbilical callus small, funicle low but distinct. Anterior inner lip and basal lip thickened.

Operculum: Unknown.

Specimens examined. — Holotype and paratype only.

Stratigraphic occurrence. — Known only from middle Eocene strata at type locality. Middle Eocene: type section, Domengine Fm., Coalinga Quad., Fresno Co., Calif. (Vokes, 1939; UCB).

Type locality. — Massive sandstone forming southern portion of the crest of Parson's Peak, Coalinga quadrangle, Fresno County, California; SE¼ NW¼ sec. 24, T. 18 S., R. 14 E.; about 45 feet above base of Domengine Formation at its type section (Vokes, 1939).

Type material. — Holotype, UCB 15843; paratype, UCB 15844.

Discussion. — Because this species is known only by the two type specimens, it is difficult to evaluate. However, it is similar in form to the middle to late Eocene *N. (N.) wasana* Gabb, 1864, and may be a juvenile of that species. Individuals of *N. (N.) wasana*, even juveniles, consistently have a more robust umbilical callus and funicle than *N. (N.) domenginica*, however, and the two species are not known to intergrade. It is possible that *N. (N.) domenginica*

is a juvenile of *N. (N.) teglandae* Hanna & Hertlein, 1938, of the middle Oligocene to middle Miocene, but this seems less likely because of the great difference in known stratigraphic ranges of these species. Search of the type locality of *N. (N.) domenginica* for additional specimens might clarify the relationships of this species with others in *Naticarius*.

Subgenus **CARINACCA** Marwick, 1924, p. 553

Type species: *Ampullina waihaoensis* Suter, 1917, by original designation. Eocene, New Zealand.

Diagnosis. — Shell small to large, somewhat elongate, spire low to moderately elevated, umbilicus broadly open and bounded by strongly raised or swollen cord, umbilical callus compact, funicle narrow but robust. Shell smooth or with spiral sculpture of obscure spiral threads and axial sculpture of minute retractive grooves below suture and on base.

Discussion. — *Carinacca* is characterized by the raised or swollen cord bounding its broadly open umbilicus. The species below is the only *Carinacca* known outside of New Zealand.

Natica (Carinacca) rosensis M. A. Hanna, 1927 Pl. 39, figs. 10-12;
Pl. 41, fig. 1

Natica rosensis M. A. Hanna, 1927, p. 305, pl. 47, fig. 7 [not pl. 44, figs. 13-15, as stated].

Natica (Carinacca) rosensis M. A. Hanna, Keen & Bentson, 1944, p. 177; Givens, 1974, p. 77, pl. 8, fig. 12.

Description. —

Size: Average specimen, height 6.6 mm, diameter 5.7 mm; largest specimen, height 7.0 mm (incomplete), diameter 5.7 mm (incomplete) [paratype, UCB 30928, La Jolla Group, Rose Canyon, San Diego, California, middle Eocene].

Shell form: Shell somewhat elongate, spire moderately elevated; body whorl not greatly inflated; shell of average thickness, with solid appearance; whorls at least four (apexes missing from all known specimens); suture moderately impressed. Axial sculpture of minute retractive grooves that extend down from suture one-third of way to periphery (best developed on early adult whorls) and also extend a short distance from raised basal part of shell; spiral sculpture of minute, obscure threads on raised basal part of shell. Parietal callus moderately thick, heavily filling posterior apertural angle, with

moderate anterior lobe slightly overhanging umbilicus. Umbilicus broadly open, exposing earlier whorls, with moderate but distinct sulcus. Umbilical callus small, narrow, tapering gently above and below; funicle narrow but robust. Anterior inner lip greatly thickened. Umbilical area distinctly set off by a broad, strongly raised cord that is sculptured by obscure spiral threads.

Operculum: Unknown.

Specimens examined. — Twenty.

Stratigraphic occurrence. — Middle Eocene strata of southern California. Middle Eocene: Juncal Fm., *Turritella wasana applinae* fauna, Mount Pinos area, Ventura Co., Calif. (Givens, 1974; UCR); upper part of La Jolla Group, Rose Canyon, San Diego Co., Calif. (M. A. Hanna, 1927; UCB; UCLA).

Type locality. — South of benchmark 176 0.2 mile, 2 miles east of La Jolla, San Diego County, California. In the bottom of Rose Creek where the creek makes a strong bend to the west. Just west of the brick plant (M. A. Hanna, 1927). Upper part of the La Jolla Group, middle Eocene.

Type material. — Holotype, UCB 30926; paratypes, UCB 30927 and 30928.

Discussion. — This species is unique among northeastern Pacific Cenozoic naticids by having a strongly raised basal cord that bounds the umbilicus. In addition, it is characterized by its small size, compact umbilical callus and relatively robust funicle.

Carinacca is a genus proposed for New Zealand Eocene naticids and *N. (C.) rosensis* is the only species yet allocated to it in the eastern Pacific.

Subgenus **LUNAIA** Berry, 1964, p. 148

Type species: *Lunaia lunaris* Berry, 1964, by original designation. Living, tropical eastern Pacific. Figured herein.

Diagnosis. — Shell medium in size, globose, thin; spire low to moderately elevated. Axial sculpture of short, retractive axial grooves extending from suture part way to periphery on early adult whorls, usually absent on later adult whorls. Umbilicus narrow. Umbilical callus slender, merely an elongate thickening along edge of inner lip; funicle distinct but low. Operculum with one spiral rib near outer margin.

Discussion. — This subgenus is characterized by its peculiar

funicle, which is reduced to a narrow twisted vertical ridge along the inner lip. It is known only by the type species.

Natica (Lunaia) lunaris (Berry, 1964)

Pl. 40, figs. 2, 3

Lunaia lunaris Berry, 1964, pp. 148-149.

Natica (Lunaia) lunaris (Berry), Keen, 1971, p. 477, fig. 869.

Description. —

Color: Shell light to medium brown, with grayish cast in juveniles; base and umbilicus paler than rest of shell, usually white, narrow whitish band occurs below suture; may show white blotches on shoulder; white base sometimes bounded above and at aperture by narrow band of dark brown; interior reflects exterior colors. Periostracum thin, light to medium yellowish brown, obscures shell colors in some individuals.

Size: Average specimen, height 22 mm, diameter 19 mm; largest specimen, height 27.7 mm, diameter 25.5 mm [S. S. Berry collection, paratype, Estero Tastiota, Sonora, Mexico].

Shell form: Shell relatively high, spire moderately elevated to low; body whorl highly inflated, slightly tabulate below suture; shell thin; nuclear whorls three, smooth; postnuclear whorls three; suture strongly impressed. Axial sculpture of fine, retractive grooves below suture that are best developed on first 1½ adult whorls, usually absent later on. Spiral sculpture of minute, closely spaced, slightly wavy costellae, three of which are more prominent at periphery of juveniles. Parietal callus extremely thin, transparent, inconspicuous, lacking anterior lobe, lightly filling posterior apertural angle. Umbilicus open posteriorly, narrow; sulcus shallow; channel reduced to shallow groove alongside callus. Umbilical callus narrow, merely a thickening of inner lip, fills anterior half of umbilicus; funicle low, indistinct. Basal lip thin.

Operculum: Calcareous, white, central area often brown from incorporated sediment grains. Outer surface sculptured with minute, weakly developed spiral costellae, and with one narrow rib near outer margin; rib is undercut on each side and separated by shallow, flattened groove from upturned outer margin of operculum.

Specimens examined. — Thirty-two.

Geographic occurrence and habitat. — Estero Tastiota, Sonora, Mexico (28°22' N.), to Paita, Peru (5° S.). South of the Gulf of

California, known only by one specimen from Panama and two from Paita, Peru [CAS, Frizzell collection]. Found on mud bottoms in depths of 13 to 46 metres.

Type locality. — Off Estero Tastiota, Sonora, Mexico, in 14 to 25 fathoms depth (Berry, 1964).

Type material. — Holotype, S. S. Berry collection, Redlands, California.

Discussion. — The three heavier spiral costellae at the periphery, noted by Berry (1964), are distinct only on juveniles. The operculum of this species has not previously been described.

Subgenus **GLYPHEPITHEMA** Rehder, 1943, p. 196

Type species: *Natica idiopoma* Pilsbry & Lowe, 1932. Living, tropical eastern Pacific. Figured herein.

Diagnosis. — Shell medium in size, globose to slightly elongate; whorls slightly flattened below suture, distinctly inflated, with short, sharply incised grooves that extend part way from the suture to the periphery and are indistinct on final adult whorl. Umbilicus broad, with cavernous sulcus and broad channel. Parietal callus thin. Umbilical callus small, semicircular, with a deep posterior notch that isolates the posterior margin as a low, sharp riblet; funicle robust. Operculum with several spiral ribs; outermost rib hollow; ribs have pustulate summits and two outermost ribs have pustules commonly elongated into rods that roof over the intervening grooves.

Discussion. — *Glypheapithema* is characterized by having the posterior margin of its umbilical callus isolated as a low, sharp riblet, and by its elaborately sculptured operculum with short rods joining the summits of adjacent spiral ribs. The name was applied by Rehder (1943) to two Caribbean and one eastern Pacific species with certainty.

Natica (Glypheapithema) idiopoma Pilsbry & Lowe, 1932 Pl. 40, figs. 4, 5

Natica (Naticarius) idiopoma Pilsbry & Lowe, 1932, p. 84, pl. 9, figs. 8-11.

Natica idiopoma Pilsbry & Lowe, M. Smith, 1944, p. 12, fig. 133.

Natica (Natica) idiopoma Pilsbry & Lowe, Keen, 1958, p. 320, fig. 261; Keen, 1971, p. 475, fig. 864.

Glypheapithema idiopoma (Pilsbry & Lowe), Rehder, 1943, p. 196.

Description. —

Color: Shell light to medium brown with four narrow spiral bands of white marked with medium-brown spots; uppermost band

on shoulder, one at periphery, and two on base; one or both basal bands may be absent; shoulder between two upper bands is often darker brown than rest of shell; callus white; interior white near outer lip, pale brown within. Periostracum thin, pale yellowish white, may obscure shell colors.

Size: Average specimen, height 15 mm, diameter 14 mm; largest specimen, height 21.3 mm, diameter 22.0 mm [USNM 4120, Cabo San Lucas, Baja California, Mexico].

Shell form: Shell somewhat elongate, spire moderately elevated, body whorl inflated; whorls distinctly flattened at suture; shell thin; nuclear whorls $2\frac{1}{2}$, with weak, microscopic, closely spaced spiral costellae; postnuclear whorls three; suture strongly impressed. Adult whorls smooth except for retractive grooves extending from suture halfway to periphery, grooves are well developed and closely spaced on early whorls, obscure and widely spaced on final whorl; incremental axial growth lines are strongest below suture. Parietal callus thin, lightly filling posterior apertural angle; anterior lobe weak. Umbilicus widely open, deeply excavates posterior inner lip of aperture; sulcus broad, fairly deep, rounded; channel broadly open to inner lip. Umbilical callus relatively small, gently tapered anteriorly, with a deep posterior notch that isolates the posterior margin as a low, sharp riblet; funicle robust. Anterior inner lip and basal lip slightly thickened.

Operculum: Calcareous, white, with five spiral ribs in adults; innermost rib poorly developed, may appear as thickening of nucleus; second rib is largest, irregularly pustulate; third rib narrow, undercut on its outer side; fourth rib narrow, set close to fifth rib; a weak riblet usually occurs between third and fourth ribs. Fifth rib hollow, contains narrow cavity formed by addition of thin wall to outer surface; both walls of fifth rib have minutely pustulate summits, with pustules commonly elongated into rods that join the two walls and roof over intervening cavity; one minute, irregularly beaded costella runs along outer margin of operculum.

Specimens examined. — One hundred twenty-nine.

Geographic occurrence and habitat. — Bahía San Quintin, western Baja California, Mexico ($30^{\circ}22'$ N.), in the southern Gulf of California, and south to Puerto Utria, Colombia ($5^{\circ}59'$ N.), and the Galápagos Islands, Ecuador. Rare north of the southern tip of

Baja California, or south of Panama Bay, Panama. Collected living in depths of 4 to 61 metres, most abundantly in 18 to 35 metres, on bottoms of mud, sand, and shell debris.

Type locality. — San Juan del Sur, Nicaragua (Pilsbry & Lowe, 1932).

Type material. — Holotype, ANSP 155437.

Nomenclatural commentary. — *Natica* (*Glypheapithema*) *idiopoma* was designated the type species of *Glypheapithema* by Rehder (1943), who also included Atlantic, Caribbean, and Indo-Pacific species in the genus. *Glypheapithema* was founded upon the opercular features of *N. (G.) idiopoma*, although Rehder did not describe the operculum in detail or contrast it to opercula of other species. Although *N. (G.) idiopoma* has the most elaborately sculptured operculum of eastern Pacific naticids, opercular sculpture alone is an insecure basis for generic distinctions in this family, because it may vary widely within one species, and because it shows no consistent relationship to shell features of accepted generic significance. Fortunately, as described here, there are shell features of *N. (G.) idiopoma* that distinguish it from other naticids and place it in a separate subgenus.

Discussion. — This species is readily identified by the deep notch on the posterior side of the umbilical callus, its color pattern and tabulate whorls, and its highly sculptured operculum. The slender riblet distinct from the main mass of the umbilical callus is unique among eastern Pacific naticids. On some individuals, this riblet is not developed strongly, and the umbilical callus has a more gradual anterior termination, giving the shell an atypical appearance.

There are more spiral ribs on opercula of juveniles than on those of adults. In young shells, the massive second rib is lacking and replaced by four or five narrower ribs, which later coalesce at their crests to form a single rib. The more numerous juvenile ribs are concealed later by irregular calcareous deposits on the central area of the operculum.

Subgenus **STIGMAULAX** Mörch, 1852, p. 133

Type species: *Nerita sulcata* Born, 1778, by subsequent designation (Harris, 1897). Living, West Indies.

Diagnosis. — Shell small to medium in size, globose to slightly

elongate, body whorl distinctly inflated. Sculpture of sharply incised axial grooves that extend from suture to base, sometimes also with weaker spiral grooves to form a reticulate pattern. Umbilicus broad, with deep sulcus separating umbilical and parietal calluses. Parietal callus thick. Umbilical callus semicircular, with concave anterior surface; posterior portion of callus distinctly extended as a low swelling; funicle massive. Inner lip sinuous. Operculum with several small ribs on outer portion and more massive, elevated inner ridge formed of coalesced ribs.

Discussion. — *Stigmaulax* is characterized by its axial or reticulate pattern of sharply incised grooves, its broadly open umbilicus with deep sulcus, and its operculum with a massive inner ridge. It is an exclusively tropical subgenus.

Natica (Stigmaulax) broderipiana Récluz, 1844 Pl. 40, figs. 6, 7

Natica broderipiana Récluz, 1844, p. 205; Philippi, 1851, pp. 134-135, pl. 17, fig. 5, pl. 19, fig. 2 (text 1853); Reeve, 1855, pl. 15, figs. 66a, b; Sowerby, 1883, p. 80, pl. 7, fig. 91; Dall, 1909a, p. 235; Jordan, 1936, p. 163; Hertlein & Strong, 1955, pp. 284-285, pl. 3, fig. 8.

Natica (Stigmaulax) broderipiana Récluz, M. Smith, 1944, p. 12, fig. 126 [as "*broderipiana* Reeve"]; Keen, 1958, p. 321, fig. 263; Parker, 1964, p. 153, pl. 4, fig. 3; Keen, 1971, p. 477, fig. 870.

Natica alapa-pilionis var. *broderipiana* Récluz, Tryon, 1886, p. 21, pl. 4, figs. 65-67.

"*Natica alapa-pilionis* (Röding)," Carpenter, 1864, p. 624 [not *N. alapa-pilionis* (Röding, 1798), living, Indo-Pacific].

"*Natica zonaria* Lamarck," Stearns, 1894a, p. 195 [not *N. zonaria* Lamarck, 1816, = *N. alapa-pilionis* (Röding, 1798), living, Indo-Pacific].

Natica iostoma Menke, 1847, p. 178; Tryon, 1886, p. 21, pl. 4, fig. 67 [as synonym of *N. alapa-pilionis* var. *broderipiana*].

Natica broderipiana var. *iostoma* Menke, Philippi, 1851, p. 120, pl. 17, fig. 5.

Natica taslei Récluz, 1853a, pp. 53-54, pl. 2, figs. 11, 12; Tyron, 1886, p. 21, pl. 4, fig. 66 [as synonym of *N. alapa-pilionis* var. *broderipiana*].

Description. —

Color: Shell buff to medium orange brown, with three spiral bands of alternating white and purplish brown; middle spiral band divided into wider upper portion and narrower lower portion; base white; narrow white band occurs just below in darker colored shells; callus white; interior white. Periostracum thin, pale yellowish white, inconspicuous.

Size: Average specimen, height 19 mm, diameter 17.5 mm; largest specimen, height 21.4 mm, diameter 19.9 mm [AHF 945-39, Secas Islands, Panama].

Shell form: Shell elongate, spire moderately elevated to high; body whorl inflated, aperture large; whorls evenly rounded; shell

moderately thick; nuclear whorls $2\frac{1}{2}$, smooth; postnuclear whorls three; suture strongly impressed. Spiral sculpture of weak, minute, closely spaced costellae that are slightly wavy. Axial sculpture of sharply incised grooves extending from suture to umbilicus, strongest on shoulder and base; low, rounded riblets formed between grooves at suture; axial incremental growth lines also present. Parietal callus fairly heavy, thickly filling posterior apertural angle, acutely tapered anteriorly; anterior lobe inconspicuous. Umbilicus broadly open, with large sulcus and a broad channel tapering to a groove anteriorly. Umbilical callus large, broad, semicircular in outline, with concave anterior portion; low ridge on posterior side of callus is reflected as bump on callus margin; funicle large, filling anterior half of umbilicus, with a sharply incised groove along its anterior margin. Anterior inner lip and basal lip thickened.

Operculum: Calcareous, white, usually with pale gray or brown along median rib. Central area depressed, slightly concave, smooth, with distinct blisterlike swelling covering its earliest-formed portion. Outer surface sculptured with numerous spiral ribs, several of which merge to form a relatively narrow, sharply crested median ridge with a pustulate surface; three outer ribs flat topped, undercut by intervening grooves; outermost rib narrow, sharp, minutely beaded on inner side, often connected to adjacent rib by calcareous roofing of intervening groove. Outer margin with four to five minute, finely beaded riblets.

Specimens examined. — Two hundred thirty-nine.

Geographic occurrence and habitat. — Cabo San Lucas, southernmost Baja California, Mexico ($22^{\circ}45'$ N.), throughout the Gulf of California, and south to Manglar Alto, Ecuador ($1^{\circ}55'$ S.). Found alive in depths of 2 to 70 metres, mostly between 15 and 45 metres, in sand and mud.

Stratigraphic occurrence. — Pliocene(?): Costa Rica, Panama and Ecuador (Hertlein & Strong, 1955). Pleistocene: Magdalena Bay, Baja California (Jordan, 1936), Islas Tres Marías, Mexico, and Panama (Hertlein & Strong, 1955).

Type localities. —

Natica broderipiana — "Xipixapi, West Columbia" [Jipijapa, Ecuador], 29 metres, sandy mud (Récluz, 1844).

Natica iostoma — Mazatlán, Mexico (Menke, 1847).

Natica taslei — Mazatlán, Mexico (Récluz, 1853a).

Type material. —

Natica broderipiana — Holotype, No. 1350/51, in Muséum d'Histoire Naturelle, Geneva, Switzerland (E. Binder, written comm.).

Natica iostoma — Unknown, sold to a dealer (Zilch, 1958, p. 53).

Natica taslei — Unknown.

Nomenclatural commentary. — This species was often confused with the Indo-Pacific species *N. alapapilionis* (Röding, 1798) by early workers, because of similar color patterns. However, *N. alapapilionis* lacks the axial grooves from suture to umbilicus that places *N. (S.) broderipiana* in the subgenus *Stigmaulax*.

Discussion. — There is a functional relationship between the sculpture of the operculum and the shape of the umbilicus and umbilical callus in this species. When the animal is extended from the shell, the spiral median opercular ridge fits closely into the curved umbilical opening and the blisterlike swelling over the origin of the operculum fits exactly into the concave anterior portion of the umbilical callus. The greatest width of the opercular ridge is the same as the width of the umbilical sulcus where it notches the inner lip; the opercular ridge thus rests in this sulcal notch and fixes the operculum in one position when the animal is extended. This relationship is also clearly seen in *N. (S.) elenae* Récluz, 1844, which has a closely similar operculum and umbilicus, and has not been previously described. The matching opercular and umbilical features may be a defense mechanism that maintains the operculum in the best position for rapid closing in case of danger. This, however, would be an elaborate method of achieving a condition that would probably have been selected for anyhow under normal living conditions. Rapid closing response is probably beneficial to any operculate marine snail, especially to active ones such as the naticids, and would likely not be dependent upon matching opercular and umbilical morphology. Among eastern Pacific naticids, this is seen only in *N. (S.) broderipiana* and *N. (S.) elenae*. This relationship may somehow be beneficial when the animal is plowing beneath the substrate in search of prey. The interlocked operculum and shell may provide a point for leverage when the animal is extending itself from

its shell and wrapping its body around a victim. Similarly, the locked operculum and shell may be of help when maneuvering within the substrate, providing leverage for twisting its body to and fro while seeking out prey. This relationship between shell and operculum is also true for the Caribbean Miocene species *N. (S.) guppiana* (Toula, 1909), judging from illustrations (Woodring, 1957, pl. 20, figs. 11-18).

***Natica (Stigmaulax) elenae* Récluz, 1844**

Pl. 40, figs. 8, 9

Natica elenae Récluz, 1844, pp. 205-206; Philippi, 1851, pp. 135-136, pl. 19, fig. 4 (text 1853); Reeve, 1855, pl. 21, figs. 9a, b; Sowerby, 1883, p. 79, pl. 9, fig. 150; Tryon, 1886, pp. 28-29, pl. 8, figs. 55, 56; Dall, 1909a, p. 235; M. Smith, 1944, p. 12, fig. 128; Hertlein & Strong, 1955, pp. 285-286, pl. 3, fig. 31.

Stigmaulax elenae (Récluz), Abbott, 1954, pl. 5, fig. m; Woodring, 1957, p. 87.

Natica (Stigmaulax) elenae (Récluz), Keen, 1958, p. 321, fig. 264; Parker, 1964, p. 153; Keen, 1971, p. 477, fig. 871.

Natica hancti Récluz, 1850, pp. 389-391, pl. 13, figs. 6, 7; Tryon, 1886, p. 29, pl. 8, fig. 56 [as junior synonym of *N. elenae*].

Natica sulculosa Philippi, 1851, pp. 76-77, pl. 11, fig. 15 (plate 1850) [plate caption as "*N. elenae* Récluz"]; Hertlein & Strong, 1955, p. 286 [as probable junior synonym of *N. elenae*].

Not *Natica sulculosa* MacClelland, 1841, p. 243 [fossil, India].

Natica excavata Carpenter, 1856, p. 165; Carpenter, 1857d, p. 282; Tryon, 1886, p. 29 [as synonym of *N. elenae*]; Stearns, 1894a, p. 195; Palmer, 1963, p. 345, pl. 67, figs. 12, 13.

Not *Natica excavata* Michelin, 1838, p. 99 [Cretaceous, France].

Description. —

Color: Shell with alternating, thin axial lines of pale yellowish white and reddish brown, which are usually irregular and discontinuous between suture and base, sometimes with gray tint, especially on later adult whorls; umbilicus, base and narrow band at the suture are pale yellowish white; aperture white tinted with violet or brown; callus white; nuclear whorls pale orange brown. Periostracum very thin, pale yellowish white, inconspicuous.

Size: Average specimen, height 29 mm, diameter 26 mm; largest specimen: height 34.3 mm, diameter 31.0 mm [LACM 66-18, Punta Gorda, Baja California, Mexico].

Shell form: Shell elongate, spire moderately elevated to high; body whorl inflated, aperture large; whorls evenly rounded to slightly tabulate; shell thick; nuclear whorls 2½, smooth; postnuclear whorls 3¼; suture strongly impressed. Spiral sculpture of weak, minute, closely spaced costellae that are usually wavy. Axial sculpture of sharply incised grooves running from suture to umbilicus,

strongest at suture where they are separated by rounded riblets, weakest at the periphery where they may be inconspicuous, do not extend all the way to umbilicus on final $\frac{1}{4}$ whorl of large adults; axial incremental growth lines also present. Parietal callus massive, thickly filling posterior apertural angle, acutely tapered anteriorly; anterior lobe inconspicuous. Umbilicus broadly open, with cavernous sulcus and a broad channel tapering to a sharp point anteriorly. Umbilical callus large, broad, semicircular in outline, with concave anterior portion; small bump at posterior end intrudes into umbilical sulcus; funicle massive, filling anterior half of umbilicus, with a shallow groove along its posterior side. Anterior inner lip and basal lip thickened.

Operculum: Calcareous, white, sometimes with pale gray or brown at its center. Central area depressed, concave. Outer surface sculptured with numerous spiral ribs, several of which merge to form a broad median ridge with a mostly pustulate surface; central area bounded by this ridge may be smooth or bear up to ten low riblets; outer ribs usually three to five, of various sizes, two larger ribs may nearly roof over groove between them. Outer opercular margin with one to four microscopic costellae that show sometimes discontinuous beading. Inner margin serrated by ends of opercular ribs, with microscopic costellae along the inner edge and parallel to it.

Specimens examined. — Ninety-six.

Geographic occurrence and habitat. — Magdalena Bay, western Baja California, Mexico ($24^{\circ}30'$ N.), to Santa Elena ($2^{\circ} 10'$ S.) and the Galápagos Islands, Ecuador. There are few records from the Gulf of California, and the species is uncommon throughout its range. Rare intertidally, mostly in depths of 15 to 70 metres, in substrates of mud and sand.

Type localities. —

Natica elenae — Santa Elena, Ecuador, in sandy mud at 6 fathoms (Récluz, 1844).

Natica haneti — “Habit. la côte de Bahía” (Récluz, 1850), probably Bahía, Ecuador ($0^{\circ}0.5'$ S.) [not Bahía, Brazil, as speculated by Hertlein & Strong, 1955].

Natica sulculosa — “West Coast of Mexico or South America” (Philippi, 1851).

Natica excavata — Panama (Carpenter, 1856).

Type material.—

Natica elenae — Unknown.

Natica haneti — Holotype, No. 1300/66, in Muséum d'Histoire Naturelle, Geneva, Switzerland (E. Binder, pers. comm.)

Natica sulculosa — Unknown.

Natica excavata — Holotype, BM(NH) reg. No. 1963.22 (Palmer, 1963).

Nomenclatural commentary.— In his type description of *N. elenae*, Récluz separated some specimens as "Var. B. ?," and thought they might be a new species distinct from *N. elenae*. He may have had this in mind when he described the synonymous species *N. haneti* in 1850.

Discussion.— *N. (S.) elenae* is most similar in form to *N. (S.) guppiana* (Toula, 1909), which occurs in middle Miocene to lower Pliocene deposits of the Caribbean area (Woodring, 1957, pp. 86-88). The latter species seems to differ from *N. elenae* by having a thicker shell, a slightly more massive parietal callus, and an operculum with a more variable number of ribs. Considering the minor differences between some Naticinae species, as in the *Natica (Naticarius) othello* species-group, these differences may be enough to separate *N. (S.) elenae* and *N. (S.) guppiana* but further study may place *N. (S.) guppiana* as a synonym of *N. (S.) elenae*. *Natica (S.) elenae* is also related to *N. canrena* Linnaeus, 1758, of the modern Caribbean fauna, as well as to several Holocene through Miocene Caribbean species. Along with other living eastern Pacific species such as *N. (S.) broderipiana* Récluz, 1844, *Polinices (Polinices) uber* (Valenciennes, 1832), and *P. (P.) panamaensis* (Récluz, 1844), *N. (S.) elenae* provides a clear link to the modern Caribbean naticid fauna and to the ancestral Miocene fauna that gave rise to the living naticids of each region.

In the modern eastern Pacific fauna, *N. (S.) elenae* is closest to *N. (S.) broderipiana* Récluz. The most obvious difference between this species is that *N. (S.) elenae* has an axial color pattern, whereas *N. (S.) broderipiana* is decorated with spiral color bands. In form, *N. (S.) broderipiana* is distinct from *N. (S.) elenae* by having stronger axial grooves, a much less massive parietal callus, and a less cavernous umbilical sulcus, besides reaching only about half the adult height of *N. (S.) elenae*.

Subgenus **TECTONATICA** Sacco, 1890, p. 33

Type species: *Natica tectula* Bonelli, 1826, by monotypy. Pliocene, Italy. Figured in Wenz (1941, p. 1041, fig. 2979).

Diagnosis.—Shell small to medium in size, globose to slightly elongate; whorls smooth, not greatly inflated. Umbilicus narrowly open along margin of semicircular umbilical callus. Parietal callus thin.

Discussion.—*Tectonatica* is characterized by having a smooth shell and an umbilicus that is narrowly open along the margin of a semicircular umbilical callus. The operculum of the extinct type species is unknown. *Tectonatica* differs from *Cryptonatica* by having an open umbilicus, whereas the umbilicus of *Cryptonatica* is entirely closed by the semicircular umbilical callus. Its geologic history extends into the Pleistocene of Italy and Pliocene of western North America, and it is represented in modern seas by at least two cool-water Japanese species and four tropical Caribbean species.

Natica (Tectonatica) janthostoma Deshayes, 1839 Pl. 40, figs. 10-13;
Pl. 41, figs. 2-5

Natica janthostoma Deshayes, 1839, p. 361; Philippi, 1852, pp. 53-54, pl. 8, fig. 8 (plate 1850); Reeve, 1855, pl. 18, figs. 79a, b; Sowerby, 1883, p. 82, pl. 4, fig. 52; Pilsbry, 1895, p. 71; Kuroda & Habe, 1952, p. 71.

Natica (Cryptonatica) janthostoma Deshayes, Dall, 1921, p. 164, pl. 14, fig. 12; Oldroyd, 1927, p. 725, pl. 97, fig. 5; MacNeil, Mertie, & Pilsbry, 1953, p. 84, pl. 11, figs. 12, 14 [as "aff."].

Natica (Tectonatica) janthostoma Deshayes, Burch, 1946, p. 2; Kuroda & Habe, 1949, p. 71, figs. 1a, b.

Tectonatica janthostoma (Deshayes), Habe & Ito, 1965, p. 32, pl. 8, figs. 10-11.

Natica clausa var. *janthostoma* Deshayes, Tryon, 1836, p. 31, pl. 9, fig. 68, pl. 19, fig. 89.

Natica severa Gould, 1859, p. 43; Gould, 1862, p. 109; Kuroda & Habe, 1952, p. 71; Johnson, 1964, p. 149, pl. 16, fig. 14.

Polinices (Natica) severa (Gould), Pilsbry, 1895, p. 72.

Natica (Cryptonatica) consors Dall, 1909b, pp. 86-87 [in part; see nomenclatural commentary of *N. (C.) clausa* Broderip & Sowerby, 1829, herein].

Tectonatica? satsopensis Addicott, 1966a, p. 639, pl. 77, figs. 8, 9.

Description.—

Color: Shell light to medium pinkish brown, usually with narrow, vague whitish bands on shoulder, periphery, and base; callus and adjacent part of base white; nuclear whorls white on shoulder, medium brown below; axial streaking of colors common, especially on early adult whorls. Interior mottled medium brown and white. Periostracum thin, pale yellowish white.

Size: Average specimen, height 53 mm, diameter 50 mm; largest

specimen, height 61.0 mm, diameter 54.0 mm (broken) [USNM 635660, St. George Island, Pribilof Islands, Alaska].

Shell form: Shell globose to slightly elevated; body whorl not strongly inflated; whorls evenly rounded except for narrow tabulation at suture; shell thick; nuclear whorls $2\frac{1}{2}$, smooth; postnuclear whorls $4\frac{1}{2}$; suture moderately impressed. Spiral sculpture of minute, weakly developed, closely spaced costellae that may be better developed just below suture; axial sculpture of incremental growth lines that are best developed near suture and on base. Parietal callus thin, moderately fills posterior apertural angle; anterior lobe very weak. Umbilicus narrowly open at sulcus, closed anteriorly; sulcus narrow, deep; channel reduced to a marginal groove; funicle large, filling anterior end of umbilicus. Basal lip thickened.

Operculum: Calcareous, white, inner margin thickened; thickening greatest over nucleus; outer surface with minute, weakly developed spiral striations, usually strongest near outer margin.

Specimens examined. — One hundred seventy-three.

Geographic occurrence and habitat. — Kamchatka to Hokkaido, northern Japan (44° N.), and Vladivostok, U.S.S.R. (43° N.). Reported from Korea by Habe (1950). The bathymetric range is not known.

Stratigraphic occurrence. — Ranges from lower Pliocene to Holocene. Lower Pliocene: Empire Fm., Coos Bay, Ore. (CAS); upper Montesano Fm, Grays Harbor Co., Wash. (CAS); Montesano(?) Fm., Montesano, Wash. (CAS). Middle Pliocene to Pleistocene: Merced Fm., Wilson Ranch, Sonoma Co., Calif. (CAS). Upper(?) Pliocene: Montesano Fm. of Weaver (1912), Wynoochee Valley Quad., Wash. (Addicott, 1966a; USNM). Lower Pleistocene: Elk River Beds, Curry Co., Ore. (UCB).

Type localities. —

Natica janthostoma — Kamchatka, U.S.S.R. (Deshayes, 1839).

Natica severa — Hakodate Bay, Japan (Gould, 1859).

Tectonatica? salsopensis — Cut on south side of Still Creek logging road, 400 feet north and 2,200 feet west of southeast corner sec. 5, T. 18 N., R. 7 W., Wynoochee Valley quadrangle, Washington (Addicott, 1966a). Montesano Formation of Weaver (1912), upper(?) Pliocene.

Type material. —

Natica janthostoma — Unknown, presumably in École des Mines, Paris, France, or BM(NH) (Dance, 1966).

Natica severa — Holotype, MCZ 169369.

Tectonatica? satspensis — Holotype, USNM 649134.

Discussion. — *Natica janthostoma* has not previously been recognized as a fossil in the northeastern Pacific but was in collections and labeled as "*Natica consors* Dall, 1909" [= *N. clausa* Broderip & Sowerby, 1829]. Typical fossil specimens of *N. (T.) janthostoma* have lower spires, a tendency toward smaller umbilical openings, and attain a smaller maximum size than typical living specimens but are otherwise identical. The largest known fossil specimen [CAS 4, Empire Formation, Coos Bay, Oregon, lower Pliocene] is 34.2 mm in height and 34.6 mm in diameter, compared to the largest living individual at 61.0 mm and 54.0 mm (broken), respectively. No fossil opercula are known.

N. (T.) janthostomoides (Kuroda & Habe, 1949), of Japan, is closely related to *N. (T.) janthostoma*. The principal differences are that *N. (T.) janthostomoides* (Pl. 42, figs. 10, 11) has two shallow grooves near the outer margin of its operculum, and has a narrower umbilical callus, such that the umbilicus is open along most of the callus margin instead of only at its posterior end. The umbilical sulcus of *N. (T.) janthostomoides* is much reduced in size relative to that of *N. (T.) janthostoma*. Some specimens of *N. (T.) janthostoma* have faint spiral striations along the outer margins of their opercula but never distinct grooves.

Fossil and living specimens of *N. (T.) janthostoma* and *Natica (Cryptonatica) clausa* are similar in general aspect, with equivalent sizes and nearly identical opercula, although the closed umbilicus of *N. (C.) clausa* clearly characterizes it. Given their similarities, and the fact that *N. (C.) clausa* is known in deposits of late Miocene to Holocene age, *N. (T.) janthostoma* is almost certainly a descendant from early Pliocene stocks of *N. (C.) clausa*.

This species formerly was reported in many Japanese upper Tertiary and Quaternary formations (Yokoyama, 1920, 1922; Nomura, 1935) but more recent workers (Hatai and Nisiyama, 1952; Hayasaka, 1961; Shuto, 1964) have attributed all fossil records to *N. (T.) janthostomoides* (Kuroda and Habe, 1949). The

occurrence of *N. (T.) janthostomoides* in Japan extends from Miocene to Holocene (Yokoyama, 1920; Hayasaka, 1961) and all illustrations I have seen of Japanese fossils appear to be *N. (T.) janthostomoides*. This species seem to have evolved in the northwestern Pacific during the Miocene and lived there continuously since then. In the early Pliocene its range was expanded to include the northeastern Pacific, where *N. (T.) janthostoma* arose and lived through the early Pleistocene. In the late Pleistocene *N. (T.) janthostoma* withdrew from the eastern and central North Pacific and lives today only in the northwestern Pacific along with *N. (T.) janthostomoides*. Because there are no fossil or modern occurrences of *N. (T.) janthostomoides* outside the northwestern Pacific, the exact biostratigraphic relations of the two species are not known.

Natica (Tectonatica) gabbi Clark, 1918

Pl. 41, fig. 6

Natica (Ampullina) gabbi Clark, 1918, p. 166, pl. 19, figs. 12, 14, 15.

Not *Ampullina gabbi* Woods in Bosworth, 1922, p. 77, pl. 7, fig. 2 [Eocene, Peru; renamed *Ampullina woodsi* Hanna & Israelsky, 1925, p. 49].

Description. —

Size: Average specimen, height 14 mm, diameter 12 mm; largest specimen, height 22.2 mm, diameter 22.4 mm [USGS M2120, Nye Mudstone, Yaquina Quadrangle, Lincoln County, Oregon, lower Miocene].

Shell form: Shell globose, spire moderately elevated; body whorl moderately inflated; shell thickness average; whorls at least 4½ (apexes eroded on all known specimens); suture moderately impressed. Shell smooth except for incremental growth lines. Parietal callus thin, lightly filling posterior apertural angle. Umbilicus narrowly open, with distinct sulcus above umbilical callus and very narrow channel. Umbilical callus narrow, abruptly bounded posteriorly by umbilical sulcus, tapering very gradually anteriorly to meet thickened inner lip; funicle largely filling umbilicus. Anterior inner lip thickened, approximately as wide as umbilical callus.

Operculum: Unknown.

Specimens examined. — Twenty-one.

Stratigraphic occurrence. — Known only from lower Miocene strata. Lower Miocene: Nye Mudstone, Yaquina Quad., Lincoln Co., Oreg. (USGS); San Ramon Ss., Walnut Creek Quad., Contra Costa Co., Calif. (Clark, 1918; UCB).

Type locality. — In creek bed about 100 yards to east of Oakland and Antioch bridge, one-half mile southwest of town of Walnut Creek, Contra Costa County, California; elevation 100 feet, lat 37°53'7" N., long 122°4'8" W. (Clark, 1918). San Ramon Sandstone, mostly lower Miocene but perhaps in part upper Oligocene.

Type material. — Holotype, UCB 11252; paratype, UCB 11255. A second paratype, UCB 11250, was figured by Clark (1918) but is now missing from the UCB collection, as first noted by Keen & Benton (1944). In its place is a calcareous naticid operculum 16.0 mm long and 9.5 mm wide [larger than the two type specimens of *N. (T.) gabbi*], with an inked-on number indicating that it came from an entirely different locality and formation.

Discussion. — This species is characterized by its umbilical callus not tapering much anteriorly but maintaining its width when it merges with the equally wide, thickened inner lip. It is easily distinguished from the early Pliocene to Holocene *N. (T.) janthostoma* Deshayes, 1839, as the latter species is much larger and has a semicircular umbilical callus that has an abrupt rather than gradual anterior taper.

Besides the types, Clark (1918) mentioned specimens from several localities in the San Ramon Sandstone. Examination of collections from these localities produced no additional specimens of *N. (T.) gabbi*, although several naticids were present but too poorly preserved to identify.

Subgenus **CRYPTONATICA** Dall, 1892, p. 362

Type species: *Natica clausa* Broderip & Sowerby, 1829, by original designation. Lower Miocene to Holocene, North Pacific. Figured herein.

Diagnosis. — Shell medium to large, globose to slightly elongate; whorls smooth, not greatly inflated. Umbilicus completely filled by thick, smooth, semicircular callus. Operculum smooth or with single low rib at outer margin, outer surface distinctly concave.

Discussion. — *Cryptonatica* is characterized by its semicircular umbilical callus that completely fills the umbilicus. It is represented by only two known species, both of which are treated here, and is a cool-temperate to Arctic group.

Natica (*Cryptonatica*) *clausa* Broderip & Sowerby, 1829 Pl. 41, figs. 7-10;
Pl. 42, figs. 1-6; Text-fig. 8

Natica clausa Broderip & Sowerby, 1829, p. 372; Gray, 1839, p. 136, pl. 34, fig. 3, pl. 37, fig. 6; Gould, 1841, p. 238, fig. 167; Philippi, 1851, pp. 98-99, pl. 14, fig. 5; Reeve, 1855, pl. 20, fig. 88, pl. 25, fig. 113; Gould, 1870, p. 342, fig. 612; Dall, 1874, p. 251 [as of Broderip]; Sars, 1878, pp. 159-169, pl. 21, figs. 12a, b, 13, pl. 12, figs. 1a-c; Sowerby, 1883, p. 96, pl. 4, fig. 48; Tryon, 1886, pp. 30-31, pl. 9, figs. 65, 67-69, 73; Dall, 1892, p. 362; Arnold & Anderson, 1907, p. 144, pl. 21, fig. 16; Odhner, 1913, pp. 7, 14-23, pl. 3, figs. 1-3, 5-14, 16, 17, pl. 5, figs. 7-14; Harmer, 1921, pp. 672-674, pl. 56, figs. 1-5; Thorson, 1951, pp. 21-22; MacGinitie, 1959, pp. 90-91, pl. 1, fig. 10, pl. 12, fig. 8; Bousfield, 1960, p. 17, pl. 2, fig. 24; MacPherson, 1971, pp. 56-58, pl. 3, fig. 9.

Natica (*Cryptonatica*) *clausa* Broderip & Sowerby, Arnold, 1903, pp. 313-314, pl. 10, fig. 13; Moody, 1916, p. 44; Dall, 1921, p. 163, pl. 14, fig. 11; Oldroyd, 1924, p. 161, pl. 3, fig. 3; Oldroyd, 1927, p. 724, pl. 97, fig. 2; MacNeil, 1957, p. 109, pl. 13, figs. 12-13, pl. 15, fig. 19.

Natica (*Tectonatica*) *clausa* Broderip & Sowerby, Grant & Gale, 1931, pp. 797-798, text-fig. 11; Soper & Grant, 1932, p. 1063; Burch, 1946, p. 26; Kotaka, 1962, pp. 134-135, pl. 33, fig. 17; Burch, 1963, p. 152; Faustman, 1964, pp. 135-136.

Cryptonatica clausa (Broderip & Sowerby), Woodring, Bramlette, & Kew, 1946, p. 71; Addicott, 1966b, p. 4, pl. 1, fig. 13.

Tectonatica clausa (Broderip & Sowerby), Okutani, 1964, p. 395, pl. 1, fig. 18, pl. 5, fig. 7; Habe & Ito, 1965, p. 30, pl. 8, fig. 4; Okutani, 1966, p. 17.

Polynices clausa (Broderip & Sowerby), Weaver, 1916a, pp. 216, 218.

Natica clausa forma *normalis* Middendorff, 1849, p. 420.

Natica clausa forma *elatior* Middendorff, 1849, p. 420.

Natica clausa forma *depressior* Middendorff, 1851, pp. 209-210.

Natica clausa var. *minor* Philippi, 1851, pp. 99-100, pl. 14, fig. 6.

Not *Natica minor* Lea, 1833, p. 107 [fossil, eastern United States].

Natica clausa forma *typica* Sars, 1878, pp. 159-160, pl. 21, figs. 12a, b, 13.

?*Natica beverlii* Leach, 1819, p. 61; Philippi, 1853, p. 146; Carpenter, 1864, p. 523.

?*Natica consolidata* Couthouy, 1838, pp. 89-90, pl. 3, fig. 14; Philippi, 1842, v. 1, p. 17, pl. 1, fig. 11.

Natica septentrionalis Möller ex Beck MS, 1842a, p. 80.

Lunatia septentrionalis (Möller), Dall, 1874, p. 251.

Neverita russa Gould, 1859, p. 43.

Natica russa (Gould), Gould, 1862, p. 109; Dall, 1874, p. 251; Dall, 1886, p. 218; Tryon, 1886, p. 53; Cooper, 1894, p. 29; Keen, 1937, p. 41.

Natica (*Cryptonatica*) *russa* (Gould), Dall, 1921, p. 163; Oldroyd, 1927, p. 725.

Natica (*Tectonatica*) *russa* (Gould), Grant & Gale, 1931, p. 798; Burch, 1946, p. 27; Glen, 1959, p. 183; Kotaka, 1962, p. 135, pl. 33, fig. 18; Faustman, 1964, p. 136, pl. 5, figs. 23-24.

Tectonatica russa (Gould), Habe, 1950, p. 13.

Natica operculata Jeffreys, 1885, pp. 34-35, pl. 4, figs. 7, 7a; Tryon, 1886, p. 31 [as junior synonym of *N. clausa*].

Natica (*Cryptonatica*) *consors* Dall, 1909b, pp. 86-87 [in part; see nomenclatural commentary], pl. 5, fig. 10, pl. 6, fig. 9; Grant & Gale, 1931, p. 797 [as junior synonym of *N. clausa*].

Not *Natica millepuncta* var. *consors* Wood, 1848, p. 148 [fossil, England].

Tectonatica dalli Cossmann, 1925, p. 121 [new name for *N. consors* Dall, 1909b, not Wood, 1848]; Weaver, 1943, p. 330, pl. 67, fig. 30.

Not *Natica* (*Natica*) *dalli* Tegland, 1933, p. 138, pl. 14, figs. 8-12 [= *Natica* (*Naticarius*) *teglandi* Hanna & Hertlein, 1938, Tertiary, California and Washington, treated herein].

- Natica (Neverita) convexa* Nomland, 1916a, pp. 86-87, pl. 7, figs. 1, 2; Grant & Gale, 1931, p. 797 [as junior synonym of *N. clausa*]; Keen & Bentson, 1944, p. 176.
- Neverita convexa* (Nomland), Adegoke, 1969, p. 169.
- Natica convexa* (Nomland), Nomland, 1917a, p. 221.
- Cryptonatica salimba* Dall, 1919b, p. 351.
- Natica (Cryptonatica) salimba* (Dall), Dall, 1921, p. 164; Oldroyd, 1927, pp. 725-726.
- Natica salimba* (Dall), Keen, 1937, p. 41.
- Natica (Tectonatica) salimba* (Dall), Burch, 1946, p. 28.
- Euspira acosmita* Dall, 1919b, p. 352.
- Polinices (Euspira) acosmitus* (Dall), Dall, 1921, p. 164; Oldroyd, 1927, pp. 726-727; Burch, 1946, p. 29.
- Cryptonatica aleutica* Dall, 1919a, p. 352 [*nomen nudum*]; Dall, 1919b, p. 251 [described]; Woodring & Bramlette, 1950, pp. 63, 72, pl. 10, fig. 1; Winterer & Durham, 1962, p. 296.
- Natica (Cryptonatica) aleutica* (Dall), Dall, 1921, p. 164, pl. 14, fig. 10; Oldroyd, 1924, p. 161, pl. 22, fig. 12; Oldroyd, 1927, p. 726.
- Natica aleutica* (Dall), Keen, 1937, p. 41 [as junior synonym of *N. clausa*].
- Natica (Tectonatica) aleutica* (Dall), Burch, 1946, p. 28; Burch, 1963, p. 152.
- "*Nerita affinis* Gmelin," Jeffreys, 1867, p. 229 [not *Natica affinis* (Gmelin, 1791)].
- "*Natica affinis* (Gmelin)" [not *Natica affinis* (Gmelin, 1791)], Philippi, 1851, pp. 86-87, pl. 13, fig. 3; Mörch *in* Rink, 1857, p. 80; Jeffreys, 1869, pp. 215-216, pl. 102, fig. 3; Jeffreys, 1885, p. 35; Carpenter *in* Dawson, 1872, p. 392; Sars, 1878, pp. 160-161, pl. 21, figs. 14a, b, pl. V, fig. 16; Watson, 1886, p. 430; Friele & Grieg, 1901, p. 70; Oldroyd, 1927, p. 794.
- "*Natica (Tectonatica) affinis* (Gmelin)" [not *Natica affinis* (Gmelin, 1791)], Burch, 1946, p. 28.
- Natica affinis* var. *vittata* Jeffreys, 1877, pp. 318-319.
- Not *Nerita vittata* Gmelin, 1791, p. 3674 [living, northern Atlantic].
- "*Natica clausa* var. *occlusa* Wood," Friele & Grieg, 1901, p. 70 [not *N. clausa* var. *occlusa* Wood, 1848, p. 146, pl. 12, figs. 4a, b; fossil, England].

Description. —

Color: Shell exterior and callus white. Periostracum thin, pale yellowish white to dark orange brown, most commonly pale yellowish brown; base commonly paler; pale band may occur on shoulder; axial banding of light and dark uncommonly seen on juveniles. Interior white or pinkish to medium brown.

Size: Average Arctic specimen, height 30 mm, diameter 28 mm. Average southern specimen, height 13 mm, diameter 11.5 mm. Largest specimen, height 61.0 mm, diameter 54.0 mm (broken) [USNM 635660, St. George Island, Alaska].

Shell form: Shell globose, spire low to moderately elevated; body whorl not greatly inflated, flattened or slightly concave just below suture; shell thin to thick, nuclear whorls two, smooth; post-nuclear whorls 3½; suture slightly to moderately impressed. Spiral sculpture of minute, weak, slightly wave striae; axial sculpture of in-

cremental growth lines. Parietal callus relatively thin at midpoint, thickens to moderately fill posterior apertural angle; anterior lobe lacking. Umbilicus closed. Umbilical callus smooth, semicircular, flat to slightly concave; margin blending smoothly into underlying whorl or raised slightly above it. Anterior inner lip and basal lip thickened.

Operculum: Calcareous, white, shallowly concave; central area thickened; margins smooth.

Specimens examined.—Twenty-three hundred.

Geographic occurrence and habitat.—Circumboreal. In the eastern Pacific, south to San Diego, California ($32^{\circ}43'$ N.), in the western Pacific, south to Japan and Korea; in the western Atlantic, south to Cape Hatteras, North Carolina; in the eastern Atlantic, south to Spain and perhaps the Mediterranean. Known on soft bottoms in depths from 9 to 970 metres, in progressively greater depths from north to south.

Stratigraphic occurrence.—Lower Miocene to Holocene. Lower Miocene: Poul Creek Fm., Yakataga district, south-central Alaska (Clark, 1932; UCB; USGS). Middle Miocene: lower part of Yakataga Fm., Yakataga and Malaspina districts, and Big Sitkinak Island, Trinity Islands, Alaska (USGS); Astoria Fm., Newport, Lincoln Co., Oreg. (CAS): Upper Miocene: Cierbo Ss., Pleasanton Quad., California (UCB); unnamed formation, western Wash. (Weaver, 1916a). Upper Miocene to lower Pliocene: Montesano Fm., Grays Harbor Co. (UCB), Humptulips Quad., Grisdale Quad., Aberdeen Quad. (USGS), and Sylvia Creek (SU), Wash.; Quillayute Fm., La Push Quad., Clallam Co., Wash. (USGS). Lower Pliocene: Empire Fm., Coos Bay (Dall, 1909b; Arnold & Hannibal, 1913; Howe, 1922; Weaver, 1943, 1945; UCB), Curry Co. (UCB), and Cape Blanco (Arnold & Hannibal, 1913), Oreg. Middle Pliocene: Merced Fm., Sonoma Co. (USGS; UCB), Santa Cruz area (Arnold, 1908a), Bolinas Bay (Martin, 1916), Sebastopol Quad. (CAS), Palo Alto Quad. (USGS), and type Merced, San Francisco peninsula (Martin, 1916; Glen 1959), Calif.; Etchegoin Fm., Coalinga area, Calif. (Nomland, 1916a; Adegoke, 1969). Middle to upper Pliocene: Rio Dell Fm. of Ogle (1953), Humboldt Co., Calif. (Faustman, 1964; UCB). Upper Pliocene: Pico Fm., southeastern Ventura basin, Calif. (Winterer & Durham, 1962); San Diego Fm., San Diego Co., Calif. (LACM; UCB); Fernando Fm., central Los Angeles basin

(Moody, 1916; Soper & Grant, 1932; LACM) and Newport Bay (LACM), Calif. Pliocene: Wildcat Fm., Humboldt Co., Calif. (Martin, 1916; UCB); Purisima Fm. of Durham (1950b), Halfmoon Bay (Martin, 1916), Santa Cruz Quad. (Arnold, 1908a; UCB); Año Nuevo Quad. (SU), and San Mateo Mountains (SU), Calif.; Quinalt Fm., Taholah Quad., Wash. (USGS); Foxen Mudstone and Cebado fine-grained Memb. of Careaga Sand, Santa Maria basin, Calif. (Woodring & Bramlette, 1950). Pliocene to Pleistocene: Breidavic and Tjörnes sequences, Iceland (USGS). Lower Pleistocene: Timms Point Silt Memb. (Clark, 1931; Valentine, 1961; LACM), Lomita Marl Memb. (Woodring, Bramlette, & Kew, 1946; LACM), and the so-called San Pedro Sand Memb. (Woodring *et al.*, 1946; LACM) of San Pedro Fm., San Pedro, Calif.; Santa Barbara Fm. of Smith (1912), Santa Barbara, Calif. (LACM; UCB); Elk River Beds, Cape Blanco, Oreg. (USGS; CAS; SU; UCB); Anchor Silt, northwestern Los Angeles basin, Calif. (Rodda, 1957). Upper Pleistocene: Palos Verdes Sand, San Pedro, Calif. (Arnold, 1903; Valentine, 1961; LACM; UCB); Bahia San Quintin, western Baja Calif., Mexico (Valentine, 1961, as "cf."). Pleistocene: Peard Bay, Alaska (Meek, 1923).

Type localities. —

Natica clausa — Unknown (Broderip & Sowerby, 1829).

Natica clausa forma *normalis* — "Ins. Sitcha" [probably Kruzof Island, northwest of Sitka, Alaska] (Middendorff, 1849).

Natica clausa forma *elatio*r — Novaya Zemlya Island, U.S.S.R. (Middendorff, 1849).

Natica clausa forma *depressior* — Unknown (Middendorff, 1851).

Natica clausa var. *minor* — "coasts of the United States and Greenland" (Philippi, 1851).

Natica clausa forma *typica* — Unknown (Sars, 1878).

Natica beverlii — Baffin Bay, Canada (Leach, 1819).

Natica consolidata — "coast of New England" (Couthouy, 1838).

Natica septentrionalis — Greenland (Möller, 1842a).

Neverita russa — Arctic Ocean (Gould, 1859).

Natica operculata — North Japan (Jeffreys, 1885).

Natica (Cryptonatica) consors — Empire Formation, Coos Bay, Oregon; lower Pliocene (Dall, 1909b).

Natica convexa — Etchegoin Formation, northeast of Coalinga, California; middle Pliocene (Nomland, 1916a).

Cryptonatica salimba — U.S. Fisheries Commission station 4423, between Santa Barbara and San Nicolas islands, southern California, 395 to 620 metres depth, sand (Dall, 1919b).

Euspira acosmita — USFC station 3128, off Monterey Bay, California, 1,147 metres depth, mud (Dall, 1919b).

Cryptonatica aleutica — St. George Island, Pribilof Islands, Alaska, 30 fathoms [see nomenclatural commentary].

Natica affinis var. *vittata* — Godhavn [Greenland] (Jeffreys, 1877).

Type material. —

Natica clausa — Unknown, presumably in BM(NH) (Dance, 1966).

Natica clausa forma *normalis* — Academy of Sciences, Leningrad (Dance, 1966).

Natica clausa forma *elatiior* — As above.

Natica clausa forma *depressior* — As above.

Natica clausa var. *minor* — Unknown.

Natica clausa forma *typica* — Unknown, presumably in Oslo Museum (Dance, 1966).

Natica beverlii — Unknown, presumably in BM(NH) (Dance, 1966).

Natica consolidata — Unknown.

Natica septentrionalis — Lectotype, designated herein, and three paralectotypes, Zoological Museum, University of Copenhagen, Denmark.

Neverita russa — Unknown (Johnson, 1964).

Natica operculata — Unknown, presumably in BM(NH) (Dance, 1966).

Natica (Cryptonatica) consors — Lectotype, designated herein, USNM 236895; three paralectotypes, USNM 153917 [one specimen erroneously bears number 154917].

Natica convexa — Holotype, UCB 12064.

Cryptonatica salimba — Holotype, USNM 209295.

Euspira acosmita — Holotype, USNM 207218.

Cryptonatica aleutica — Lectotype, designed herein, USNM 217516; seven paralectotypes, USNM 635660.

Natica affinis var. *vittata* — Unknown, presumably in BM(NH) (Dance, 1966).

Nomenclatural commentary. — The complex taxonomic history of *N. (C.) clausa* has resulted from variations in size, shell thickness, spire height, and umbilical callus morphology, plus broad geographic distribution. The subspecies *normalis*, *elatio*, and *depressior* of Middendorff (1849, 1851), *minor* of Philippi (1851), and *typica* of Sars (1878) are based on individuals with higher or lower spires, or smaller size, than average specimens. Possible synonyms, such as *N. beverlii* Leach, 1819, and *N. consolidata* Couthouyi, 1838, are poorly described in the literature and difficult to evaluate but seem closer to *N. clausa* than to any other recognized species. *Cryptonatica salimba* and *Euspira acosmita* of Dall (1919b) are based on specimens from off southern California that differ from typical northern specimens only by their smaller size. Pliocene specimens from California and Oregon have been referred by others to *N. convexa* Nomland, 1917, and *N. consors*, Dall, 1909, respectively.

Natica (Cryptonatica) clausa may be a junior synonym of *Natica affinis* (Gmelin, 1791) of the northeastern Atlantic, but the problem is difficult to evaluate because the original description of *N. affinis* is vague and subsequent interpretations of it have differed among workers. The two species are similar in general shape, but *N. affinis* is said to have an open umbilicus by some workers (Verrill, 1873; Tryon, 1886) and a closed umbilicus by others (Jeffreys, 1885; Harmer, 1921). *Natica affinis* was considered to be the southern white or semipellucid form of *N. (C.) clausa* by Odhner (1913), and to be a *nomen dubium* by MacPherson (1971). All museum specimens I have seen labeled as *N. affinis* are identical to *N. (C.) clausa*.

Natica clausa occlusa Wood, 1848, an English Pliocene fossil, has a much more elevated spire than specimens of *N. (C.) clausa* I have seen, but the species seem otherwise identical. A proper comparison of the two species would center on a study of shell form in

N. clausa occlusa to determine whether or not the spire is consistently elevated in large populations.

The most recent taxonomic controversy surrounding *N. (C.) clausa* has been its relationship to *N. russa* and *N. aleutica*. *Natica russa* was described by Gould (1859) as having a thin shell and shouldered whorls. *Natica aleutica* was not originally differentiated from either *N. russa* or *N. (C.) clausa* but was said to be larger than *N. russa* (Dall, 1919b). More recent workers have most often considered *N. russa* a thin-shelled species with a dark-orange-brown periostracum, *N. aleutica* a large, thick-shelled species with a buff or pinkish color, and *N. (C.) clausa* a species of average shell thickness and pale-yellowish-brown color. *Natica russa* was thought to be restricted to the Bering Sea, *N. aleutica* was reported between Alaska and Puget Sound, Washington, and *N. (C.) clausa* was recognized as far south as southern California. These forms are here considered to be conspecific because their characteristics intergrade to the extent that assignment to one taxon or the other is uncertain. Large thick-shelled living specimens of *N. (C.) clausa* are known in the eastern Pacific from Alaska to Puget Sound; the darker, thin-shelled form from the Bering Sea to Monterey, California, but these variations of *N. (C.) clausa* seem to be developed to lesser degrees in other areas.

Lectotypes are designated here for three junior synonyms of *N. (C.) clausa*: *Natica septentrionalis* Möller, 1842a, *Natica (Cryptonatica) consors* Dall, 1909b, and *Cryptonatica aleutica* Dall, 1919b. The type lot of *N. septentrionalis* contains four specimens, from which Möller did not select a holotype. A small slip of blue paper, apparently Möller's original label, identifies the lot as "*Natica septentrionalis*." All four specimens are *N. (C.) clausa*, and an individual in good condition and with its operculum in place, measuring 16.6 mm in height and 16.7 mm in diameter, is hereby selected as lectotype (Pl. 41, fig. 8).

The type lot of *N. (C.) consors* also contains four specimens, from which Dall (1909b) did not select a holotype. Only two of the four syntypes are *N. (C.) clausa*; the other two are *Natica (Tectonatica) janthostoma* Deshayes, 1839, an early Pliocene to Holocene species discussed earlier in this study. Each of the four syntypes bears the original USNM number 2954, and a second number,

153917, added at a later date. However, two of the specimens, including the one I am designating lectotype, were erroneously numbered 154917 in an apparent *lapsus calami*. As lectotype I hereby designate the best-preserved and smaller of the two *N. (C.) clausa* specimens in the type lot, which measures 16.3 mm in height and 14.7 mm in diameter (Pl. 41, fig. 9). The lectotype assumes a new USNM number, 236895, whereas the three paralectotypes retain their previous number of 153917.

There are eight syntypes of *C. aleutica* and six calcareous opercula in the type lot, and all are of *N. (C.) clausa*. Dall (1919b) did not select a holotype, but he referred to one specimen as being 46 mm in height and 40 in diameter. The syntype closest to those dimensions measures 44.9 mm in height and 39.5 mm in diameter, still retains its operculum in place, and is hereby designed lectotype (Pl. 41, fig. 7). The lectotype retains the number of the syntype lot, USNM 217156, and the seven paralectotypes are assigned a new number, USNM 635660. In the original description of *C. aleutica*, Dall (1919b) gave the type locality as "Unalaska, Aleutian Islands," but this is in error. The type locality written on the syntype label is St. George Island, Pribilof Islands, Alaska, which is about 275 kilometres (170 miles) north of the published type locality of Unalaska Island.

Discussion.—Variations in size and shell morphology of *N. (C.) clausa* have been exhaustively documented by Odhner (1913) and confirmed in the present study. Specimens from the Bering Sea are the largest found; the largest Bering Sea specimen has a height of 61.0 mm and a diameter of 54.0 mm (broken), whereas the largest specimens from other areas are: western Pacific, 29.7 mm \times 27.1 mm [USNM 205686, Sea of Okhotsk]; western Atlantic, 36.2 mm \times 31.1 mm [USNM 600921, Labrador]; eastern Atlantic, height 30.0 mm [Odhner, 1913, Berufjord, Iceland]. Comparing Arctic and southern forms, the number of adult whorls is constant despite great differences in size, showing that the southern specimens are dwarfed and not merely juveniles. In the eastern Pacific, an average Arctic specimen measures about 30 mm \times 28 mm, whereas one from southern California measures about 13 mm \times 11.5 mm. Southern individuals tend to be lighter in color than northern ones. The dark-orange-brown specimens are known mainly from Arctic seas, with

rare occurrences in the eastern Pacific south to Monterey, California.

In addition to being much smaller, southern *N. (C.) clausa* live at progressively greater depths. Specimens live as shallowly as nine metres in Arctic Alaska, but no shallower than about 150 metres off of southern California. Odhner (1913) noted that Atlantic individuals from deeper water tend to have higher spires and shorter apertures, although I have not seen this among eastern Pacific specimens. He also noted that the radula was broader in shallow-water forms and narrower in deeper water forms, but his observation is based on only five specimens. Northern specimens are also larger among fossils. In the abundant Pacific Coast Pliocene populations, the largest specimens, up to 47 mm \times 46 mm, are from northern Washington, whereas the largest southern California Pliocene specimens measure about 15 mm \times 13 mm. Miocene and Pleistocene specimens from southern and central California are equally small.

The earliest known fossils of *N. (C.) clausa* are from lower Miocene beds of the Poul Creek Formation, Yakataga district, south-central Alaska, which seems to confirm the anticipated northern origin of this species. The only other known lower Miocene fossils are also from Alaska, whereas middle Miocene specimens are known in Oregon, and upper Miocene and later specimens in northern California. The species took a considerable time to extend its range southward, presumably in response to progressive marine cooling from Miocene through Pleistocene time (Text-fig. 8). The Pleistocene southern range limit was at Bahía San Quintín, northwestern Baja California, Mexico (Valentine & Meade, 1961), about 250 kilometres (150 miles) south of its present southern limit, in response to late Pleistocene cool-water conditions there. Fossil occurrences in the western Pacific and Atlantic are not well documented.

Natica (Cryptonatica) oregonensis (Conrad, 1865) Pl. 42, figs. 7-9

Sigaretus scopulosus Conrad, 1849, app. p. 727 [in part], pl. 19, figs. 6b, c [not figs. 6, 6a, = *Sinum scopulosum*, or fig. 6d, = not determinable].

Lunatia oregonensis Conrad, 1865, p. 151.

Natica (Natica) oregonensis (Conrad), Dall, 1909b, p. 86, pl. 4, fig. 7.

Natica oregonensis (Conrad), Arnold, 1908a, p. 349; Weaver, 1912, pp. 20, 22; Arnold & Hannibal, 1913; pp. 576, 583, 588; Weaver, 1916a, pp. 162, 176.

Natica (Tectonatica) oregonensis (Conrad), Weaver, 1943, p. 331, pl. 100, fig. 27.

Cryptonatica oregonensis (Conrad), Moore, 1963, p. 27, pl. 2, figs. 3, 4 [not fig. 2, = *Natica (Natica) clarki* Etherington, 1931, or figs. 16, 17, = ?*Natica (Cryptonatica) clausa* Broderip & Sowerby, 1829; both species treated herein]; Moore, 1971, p. 23; Addicott, 1966a, p. 639 [not pl. 77, fig. 10, = ?*N. (C.) clausa*, treated herein].

Ampullina (Amauropsis) oregonensis Dall, 1909b, p. 91, pl. 3, fig. 7 [homonym].

Ampullina oregonensis Dall, Weaver, 1912, p. 18.

Amauropsis oregonensis (Dall), Grant & Gale, 1931, p. 807; Weaver, 1943, pp. 347-348, pl. 71, figs. 7, 11.

Description. —

Size: Average specimen, height 24 mm, diameter 19 mm; largest specimen, height 37.1 mm (incomplete), diameter 29.6 mm (incomplete) [CAS 1, Coos Bay, Oregon. Empire Formation, lower Pliocene].

Shell form: Shell elongate, spire elevated; body whorl not greatly inflated, flattened to slightly concave near suture; shell thickness average; whorls about five; suture slightly to moderately impressed. Shell smooth except for minute incremental growth lines. Parietal callus average to thick, moderately filling posterior apertural angle; anterior lobe weak. Umbilicus closed. Umbilical callus thick, semicircular, smooth; margin evenly rounded, bounded by groove. Anterior inner lip slightly thickened.

Operculum: Calcareous, surface smooth, with a single low rib along outer margin; central area slightly thickened.

Specimens examined. — Sixty-five.

Stratigraphic occurrence. — Ranges from middle Miocene to lower Pliocene. Middle Miocene: Astoria Fm., Lincoln Co. (CAS; SU, UCB), Curry Co. (UCB), Thurston Co. (UCB), Oreg., coastal Oregon (Moore, 1963), Seattle, Wash. (Arnold & Hannibal, 1913). Lower Pliocene: Empire Fm., Coos Bay, Oreg. (CAS; UCB; Dall, 1909b).

Type localities. —

Lunatia oregonensis — Astoria, Oregon (Conrad, 1849) [Presumably from the Astoria Formation, middle Miocene].

Ampullina (Amauropsis) oregonensis — Coos Bay, Oregon. Empire Formation, lower Pliocene (Dall, 1909b).

Type material. —

Lunatia oregonensis — Holotype, USNM 561551.

Ampullina (Amauropsis) oregonensis — Holotype, USNM 107780.

Nomenclatural commentary.—*Natica* (*Cryptonatica*) *oregonensis* and *Ampullina oregonensis* are considered synonymous and, therefore, homonymous for the first time here. The holotype of each species is somewhat worn but shows the elevated spire and simple callus covering the umbilicus that characterizes this species. Representative suites of specimens from the type areas of each species shows similar ranges of morphologic variation.

Discussion.—Specimens are almost invariably decorticated, resulting in confusion as to the morphologic limits of the species. For example, Moore (1963) figured the holotype of *N. (C.) oregonensis* and included figures of two other species under the same name, and Addicott (1966a) figured a probable specimen of *N. (C.) clausa* Broderip & Sowerby, 1829, as this species. *Natica* (*Cryptonatica*) *oregonensis* is the only species in the Neogene of the Pacific Northwest with an elevated spire and simple semicircular callus that covers the umbilicus.

The operculum has not previously been found associated with the shell, as discovered during this study on specimens from the lower Pliocene Empire Formation of Coos Bay, Oregon. One specimen (Pl. 42, fig. 9) has the operculum in living position, another has the operculum slightly askew, and a third has the operculum lying loose in the shell. The operculum has a smooth outer surface and looks much like that of *N. (C.) clausa* except for the single low rib along the outer margin. Two opercula figured by Moore (1963) from the middle Miocene Astoria Formation are probably of this species, although their outer surfaces are concealed by matrix. If they lack a rib along their outer margins, they would then probably be of *N. clausa*, which occurs uncommonly in the Astoria Formation.

The report of this species in the Oligocene Blakeley Formation of western Washington (Weaver, 1916a) is unreliable, considering the past difficulty in identifying this species and the considerable extension of stratigraphic range that would otherwise be necessary.

REJECTED AND INDETERMINATE TAXA

Natica geniculata Conrad, 1855, p. 18, is a prior name for *Bruclarkia barkeriana* (Cooper, 1894), in the family Neptuneidae, as noted by Clark (1937, p. 387).

Natica glabella Reeve, 1855, pl. 27, figs. 124a, b, a sinistral

shell from an undescribed locality, was reported from Central America by Smith (1944, p. 120) but is unknown in the eastern Pacific.

Natica inezana Conrad, 1857, p. 195, pl. 10, figs. 5, 6, is indeterminate from the type indication and specimens. The two type specimens were supposedly collected from Miocene beds in the Santa Ynez Mountains near Santa Barbara, California, are badly decorticated, and entirely lack umbilical features or other diagnostic shell characters. Although Miocene strata containing shallow-water mollusks do crop out in the Santa Ynez Mountains (Dibblee, 1950), Weaver & Kleinpell (1963) considered *N. inezana* to be an Oligocene species and reported it from the Gaviota Formation of Effinger (1935). Dall (1909b) thought that the two syntypes belonged to different genera, *Neverita* and *Ampullinopsis*, although Woodring (1931) attributed the supposed generic differences to weathering. Weaver & Kleinpell (1963) agreed that there were two genera among the types, as I do, and designated as lectotype the specimen with tabulate whorls that Dall (1909b) thought to be an *Ampullinopsis*. Unfortunately, both type specimens are too worn and broken for identification even to genus. Neither type specimen is assignable to any naticid species known from Oligocene, Miocene, or other rocks from the Santa Ynez Mountains, and the paralectotype might not even be a naticid. Additional collecting in the type area may produce specimens with well-preserved shell characters, but until then *N. inezana* is not a recognizable species.

Natica moquiniana Récluz, 1853b, pp. 154-156, pl. 5, figs. 9, 10, was reported to live on the west coast of America or on one of the Pacific islands. It is not known from the eastern Pacific.

Natica ocoyana Conrad, 1855, p. 18; and 1857, p. 328, pl. 7, figs. 51, 51a [not figs. 57, 57a, as stated in text], is indeterminate from the type indication. It was described from Miocene strata at "Ocoya Creek" [Poso Creek], near Bakersfield, Kern County, southern California, and the type material is missing (Keen & Bentson, 1944). Conrad's (1857) drawings show apical and backside views of an incomplete internal mold devoid of diagnostic features. Although it is conceivable that this species is identical with the well-known Miocene species *Neverita (Glossaulax) andersoni* (Clark, 1918), as suggested by Addicott (1970a, p. 68, cited as *nomen dubium*), it is not certain that *N. ocoyana* is a naticid. Judging by

the poor specimen illustrated by Conrad, rediscovery of the type material would not significantly aid in identifying this species.

Natica oligocenica Van Winkle, 1918, pp. 76, 86, pl. 7, fig. 23, is a minute species that probably belongs in the family Turbinidae. The type specimen (CAS 7527) is 5.0 mm in height, 4.5 mm in diameter, and has a nacreous interior. The type locality near Galvin, Washington, is in Oligocene strata of the Lincoln Creek Formation.

Natica saxea Conrad, 1849, appendix p. 727, pl. 19, figs. 7a, b, is unrecognizable from the original indication and the type specimen has been lost. The type locality is Astoria, Oregon, possibly in strata of the middle Miocene Astoria Formation. As noted by Moore (1963), none of the 11 specimens in the USNM type collection labeled as *N. saxea* is the one illustrated in the original description. Five of the 11 supposed syntypes are *Natica (Cryptonatica) oregonensis* (Conrad, 1865) which is common in the Astoria Formation; the rest are not determinable even to genus. Specimens attributed to this species and illustrated by Etherington (1931) and Weaver (1943) are *Natica (Natica) kanakoffi* Marinovich, 1975, and *Polinices (Euspira) lincolnensis* (Weaver, 1916b), respectively.

Natica vitrinelloides Carpenter, 1872, p. 79 of index, is a *lapsus calami* for *Vitrinella naticoides* Carpenter, 1857c.

Natica sp. ind. of Carpenter (1857c, p. 450), figured by Brann (1966, pl. 50, fig. 571), is not a naticid and is probably a protoconch.

Polinices (Lunatia?) olympidii Reagan, 1909, pp. 171, 194, pl. 3, fig. 29, cannot be recognized from its original description and figures, and there are no naticid species unaccounted for in its type area. The type locality is Gettysburg, Washington, in beds of the lower Miocene Clallam Formation, and the species has been reported in the middle Miocene Astoria Formation of coastal Washington (Arnold & Hannibal, 1913; Weaver, 1916a). The location of the type material is unknown. The trivial name was misspelled as "*olympi-dea*" by Reagan (1910, p. 648).

Polinices rapulum limi Pilsbry, 1931, pp. 436-437, fig. 5, is apparently a Miocene fossil reworked from formations that crop out along the shores of the type locality in Panama Bay. Pilsbry's type specimen had been identified earlier as *P. stanislasmeynieri* Maury, 1917a, by Li (1930, p. 249), who stated of this and other specimens

that "this collection is a mixture of Lower Miocene and Recent shells, for the collector was unable to keep them separate under the circumstances."

Lunatia pallidoides Carpenter, 1864, p. 585, is mentioned from "Arctic Ocean, near Behring Sts., mud, 30 fm." Lacking a description or figure, it is a *nomen nudum*.

Lunatia tenuilirata Carpenter, 1857c, p. 451, from Mazatlán, Mexico, is apparently a *Tricolia* and is regarded as indeterminate (Keen, 1971, p. 902). A figure is given by Brann (1966, pl. 50, fig. 572), and according to Keen (1971) the holotype in the British Museum (Natural History) is worn and broken, lacking part of the spire and much of the body whorl, and measures 1.4 mm in height.

Lunatia sp. ind. a, b, c, of Carpenter (1857c, p. 451), reported from Mazatlán, Mexico, are apparently based on protoconchs. Figures of these three are given by Brann (1966, pls. 49, 50).

Ampullospira luda M. A. Hanna, 1927, p. 306, pl. 48, figs. 7, 8, is a minute species that probably belongs in the family Rissoidae. The type specimen (UCB 30959) is from middle Eocene strata of the La Jolla Group near San Diego, California, and measures 2.25 mm in height and 1.4 mm in diameter.

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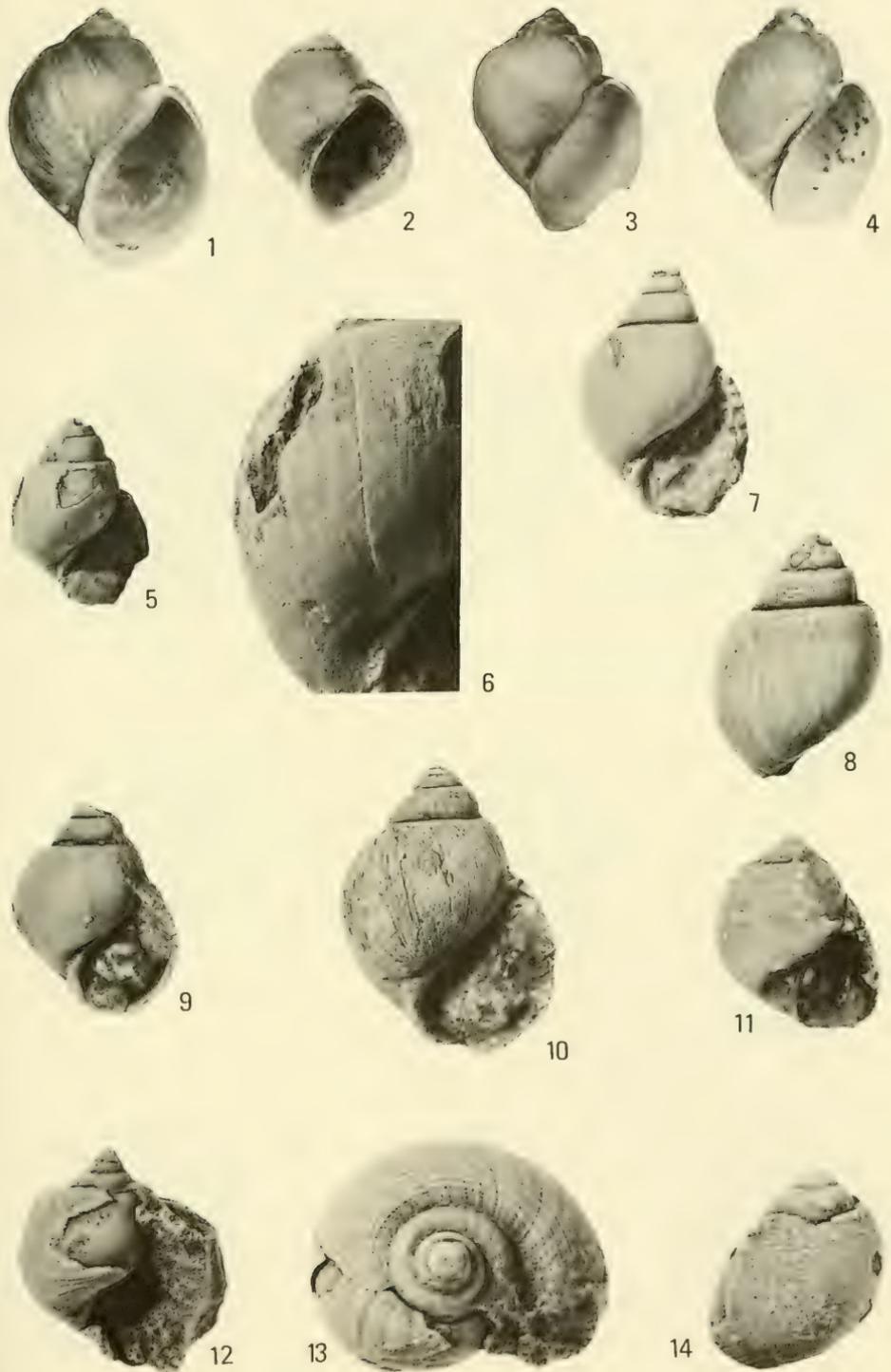
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6. Amauopsis martinezensis Dickerson	221
UCB 11702. Enlarged body whorl of holotype, showing fine spiral sculpture. $\times 3$.	
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UCR 6825/4. Upper Paleocene, Martinez Formation, Simi Hills, Ventura County, California. Height 32.0 mm. Note distinctly tabulate shoulder.	
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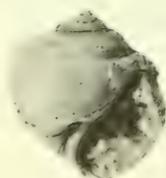
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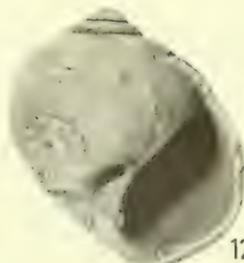
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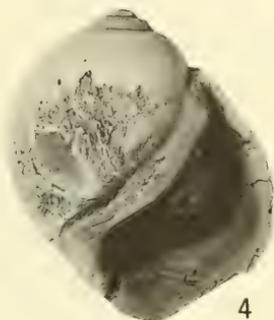
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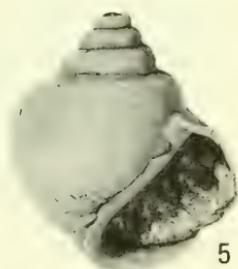
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Figure	Page
1. Euspirocrommium hewitti (Hanna & Hertlein)	237
CAS 9430. Lower Eocene, Lodo Formation, Kern County, California. Height 94.0 mm. Holotype.	
2. Euspirocrommium hewitti (Hanna & Hertlein)	237
CAS 32388. Lower Eocene, Lodo Formation, Kern County, California. Height 68.4 mm.	
3. Euspirocrommium hewitti (Hanna & Hertlein)	237
UCR 4668/21. Lower Eocene, Juncal Formation, Ventura County, California. Height 39.6 mm.	
4. Pachycrommium clarki (Stewart)	238
UCB 31385. Lower or middle Eocene, Llajas Formation, Ventura County, California. Height 41.3 mm. Holotype.	
5. Pachycrommium clarki (Stewart)	238
UCB 31386. Lower or middle Eocene, Llajas Formation, Ventura County, California. Height 37.6 mm. Paratype. Specimen more globose than average.	
6. Pachycrommium clarki (Stewart)	238
UCB 14409. Lower or middle Eocene, Crescent Formation, Clallam County, Washington. Height 45.3 mm. Typical specimen, with nearly complete outer lip.	
7. Pachycrommium clarki (Stewart)	238
CAS 25. Middle Eocene, "Umpqua" [Flournoy] Formation, Douglas County, Oregon. Height 55.6 mm. Specimen with body whorl more elongate than usual.	
8. Pachycrommium clarki (Stewart)	238
UCB 15866. Middle Eocene, Domengine Formation, San Benito County, California. Height 17.6 mm. Holotype of <i>Amaurellina</i> (?) <i>multiangulata</i> Vokes.	
9. Pachycrommium clarki (Stewart)	238
UCB 15866. Enlarged backside view of holotype of <i>Amaurellina</i> (?) <i>multiangulata</i> Vokes, seen in strong oblique lighting to emphasize spiral sculpture.	
10. Pachycrommium clarki (Stewart)	238
UCB 14410. Lower or middle Eocene, Llajas Formation, Ventura County, California. Height 26.5 mm. Showing atypical spiral sculpture.	
11. Amaurellina caleocia Vokes	241
UCB 33781. Middle Eocene, Domengine Formation, Fresno County, California. Height 14.8 mm. Holotype.	
12. Amaurellina caleocia Vokes	241
UCB 33781. Diameter 12.5 mm. Apical view of holotype, showing narrowly channeled suture and spiral sculpture.	
13. Amaurellina caleocia Vokes	241
UCB 15863. Middle Eocene, Domengine Formation, Kings County, California. Height 8.7 mm. Holotype of <i>Amaurellina garzaensis</i> Vokes.	

EXPLANATION OF PLATE 21

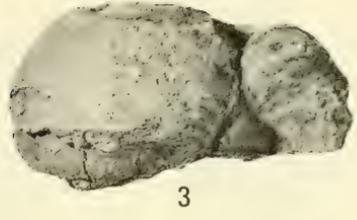
Figure	Page
1. Amaurellina caleocia Vokes	241
UCB 15862. Middle Eocene, Domengine Formation, Fresno County, California. Height 19.1 mm. Paratype. Note small umbilical opening.	
2. Amaurellina caleocia Vokes	241
UCB 15864. Middle Eocene, Domengine Formation, Kings County, California. Height 10.7 mm. Paratype of <i>Amaurellina garzaensis</i> Vokes.	
3. Gyrodus robustus Waring	243
SU 147. Upper Paleocene, Martinez Formation, Ventura County, California. Height 28.4 mm. Lectotype designated herein, apertural view.	
4. Gyrodus robustus Waring	243
SU 147. Lectotype, apical view. Diameter 53.5 mm.	
5. Gyrodus robustus Waring	243
SU 147. Lectotype, basal view. Diameter 53.5 mm.	
6. Gyrodus robustus Waring	243
SU 148. Upper Paleocene, Martinez Formation, Ventura County, California. Height 33.6 mm. Paralectotype.	
7. Gyrodus robustus Waring	243
UCR 6899/2. Upper Paleocene, Martinez Formation, Ventura County, California. Height 39.5 mm.	
8. Gyrodus robustus Waring	243
UCR 6899/2. Apical view of specimen in Figure 7. Diameter 40.6 mm.	
9. Gyrodus robustus Waring	243
UCR 6899/2. Basal view of specimen in Figure 7, showing large umbilical opening. Diameter 40.6 mm.	
10. Polinices (Polinices) gesteri (Dickerson)	251
UCB 11829. Upper Paleocene, Lodo Formation, Fresno County, California. Height 14.9 mm. Holotype.	
11. Polinices (Polinices) gesteri (Dickerson)	251
UCB 14411. Upper Paleocene, Meganos Formation, Contra Costa County, California. Height 13.7 mm.	
12. Polinices (Polinices) hornii (Gabb)	261
ANSP 4214. Upper Eocene, Tejon Formation, Kern County, California. Height 32.6 mm. Lectotype of Stewart (1927).	
13. Polinices (Polinices) hornii (Gabb)	261
ANSP 4214. Upper Eocene, Tejon Formation, Kern County, California. Height 23.0 mm. Paralectotype. Note umbilicus reduced to a shallow pit.	
14. Polinices (Polinices) hornii (Gabb)	261
ANSP 4214. Upper Eocene, Tejon Formation, Kern County, California. Height 12.0 mm. Paralectotype. Note distinctly open umbilicus.	



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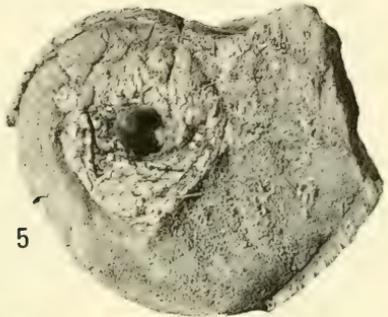
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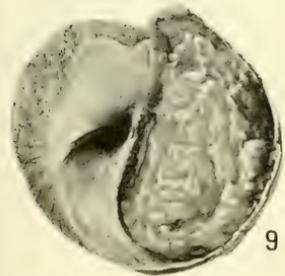
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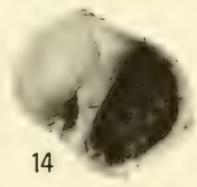
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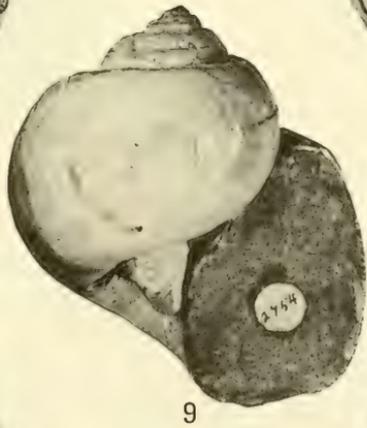
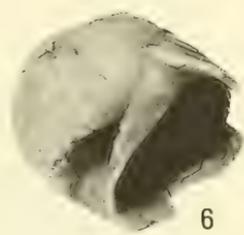
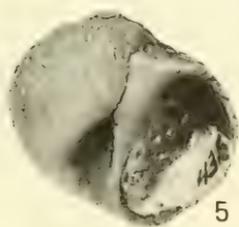
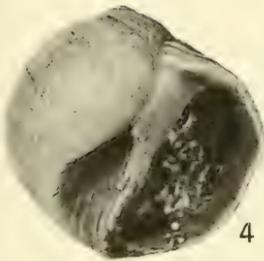
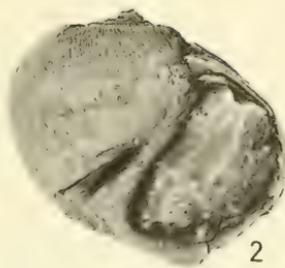
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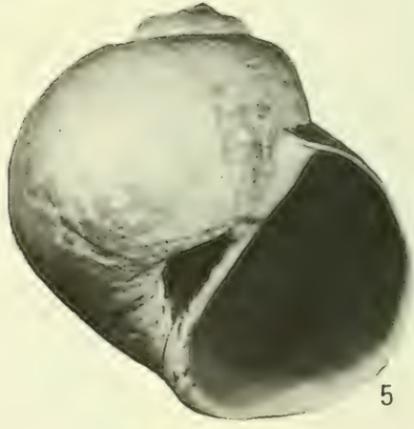
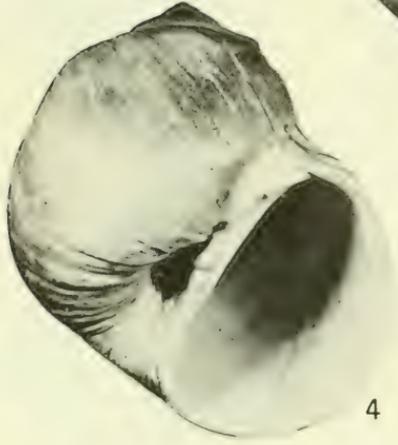
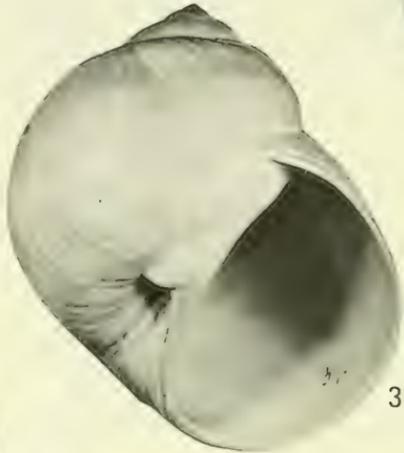
EXPLANATION OF PLATE 22

Figure	Page
1. Amauropsis islandica (Gmelin)	217
USNM 214720. Holocene, Eschscholtz Bay, Kotzebue Sound, Alaska. Height 20.6 mm. Note more globose shape compared to individual in Plate 17, figure 4, from same locality.	
2. Polinices (Polinices) uber (Valenciennes)	246
AMNH 73742. Holocene, Santa Elena, Ecuador. Height 23.3 mm. Large adult.	
3. Polinices (Polinices) uber (Valenciennes)	246
LACM 69-8. Holocene, Bahía San Luis Gonzaga, Baja California, Mexico. Height 11.4 mm. Typical proportions for small adults.	
4. Polinices (Polinices) uber (Valenciennes)	246
LACM 69-8. Holocene, Bahía San Luis Gonzaga, Baja California, Mexico. Height 12.7 mm. Especially elongate specimen.	
5. Polinices (Polinices) panamaensis (Récluz)	252
AMNH 154110. Holocene, Viqui Point, Vacamonte, Panama. Height 36.8 mm. Shows typical development of umbilical callus.	
6. Polinices (Polinices) panamaensis (Récluz)	252
AMNH 154110. Holocene, Viqui Point, Vacamonte, Panama. Height 33.8 mm. Showing swollen umbilical and parietal calluses.	
7. Polinices (Polinices) panamaensis (Récluz)	252
AMNH 154110. Holocene, Viqui Point, Vacamonte, Panama. Height 40.9 mm. Showing greatly swollen umbilical and parietal calluses.	
8. Polinices (Polinices) intemeratus (Philippi)	253
SU 10274. Holocene, Panama Bay, Panama. Height 26.9 mm.	
9. Polinices (Polinices) intemeratus (Philippi)	253
USNM 110656. Holocene, Panama Bay, Panama. Height 19.5 mm.	
10. Polinices (Polinices) otis (Broderip & Sowerby)	255
USNM 46544. Holocene, Panama. Height 30.4 mm. Holotype of <i>Ruma subfusca</i> Dall. Form with white umbilical callus.	
11. Polinices (Polinices) otis (Broderip & Sowerby)	255
USNM 154074. Holocene, Isla Viveros, Panama. Height 36.2 mm. Form with dark-brown spot on umbilical callus.	
12. Polinices (Polinices) amiculatus (Philippi)	258
USNM 538002. Holocene, Isla Lobos de Tierra, Peru, Height 46.0 mm.	
13. Polinices (Polinices) amiculatus (Philippi)	258
USNM 538002. Basal view of specimen in Figure 12, showing circu- lar umbilicus.	

EXPLANATION OF PLATE 23

Figure	Page
1. Polinices (Polinices) hornii (Gabb)	261
UCB 14412. Upper Eocene, Cowlitz Formation, Cowlitz County, Washington. Height 20.3 mm.	
2. Polinices (Polinices) hornii (Gabb)	261
UCR 7529/1. Upper Paleocene, Martinez Formation, Ventura County, California. Height 29.3 mm.	
3. Polinices (Polinices) susanaensis Nelson	263
UCB 30711. Upper Paleocene, Martinez Formation, Ventura County, California. Height 35.0 mm. Holotype. Umbilical area badly eroded.	
4. Polinices (Polinices) susanaensis Nelson	263
UCB 14413. Upper Paleocene, Lodo Formation, Fresno County, California. Height 36.0 mm.	
5. Polinices (Polinices) susanaensis Nelson	263
SU 10276. Upper Paleocene, Lodo Formation, Fresno County, California. Height 29.4 mm.	
6. Polinices (Polinices) susanaensis Nelson	263
UCB 14414. Upper Paleocene, Lodo Formation, Fresno County, California. Height 32.8 mm.	
7. Polinices (Euspira) galianoi Dall	264
CAS 4. Lower Pliocene, Empire Formation, Coos County, Oregon. Height 34.6 mm.	
8. Polinices (Euspira) galianoi Dall	264
UCB 12058. Lower Pliocene, lower Etchegoin Formation, Fresno County, California. Height 38.0 mm. Holotype of <i>Natica orbicularis</i> Nomland.	
9. Polinices (Euspira) galianoi Dall	264
USNM 153916. Lower Pliocene, Empire Formation, Coos County, Oregon. Height 53.5 mm. Holotype.	
10. Polinices (Euspira) diabloensis (Clark)	267
UCB 11595. Upper Miocene, upper part of San Pablo Formation, Contra Costa County, California. Height 49.0 mm. Holotype.	
11. Polinices (Euspira) ramonensis (Clark)	269
UCB 12381. Upper Oligocene or lower Miocene, Poul Creek Formation, Yakataga District, Alaska. Height 11.0 mm. Hypotype of Clark (1932).	

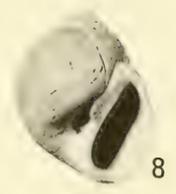
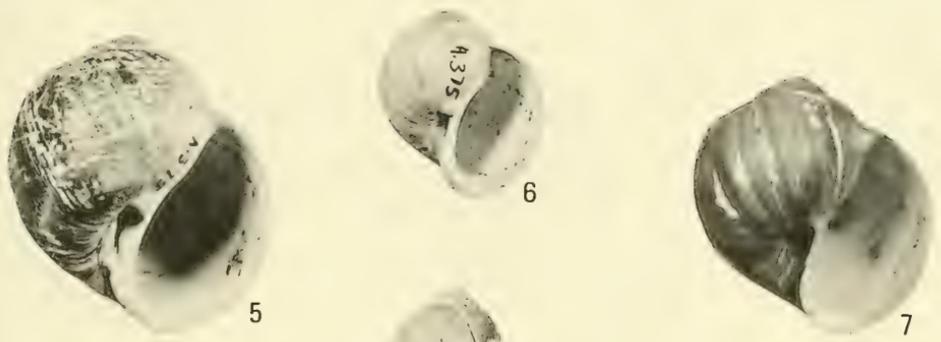
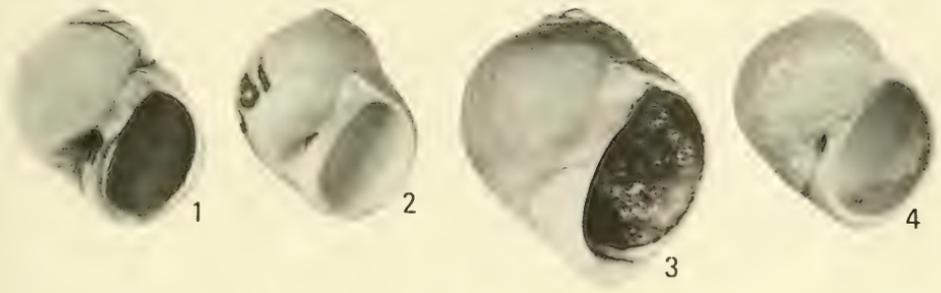




EXPLANATION OF PLATE 24

Figure	Page
1. Polinices (Polinices) bifasciatus (Griffith & Pidgeon)	259
LACM 69-8. Holocene, Bahía San Luis Gonzaga, Baja California, Mexico. Height 46.1 mm.	
2. Polinices (Polinices) bifasciatus (Griffith & Pidgeon)	259
LACM 69-8. Holocene, Bahía San Luis Gonzaga, Baja California, Mexico. Height 35.4 mm. Note narrower umbilical opening than in preceding figure.	
3. Polinices (Euspira) lewisii (Gould)	271
USNM 3903. Holocene, Puget Sound, Washington. Height 126.4 mm. Holotype.	
4. Polinices (Euspira) lewisii (Gould)	271
LACM, no number. Holocene, Los Angeles County, California. Height 118.8 mm.	
5. Polinices (Euspira) lewisii (Gould)	271
USNM 183061. Holocene, Los Angeles County, California. Height 112.0 mm.	
6. Polinices (Euspira) draconis (Dall)	276
USNM 172859. Holocene, Monterey Bay, Monterey County, California. Height 51.5 mm. Holotype.	
7. Polinices (Euspira) draconis (Dall)	276
USNM 172859. Basal view of holotype shown in Figure 6. Note broadly open umbilicus.	

Figure	EXPLANATION OF PLATE 25	Page
1.	Polinices (Euspira) pallidus (Broderip & Sowerby) Zoological Museum, Univ. Copenhagen, no number. Holocene, Greenland. Height 15.3 mm. Lectotype designated herein of <i>Natica groenlandica</i> Möller <i>ex Beck</i> MS.	278
2.	Polinices (Euspira) pallidus (Broderip & Sowerby) MCZ 169081. Holocene, Straits of Juan de Fuca, Washington. Height 12.5 mm. Lectotype designated by Johnson (1964) of <i>Natica caurina</i> Gould.	278
3.	Polinices (Euspira) pallidus (Broderip & Sowerby) USNM 220856. Holocene, Aleutian Islands, Alaska. Height 19.0 mm. Holotype of <i>Euspira monterona</i> Dall.	278
4.	Polinices (Euspira) pallidus (Broderip & Sowerby) USNM 209411. Holocene, off San Diego, San Diego County, California. Height 8.0 mm. Holotype of <i>Euspira canonica</i> Dall.	278
5.	Polinices (Euspira) pallidus (Broderip & Sowerby) LACM A.375. Holocene, Petersburg, Alaska. Height 41.5 mm. Typical living adult specimen.	278
6.	Polinices (Euspira) pallidus (Broderip & Sowerby) LACM A.375. Holocene, Petersburg, Alaska. Height 21.6 mm. Typical living juvenile, with umbilicus narrower than seen in adults.	278
7.	Polinices (Euspira) agujanus Dall USNM 110566. Holocene, off Punta Aguja, Peru. Height 25.9 mm. Holotype.	291
8.	Polinices (Euspira) pallidus (Broderip & Sowerby) CAS 15. Lower Pleistocene, Elk River Beds, Curry County, Oregon. Height 19.5 mm.	278
9.	Polinices (Euspira) crawfordianus Dall USNM 123044. Holocene, Gulf of Panama, Panama. Height 14.1 mm. Holotype.	292
10.	Polinices (Euspira) litorinus Dall USNM 96481. Holocene, near Galápagos Islands, Ecuador. Height 7.7 mm. Holotype.	293
11.	Polinices (Euspira) pardoanus Dall USNM 123046. Holocene, Gulf of Panama, Panama. Height 12.8 mm. Holotype.	294
12.	Polinices sookensis Clark & Arnold SU 245. Supposedly from lower Miocene(?) Sooke Formation, Vancouver Island, British Columbia, Canada. Height 14.6 mm. Supposed holotype (see text); true identity is <i>Natica (Tectonatica) gabbi</i> Clark.	295
13.	Polinices (Mammilla) caprae (Philippi) AMNH 110382. Holocene, Santa Cruz Island, Galápagos Islands, Ecuador. Height 26.8 mm.	299
14.	Polinices (Mammilla) caprae (Philippi) Natural History Museum, Santiago, Chile, 61.567. Holocene, Mazatlán, Mexico. Height approximately 17 mm. Syntype. Photo courtesy of Nivaldo Bahamonde N.	299





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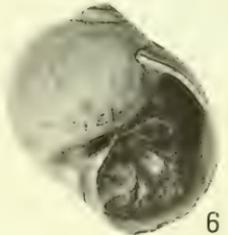
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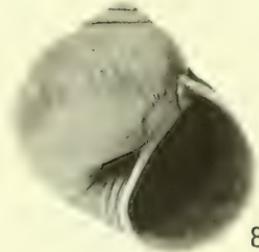
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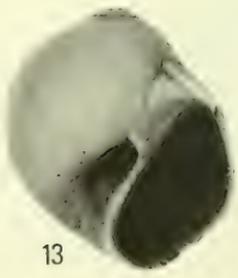
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EXPLANATION OF PLATE 26

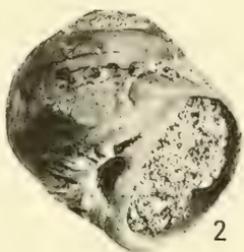
Figure	Page
1. Polinices (Euspira) ramonensis (Clark)	269
UCB 11257. Upper Oligocene or lower Miocene, San Ramon Sandstone, Contra Costa County, California. Height 15.7 mm. Holotype.	
2. Polinices (Euspira) ramonensis (Clark)	269
UCB 12396. Upper Oligocene or lower Miocene, Poul Creek Formation, Yakataga District, Alaska. Height 13.4 mm. Hypotype of Clark (1932).	
3. Polinices (Euspira) ramonensis (Clark)	269
USNM 239908. Upper Oligocene, Blakeley Formation, Kitsap County, Washington. Height 9.9 mm.	
4. Polinices (Euspira) blakeleyensis Tegland	270
UCB 32216. Oligocene, Blakeley Formation, Kitsap County, Washington. Height 27.6 mm. Holotype.	
5. Polinices (Euspira) blakeleyensis Tegland	270
USNM 219864. Lower Miocene, Twin River Formation, Clallam County, Washington. Height 23.2 mm.	
6. Polinices (Euspira) nuciformis (Gabb)	281
ANSP 4213. Upper Eocene, Tejon Formation, Kern County, California. Height 21.2 mm. Lectotype of Stewart (1927).	
7. Polinices (Euspira) nuciformis (Gabb)	281
UCB 32706. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 21.0 mm. Typical specimen.	
8. Polinices (Euspira) nuciformis (Gabb)	281
UCLA 38779. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 23.9 mm. Note broad umbilical opening and somewhat elevated spire.	
9. Polinices (Euspira) nuciformis (Gabb)	281
UCLA 38780. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 28.7 mm. Note narrow umbilical opening and elevated spire.	
10. Polinices (Euspira) hotsoni Weaver & Palmer	285
CAS 7830. Upper Eocene, Cowlitz Formation, Cowlitz County, Washington. Height 22.4 mm. Holotype.	
11. Polinices (Euspira) hotsoni Weaver & Palmer	285
UCB 14527. Upper Eocene, Cowlitz Formation, Cowlitz County, Washington. Height 11.3 mm.	
12. Polinices (Euspira) hotsoni Weaver & Palmer	285
USNM 239909. Upper Eocene, Keasey Formation, southwestern Oregon. Height 22.8 mm.	
13. Polinices (Euspira) hotsoni Weaver & Palmer	285
UCB 14415. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 12.0 mm.	

EXPLANATION OF PLATE 27

Figure	Page
1. Polinices (Euspira) lincolnensis (Weaver)	286
CAS 463. Oligocene, Lincoln Creek Formation, Lewis County, Washington. Height 29.6 mm. Lectotype of Weaver (1943).	
2. Polinices (Euspira) lincolnensis (Weaver)	286
CAS 582. Lower Miocene (?), Sooke Formation, Vancouver Island, British Columbia, Canada. Height 29.8 mm. Holotype of <i>P. (E.) victoriana</i> Clark & Arnold.	
3. Polinices (Euspira) lincolnensis (Weaver)	286
USNM 563134. Middle Miocene, Astoria Formation, Lincoln County, Oregon. Holotype of <i>Polinices canalis</i> Moore.	
4. Polinices (Euspira) lincolnensis (Weaver)	286
UCLA 38781. Middle Oligocene, Pittsburg Bluff Formation, Columbia County, Oregon. Height 23.2 mm.	
5. Polinices (Euspira) lincolnensis (Weaver)	286
CAS 163. Middle Oligocene, Pittsburg Bluff Formation, Columbia County, Oregon. Height 22.3 mm.	
6. Polinices (Euspira) lincolnensis (Weaver)	286
USNM 339910. Middle Miocene, Round Mountain Silt, Kern County, California. Height 27.8 mm. Note swelling at midpoint of umbilical callus.	
7. Polinices (Euspira) simiensis Nelson	289
UCB 30710. Upper Paleocene, Martinez Formation, Ventura County, California. Height 13.6 mm. Holotype.	
8. Polinices (Euspira?) clementensis (M. A. Hanna)	290
UCB 31003. Middle Eocene, Ardath Shale, San Diego County, California. Height 10.1 mm. Holotype.	
9. Polinices (Euspira?) clementensis (M. A. Hanna)	290
USNM 239911. Upper Eocene, Keasey Formation, southwestern Oregon. Height 13.3 mm.	
10. Polinices (Euspira?) clementensis (M. A. Hanna)	290
UCLA 38782. Upper Eocene, Keasey Formation, Washington County, Oregon. Height 8.6 mm.	
11. Neverita (Neverita) nana (Möller)	301
Zoological Museum, Copenhagen, No number. Holocene, Greenland. Height 6.2 mm. Lectotype designated herein.	
12. Neverita (Neverita) nana (Möller)	301
USNM 267170. Holocene, off Santa Barbara, Santa Barbara County, California. Height 17.0 mm.	
13. Neverita (Neverita) lamonae Marincovich	304
USNM 741012. Holocene, off central Oregon. Height 18.5 mm. Holotype.	
14. Neverita (Neverita) lamonae Marincovich	304
AMNH 181738. Holocene, off of central Oregon. Height 19.8 mm. Paratype.	



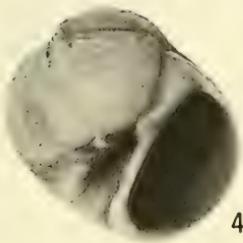
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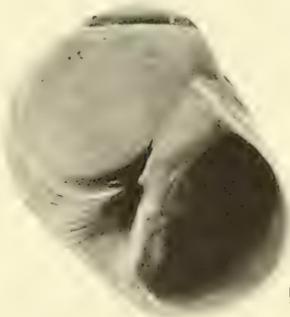
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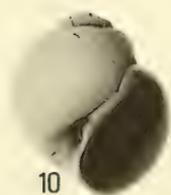
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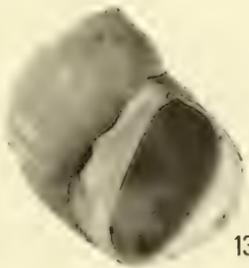
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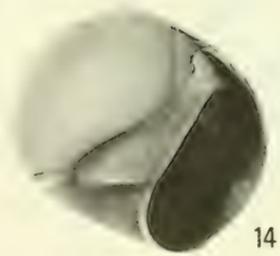
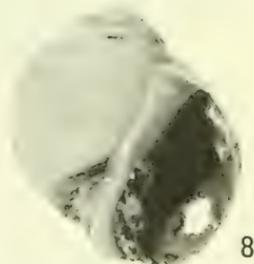
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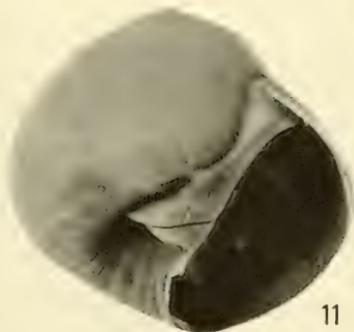
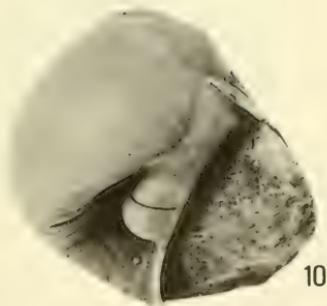


EXPLANATION OF PLATE 28

Figure	Page
1. Neverita (Neverita) kirkensis (Clark)	306
UCB 11591. Upper Miocene, San Pablo Formation, Contra Costa County, California. Height 35.8 mm. Holotype.	
2. Neverita (Neverita) kirkensis (Clark)	306
UCB 11594. Upper Miocene, San Pablo Formation, Contra Costa County, California. Height 39.0 mm. Holotype of <i>Natica (Neverita) arnoldi</i> Clark.	
3. Neverita (Neverita) washingtonensis (Weaver)	307
CAS 462-C. Oligocene, Lincoln Creek Formation, Lewis County, Washington. Height 14.0 mm. Lectotype designated herein.	
4. Neverita (Neverita) washingtonensis (Weaver)	307
USNM 239912. Upper Eocene or Oligocene, Lincoln Creek Formation, Grays Harbor County, Washington. Height 12.6 mm. Note shallow depression that falsely appears to be an umbilical opening.	
5. Neverita (Neverita) washingtonensis (Weaver)	307
UCB 32191. Oligocene, Blakeley Formation, Kitsap County, Washington. Height 14.1 mm. Holotype of <i>Polinices (Euspira) rectus</i> Tegland.	
6. Neverita (Neverita) washingtonensis (Weaver)	307
USNM 213951. Middle Oligocene, Pittsburgh Bluff Formation, Columbia County, Oregon. Height 15.4 mm. Holotype of <i>Cryptonatica pittsburgensis</i> Moore.	
7. Neverita (Neverita) washingtonensis (Weaver)	307
UCLA 38783. Middle Oligocene, Pittsburg Bluff Formation, Columbia County, Oregon. Height 21.4 mm.	
8. Neverita (Neverita) washingtonensis (Weaver)	307
UCLA 38784. Middle Oligocene, Pittsburg Bluff Formation, Columbia County, Oregon. Height 24.0 mm.	
9. Neverita (Neverita) washingtonensis (Weaver)	307
UCLA 38785. Middle Oligocene, Pittsburgh Bluff Formation, Columbia County, Oregon. Height 14.1 mm. Note false umbilical opening produced by erosion of body whorl.	
10. Neverita (Neverita) globosa Gabb	312
MCZ 27859. Middle Eocene, Domengine(?) Formation, San Benito County, California. Height 28.9 mm. Holotype.	
11. Neverita (Neverita) globosa Gabb	312
UCB 15855. Middle Eocene, Domengine Formation, Kings County, California. Height 21.3 mm. Holotype of <i>Neverita globosa reefensis</i> Vokes.	
12. Neverita (Neverita) globosa Gabb	312
CAS 411. Oligocene, Lincoln Creek Formation, Cowlitz County, Washington. Height 12.6 mm. Holotype of <i>Neverita nomlandi</i> Dickerson.	
13. Neverita (Neverita) globosa Gabb	312
CAS 278. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 9.5 mm. Holotype of <i>Neverita weaveri</i> Dickerson.	
14. Neverita (Neverita) globosa Gabb	312
USNM 239913. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 11.5 mm. Typical specimen.	
15. Neverita (Neverita) globosa Gabb	312
USNM 239914. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 12.1 mm. Note deep groove along margin of umbilical callus; umbilicus imperforate.	

EXPLANATION OF PLATE 29

Figure	Page
1. Neverita (Neverita) globosa Gabb	312
USNM 239915. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 10.7 mm. Note deep groove along margin of umbilical callus; umbilicus imperforate.	
2. Neverita (Neverita) globosa Gabb	312
UCB 14416. Middle Eocene, Flournoy Formation, Douglas County, Oregon. Height 16.0 mm. Note elongate proportions, open umbilicus and reduced umbilical callus.	
3. Neverita (Neverita) globosa Gabb	312
UCB 14417. Middle Eocene, Flournoy Formation, Douglas County, Oregon. Height 13.0 mm. Note elongate proportions, open umbilicus and reduced umbilical callus.	
4. Neverita (Glossaulax) reclusiana (Deshayes)	317
ANSP 4212. Upper Eocene, Tejon Formation, Kern County, California. Height 21.2 mm. Holotype of <i>Neverita secta</i> Gabb.	
5. Neverita (Glossaulax) reclusiana (Deshayes)	317
UCB 12482. Upper Eocene, Markley Sandstone, Member of Kreyenhagen Formation, Solano County, California. Height 15.6 mm. Holotype of <i>Neverita secta hemisecta</i> Clark.	
6. Neverita (Glossaulax) reclusiana (Deshayes)	317
ANSP 147585. Upper Pleistocene, Palos Verdes Sand, Los Angeles County, California. Height 30.0 mm. Neotype designated by Pilsbry (1929) of <i>Polynices (Neverita) reclusianus altus</i> Arnold.	
7. Neverita (Glossaulax) reclusiana (Deshayes)	317
USNM 36633. Holocene, "probably San Diego," San Diego County, California. Height 30.5 mm. Lectotype designated herein of <i>Polynices (Neverita) reclusianus imperforatus</i> Dall.	
8. Neverita (Glossaulax) reclusiana (Deshayes)	317
SU 293. Upper Oligocene or lower Miocene, Sooke Formation, Vancouver Island, British Columbia, Canada. Height 26.1 mm. Holotype of <i>Polynices (Neverita) reclusiana vancouverensis</i> Clark & Arnold.	
9. Neverita (Glossaulax) reclusiana (Deshayes)	317
University of Oregon 27366. Middle Oligocene, Pittsburg Bluff Formation, Columbia County, Oregon. Height 34.1 mm. Holotype of <i>Neverita thomsonae</i> Hickman.	
10. Neverita (Glossaulax) reclusiana (Deshayes)	317
UCB 14418. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 22.8 mm.	
11. Neverita (Glossaulax) reclusiana (Deshayes)	317
UCB 14419. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 21.5 mm.	
12. Neverita (Glossaulax) reclusiana (Deshayes)	317
UCB 14420. Upper Eocene, Tejon Formation, Kern County, California. Height 31.6 mm. Note elongate proportions and small umbilical callus; specimen somewhat decorticated.	





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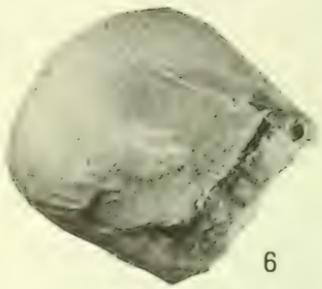
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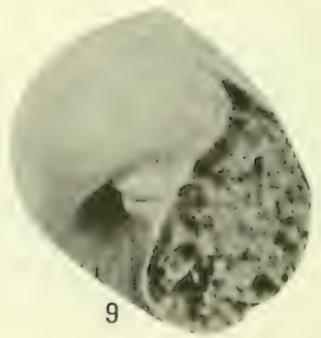
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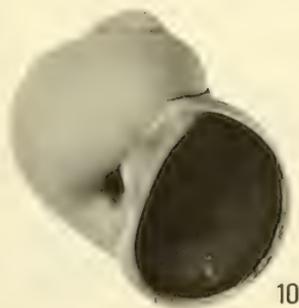
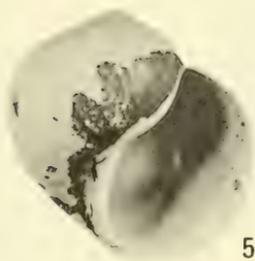
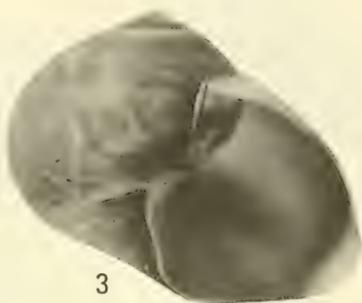
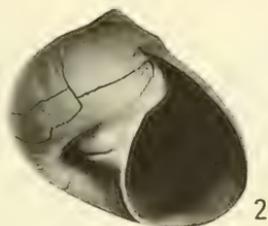
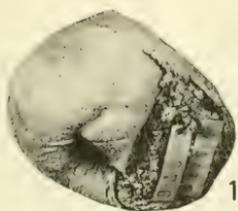
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EXPLANATION OF PLATE 30

Figure	Page
1. Neverita (Glossaulax) reclusiana (Deshayes)	317
CAS 163. Middle Oligocene, Pittsburg Bluff Formation, Columbia County, Oregon. Height 23.5 mm.	
2. Neverita (Glossaulax) reclusiana (Deshayes)	317
LACM, no number. Holocene, Monterey Bay, California. Height 25.1 mm.	
3. Neverita (Glossaulax) reclusiana (Deshayes)	317
LACM P.465.62. Holocene, Anaheim Bay, California. Height 32.2 mm. A well-developed modern example of the so-called <i>alta</i> form of this species.	
4. Neverita (Glossaulax) reclusiana (Deshayes)	317
LACM R-498. Holocene, Alamitos Bay, California. Height 57.5 mm.	
5. Neverita (Glossaulax) andersoni (Clark)	328
UCB 11212. Upper Miocene(?), San Ramon Formation, Contra Costa County, California. Height 15.3 mm. Holotype.	
6. Neverita (Glossaulax) andersoni (Clark)	328
UCB 11592. Upper Miocene, San Pablo Group, Contra Costa County, California. Height 36.8 mm. Holotype of <i>Natica (Neverita) pabloensis</i> Clark.	
7. Neverita (Glossaulax) andersoni (Clark)	328
SU 10273. Middle Miocene, Olcese Sand, Kern County, California. Height 27.0 mm.	
8. Neverita (Glossaulax) andersoni (Clark)	328
UCB 14421. Middle Miocene, Topanga Formation, Los Angeles County, California. Height 54.0 mm. Note elongate proportions.	
9. Neverita (Glossaulax) jamesae Moore	332
UCB 14422. Middle Miocene, Round Mountain Silt, Kern County, California. Height 20.1 mm.	

EXPLANATION OF PLATE 31

Figure	Page
1. Neverita (Glossaulax) jamesae Moore	332
USNM 563129. Middle Miocene, Astoria Formation, Lincoln County, Oregon. Height 22.0 mm. Holotype.	
2. Neverita (Glossaulax) jamesae Moore	332
UCB 15498. Middle Miocene, Round Mountain Silt, Kern County, California. Height 22.7 mm.	
3. Calinaticina oldroydii (Dall)	334
SU 6447. Holocene, Catalina Island, Los Angeles County, California. Height 35.0 mm. Holotype.	
4. Bulbus fragilis (Leach)	335
CAS 35051. Holocene, Eluiktak Pass, Beaufort Sea, Alaska. Height 14.9 mm.	
5. Bulbus fragilis (Leach)	335
USNM 50319. Holocene, St. Peter's Bank, North Atlantic. Height 22.6 mm.	
6. Bulbus fragilis (Leach)	335
CAS 35051. Holocene, Eluiktak Pass, Beaufort Sea, Alaska. Height 13.0 mm.	
7. Bulbus fragilis (Leach)	335
USNM 109468. Holocene, Unalaska Island, Aleutian Islands, Alaska. Height 17.3 mm.	
8. Choristes carpenteri Dall	340
USNM 123038. Holocene, Gulf of Panama, Panama. Height 20.5 mm. Holotype.	
9. Choristes carpenteri Dall	340
LACM, no number. Holocene, off central Oregon. Height 24.0 mm.	
10. Choristes coani Marincovich	341
USNM 741014. Holocene, off central Oregon. Height 13.9 mm. Holotype. Note much more narrowly channeled suture than on <i>C. carpenteri</i> .	
11. Choristes coani Marincovich	341
LACM 1733. Holocene, off central Oregon. Height 17.1 mm. Paratype.	
12. Choristes coani Marincovich	341
LACM 1733. Holocene, off central Oregon. Height 13.8 mm. Paratype.	

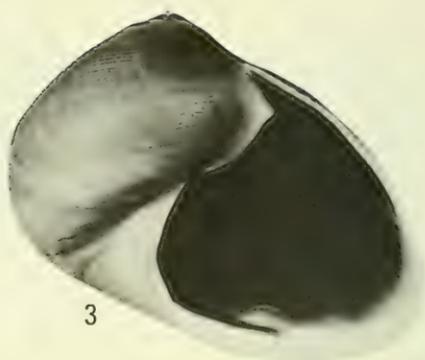




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EXPLANATION OF PLATE 32

Figure	Page
1. Sinum cymba (Menke)	343
Natural History Museum, Santiago, Chile, 60.181. Holocene, Peru. Diameter about 45 mm. Syntype of <i>Sigaretus maximus</i> Philippi, apical view. Photo courtesy Nibaldo Bahamonde N.	
2. Sinum cymba (Menke)	343
Natural History Museum, Santiago, Chile, 60.181. Holocene, Peru. Diameter about 36 mm. Syntype of <i>Sigaretus maximus</i> Philippi, basal view. Photo courtesy Nibaldo Bahamonde N.	
3. Sinum cymba (Menke)	343
AMNH 155878. Holocene, Caldera, Chile. Height 54.5 mm.	
4. Sinum cymba (Menke)	343
AMNH 155878. Apical view of specimen in Figure 3.	
5. Sinum cymba (Menke)	343
AMNH 155878. Basal view of specimen in Figure 3.	
6. Sinum cymba (Menke)	343
AMNH 119534. Holocene, Pucusana, Peru. Height 35.6 mm. Note typically shouldered body whorl.	
7. Sinum grayi (Deshayes)	345
LACM, no number. Holocene, off northern Peru. Height 25.7 mm.	
8. Sinum grayi (Deshayes)	345
LACM, no number. Apical view of specimen in Figure 7.	
9. Sinum grayi (Deshayes)	345
LACM, no number. Basal view of specimen in Figure 7.	
10. Sinum grayi (Deshayes)	345
CAS 12601. Holocene, near Mazatlán, Mexico. Height 13.9 mm. Holotype of <i>S. cortezi</i> Burch & Burch.	

EXPLANATION OF PLATE 33

Figure	Page
1. Sinum obliquum (Gabb)	347
ANSP 4215. Upper Eocene, Tejon Formation, Kern County, California. Height 12.5 mm. Lectotype designated by Stewart (1927).	
2. Sinum obliquum (Gabb)	347
ANSP 4215. Apical view of specimen in Figure 1.	
3. Sinum obliquum (Gabb)	347
ANSP 4215. Basal view of specimen in Figure 1.	
4. Sinum obliquum (Gabb)	347
CAS 851. Upper Eocene, Tejon Formation, Kern County, California. Height 11.5 mm. Holotype of <i>Sinum coryliforme</i> Anderson & Hanna.	
5. Sinum obliquum (Gabb)	347
CAS 851. Apical view of specimen in Figure 4.	
6. Sinum obliquum (Gabb)	347
CAS 851. Basal view of specimen in Figure 4.	
7. Sinum obliquum (Gabb)	347
CAS 7509. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 11.0 mm. Holotype of <i>Sinum occidentis</i> Weaver & Palmer.	
8. Sinum obliquum (Gabb)	347
CAS 7509. Apical view of specimen in Figure 7.	
9. Sinum obliquum (Gabb)	347
CAS 7509. Basal view of specimen in Figure 7.	
10. Sinum obliquum (Gabb)	347
UCB 14423. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 16.5 mm. Note especially elongate shape.	
11. Sinum obliquum (Gabb)	347
UCB 14424. Upper Eocene, Cowlitz Formation, Lewis County, Washington. Height 12.8 mm. Note broadly open umbilicus.	
12. Sinum obliquum (Gabb)	347
UCB 14424. Basal view of specimen in Figure 11.	
13. Sinum scopulosum (Conrad)	350
USNM 3553. Middle Miocene (?), presumably from Astoria Formation, Clatsop County, Washington. Height 22.0 mm. Lectotype designated by Moore (1963).	
14. Sinum scopulosum (Conrad)	350
ANSP 4326. Upper Pliocene, Pico Formation, Los Angeles County, California. Height 29.3 mm. Lectotype designated by Stewart (1927) of <i>Sinum planicostum</i> Gabb.	



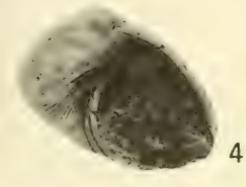
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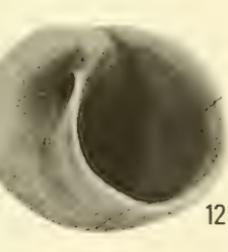
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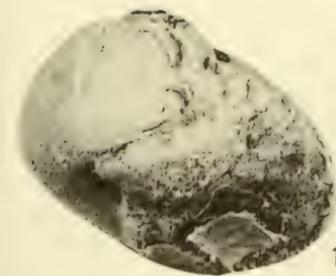
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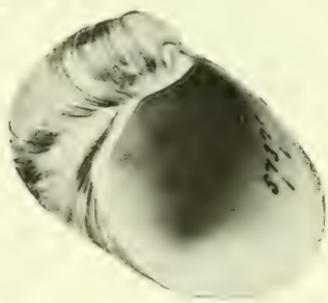
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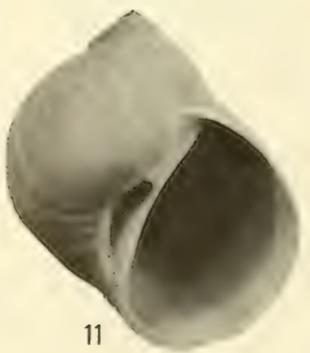
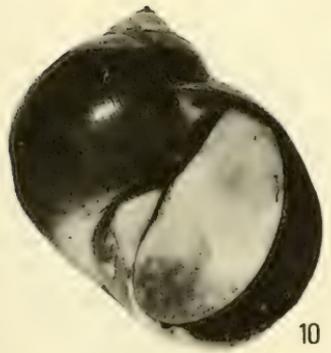
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EXPLANATION OF PLATE 34

Figure	Page
1. Sinum scopulosum (Conrad)	350
UCB 12386. Upper Miocene, Briones Sandstone, Solano County, California. Height 26.0 mm. Holotype of <i>Sinum</i> (<i>Sigarctus</i>) <i>trigernarium</i> Trask.	
2. Sinum scopulosum (Conrad)	350
USNM 206152. Holocene, Catalina Island, California. Height 3.5 mm. Holotype of <i>Sinum keratium</i> Dall.	
3. Sinum scopulosum (Conrad)	350
USNM 57375. Holocene, San Pedro, California. Height 22.9 mm.	
4. Sinum scopulosum (Conrad)	350
USNM 57375. Apical view of specimen in Figure 3.	
5. Sinum scopulosum (Conrad)	350
USNM 57375. Basal view of specimen in Figure 3.	
6. Sinum debile (Gould)	354
MCZ 169117. Holocene, La Paz, Baja California, Mexico. Height 6.0 mm. Holotype.	
7. Sinum debile (Gould)	354
MCZ 169117. Apical view of specimen in Figure 6.	
8. Sinum debile (Gould)	354
MCZ 169117. Basal view of specimen in Figure 6.	
9. Eunaticina insculpta (Carpenter)	359
CAS 5557. Pleistocene, Magdalena Bay, Baja California, Mexico. Height 9.6 mm. Holotype of <i>Eunaticina heimi</i> Jordan.	
10. Eunaticina insculpta (Carpenter)	359
AHF 1725-49. Holocene, Cabeza Ballena, Baja California, Mexico. Height 9.0 mm. Operculum showing typical partially calcified outer surface with radial rows of coalesced calcareous beads.	

EXPLANATION OF PLATE 35

Figure	Page
1. Eunaticina insculpta (Carpenter)	359
USNM 11841. Holocene, Acapulco, Mexico. Height 6.9 mm. Holotype.	
2. Sinum noyesii Dall	355
USNM 170298. Holocene, Isla Gorgona, Colombia. Height 16.2 mm. Holotype.	
3. Sinum noyesii Dall	355
USNM 170298. Apical view of specimen in Figure 2.	
4. Sinum noyesii Dall	355
USNM 170298. Basal view of specimen in Figure 2.	
5. Sinum sanctijohannis (Pilsbry & Lowe)	357
CAS 33281. Holocene, San Felipe, Baja California, Mexico. Height 15.5 mm. Holotype.	
6. Sinum sanctijohannis (Pilsbry & Lowe)	357
CAS 33281. Apical view of specimen in Figure 5.	
7. Sinum sanctijohannis (Pilsbry & Lowe)	357
CAS 33281. Basal view of specimen in Figure 5.	
8. Sinum perrini (Arnold)	358
USNM 164979. Middle Miocene, Topanga Formation, Los Angeles County, California. Height 19.6 mm. Holotype.	
9. Natica (Naticarius) unifasciata Lamarck	375
LACM 65-24. Holocene, Farfan Beach, Canal Zone, Panama. Height 30.6 mm.	
10. Natica (Naticarius) unifasciata Lamarck	375
LACM 65-24. Holocene, Farfan Beach, Canal Zone, Panama. Height 32.0 mm.	
11. Natica (Naticarius) othello Dall	377
USNM 96798. Holocene, Panama Bay, Panama. Height 24.5 mm.	





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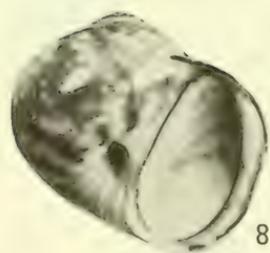
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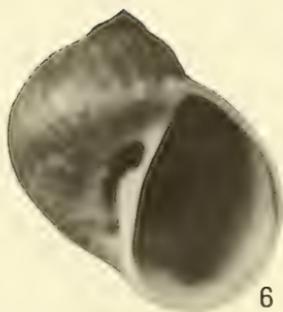
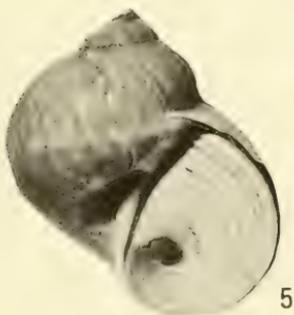
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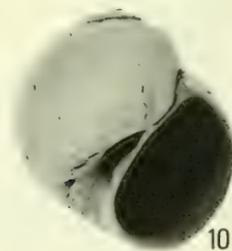
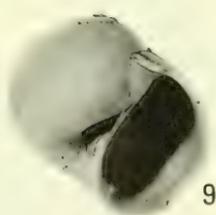
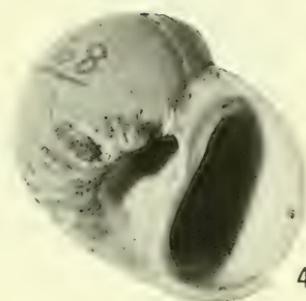
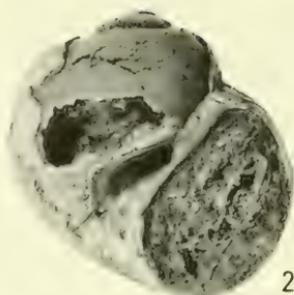
EXPLANATION OF PLATE 36

Figure	Page
1. Polinices (Hypterita) helicoides (Gray)	296
USNM 609343. Holocene, Bahía Salinas, Costa Rica. Height 13.0 mm.	
2. Polinices (Hypterita) helicoides (Gray)	296
USNM 609343. Basal view of specimen in Figure 1, showing broadly open umbilicus and umbilical callus as a flattened lobe.	
3. Polinices (Hypterita) helicoides (Gray)	296
LACM, no number. Holocene, near Topolobampo, Sinaloa, Mexico. Height 27.7 mm.	
4. Polinices (Hypterita) helicoides (Gray)	296
LACM, no number. Basal view of specimen in Figure 3.	
5. Neverita (Neverita) politiana (Dall)	311
USNM 205653. Holocene, Bering Sea, Alaska. Height 15.0 mm. Holotype.	
6. Natica (Natica) inexpectans Olsson	370
USNM 701161. Holocene, near Cabo Mala, Panama. Height 23.1 mm. Holotype.	
7. Natica (Natica) inexpectans Olsson	370
USNM 701161. Operculum of specimen in Figure 6, enlarged. Height 16.5 mm.	
8. Natica (Natica) sigillata McLean	370
LACM 1284. Holocene, Isabel Island, Galápagos Islands, Ecuador. Height 10.0 mm. Holotype.	
9. Natica (Natica) sigillata McLean	370
SU 10272. Holocene, Carmen Island, Gulf of California, Mexico. Height 20.4 mm.	
10. Natica (Naticarius) chemnitzii Pfeiffer	372
LACM 69-8. Holocene, Bahía San Luis Gonzaga, Baja California, Mexico. Height 26.5 mm.	
11. Natica (Naticarius) chemnitzii Pfeiffer	372
LACM 69-8. Apical view of specimen in Figure 10, showing well-developed color pattern on shoulder.	
12. Natica (Naticarius) chemnitzii Pfeiffer	372
AHF B-285. Holocene, Venado Beach, Panama. Height 28.0 mm.	

EXPLANATION OF PLATE 37

Figure	Page
1. Natica (Naticarius) othello Dall	377
USNM 46446. Holocene, Panama Bay, Panama. Height 22.0 mm. Holotype.	
2. Natica (Naticarius) othello Dall	377
AMNH 90853. Holocene, Gorda Bank, Gulf of California. Mexico. Operculum of adult individual, enlarged.	
3. Natica (Naticarius) caneloensis Hertlein & Strong	379
LACM, no number. Holocene, off of northern Peru. Height 30.0 mm.	
4. Natica (Naticarius) caneloensis Hertlein & Strong	379
LACM, no number. Operculum of specimen in Figure 3, enlarged.	
5. Natica (Naticarius) colima Strong & Hertlein	380
CAS 6996. Holocene, near Manzanillo, Mexico. Height 21.0 mm. Holotype.	
6. Natica (Naticarius) colima Strong & Hertlein	380
LACM 67-20. Holocene, Mazatlán, Mexico. Height 21.0 mm.	
7. Natica (Naticarius) scethra Dall	382
USNM 123048. Holocene, Gulf of Panama, Panama. Height 15.1 mm. Holotype.	
8. Natica (Naticarius) scethra Dall	382
LACM, no number. Holocene, off of northern Peru. Height 27.6 mm.	
9. Natica (Naticarius) brunneolinea McLean	384
AMNH 163358. Holocene, Santa Cruz Island, Galápagos Islands, Ecuador. Height 32.6 mm.	
10. Natica (Naticarius) brunneolinea McLean	384
AMNH 163358. Operculum of specimen in Figure 9, enlarged.	
11. Natica (Naticarius) brunneolinea McLean	384
LACM 1283. Holocene, Santa Cruz Island, Galápagos Islands, Ecuador. Height 45.8 mm. Paratype.	
12. Natica (Naticarius) grayi Philippi	385
USNM 517737. Holocene, Venado Beach, Panama. Height 13.0 mm.	



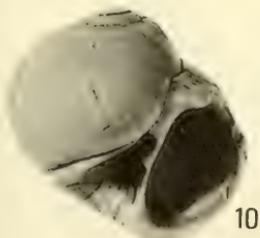
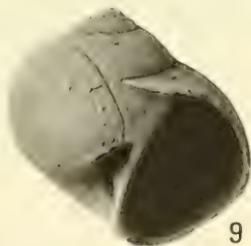
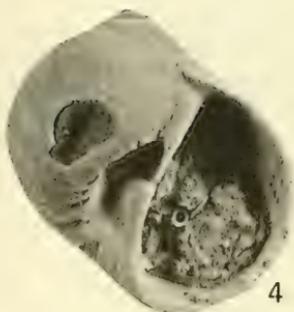
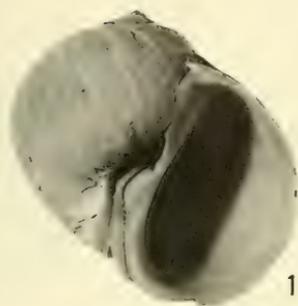


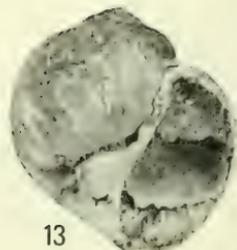
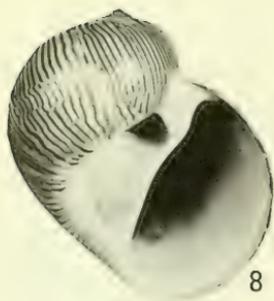
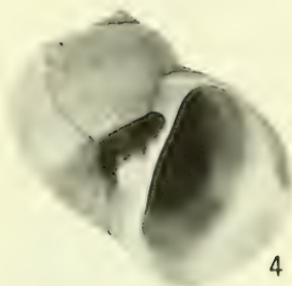
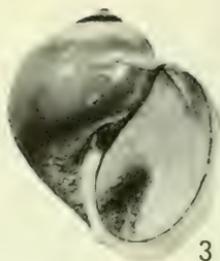
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USNM 239916. Upper Eocene, Keasey Formation, Washington County, Oregon. Height 10.8 mm. Note relatively elongate shell, and slender umbilical callus.	
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USNM 239917. Upper Eocene, Keasey Formation, Washington County, Oregon. Height 9.7 mm. Note relatively small umbilicus.	
12. Natica (Natica) weaveri Tegland	367
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6. Natica (Naticarius) uvasana Gabb	390
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S. S. Berry Collection, 34003. Holocene, Sinaloa, Mexico. Height 16.4 mm.	
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LACM 66-18. Holocene, Punta Gorda, Baja California, Mexico. Height 34.5 mm.	
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USNM 210941. Holocene, Bering Island, Commander Islands, U.S.S.R. Height 53.3 mm.	
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MCZ 169369. Holocene, Hakodate Bay, Japan. Height 40.0 mm. Holotype of <i>Natica severa</i> Gould.	
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USNM 210941. Holocene, Bering Island, Commander Islands, U.S.S.R. Operculum of specimen in Figure 10.	
13. <i>Natica (Tectonatica) janthostoma</i> Deshayes	405
CAS 200. Upper Miocene or lower Pliocene, Montesano Formation of Weaver (1912), Grays Harbor County, Washington. Height 21.4 mm.	

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UCLA 38778. Middle Eocene, Ardath Shale, San Diego County, California. Height 5.8 mm.	
2. Natica (Tectonatica) janthostoma Deshayes	405
CAS 4. Lower Pliocene, Empire Formation, Coos County, Oregon. Height 34.9 mm.	
3. Natica (Tectonatica) janthostoma Deshayes	405
USNM 649134. Upper? Pliocene, Montesano Formation of Weaver (1912), Grays Harbor County, Washington. Height 20.7 mm. Holotype of <i>N. (T.) satsopensis</i> Addicott.	
4. Natica (Tectonatica) janthostoma Deshayes	405
USNM 649135. Upper? Pliocene, Montesano Formation of Weaver (1912), Grays Harbor County, Washington. Height 23.0 mm. Paratype of <i>N. (T.) satsopensis</i> Addicott.	
5. Natica (Tectonatica) janthostoma Deshayes	405
USNM 153917. Lower Pliocene, Empire Formation, Coos County, Oregon. Height 22.4 mm. Paralectotype designated herein of <i>Natica (Cryptonatica) consors</i> Dall.	
6. Natica (Tectonatica) gabbi Clark	408
UCB 11252. Lower Miocene, San Ramon Sandstone, Contra Costa County, California. Height 13.7 mm. Holotype.	
7. Natica (Cryptonatica) clausa Broderip & Sowerby	410
USNM 217156. Holocene, St. George Island, Pribilof Islands, Alaska. Height 44.9 mm. Lectotype designated herein of <i>Cryptonatica aleutica</i> Dall.	
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Zoological Museum, Univ. Copenhagen, no number. Holocene, Greenland. Height 16.6 mm. Lectotype designated herein of <i>Natica septentrionalis</i> Möller ex Beck MS.	
9. Natica (Cryptonatica) clausa Broderip & Sowerby	410
USNM 236895. Lower Pliocene, Empire Formation, Coos County, Oregon. Height 16.3 mm. Lectotype designated herein of <i>N. (C.) consors</i> Dall.	
10. Natica (Cryptonatica) clausa Broderip & Sowerby	410
UCB 12064. Middle Pliocene, Etchegoin Formation, Fresno County, California. Height 19.0 mm. Holotype of <i>Natica convexa</i> Nomland.	



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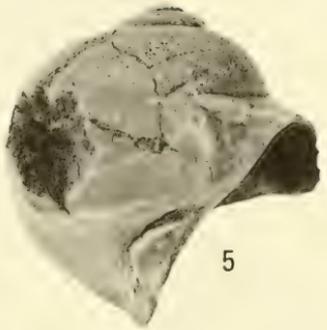
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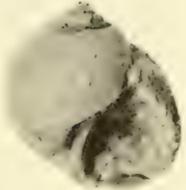
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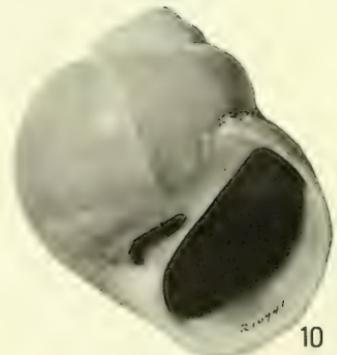
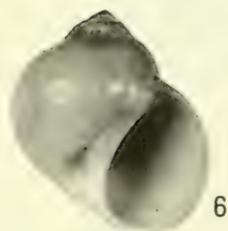
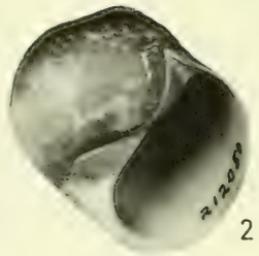
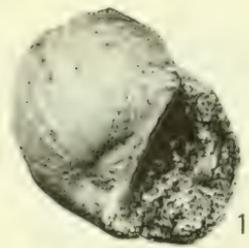
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2. Natica (Cryptonatica) clausa Broderip & Sowerby	410
USNM 212050. Holocene, Unimak Island, Aleutian Islands, Alaska. Height 23.3 mm.	
3. Natica (Cryptonatica) clausa Broderip & Sowerby	410
USNM 209295. Holocene, Channel Islands, southern California. Height 14.0 mm. Holotype of <i>Cryptonatica salimba</i> Dall.	
4. Natica (Cryptonatica) clausa Broderip & Sowerby	410
USNM 207218. Holocene, Monterey Bay, California. Height 16.0 mm. Holotype of <i>Euspira acosmita</i> Dall.	
5. Natica (Cryptonatica) clausa Broderip & Sowerby	410
USNM 188401. Holocene, Bering Strait, Alaska. Height 32.0 mm.	
6. Natica (Cryptonatica) clausa Broderip & Sowerby	410
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7. Natica (Cryptonatica) oregonensis (Conrad)	418
USNM 561551. Middle Miocene?, presumably from Astoria Formation, Clatsop County, Oregon. Height 14.1 mm. Holotype.	
8. Natica (Cryptonatica) oregonensis (Conrad)	418
USNM 107780. Lower Pliocene, Empire Formation, Coos County, Oregon. Height 18.5 mm. Holotype of <i>Ampullina (Amauropsis) oregonensis</i> Dall.	
9. Natica (Cryptonatica) oregonensis (Conrad)	418
CAS 3. Lower Pliocene, Empire Formation, Coos County, Oregon. Height 16.0 mm. Note calcareous operculum, as found in life position.	
10. Natica (Tectonatica) janthostomoides (Kuroda & Habe)	407
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