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Cenozoic Fossil Naticidae (Mollusca: Gastropoda) in Japan

by

Ryuichi Majima

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By

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ABSTRACT

The gastropod family Naticidae consists of carnivorous prosobranchs that occur commonly in worldwide Cenozoic marine strata and in modern seas. Important taxonomic characters are umbilical morphology, shell-surface sculpture, opercular morphology and radular dentition. Umbilical morphology is the most useful for discriminating species, whereas the other characters are more useful for supraspecific classification.

A total of 47 species and subspecies belonging to 19 genera in four subfamilies are treated here. Among them, *Euspira marincovichi* and *Glossaulax didyma dainichiensis* are described as new taxa. Naticids occurring only in the Holocene Japanese fauna are not included here.

The Japanese Neogene and Early Quaternary naticids are classifiable into three paleoclimatic preference types: warm-water, cold-water, and broad temperature tolerance. These types are defined on the basis of paleogeographic distributions, associated molluscs, and the geographic distributions of extant naticid taxa. Paleogeographic distributions of the warm- and cold-water types clearly reveal Neogene and early Quaternary fluctuations of the biogeographic boundary between southern and northern faunal types in Japan.

Many Japanese naticid species have evolved or become extinct in response to Cenozoic climatic fluctuations and several species are grouped into five lineages, based upon a combination of shell morphology and stratigraphic distribution: the *Glossaulax hyugensis* – *G. nodai* – *G. hagenoshitensis* lineage (lower Pliocene – lower Pleistocene), the *Glossaulax didyma coticazae* – *G. didyma didyma* – *G. didyma dainichiensis* – *G. vesicalis* lineage (lower middle Miocene – Holocene), the *Euspira meisensis* – *E. marincovichi* – *E. mitsuganoensis* lineage (Oligocene – middle middle Miocene), the *Euspira pallida* – *E. pila* – *E. yokoyamai* lineage (lower Pliocene – Holocene), and the *Cryptonatica clausa* – *C. ichishiana* – *C. janthostoma* – *C. andoi* lineage (lower middle Miocene – Holocene).

The three Japanese taxa, *Euspira meisensis*, *Polinices didymoides*, and *Glossaulax didyma coticazae*, are closely similar to *Euspira hotsoni*, *Polinices hornii*, and *Glossaulax reclusiana*, respectively, of western North America and are considered to be descendants of migrants from the northeastern Pacific.

INTRODUCTION

Naticid snails, carnivorous prosobranchs, are one of the dominant groups of Cenozoic molluscs in Japan, and occur commonly in habitats ranging from the intertidal to the deep sea. They are divisible into four subfamilies on the basis of a combination of characters: Ampullospirinae Cox, 1930 (reflexed inner lip and tabulate shoulder), Polinicinae Finlay and Marwick, 1937 (smooth shell surface and corneous operculum), Sininae Woodring, 1928 (spiral ornamentation and corneous operculum smaller than the aperture), and Naticinae Forbes, 1838 (semicircular umbilical callus and entirely calcareous operculum). Polinicines, sinines, and naticines first appeared during the Late Cretaceous and Early Tertiary and feed by boring holes in molluscan shells, whereas ampullospirines first appeared in the Early Jurassic (Sohl, 1969) or Late Triassic (Fürsich and Jablonski, 1984) and at least the earliest species may not have been borers. Drill holes evidently bored by naticids are not recognized before the Late Cretaceous (Sohl, 1969), except for one record in the Late Triassic (Fürsich and Jablonski, 1984). For Late Cretaceous and Cenozoic faunas, therefore, even if naticid shells are not found, their past presence may be inferred from the beveled circular holes bored into their prey.

Although the occurrence of Cenozoic fossil naticids in Japan has been cited frequently for over a hundred years, the literature is scattered and work on the group has suffered because of the lack of a general revision. This study is an attempt to gather available data, and to provide an evaluation and synthesis of the Japanese Cenozoic fossil species of Naticidae Forbes, 1838, in which many modern Japanese naticids are included. Japanese Cenozoic naticids also include some circumboreal and tropical western Pacific species as the result of the influence of the warm-water Kuroshio current and the cold-water Oyashio current since at least the early Miocene. Naticids belonging only to the Holocene fauna are mostly rare species and will be studied at a future date.

Naticids commonly have simple shells and frequently exhibit wide morphological variability. Although umbilical morphology is the most useful character for distinguishing species, it too may be variable within a single species. The combination of simple shells and wide ranges of variation sometimes makes it difficult to discriminate species, especially fossil species. In such cases, other characters such as shell form, morphology of the protoconch, degree of channeling of the suture and/or shell-surface ornamentation are commonly useful for defining species. And in some cases, morphological variation itself, especially ontogenetic variation, may be a useful specific character. In order to determine ranges of specific variation, I studied a large number of Holocene specimens whose identifications are relatively simple, due to the presence of an operculum, coloration, periostracum and other features. However, in the polinicine genus *Mammilla* Schumacher, 1817, I reserved some specific determinations as a future problem since their shell morphologies are extremely conservative.

The fossil localities treated herein are given in Text-figure 1. The chronology of Neogene and Quaternary strata is, for the most part, based upon data compiled by Tsuchi (1979; 1981), except for strata not included in these works. In such cases, I tentatively base geologic ages of the strata on molluscan faunal composition. The ages of the Neogene and Quaternary molluscan faunas in Japan have been well documented by the studies of Chinzei (1978) and Tsuchi and Shuto (1984). The geologic ages of Paleogene strata treated herein are in accordance with the data of Mizuno (1964a; 1964b).

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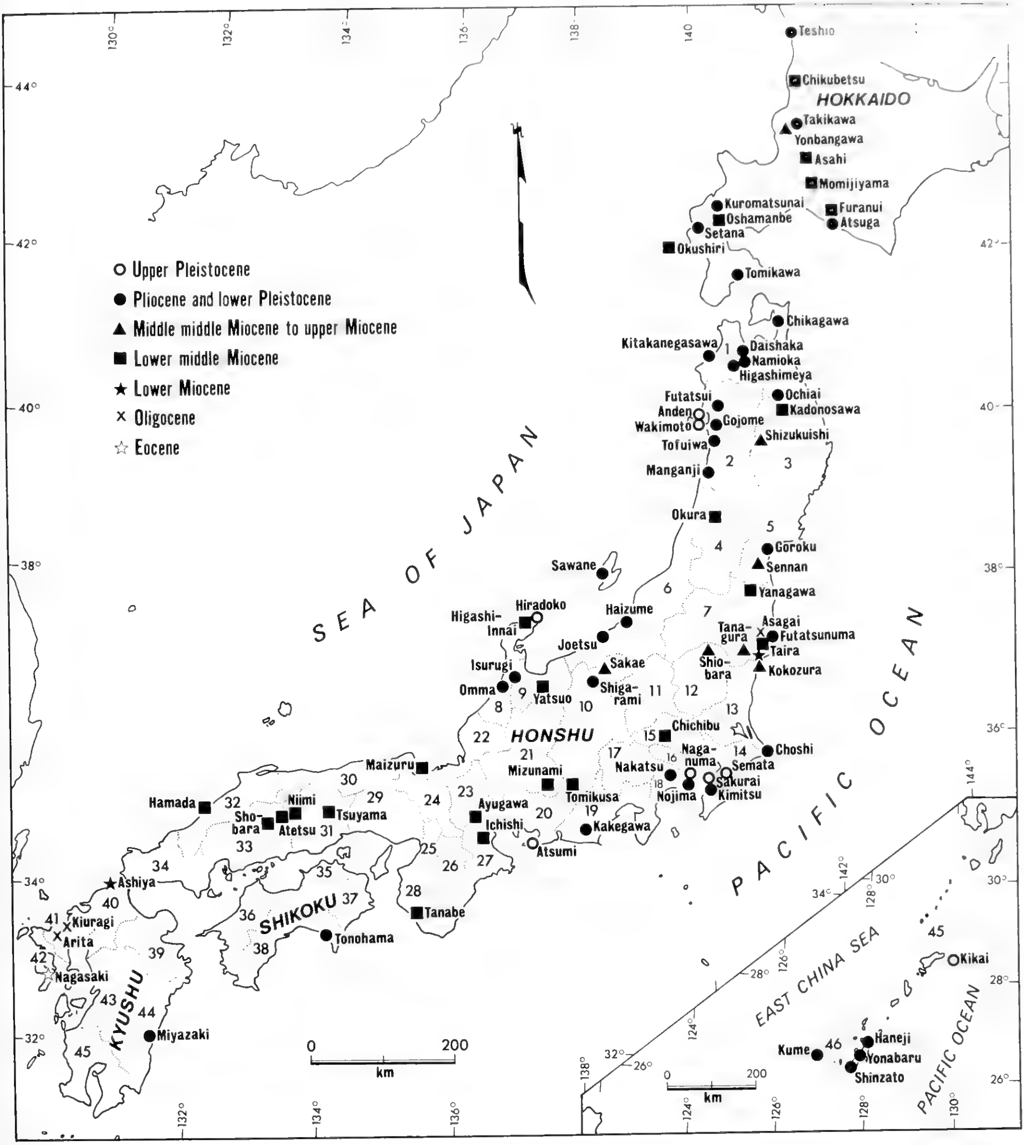
PALEOBIOGEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION

INTRODUCTION

The paleobiogeographic and stratigraphic distributions of Japanese Cenozoic fossil Naticidae are briefly documented here. The paleogeographic range is based on the distribution of fossil localities (Text-figs. 3, 4, 5). The stratigraphic range is given in Text-figure 7.

The paleogeographic distribution of Japanese fossil Naticidae during the Cenozoic was controlled by the distribution of water masses. Late Cenozoic water masses around Japan are evidently divisible into two different current systems that were the precursors of the present-day warm Kuroshio current and cold Oyashio current. The Neogene and Early Quaternary distribution of warm- and cold-water masses of Japan is illustrated in Text-figure 2, modified from Chinzei (1978, figs. 2, 4, 5), who inferred them from the geographic distribution of molluscan faunas. According to Chinzei (1978) and Tsuchi and Shuto (1984), Neogene and Early Quaternary molluscan faunas in Japan are clearly divisible into a warm-water Kuroshio type and a cold-water Oyashio type. The Ashiya (early Miocene), Kadonosawa (early middle Miocene), and Kakegawa (late Miocene to early Pleistocene) faunas are of the warm-water type, whereas the Chikubetsu (early



Text-figure 1.—Map showing naticid fossil localities treated in this study. Numerals indicate prefectures of Japan, as follows (alphabetically ordered): Aichi (20), Akita (2), Aomori (1), Chiba (14), Ehime (36), Fukui (22), Fukuoka (40), Fukushima (7), Gifu (21), Gumma (11), Hiroshima (33), Hyogo (29), Ibaraki (13), Ishikawa (8), Iwate (3), Kagawa (35), Kagoshima (45), Kanagawa (18), Kochi (38), Kumamoto (43), Kyoto (24), Mie (27), Miyagi (5), Miyazaki (44), Nagano (10), Nagasaki (42), Nara (26), Niigata (6), Okayama (31), Okinawa (46), Ooita (39), Osaka (25), Saga (41), Saitama (15), Shiga (23), Shimane (32), Shizuoka (19), Tochigi (12), Tokushima (37), Tokyo (16), Tottori (30), Toyama (9), Wakayama (28), Yamagata (4), Yamaguchi (34), and Yamanashi (17).

middle Miocene), Shiobara (middle middle Miocene to late Miocene), and Omma-Manganji (Pliocene and early Pleistocene) faunas are of the cold-water type.

For the Neogene and Early Quaternary naticids, I have inferred their paleoclimatic preferences from their geographic distributions (Text-figs. 3, 4, 5) and their associated faunas. The geographic distributions of modern populations of extant species are used to reinforce those inferences, and are mainly based upon the data of Kuroda and Habe (1952) and Higo (1973). Japanese Neogene and Early Quaternary naticids are classifiable into the following three paleoclimatic preference types: **C** (cold-water), **W** (warm-water) and **Bt** (broad temperature tolerance). Species of the **C** and **W** types lived in areas influenced by cold-water (Oyashio) and warm-water (Kuroshio) currents, respectively. Species of **Bt** type lived in both warm and cold waters in Japan. Both the **C** and **W** types are further divisible into two subtypes on the basis of their paleogeographic distributions: **Ce** (Cold-water endemic) and **Cw** (Cold-water widespread), and **We** (Warm-water endemic) and **Ww** (Warm-water widespread). Species of the **Ce** and **We** types were endemic to Japan and adjacent areas. Species of the **Cw** and **Ww** types were more widespread: **Cw** species also lived in the arctic region, and **Ww** species in the East Indies and farther south.

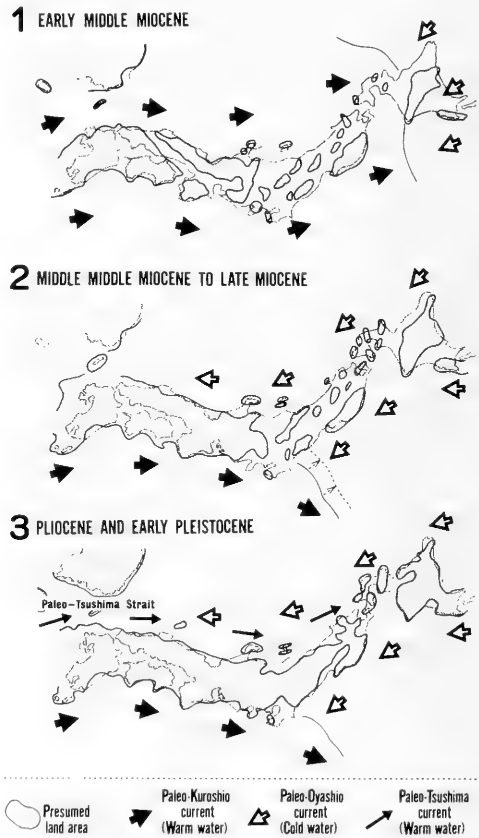
In the following discussion, I divide the Neogene and Early Quaternary into four stages: early Miocene, early middle Miocene, middle middle Miocene to late Miocene, and Pliocene and early Pleistocene. There is a distinct difference in the molluscan faunal composition of each stage.

PALEOGENE

Paleogene naticids are known from the Ryukyu Islands, from northern Kyushu and from the Joban coal field of northeastern Honshu, where they are represented by three Eocene and four Oligocene species. No Paleocene naticids are known in Japan. Even though marine Paleogene deposits are widely distributed in central and eastern Hokkaido and commonly bear molluscan fossils (Mizuno, 1964b), no identifiable naticid specimens were available for the present study.

The three known Eocene naticids are *Ampullinopsis* sp., *Neverita eocenica* (Nagao, 1928a) and *Pliconacca nomii* (Nagao, 1928b). *Ampullinopsis* sp. from Ishigaki-jima, Okinawa Prefecture is similar to *Ampullinopsis sigaretina* (Lamarck, 1804) from Oligocene deposits of Pakistan and Burma (Vredenburg, 1922). *Neverita eocenica* from northern Kyushu is very closely related to *Neverita wanneri* (Martin, 1914) from the late Eocene of Java, Indonesia, and is also closely allied to *Neverita globosa* Gabb, 1869 from the late Paleocene to late Eocene of western North America where *N. globosa* is associated with tropical to subtropical molluscs (Marincovich, 1977). *Pliconacca nomii* from northern Kyushu is related to *Pliconacca trisulcata* (Martin, 1914) from the late Eocene of Java, Indonesia. Judging from these species-level relationships, the three Eocene naticids are inferred to be of the **W** type.

Oligocene naticids are represented by "*Pachycrommium*" *nagaoi* (Hatai and Nisiyama, 1952), *Euspira meisensis* (Makiyama, 1926), "*Euspira*" *aritensis* (Shuto and Ueda, 1967), and *Mammilla insignis* (Nagao, 1928b). Of those, "*Pachycrommium*" *nagaoi*, "*Euspira*" *aritensis*, and *Mammilla insignis* occur in deposits of northern Kyushu. *Euspira meisensis* first appeared in the Oligocene Asagai Formation, Fukushima



Text-figure 2.—Distribution of presumed paleogeography of Japan (after Chinzei, 1978) and presumed sea current system during (1) early middle Miocene, (2) middle middle Miocene to late Miocene, and (3) Pliocene and early Pleistocene.

Prefecture, northeastern Honshu (**X** in Text-fig. 3.3), and later became one of the most common naticids of the first half of the Miocene.

EARLY MIOCENE

As noted above, *Euspira meisensis* (Makiyama, 1926) first appeared in the Oligocene, and is the only known warm-water naticid species (**We** type) of this age. In the early Miocene, *E. meisensis* occurs in northern and central Kyushu and westernmost Honshu (solid stars in Text-fig. 3.3), and is associated with the warm-water Ashiya faunas. *Bulbus fragilis* (Leach, 1819) occurs in the Honya Mudstone of Fukushima Prefecture, which is the earliest stratigraphic record of this species. *Bulbus fragilis* lives mainly in arctic waters today (Marincovich, 1977) and its occurrence in the Honya Mudstone is strong evidence for the presence of a cold water mass as far south as northeastern Honshu during the early Miocene. *Bulbus fragilis* is, therefore, a species of the **Cw** type.

EARLY MIDDLE MIOCENE

Shallow marine deposits with abundant molluscs of this age are widespread in Japan. The boundary between warm and cold waters at this time occurred in central Hokkaido (Text-fig. 2.1), and the warm- and cold-water molluscan faunas are called the Kadonosawa and Chikubetsu faunas, respectively.

The most characteristic naticids of the warm-water Kadonosawa faunas are *Cernina fluctuata nakamurai* (Otuka, 1938) and *Pachycrommium harrisi* (Pannekoek, 1936) (Text-fig. 3.1). Both are **Ww** types and are considered to be tropical elements. As mentioned in the systematic section, *Cernina fluctuata fluctuata* (Sowerby, 1825) has lived in the East Indies from the early Miocene to the Holocene, and *Pachycrommium harrisi* lived in the East Indies and adjacent areas from the early to late Miocene (? Pliocene). The two Japanese ampullospirines are thus the northernmost peripheral populations of these species that migrated northward in the early middle Miocene.

The **We**-type species in the Kadonosawa faunas are as follows: *Polinices mizunamiensis* Itoigawa, 1960 (Text-fig. 3.2), *Euspira meisensis* (Makiyama, 1926) (solid squares in Text-fig. 3.3), *E. marincovichi*, n. sp., *E. mitsuganoensis* Shibata, 1970, *Sigatica kurodai* Itoigawa and Shibata, 1976, *Tanea minoensis* (Itoigawa, 1960) (Text-fig. 3.2), and *Cryptonatica ichishiana* (Shibata, 1970). They are known only from central and southern Hokkaido, Honshu, and the Korean Peninsula. Their paleogeographic distributions and faunal associations indicate that they are **We**-type species. Except for *E. meisensis*, their stratigraphic ranges are restricted to the lower middle Miocene (Text-fig. 7), and they are useful biostratigraphic indicators.

Naticids of the cold-water Chikubetsu faunas are *Polinices didymoides* (Kanno and Matsuno, 1960), *Sinum ineptum* (Yokoyama, 1924), *Cryptonatica clausa* (Broderip and Sowerby, 1829) (open squares in Text-fig. 4.4), and *C. janthostoma* (Deshayes, 1839) (solid squares in Text-fig. 3.6). *Polinices didymoides* is only known from the Sankebetsu Formation, northern Hokkaido and is, therefore, a **Ce**-type species. *Cryptonatica clausa* is a **Cw**-type species and its ancient and modern geographic distributions have always been in the Arctic Ocean and adjacent areas (Odhner, 1913; Marincovich, 1977). It occurs in the Takinoue and Furanui formations, central Hokkaido (open squares in Text-fig. 4.4), both of which also yield the warm-water (**We**-type) species *Euspira meisensis* (Makiyama, 1926) [the two solid squares (#34, #35) in central Hokkaido in Text-fig. 3.3]. The paleozoogeographic boundary of the warm-water Kadonosawa fauna and the cold-water Chikubetsu fauna is situated in central Hokkaido (the boundary of cold-water and warm-water currents in Text-fig. 2.1), and a mixture of these two faunal types is present in both the Takinoue and Furanui formations. *Cryptonatica janthostoma* is a **Ce**-type species whose modern geographic range is from northern Hokkaido to Kamchatka, U. S. S. R. The occurrence of *C. janthostoma* in northern Hokkaido in the lower middle Miocene is the lowest stratigraphic record of this species.

In the early middle Miocene, two flourishing naticids appeared in Japan, *Glossaulax didyma coticazae* (Makiyama, 1926) (solid squares in Text-fig. 3.4) and *Sinum ineptum* (Yokoyama, 1924) (solid squares in Text-fig. 3.5). Both species commonly occur in lower middle Miocene deposits, and are the most abundant naticids in the warm-water Kadonosawa faunas. They are thought to be **Bt**-type species, as discussed in the section below on middle middle Miocene to late Miocene naticids. As listed above, *Sinum ineptum* also occurs in the cold-water Chikubetsu fauna of the Chikubetsu Formation [a solid square (#66) in northern Hokkaido in Text-fig. 3.5 (Ogasawara *et al.*, 1982)].

MIDDLE MIDDLE MIOCENE TO LATE MIOCENE

The naticid fauna of this age exhibits a striking reduction in number of species compared to that of the early middle Miocene. At the close of the early middle Miocene, naticid species were reduced in number from 14 to four (Text-fig. 7), and nearly all of the warm-water (**Ww**- and **We**-type) naticids disappeared from Japan. There were no species that first appeared at this time. Middle middle Miocene to late Miocene naticids in Japan consist of two **Bt**-, one **Ce**- and one **We**-type species. These occurrences suggest that marine-climatic conditions became distinctly cooler than those of the early middle Miocene. The cold-water mass of this age was widely distributed throughout Japan except for the Pacific side of southwestern Japan (Text-fig. 2.2). The cold-water faunas have been collectively called the Shiobara fauna and the Yama fauna, to indicate nearshore and offshore conditions, respectively (Chinzei, 1978). Warm-water molluscs of this age are restricted to deposits of the Pacific side of southwestern Japan and have been collectively called the Kakegawa fauna (Chinzei, 1978) or Sagara fauna (Tsuchi and Shuto, 1984). The boundary between warm and cold waters at this time was along the Pacific side of central Honshu (Text-fig. 2.2).

Glossaulax didyma coticazae (Makiyama, 1926) and *Sinum ineptum* (Yokoyama, 1924) are the dominant naticids of the age (open triangles in Text-figs. 3.4, 3.5), and are interpreted as **Bt**-type species, as discussed below. *Glossaulax didyma coticazae* commonly lived in association with cold-water Shiobara faunas, as well as with early middle Miocene warm-water Kadonosawa faunas. This subspecies also occurs in the upper Miocene Zushi Formation, Miura Peninsula, Pacific side of central Honshu [an open triangle (#42) in Text-fig. 3.4], where it is associated with warm-water molluscs. As mentioned earlier, *Sinum ineptum* lived in both warm and cold waters of the early middle Miocene, as part of the Kadonosawa and Chikubetsu faunas, respectively. It also lived during the middle middle Miocene to late Miocene in association with the cold-water Shiobara faunas. The geographic distributions of *Glossaulax didyma coticazae* and *Sinum ineptum* were virtually unaffected by the major change in marine climate. Both species occurred throughout Japan from the early middle Miocene to the late Miocene (Text-figs. 3.4, 3.5). Their presence in both warm- and cold-water faunas reflects their broad temperature tolerances.

The **Ce**-type species *Cryptonatica janthostoma* (Deshayes, 1839) lived in Hokkaido and northeastern Honshu at this time in association with the cold-water Shiobara faunas (open triangles in Text-fig. 3.6).

During this interval, a warm-water naticid, *Euspira meisensis* (Makiyama), occurs in the middle middle Miocene Kokozura Formation, Pacific side of northeastern Honshu [open triangle (#29) in Text-figure 3.3]. Northeastern Honshu during the middle middle Miocene has been considered to be an area influenced by cold-water (Text-fig. 2.2) (Chinzei, 1978). This occurrence of a warm-water naticid is explainable by a fluctuation of the boundary between cold- and warm-water

Text-figure 3.—Fossil localities of *Cernina fluctuata nakamurai* (Otuka, 1938), *Pachycrommium harrisi* (Pannekoek, 1936), *Polinices mizunamiensis* Itoigawa, 1960, *Tanea minoensis* (Itoigawa, 1960), *Euspira meisensis* (Makiyama, 1926), *Glossaulax didyma coticazae* (Makiyama, 1926), *Sinum ineptum* (Yokoyama, 1924), and *Cryptonatica janthostoma* (Deshayes, 1839). × = Oligocene; ★ = lower Miocene; ■□ = lower middle Miocene; △ = middle middle Miocene to upper Miocene; ○ = Pliocene and lower Pleistocene.

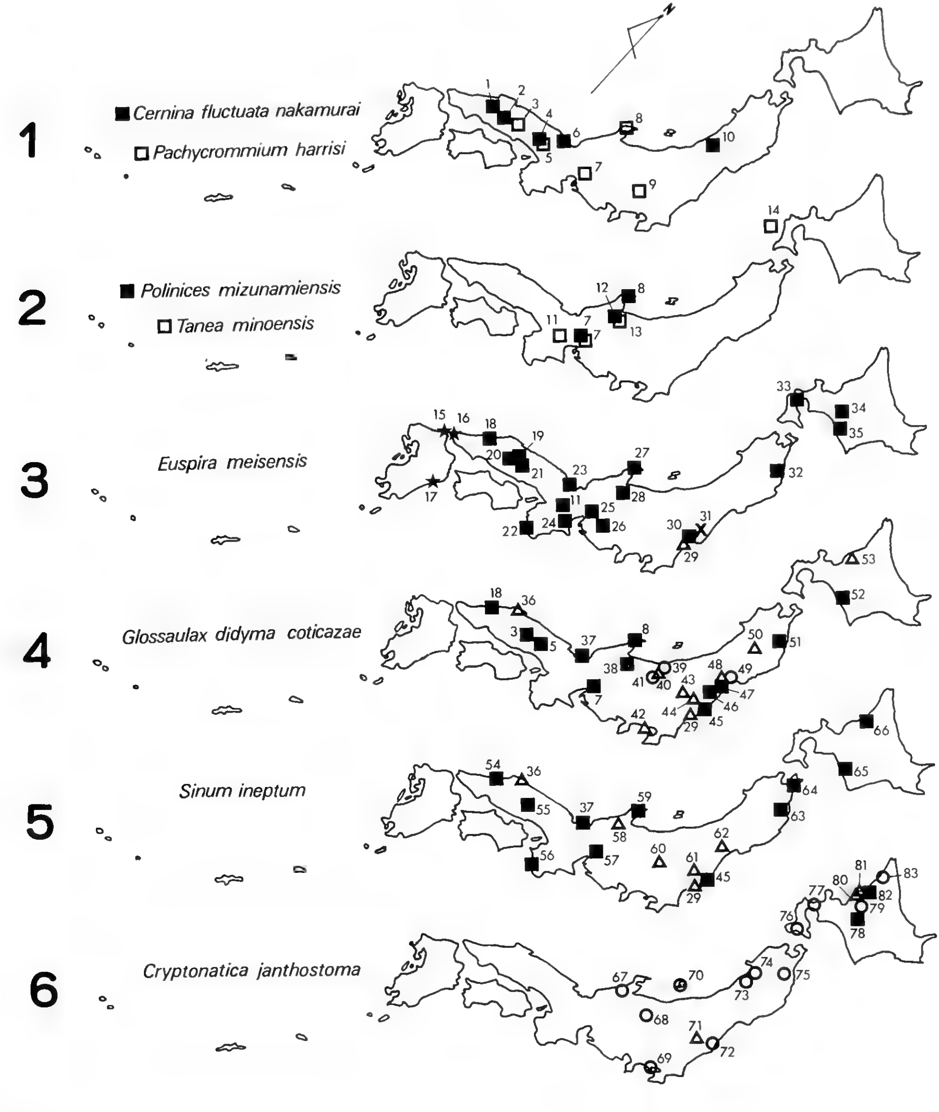
Small numerals indicate the formations at the fossil localities. 1, Bihoku Group (Sakanoue and Takayasu, 1984); 2, Bihoku Group at locs. SHOBARA 1 and SHOBARA 3; 3, Bihoku Group at loc. NIIMI; 4, Bihoku Group at "the Tsuyama Basin" (based on the specimens preserved in the Tsuyama Museum of Science Education, Tsuyama City, Okayama Pref.); 5, Bihoku Group at loc. TSUYAMA; 6, Uchiura Group at locs. MAIZURU 1 and MAIZURU 2; 7, Shukunohora Sandstone at loc. MIZUNAMI 5; 8, Higashi-Innai Fm. at loc. HIGASHI-INNAI 1; 9, Hiranita Fm. at loc. CHICHIBU; 10, Takinosawa Fm. at loc. OKURA; 11, Kurokawa Fm. at loc. AYUGAWA; 12, Yatsuo Fm. at locs. YATSUO 2 and YATSUO 3; 13, Yatsuo Fm. at loc. YATSUO 3; 14, Tsurikake Fm. at loc. OKUSHIRI; 15, Yamaga and Sakamizu fms. at locs. ASHIYA 1, ASHIYA 2, and ASHIYA 3; 16, Yamaga Fm. (Okamoto, 1975); 17, Kadogawa Fm. (Hashimoto, 1961); 18, Togane Fm. at loc. HAMADA; 19, Bihoku Group (Itoigawa and Nishikawa, 1976); 20, Bihoku Group at loc. SHOBARA 2; 21, Bihoku Group at loc. ATETSU; 22, Tanabe Group at loc. TANABE 1; 23, Uchiura Group at locs. MAIZURU 3 and MAIZURU 4; 24, Oi Fm. at loc. ICHISHI 1; 25, Togari Fm. at locs. MIZUNAMI 1, MIZUNAMI 2, and MIZUNAMI 3; 26, Nukuta Fm. at loc. TOMIKUSA; 27, Higashi-Innai Fm. at locs.HIGASHI-INNAI 1 and HIGASHI-INNAI 2; 28, Yatsuo Fm. at locs. YATSUO 1 and YATSUO 3; 29, Kokozura Fm. at loc. KOKOZURA; 30, Nakayama Fm. at loc. TAIRA 3; 31, Asagai Fm. at locs. ASAGAI 1 and ASAGAI 2; 32, Kadonosawa Fm. at locs. KADONOSAWA 1 and KADONOSAWA 2; 33, Kunnui Fm. at loc. OSHAMANBE; 34, Takinoue Fm. at loc. MOMIJIYAMA 1; 35, Furanui Fm. at locs. FURANUI 2 and FURANUI 5; 36, Fujina Fm. (Suehiro, 1979); 37, Uchiura Group (Nakagawa and Takeyama, 1985); 38, Yatsuo Fm. at locs. YATSUO 3 and YATSUO 4; 39, Nodani Fm. (Amano, Kanno, and Mizuno, 1985); 40, Aoki Fm. at loc. SAKAE; 41, Shigarami Fm. at loc. SHIGARAMI 1; 42, Zushi Fm. (Shikama, 1973); 43, Kanomatazawa Fm. at loc. SHIOBARA; 44, Kubota Fm. at locs. TANAGURA 1, TANAGURA 2, and TANAGURA 3; 45, Numanouchi Fm. at loc. TAIRA 1; 46, Yanagawa Fm. at loc. YANAGAWA; 47, Kozai Fm. (Nomura, 1939); 48, Kanagase Fm. at loc. SENNAN; 49, Tatsunokuchi Fm. at loc. GOROKU; 50, Yamatsuda Fm. at loc. SHIZUKUISHI; 51, Kadonosawa Fm. at locs. KADONOSAWA 1, KADONOSAWA 2, and KADONOSAWA 3; 52, Furanui Fm. at loc. FURANUI 4; 53, Togeshita Fm. (Amano, 1983); 54, Togane Fm. (Otuka, 1937); 55, Bihoku Group (Taguchi, Ono, and Okamoto, 1979); 56, Tanabe Group at loc. TANABE 2; 57, Nataki Fm. at loc. MIZUNAMI 4; 58, Saikawa Fm. (Ogasawara, 1976); 59, Higashi-Innai Fm. (Masuda, 1967); 60, Aimagawa Fm. (Yamagishi *et al.*, 1975); 61, Kubota Fm. at locs. TANAGURA 1 and TANAGURA 2; 62, Kanagase Fm. (Masuda and Takegawa, 1965); 63, Kadonosawa Fm. at locs. KADONOSAWA 1, KADONOSAWA 2, and KADONOSAWA 4; 64, Takahoko Fm. (Aoki, 1959); 65, Furanui Fm. at loc. FURANUI 3; 66, Chikubetsu Fm. (Ogasawara *et al.*, 1982); 67, Omma Fm. at loc. OMMA 4; 68, Shigarami Fm. at loc. SHIGARAMI 2; 69, Nojima Fm. at loc. NOJIMA 2; 70, Sawane Fm. at loc. SAWANE 3; 71, Kubota Fm. at loc. TANAGURA 2; 72, Yamadahama Fm. at locs. FUTATSUNUMA 1 and FUTATSUNUMA 2; 73, Sasaoka Fm. at loc. TOFUIWA; 74, Sasaoka Fm. at locs. GOJOME 1 and GOJOME 3; 75, Kubo Fm. at loc. OCHIAI; 76, Tomikawa Fm. at loc. TOMIKAWA; 77, Nakanokawa Fm. at locs. KUROMATSUNAI 1 and KUROMATSUNAI 2; 78, Takinoue Fm. at loc. ASAHI; 79, Horokaoshirarika and Horoka fms. at locs. TAKIKAWA 1, TAKIKAWA 2, and TAKIKAWA 3; 80, Maedonosawa Fm. at loc. YONBANGAWA; 81, Togeshita Fm. (Amano, 1983); 82, Chikubetsu Fm. at locs. CHIKUBETSU 2 (? Sankebetsu Fm.) and CHIKUBETSU 3; 83, Yuchi Fm. at locs. TESHIO 3 and TESHIO 7.

currents. When the Kokozura Formation was deposited, the warm-water current might have slightly predominated over the cold-water current (dashed line in Text-fig. 2.2).

Pliocene and Early Pleistocene

A large number of naticids first appeared in Japan at this time, so that the total number of species increased from four to 26 (Text-fig. 7). This increase was evidently not due to changed distributions of warm- and cold-water masses because these were not markedly different from those of the late Miocene (Text-fig. 2.3).

Many warm-water naticids occur at this time in faunas from the Pacific side of southwestern Japan, as one element of the warm-water Kakegawa fauna. Among



them, *Polinices candidissimus* (Le Guillou, 1842), *Pliconacca atricapilla* (Martin, 1884), *Eunaticina papilla* (Gmelin, 1791), *Sinum javanicum* (Griffith and Pidgeon, 1834), *Natica vitellus* (Linnaeus, 1758) (Text-fig. 4.1), *Notocochlis gualteriana* (Récluz, 1844), *Alloconatica niasensis* (Wissema, 1947), and *Tanea undulata* (Röding, 1798) are **Ww**-type species which extended their ranges northward from the tropical western Pacific (mainly from the East Indies). *Polinices sagamiensis* Pilsbry, 1904 (Text-fig. 4.2), *Naticarius concinnus* (Dunker, 1859), *Tanea tabularis* (Kuroda, 1961), *Glossaulax hyugensis* (Shuto, 1964) (Text-fig. 4.3), and *G. nodai* Majima, 1985 (Text-fig. 4.3) are restricted to warm-water Kakegawa faunas on the Pacific side of southwestern Japan and on Taiwan. The first three species are also known only in the modern warm-water Japanese fauna. The latter two species are known only as fossils, and are not recorded from further south than Japan. Thus, the five are **We**-type species.

Cold-water naticids of this age occurred in the cold-water Omma-Manganji faunas of the Pacific side of northeastern Honshu, of the northwest side of Honshu, and of Hokkaido. The **Cw**-type species are *Bulbus fragilis* (Leach, 1819), *Euspira pallida* (Broderip and Sowerby, 1829) (Text-fig. 4.5), and *Cryptonatica clausa* (Broderip and Sowerby, 1829) (solid circles in Text-fig. 4.4). Their ancient and modern habitats are mainly within and around the Arctic Ocean. The **Ce**-type species are *Euspira pila* (Pilsbry, 1911) (Text-fig. 4.6) and *Cryptonatica janthostoma* (Deshayes, 1839) (open circles in Text-fig. 3.6). Both species are now living in cold-water areas of Japan, Sakhalin, and the Kuril Islands.

As discussed earlier, *Glossaulax didyma coticazae* (Makiyama, 1926) is a **Bt**-type species, and its descendant, *G. didyma didyma* (Röding, 1798) also shows the paleogeographic distribution characteristic of a **Bt**-type species; that is, *G. didyma didyma* occurs in both Pliocene and early Pleistocene warm- and cold-water faunas throughout the Japanese Islands, except Hokkaido (Text-fig. 5.6). This geographic distribution suggests that *G. didyma didyma* has a broad temperature tolerance and is a **Bt**-type species. Text-figure 5.3 shows the occurrence of *Cryptonatica andoi* (Nomura, 1935b) in Pliocene and early Pleistocene faunas. *Cryptonatica andoi* also occurs throughout the Japanese Islands except for Hokkaido in association with both the warm-water Kakegawa faunas and the cold-water Omma-Manganji faunas, as does *G. didyma didyma*. These occurrences imply that *C. andoi* is a **Bt**-type species.

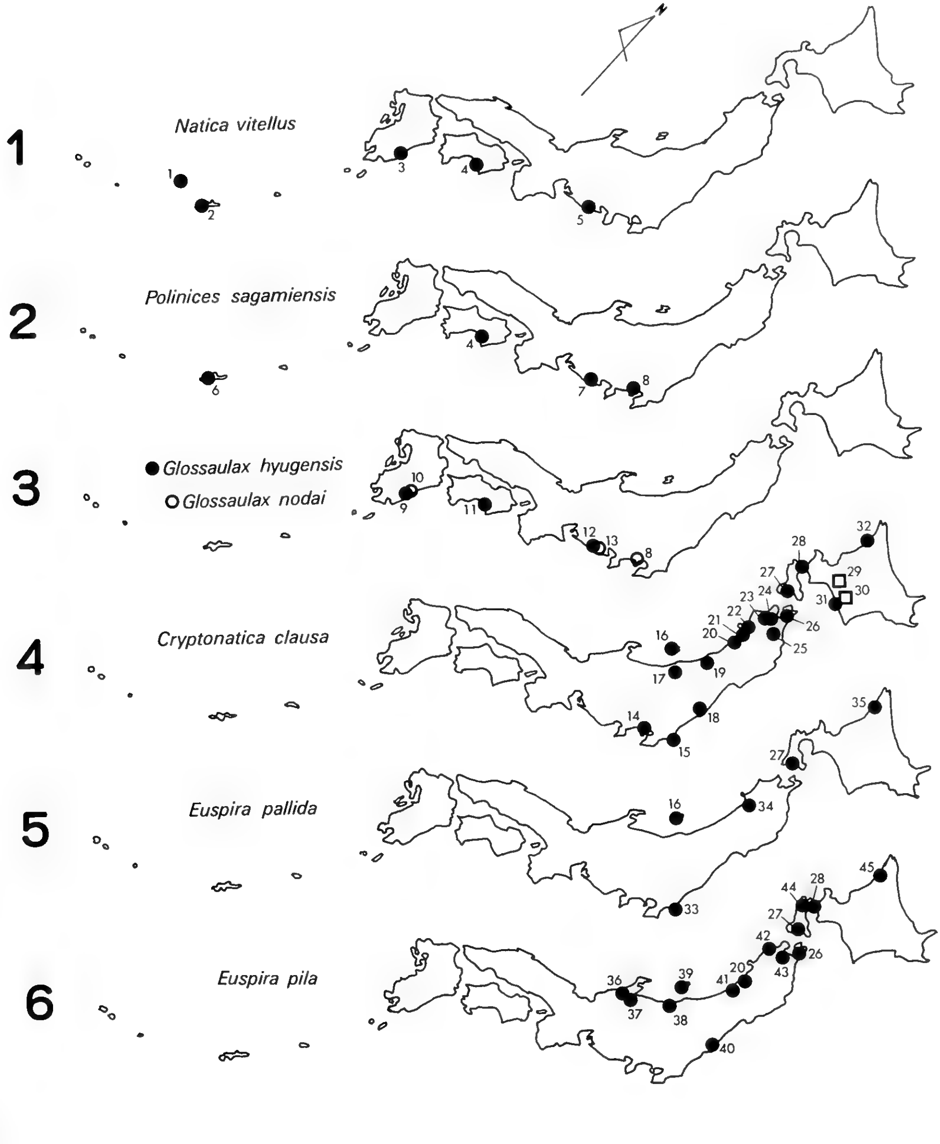
In Pliocene and early Pleistocene faunas, there were several species that occurred on both the Pacific side of southwestern Japan and on the side of Honshu toward the Sea of Japan. They are *Euspira yokoyamai* (Kuroda and Habe, 1952) (Text-fig. 5.1), *Glossaulax vesicalis* (Philippi, 1848) (Text-fig. 5.5), *G. reiniana* (Dunker, 1877), *G. hagenoshitensis* (Shuto, 1964) (Text-fig. 5.2), and *Cryptonatica adamsiana* (Dunker, 1859) (Text-fig. 5.4). They are considered to be **We**-type species in spite of their broad geographic ranges, because: (1) in number of individuals, their occurrences from the northwest side of Honshu are few in comparison with those from the Pacific side of southwestern Japan, and (2) they are now living only in the warm waters of Japan and adjacent areas (except for the extinct *G. hagenoshitensis*). The presence of Pliocene and early Pleistocene **We**-type species in cold-water Omma-Manganji faunas of the northwest side of Honshu is attributed to the influence of the Paleo-Tsushima current (thin solid arrows in Text-fig. 2.3). The Paleo-Tsushima current was a branch of the warm-water Paleo-Kuroshio current which flowed into the Paleo-Sea of Japan through Paleo-Tsushima strait (Text-fig. 2.3) during Pliocene and early Pleistocene time. The warm

Text-figure 4.—Fossil localities of *Natica vitellus* (Linnaeus, 1758), *Polinices sagamiensis* Pilsbry, 1904, *Glossaulax hyugensis* (Shuto, 1964), *G. nodai* Majima, 1985, *Cryptonatica clausa* (Broderip and Sowerby, 1829), *Euspira pallida* (Broderip and Sowerby, 1829), and *E. pila* (Pilsbry, 1911). □ = Lower middle Miocene; ● ○ = Pliocene and lower Pleistocene.

Small numerals indicate the formations at the fossil localities. 1, Higa Fm. at loc. KUME 1 and Fusakina Fm. at locs. KUME 2 and KUME 3; 2, Shinzato Fm. at loc. SHINZATO 6; 3, Koyu Fm. at locs. MIYAZAKI 1 and MIYAZAKI 2; 4, Ananai Fm. at loc. TONOHAMA 2; 5, Lower Kakegawa Fm. at locs. KAKEGAWA 1, KAKEGAWA 2, KAKEGAWA 10, KAKEGAWA 11, and KAKEGAWA 17; 6, Chinen Sandstone (MacNeil, 1960); 7, Lower Kakegawa Fm. at locs. KAKEGAWA 1, KAKEGAWA 2, and KAKEGAWA 17; 8, Nojima Fm. at loc. NOJIMA 1; 9, Koyu Fm. at locs. MIYAZAKI 1, MIYAZAKI 2, and MIYAZAKI 3; 10, Koyu Fm. at loc. MIYAZAKI 5; 11, Nobori Fm. at loc. TONOHAMA 1 and Ananai Fm. at loc. TONOHAMA 2; 12, Lower Kakegawa Fm. at loc. KAKEGAWA 9; 13, Lower Kakegawa Fm. at locs. KAKEGAWA 13 and KAKEGAWA 17; 14, Nojima Fm. at loc. NOJIMA 2; 15, Iioka Fm. at loc. CHOSHI 1; 16, Sawane Fm. at locs. SAWANE 1 and SAWANE 2; 17, Nishiyama Fm. (Itoigawa, 1958); 18, Yamadahama Fm. (Nemoto and O'hara, 1979a); 19, Kannonji Fm. (Ogasawara and Naito, 1983); 20, Sasaoka Fm. at loc. TOFUIWA; 21, Sasaoka Fm. at locs. GOJOME 2 and GOJOME 4; 22, Kobinaizawa Fm. at locs. FUTATSUI 1 and FUTATSUI 2; 23, Higashimeya Fm. at loc. HIGASHIMEYA; 24, Daishaka Fm. at locs. DAISHAKA and NAMIOKA; 25, Kubo Fm. at loc. OCHIAI; 26, Sunagomata Fm. at locs. CHIKAGAWA 1 and CHIKAGAWA 2; 27, Tomikawa Fm. at loc. TOMIKAWA; 28, Nakanokawa Fm. at locs. KUROMATSUNAI 1 and KUROMATSUNAI 2; 29, Takinoue Fm. at locs. MOMIJIYAMA 1 and MOMIJIYAMA 2; 30, Furanui Fm. at loc. FURANUI 1; 31, Atsuga Fm. at loc. ATSUGA; 32, Yuchi Fm. at locs. TESHIO 2, TESHIO 4, TESHIO 5, and TESHIO 7; 33, Iioka Fm. at locs. CHOSHI 1, CHOSHI 2, and CHOSHI 3; 34, Wakimoto Fm. (Matsui, 1985); 35, Yuchi Fm. at loc. TESHIO 9; 36, Omma Fm. at locs. OMMA 1, OMMA 2, OMMA 4, OMMA 5, and OMMA 6; 37, Natsukawa Fm. at loc. ISURUGI; 38, Haizume Fm. at locs. HAIZUME 1 and HAIZUME 2; 39, Sawane Fm. at loc. SAWANE 4; 40, Yamadahama Fm. at loc. FUTATSUNUMA 1; 41, Sasaoka Fm. at loc. TOFUIWA; 42, Narusawa Fm. at loc. KITAKANEGASAWA; 43, Daishaka Fm. at loc. DAISHAKA; 44, Chinkope Fm. at loc. SETANA; 45, Yuchi Fm. at locs. TESHIO 2, TESHIO 5, TESHIO 7, and TESHIO 8.

Paleo-Tsushima current might have allowed some **We**-type species to invade the Paleo-Sea of Japan where the cold-water Omma-Manganji faunas prevailed. No **Ww**-type species invaded the Paleo-Sea of Japan.

The early Pleistocene Nojima Formation in the southern part of Kanagawa Prefecture, Pacific side of central Honshu (loc. Nojima, Kanagawa Prefecture, in Text-fig. 1), yields both cold- and warm-water naticids. The cold-water naticids are represented by *Cryptonatica clausa* (Broderip and Sowerby) and *C. janthostoma* (Deshayes), and the warm-water ones by *Euspira yokoyamai* (Kuroda and Habe), *Polinices candidissimus* (Le Guillou), *P. sagamiensis* Pilsbry, *Glossaulax nodai* Majima, and *G. hagenoshitensis* (Shuto). Thus, one **Cw**- (*C. clausa*), one **Ce**- (*C. janthostoma*), four **We**- (*E. yokoyamai*, *P. sagamiensis*, *G. nodai*, and *G.*



hagenoshitensis), and one **Ww**- (*P. candidissimus*) type species occur in the formation. Noda and Amano (1977) considered the Pacific side of central Honshu to be a "transitional zone" between the cold-water Omma-Manganji and the warm-water Kakegawa faunas, and the presence of both cold- and warm-water naticids supports this. There might have been some minor boundary fluctuations between cold-water and warm-water masses when the Nojima Formation was deposited, as well as in the middle middle Miocene.

SUMMARY

Neogene and Early Quaternary naticids of Japan are divisible into the five paleoclimatic preference types, based on their geographic distributions and their associated molluscan faunas. They are **Cw**, **Ce**, **Bt**, **We**, and **Ww** types. The paleogeographic distributions of the **Cw**, **Ce**, **We**, and **Ww** types are clearly related to the distributions of paleo-water masses (cold and warm waters). However, the paleogeographic distributions of **Bt**-type species were not related to the distributions of paleo-water masses.

The relative proportions of Japanese Neogene naticid species representing the five paleoclimatic preference types are shown for each formation in Text-figure 6. The formations are grouped into the lower middle Miocene, middle middle Miocene to upper Miocene, and the Pliocene and lower Pleistocene. Lower Miocene formations are excluded because they are few in number and contain few naticids. Among the three cold-water faunas, including the lower middle Miocene Chikubetsu fauna (Text-fig. 6, formations 1 to 4), the middle middle Miocene to upper Miocene Shiobara fauna (formations 27 to 36) and the Pliocene and lower Pleistocene Omma-Manganji fauna (formations 38 to 61), the Shiobara fauna is considered to be warmer than the other two, because it lacks **Cw**-type naticid species and contains only **Bt**- and **Ce**-type species. *Cryptonatica clausa* (Broderip and Sowerby, 1829), a **Cw**-type species, is associated with the Chikubetsu and Omma-Manganji faunas but not with the Shiobara faunas. The relatively warmer conditions of the Shiobara faunas probably obstructed migration of **Cw**-type species into Japan during middle middle Miocene to late Miocene time.

INFERRED PHYLOGENETIC RELATIONSHIPS OF FIVE NATICID LINEAGES

INTRODUCTION

Among Cenozoic fossil naticids in Japan, phylogenetic relations of the following species-groups were inferred on the basis of shell morphology and stratigraphic occurrence: Lineage I — *Glossaulax hyugensis* (Shuto, 1964), *G. nodai* Majima, 1985, and *G. hagenoshitensis* (Shuto, 1964); Lineage II — *Glossaulax didyma coticazae* (Makiyama, 1926), *G. didyma didyma* (Röding, 1798), *G. didyma dainichiensis*, n. subsp., and *G. vesicalis* (Philippi, 1848); Lineage III — *Euspira meisensis* (Makiyama, 1926), *E. marincovichi*, n. sp., and *E. mitsuganoensis* Shibata, 1970; Lineage IV — *Euspira pallida* (Broderip and Sowerby, 1829), *E. pila* (Pilsbry, 1911), and *E. yokoyamai* (Kuroda and Habe, 1952); and Lineage V — *Cryptonatica clausa* (Broderip and Sowerby, 1829), *C. ichishiana* (Shibata, 1970), *C. janthostoma* (Deshayes, 1837), and *C. andoi* (Nomura,

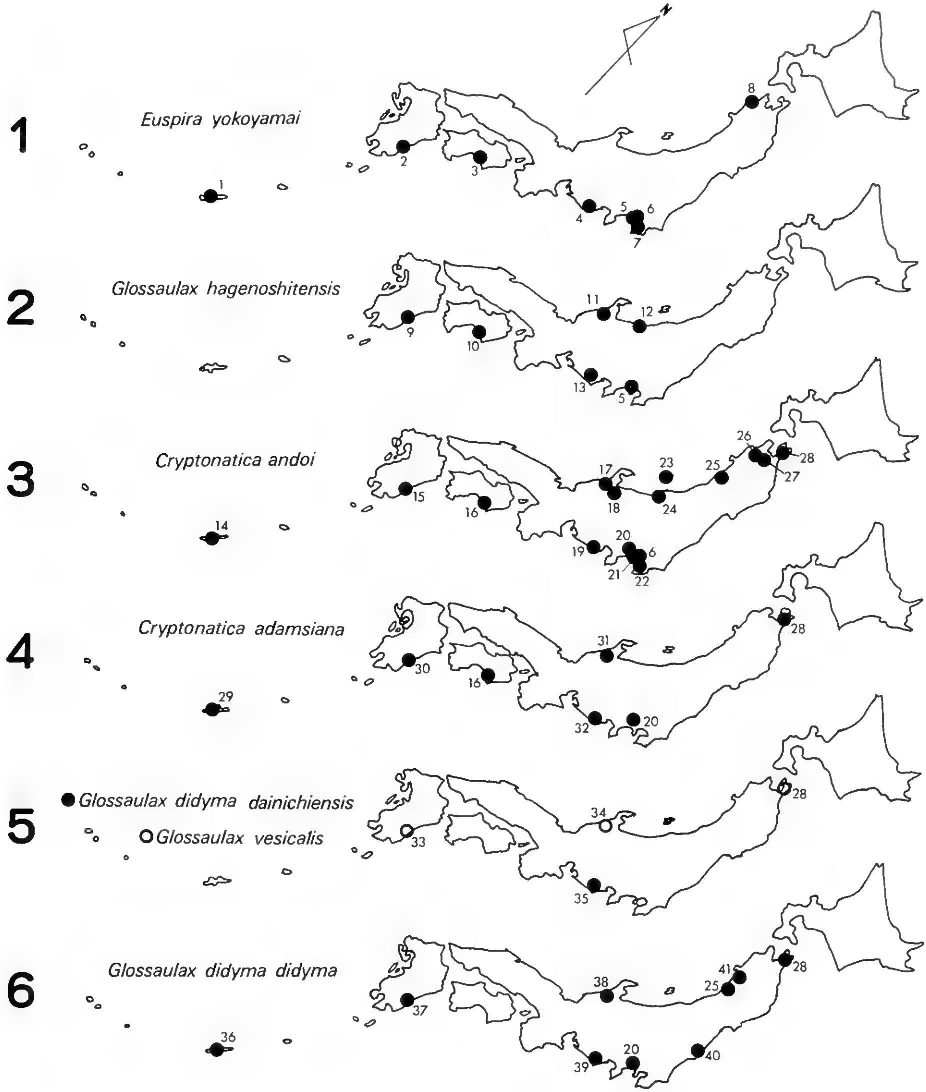
Text-figure 5.—Fossil localities of *Euspira yokoyamai* (Kuroda and Habe, 1952), *Glossaulax hagenoshitensis* (Shuto, 1964), *Cryptonatica andoi* (Nomura, 1935b), *C. adamsiana* (Dunker, 1859), *Glossaulax didyma dainichiensis*, n. subsp., *G. vesicalis* (Philippi, 1848), and *G. didyma didyma* (Röding, 1798). ● ○ = Pliocene and lower Pleistocene.

Small numerals indicate the formations at the fossil localities. 1, Yonabaru Fm. (MacNeil, 1960) and Shinzato Fm. at locs. SHINZATO 1, SHINZATO 2, SHINZATO 3, SHINZATO 4, SHINZATO 5, SHINZATO 6, and SHINZATO 9; 2, Koyu Fm. at locs. MIYAZAKI 1, MIYAZAKI 2, MIYAZAKI 3, MIYAZAKI 4, MIYAZAKI 9, and MIYAZAKI 10; 3, Ananai Fm. at loc. TONOHAMA 1; 4, Lower Kakegawa Fm. at loc. KAKEGAWA 18; 5, Nojima Fm. at loc. NOJIMA 1; 6, Koshiba Fm. (Yokoyama, 1920); 7, Mandano Fm. at loc. KIMITSU 1; 8, Narusawa Fm. at loc. KITAKANEGASAWA; 9, Koyu Fm. at locs. MIYAZAKI 1, MIYAZAKI 2, MIYAZAKI 3, and MIYAZAKI 4; 10, Nobori Fm. at loc. TONOHAMA 1; 11, Omma Fm. at locs. OMMA 1, OMMA 2, and OMMA 3; 12, Byobudani Fm. at loc. JOETSU; 13, Lower Kakegawa Fm. at locs. KAKEGAWA 1, KAKEGAWA 2, KAKEGAWA 8, KAKEGAWA 9, KAKEGAWA 10, KAKEGAWA 11, KAKEGAWA 12, KAKEGAWA 13, KAKEGAWA 14, KAKEGAWA 15, KAKEGAWA 16, and KAKEGAWA 17, and Upper Kakegawa Fm. at loc. KAKEGAWA 3; 14, Yonabaru Fm. at loc. YONABARU 1; 15, Koyu Fm. at locs. MIYAZAKI 1, MIYAZAKI 2, MIYAZAKI 6, MIYAZAKI 8, MIYAZAKI 9, MIYAZAKI 10, and MIYAZAKI 11; 16, Nobori Fm. at loc. TONOHAMA 1 and Ananai Fm. at loc. TONOHAMA 2; 17, Omma Fm. at locs. OMMA 2 and OMMA 5; 18, Natsukawa Fm. at loc. ISURUGI; 19, Lower Kakegawa Fm. at locs. KAKEGAWA 1, KAKEGAWA 2, KAKEGAWA 5, KAKEGAWA 8, KAKEGAWA 12, KAKEGAWA 17, and KAKEGAWA 22, and Upper Kakegawa Fm. at locs. KAKEGAWA 3 and KAKEGAWA 23; 20, Kanzawa Fm. at loc. NAKATSU; 21, Nojima Fm. at locs. NOJIMA 1 and NOJIMA 3; 22, Ichijuku Fm. at loc. KIMITSU 2; 23, Sawane Fm. at loc. SAWANE 4; 24, Haizume Fm. at locs. HAIZUME 1 and HAIZUME 2; 25, Sasaoka Fm. at loc. MANGANJI 1; 26, Higashimeya Fm. (Iwai, 1965); 27, Daishaka Fm. (Iwai, 1965); 28, Sunagomata Fm. at loc. CHIKAGAWA 1; 29, Yonabaru Fm. (MacNeil, 1960); 30, Koyu Fm. at locs. MIYAZAKI 1, MIYAZAKI 2, MIYAZAKI 5, and MIYAZAKI 6; 31, Omma Fm. at locs. OMMA 1 and OMMA 2; 32, Lower Kakegawa Fm. at locs. KAKEGAWA 10, KAKEGAWA 11, KAKEGAWA 13, and KAKEGAWA 17, and Upper Kakegawa Fm. at locs. KAKEGAWA 3, KAKEGAWA 19, and KAKEGAWA 20; 33, Koyu Fm. at loc. MIYAZAKI 5; 34, Omma Fm. at loc. OMMA 8; 35, Lower Kakegawa Fm. at locs. KAKEGAWA 1, KAKEGAWA 2, KAKEGAWA 6, KAKEGAWA 10, KAKEGAWA 11, KAKEGAWA 12, KAKEGAWA 15, KAKEGAWA 16, and KAKEGAWA 17; 36, Nakoshi Sandstone at locs. HANEJI 2 and HANEJI 4; 37, Koyu Fm. at loc. MIYAZAKI 1; 38, Omma Fm. at locs. OMMA 1 and OMMA 7; 39, Lower Kakegawa Fm. at locs. KAKEGAWA 5, KAKEGAWA 8, KAKEGAWA 9, and KAKEGAWA 13, and Upper Kakegawa Fm. at locs. KAKEGAWA 3 and KAKEGAWA 21; 40, Yamadahama Fm. at loc. FUTATSUNUMA 1; 41, Sasaoka Fm. at locs. GOJOME 1 and GOJOME 3.

1935b). Their ancestor–descendant relations are shown by the arrows in Text-figure 7.

LINEAGE I

Glossaulax hyugensis (Shuto, 1964), *G. nodai* Majima, 1985, and *G. hagenoshitensis* (Shuto, 1964) show great ontogenetic variation in their callus morphologies (Text-fig. 8). The callus morphology of *G. hyugensis* is represented by three forms: juvenile (form 1J: Text-fig. 8.1J), typical adult (form 1T: Text-fig. 8.1T), and unusual adult (form 1U: Text-fig. 8.1U). *Glossaulax nodai* is represented by one form (form 2: Text-fig. 8.2). *Glossaulax hagenoshitensis* is represented by three forms: juvenile (form 3J: Text-figs. 8.3Ja, 8.3Jb), typical adult (form 3T: Text-figs. 8.3Ta, 8.3Tb), and unusual adult (form 3U: Text-figs. 8.3Ua, 8.3Ub).



The adult forms of both *G. hyugensis* and *G. hagenoshitensis* show dimorphic variations in their callus morphologies, which are represented by forms 1T and 1U of *G. hyugensis*, and by forms 3T and 3U of *G. hagenoshitensis*. Juveniles of *G. hyugensis* (form 1J) and *G. hagenoshitensis* (form 3J) differ from their adult forms. *Glossaulax nodai*, on the other hand, has uniform callus morphologies (form 2) in post-larval individuals.

The following relationships among callus morphologies are recognized in this species group: (1) The adult of *G. nodai* is similar to the juvenile form (form 1J) of *G. hyugensis* in having a subtrigonal umbilical callus. (2) The typical adult form (form 1T) of *G. hyugensis* resembles the juvenile form (form 3J) of *G. hagenoshitensis* in having a subquadrate umbilical callus. (3) The adult forms 1T and 1U of *G. hyugensis* morphologically and ontogenetically correspond to adult forms 3U and 3T of *G. hagenoshitensis*, respectively. However, the frequency of the corresponding adult forms of the two species is extremely different: in *G. hyugensis*, frequency of form 1T is much greater than that of form 1U, whereas in *G. hagenoshitensis*, frequency of form 3U that corresponds to form 1T of *G. hyugensis* is much less than that of form 3T that corresponds to form 1U of *G. hyugensis*.

Glossaulax hyugensis first appeared in the early Pliocene, whereas both *G. nodai* and *G. hagenoshitensis* first appeared in the late Pliocene (Text-fig. 7). Phylogenetic relationships among the three species are interpreted as heterochronous evolution. *Glossaulax nodai* is thought to have evolved from *G. hyugensis* by paedomorphosis because of the morphological similarity between the juvenile form (form 1J) of *G. hyugensis* and the adult form of *G. nodai* (form 2). *Glossaulax hagenoshitensis* likely evolved from *G. hyugensis* by peramorphosis, based on the morphological similarity between the typical adult form (form 1T) of *G. hyugensis* and the juvenile form (form 3J) of *G. hagenoshitensis*. Further detailed discussion of these inferences is given in Majima (1985).

LINEAGE II

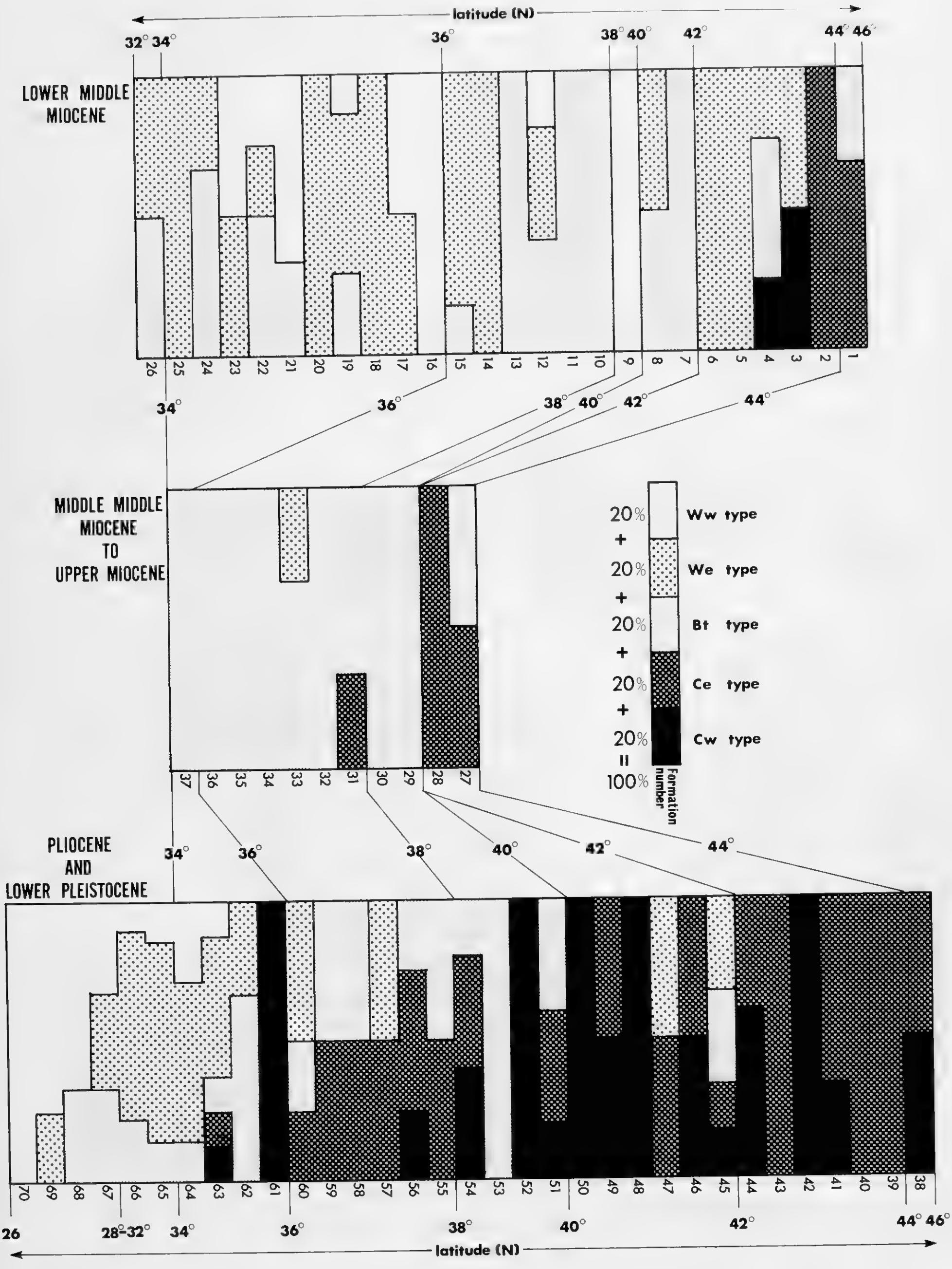
Glossaulax didyma coticazae (Makiyama, 1926) is a chronological subspecies of *G. didyma didyma* (Röding, 1798). It ranges from the early middle Miocene to Pliocene and is characterized by a moderately developed subtrigonal to subquadrate umbilical callus attached to the posterior side of the umbilicus (Text-fig. 9.1). Its shell form varies from globose to elongate (Pl. 5, figs. 1–25, Pl. 6, figs. 1–3). There is also variation in the transverse groove on the umbilical callus: some grooves are strongly incised (Text-fig. 9 [arrow **a**]) but others are weakly incised. *Glossaulax didyma didyma* ranges from the Pliocene to Holocene, and is characterized by a weakly depressed to globose conical shell (Pl. 6. figs. 4–18, Pl. 7, figs. 1–5) and by the presence of two end-form variants: one that is characterized by a small subtrigonal umbilical callus detached from the posterior side of the umbilicus (Text-fig. 9.4) and another that is characterized by a heavily developed umbilical callus largely covering the umbilicus (Text-fig. 9.6). These two end forms of *G. didyma didyma* define a continuous series of intermediate forms (Text-figs. 9.5, 21.1–21.6) and transverse callus grooves of all the variants are commonly weakly incised.

Text-figure 6.—Ratio of five types (**Ww**, **We**, **Bt**, **Ce**, and **Cw**) of fossil naticids in each formation. The ratio is computed according to the number of species (not number of individuals). **Ww**- (**W**arm-water **w**idespread) type naticids lived in warm waters of Japan, the East Indies and farther south. **We**- (**W**arm-water **e**ndemic) type naticids only lived in warm waters of Japan and adjacent areas. **Bt**- (**B**road **t**emperature tolerance) type naticids lived in both warm and cold waters in Japan. **Ce**- (**C**old-water **e**ndemic) type naticids only lived in cold waters of Japan and adjacent areas. **Cw**- (**C**old-water **w**idespread) type naticids lived in cold waters of Japan and the arctic region.

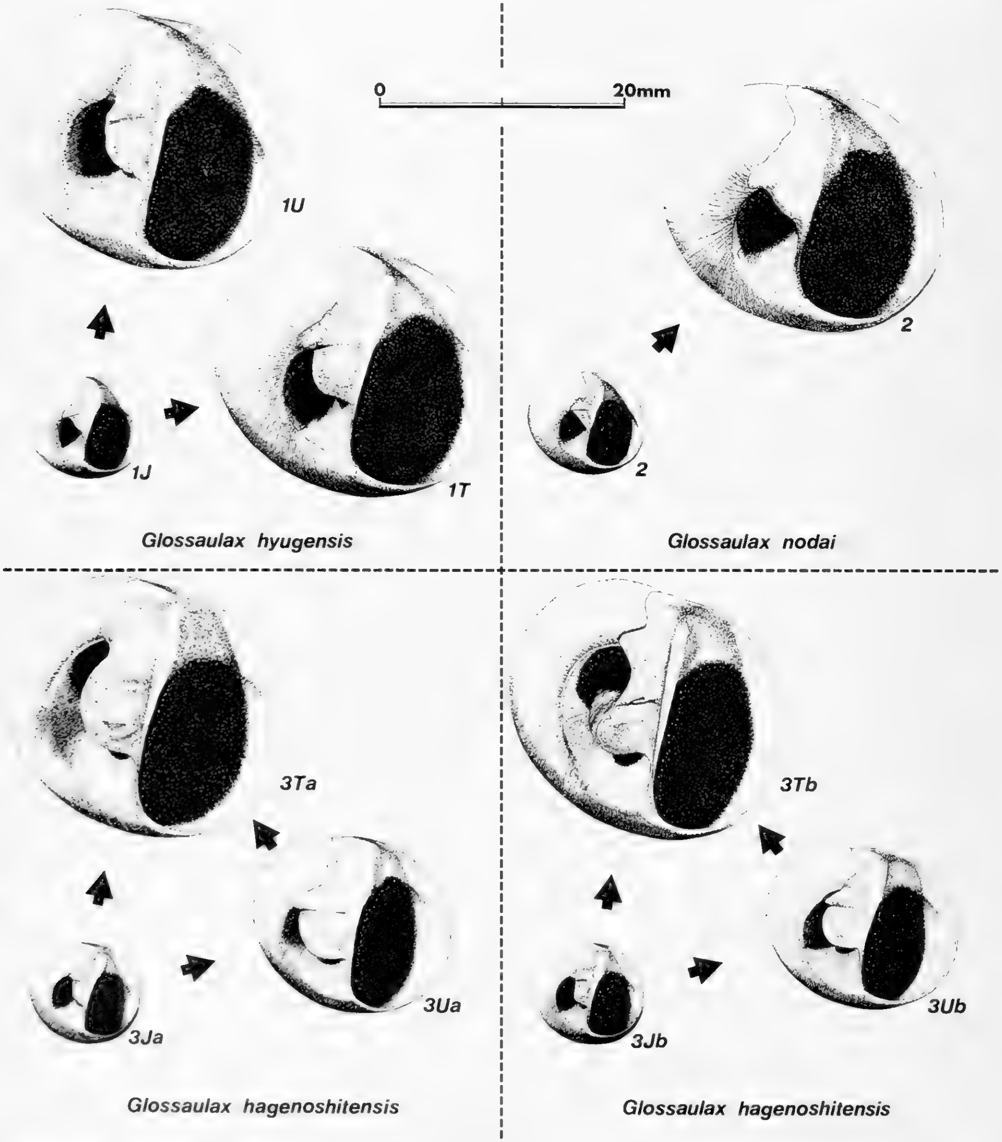
Lower middle Miocene: 1, Sankebetsu and Chikubetsu fms., Hokkaido; 2, Takinoue Fm., Asahi, Hokkaido; 3, Takinoue Fm., Momijiyama, Hokkaido; 4, Furanui Fm., Hokkaido; 5, Kunnui Fm., Hokkaido; 6, Tsurikake Fm., Hokkaido; 7, Takahoko Fm., Aomori Pref.; 8, Kadonosawa Fm., Iwate Pref.; 9, Takinosawa Fm., Yamagata Pref.; 10, Kozai Fm., Miyagi Pref.; 11, Yanagawa Fm., Fukushima Pref.; 12, Higashi-Innai Fm., Ishikawa Pref.; 13, Numanouchi Fm., Fukushima Pref.; 14, Nakayama Fm., Fukushima Pref.; 15, Yatsuo Fm., Toyama Pref.; 16, Hiranita Fm., Saitama Pref.; 17, Uchiura Group, Fukui Pref.; 18, Nukuta Fm., Nagano Pref.; 19, Mizunami Group, Gifu Pref.; 20, Kurokawa Fm., Shiga Pref.; 21, Bihoku Group, Tsuyama, Okayama Pref.; 22, Bihoku Group, Niimi, Okayama Pref.; 23, Bihoku Group, Shobara, Hiroshima Pref.; 24, Togane Fm., Shimane Pref.; 25, Oi Fm., Mie Pref.; 26, Tanabe Group, Wakayama Pref.

Middle middle Miocene to upper Miocene: 27, Togeshita Fm., Hokkaido; 28, Maedanosawa Fm., Hokkaido; 29, Yamatsuda Fm., Iwate Pref.; 30, Kanagase Fm., Miyagi Pref.; 31, Kubota Fm., Fukushima Pref.; 32, Kanomatazawa Fm., Tochigi Pref.; 33, Kokozura Fm., Fukushima Pref.; 34, Saikawa Fm., Ishikawa Pref.; 35, Aoki Fm., Nagano Pref.; 36, Aimagawa Fm., Gumma Pref.; 37, Zushi Fm., Kanagawa Pref.

Pliocene and lower Pleistocene: 38, Yuchi Fm., Hokkaido; 39, Horokaoshirarika Fm., Hokkaido; 40, Horoka Fm., Hokkaido; 41, Nakanokawa Fm., Hokkaido; 42, Atsuga Fm., Hokkaido; 43, Chinkope Fm., Hokkaido; 44, Tomikawa Fm., Hokkaido; 45, Sunagomata Fm., Aomori Pref.; 46, Daishaka Fm, Aomori Pref.; 47, Narusawa Fm., Aomori Pref.; 48, Higashimeya Fm., Aomori Pref.; 49, Kubo Fm., Iwate Pref.; 50, Kobinaizawa Fm., Akita Pref.; 51, Sasaoka Fm., Akita Pref.; 52, Kannonji Fm., Yamagata Pref.; 53, Tatsunokuchi Fm., Miyagi Pref.; 54, Sawane Fm., Niigata Pref.; 55, Haizume Fm., Niigata Pref.; 56, Yamadahama Fm., Fukushima Pref.; 57, Byobudani Fm., Niigata Pref.; 58, Shigarami Fm., Nagano Pref.; 59, Natsukawa Fm., Toyama Pref.; 60, Omma Fm., Ishikawa Pref.; 61, Iioka Fm., Chiba Pref.; 62, Kanzawa Fm., Kanagawa Pref.; 63, Nojima Fm., Kanagawa Pref.; 64, Kakegawa Group, Shizuoka Pref.; 65, Tonohama Group, Kochi Pref.; 66, Miyazaki Group, Miyazaki Pref.; 67, Nakoshi Sandstone, Okinawa Pref.; 68, Yonabaru Fm., Okinawa Pref.; 69, Shinzato Fm., Okinawa Pref.; 70, Shimajiri Group, Kume-jima, Okinawa Pref.


latitude (N)
LOWER MIDDLE MIOCENE
MIDDLE MIDDLE MIOCENE TO UPPER MIOCENE
PLIOCENE AND LOWER PLEISTOCENE
20% Ww type
+
20% We type
+
20% Bt type
+
20% Ce type
+
20% Cw type
=
100%
Formation number

Glossaulax didyma coticazae gradually evolved into *G. didyma didyma* in Pliocene time, during which their morphologies entirely overlapped. Each Pliocene population has been assigned to a subspecies herein, based on its dominant morphology. In the present study, three Pliocene populations from localities GOROKU,

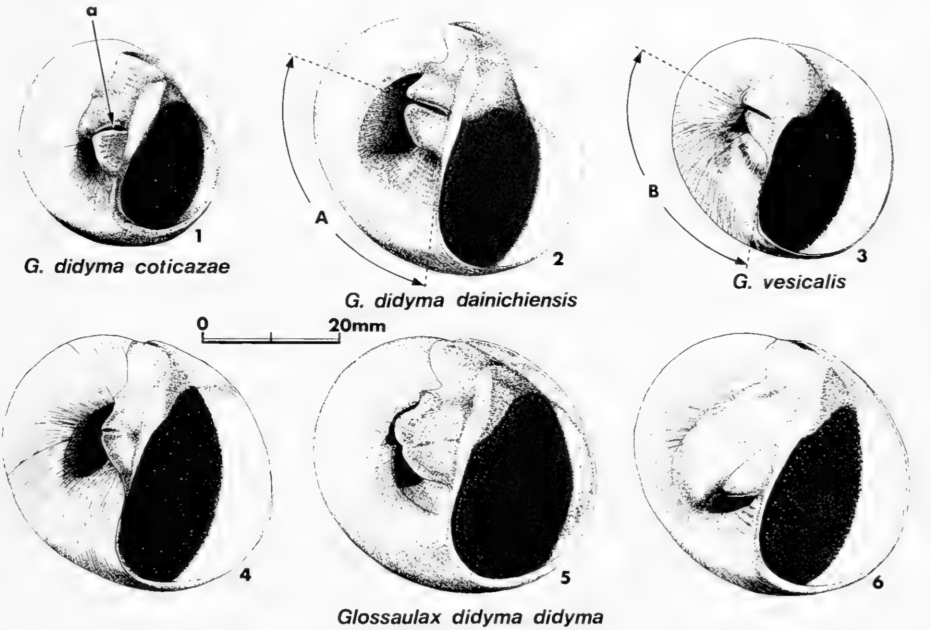


Text-figure 8.—Basal views of *Glossaulax hyugensis* (Shuto, 1964), *G. nodai* Majima, 1985, and *G. hagenoshitensis* (Shuto, 1964), showing the ontogenetic (solid arrow) and adult variations for parietal callus and umbilical callus.

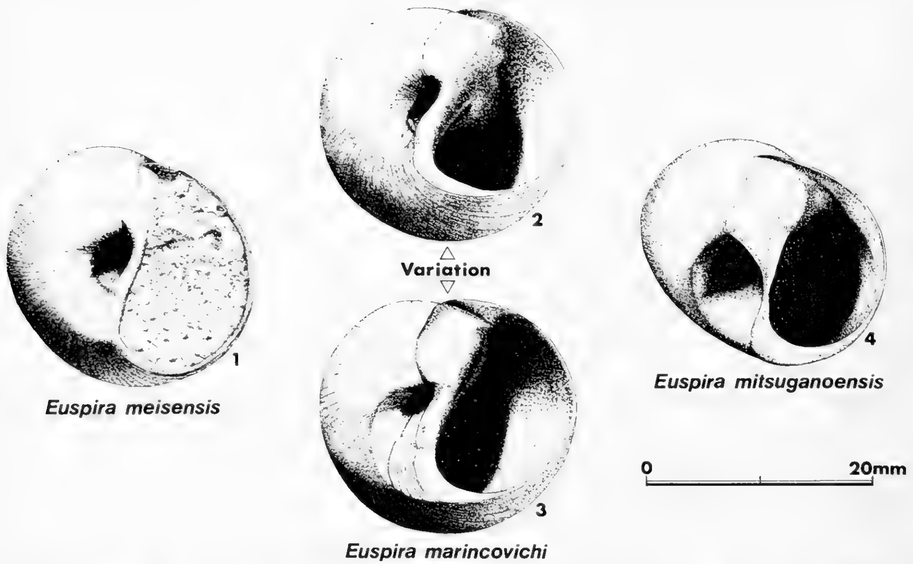
Miyagi Prefecture (Pl. 5, figs. 20–25, Pl. 6, figs. 1–2), SHIGARAMI 1, Nagano Prefecture (Pl. 6, fig. 3), and the Nodani Formation, Joetsu City, Niigata Prefecture (Amano, Kanno, and Mizuno, 1985, pl. 2, fig. 14) are assigned to *G. didyma coticazae*. They show the globose to elongate form and deeply incised umbilical callus groove of *G. didyma coticazae* but some specimens also possess the greatly developed umbilical callus that characterizes one end form of *G. didyma didyma* (Text-fig. 9.6). Thus these assignments are somewhat arbitrary. The other Pliocene populations studied herein are morphologically closer to *G. didyma didyma* and are assigned to this subspecies.

Glossaulax didyma dainichiensis, n. subsp. is a late Pliocene geographic subspecies of the *G. didyma coticazae – G. didyma didyma* lineage. It is restricted geographically to the Kakegawa area on the Pacific side of central Honshu (Shizuoka Prefecture), and stratigraphically to a narrow horizon: lower part of the upper Pliocene Dainichi Member of the Lower Kakegawa Formation. This limited occurrence suggests that *G. didyma dainichiensis* was a local subspecies in the late Pliocene. *Glossaulax didyma dainichiensis* shows a very wide range of morphology (Pl. 7, figs. 6–16), including some characteristics of both *G. didyma coticazae* (a deeply incised umbilical callus groove: Pl. 7, figs. 14–16) and *G. didyma didyma* [both the end forms of the umbilical callus: a small subtrigonal umbilical callus detached from the posterior side of the umbilicus (Pl. 7, figs. 10–11), and a greatly developed umbilical callus largely covering the umbilicus (Pl. 7, figs. 6–7)]. *Glossaulax didyma dainichiensis* also includes one variant with a greatly depressed shell (Pl. 7, figs. 13–15), and its transverse callus groove crosses obtusely to the inner margin of the aperture (Text-fig. 9 [angle **A**]). These characteristics are never observable in both *G. didyma coticazae* and *G. didyma didyma*. All specimens of *G. didyma dainichiensis* have slightly thinner shells than either *G. didyma coticazae* or *G. didyma didyma*.

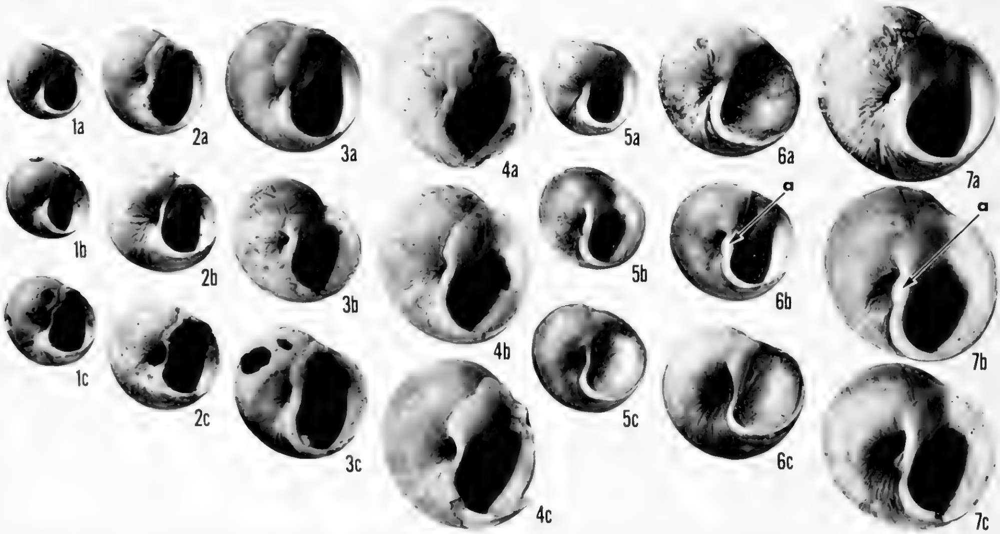
In the late Pliocene, *G. didyma dainichiensis* evidently gave rise to *G. vesicalis* (Philippi, 1848) (Pl. 7, figs. 17–24). *Glossaulax vesicalis* is characterized by having an extremely thin shell, a weakly developed umbilical callus and a weakly to strongly incised transverse callus groove that commonly crosses to the inner margin of the aperture with an obtuse angle (Text-fig. 9 [angle **B**]). The late Pleistocene to Holocene *G. vesicalis* has a globose shell with moderately elevated spire



Text-figure 9.—Basal views of (1) *Glossaulax didyma coticazae* (Makiyama, 1926), (2) *G. didyma dainichiensis*, n. subsp., (3) *G. vesicalis* (Philippi, 1848), and (4–6) *G. didyma didyma* (Röding, 1798). Arrow a indicates a distinctly incised umbilical callus groove characterizing *G. didyma coticazae*. *Glossaulax vesicalis* and *G. didyma dainichiensis* are very similar in having a transverse callus groove crossing obtusely to the inner margin of the aperture (angles **A** and **B**).



Text-figure 10.—Basal views of (1) *Euspira meisensis* (Makiyama, 1926), (2, 3) *E. marincovichi*, n. sp., and (4) *E. mitsuganoensis* Shibata, 1970.



Text-figure 11.—Basal views of fossil (1a–4c) and modern (5a–7c) specimens of *Euspira pallida* (Broderip and Sowerby, 1829). The lowercase letters **a**, **b**, and **c** of 1–7 indicate, respectively, the specimens with the most closed umbilicus, moderately open umbilicus and the most open umbilicus among all the specimens examined in each growth stage. 1a–4c, IGUT 15773 (1a, IGUT 15773-1; 1b, 15773-8; 1c, IGUT 15773-3; 2a, IGUT 15773-4; 2b, IGUT 15773-5; 2c, IGUT 15773-7; 3a, IGUT 15773-6; 3b, IGUT 15773-9; 3c, IGUT 15773-10; 4a, IGUT 15773-11; 4b, IGUT 15773-12; and 4c, IGUT 15773-13), ×1.4, locality Choshi 1, lower Pleistocene Iioka Fm.; 5a–7c, GIYU 575 (5a, GIYU 575-1; 5b, GIYU 575-2; 5c, GIYU 575-3; 6a, GIYU 575-4; 6b, GIYU 575-5; 6c, GIYU 575-6; 7a, GIYU 575-7; 7b, GIYU 575-8; and 7c, GIYU 575-9), ×1.5, off Choshi, Chiba Pref. (unknown in detail). Some specimens of *E. pallida* have a weakly developed semicircular umbilical callus (arrow **a**).

(Pl. 7, figs. 17, 21–24), whereas its earliest known representatives in early Pleistocene faunas have a greatly depressed spire (Pl. 7, figs. 18–20). The latter individuals are very similar to the depressed variant of *G. didyma dainichiensis* (Pl. 7. figs. 13–15), which is considered herein to be a forerunner of *G. vesicalis*. *Glossaulax didyma dainichiensis* is, therefore, considered to be a transitional population between *G. didyma* (including *G. didyma coticazae* and *G. didyma didyma*) and *G. vesicalis*. It shows substantial morphological overlap with both *G. didyma* and *G. vesicalis*.

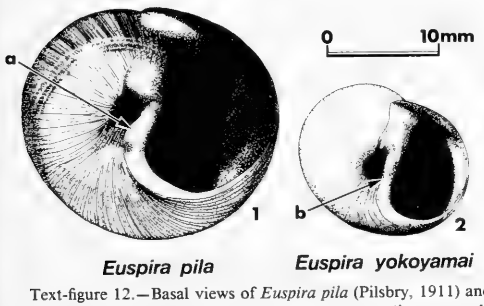
The inferred speciation process of *G. vesicalis* is conformable to that documented by Williamson (1981). Williamson studied late Cenozoic lacustrine molluscan faunas of the Turkana Basin in northern Kenya and concluded that

> these faunas provide the first fine-scaled palaeontological resolution of events during speciation: fundamental phenotypic transformation of both sexual and asexual taxa occur rapidly, in comparatively large populations, and is accompanied by a significant elevation of phenotypic variance. This increase in variance reflects extreme developmental instability in the transitional populations.

Glossaulax didyma dainichiensis, a transitional population between *G. didyma* and *G. vesicalis*, shows a significant elevation of phenotypic variance confirmed by its wide range of morphological variation.

LINEAGE III

In the *Euspira meisensis* (Makiyama, 1926) – *E. marincovichi*, n. sp. – *E. mitsuganoensis* Shibata, 1970 lineage, *E. meisensis* first occurred in Oligocene faunas, whereas both *E. marincovichi* and *E. mitsuganoensis* first appeared in early middle Miocene time. The morphological range of *E. marincovichi* occupies an intermediate position between those of the other two species and serves to link them. The base of *E. marincovichi* ranges from rounded (Text-fig. 10.2) to angulate (Text-fig. 10.3) but a rounded base is a stable feature of the presumed ancestral species, *E. meisensis* (Text-fig. 10.1). *Euspira marincovichi* evidently gave rise to *E. mitsuganoensis*, because the angulate base that is present in only some specimens of *E. marincovichi* is characteristic of the latter species (Text-fig. 10.4).



Text-figure 12.—Basal views of *Euspira pila* (Pilsbry, 1911) and *E. yokoyamai* (Kuroda and Habe, 1952). *Euspira pila* commonly has a small semicircular umbilical callus (arrow **a**) whereas *E. yokoyamai* does not (arrow **b**).

LINEAGE IV

The wide range of morphological variation of *Euspira pallida* (Broderip and Sowerby, 1829) plays a key role in clarifying the evolution of the *E. pallida* – *E. pila* (Pilsbry, 1911) – *E. yokoyamai* (Kuroda and Habe, 1952) lineage. The degree of umbilical opening in *E. pallida* varies greatly, from nearly or entirely closed (Text-figs. 11.1a, 11.2a, 11.3a, 11.4a, 11.5a, 11.6a, 11.7a) to widely open (Text-figs. 11.1c, 11.2c, 11.5c, 11.6c, 11.7c). The shell form varies from globose to globose-elongate (Pl. 3, figs. 7–13). The inner lip is commonly simple but may bear a weakly developed semicircular umbilical callus (Text-fig. 11 [arrow **a**]).

In comparison, *E. pila* and *E. yokoyamai* have much narrower ranges of morphological variation. *Euspira pila* has a globose-elongate shell (Pl. 4, figs. 1–12, 16–20), a narrowly open umbilicus (Text-fig. 12.1), and a small but distinct semicircular umbilical callus (Text-fig. 12 [arrow **a**]). *Euspira yokoyamai* exhibits a globose shell (Pl. 3, figs. 14–22), widely to moderately open umbilicus (Pl. 3, figs. 14–22, Text-fig. 12.2) and a simple anterior inner lip without a semicircular umbilical callus (Text-fig. 12 [arrow **b**]). The globose-elongate shell and small semicircular umbilical callus that characterize *E. pila* are also observable as one morphological variant of *E. pallida*. Similarly, the globose shell, simple anterior inner lip lacking a semicircular umbilical callus, and widely to moderately open umbilicus that characterize *E. yokoyamai* are also present in one morphological variant of *E. pallida*. Thus, the three species are considered to be very closely related to one another.

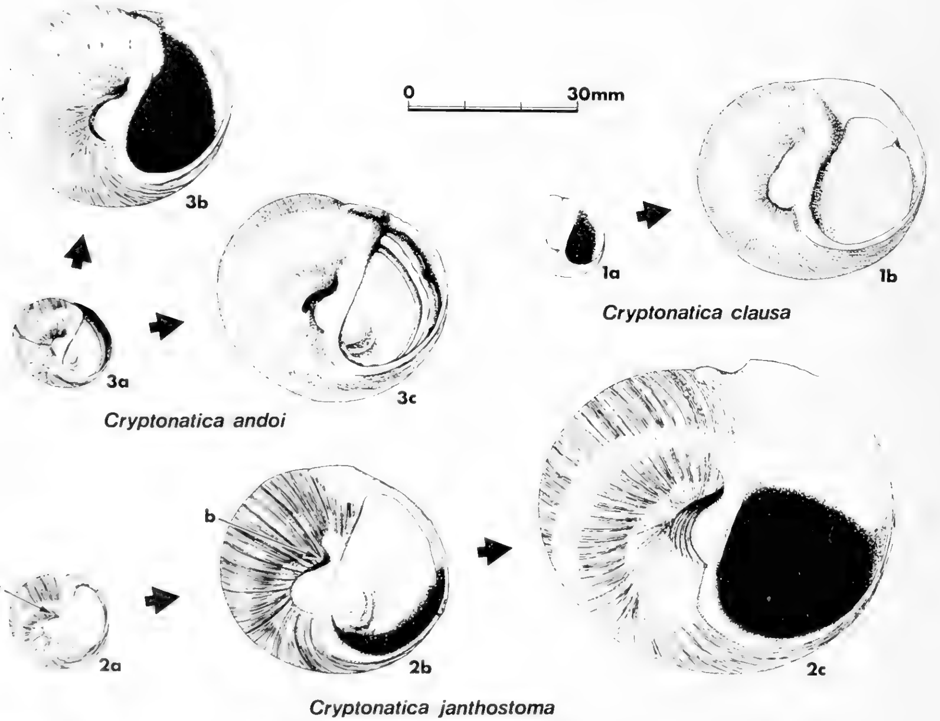
Euspira pallida first appeared in middle Miocene faunas of the western U. S. A. (Marincovich, 1977), while *E. yokoyamai* first occurred in the lower Pliocene Yonabaru Formation in Okinawa Prefecture, and *E. pila* in Pliocene deposits of northern Japan. Because *Euspira pallida* first appeared in Japan during the Pliocene, it is thought to have given rise to both *E. pila* and *E. yokoyamai* at that time.

LINEAGE V

The oldest of four species, *Cryptonatica clausa* (Broderip and Sowerby, 1829), *C. ichishiana* (Shibata, 1970), *C. janthostoma* (Deshayes, 1839), and *C. andoi* (Nomura, 1935b), is *C. clausa* (Text-fig. 13.1a, 13.1b), which first appears during the late Oligocene or earliest Miocene of Alaska (Allison and Marincovich, 1981). *Cryptonatica ichishiana*, which first appears in the early middle Miocene, is considered to be a descendant of *C. clausa*. The shell morphologies of the two species are nearly identical in having an umbilicus entirely closed by a semicircular umbilical callus (Pl. 11). However, *C. ichishiana* differs from *C. clausa* in its opercular sculpture. The operculum of *C. ichishiana* is smooth but may bear two weak striations along the outer margin (Majima, 1984), while *C. clausa* always has an entirely smooth operculum.

Cryptonatica janthostoma is considered to be a descendant of *C. clausa*, and first occurs in the lower middle Miocene Sankebetsu, Chikubetsu, and Takinoue formations of central Hokkaido. *Cryptonatica janthostoma* differs from *C. clausa* by having an umbilicus that is commonly open. The degree of opening of the umbilicus in *C. janthostoma* shows ontogenetic variation (Text-figs. 13.2a–13.2c, 25.1–25.9): juveniles (Text-fig. 13.2a) commonly have slightly open umbilici at their posterior portions where the sulcus is strongly incised (Text-fig. 13 [arrow **a**]), but a few juvenile specimens show entirely closed umbilici. The posterior portions of the umbilici of adults (Text-fig. 13.2b) are always weakly open (Text-fig. 13 [arrow **b**]). Gerontic specimens (Text-fig. 13.2c) have umbilici that are open along most of the umbilical callus margin, whereas their umbilici are very shallow except for the posterior portions.

Cryptonatica andoi is considered to be an offshoot of *C. janthostoma* and first occurs in the lower Pliocene Yonabaru Formation, Okinawa Prefecture, and in the lower Pliocene Kawabaru Member of the Koyu Formation, Miyazaki Prefecture. It characteristically shows variation in the degree of umbilical opening (Text-figs. 13.3a–13.3c, 25.17a–25.23b): juveniles (Text-fig. 13.3a) always show an entirely closed umbilicus but adults exhibit both closed (Text-fig. 13.3b) and open (Text-fig. 13.3c) umbilici. Adults with open umbilici are very similar to the gerontic form of *C. janthostoma* (Text-fig. 13.2c), due to having an open umbilicus along most of the umbilical callus margin.



Text-figure 13.—Ontogenetic (solid arrow) and adult variations of (1a–b) *Cryptonatica clausa* (Broderip and Sowerby, 1829), (2a–c) *C. janthostoma* (Deshayes, 1839), and (3a–c) *C. andoi* (Nomura, 1935b). Juvenile (2a) of *C. janthostoma* commonly has a slightly open umbilicus at its posterior portion where the sulcus is distinctly incised (arrow **a**), and umbilicus of the adult (2b) is always weakly open at the same portion (arrow **b**) as the juvenile.

Observations on the umbilical morphologies of *C. clausa*, *C. janthostoma*, and *C. andoi* are as follows (Text-fig. 13): (1) *C. clausa* is similar to the juvenile and an adult variant of *C. andoi* in having an umbilicus closed by a semicircular umbilical callus; (2) the gerontic form of *C. janthostoma* is similar to an adult variant of *C. andoi* in having an umbilicus open along most of the umbilical callus margin. These morphological similarities strongly suggest that these species are phylogenetically close.

CONCLUDING REMARKS

The five phylogenetic lineages discussed above are inferred from the presence together of one or two species (or subspecies) that show very wide ranges of morphological variation. The presence of similar variants among taxa, combined with information on stratigraphic occurrences, are used to infer direct phylogenetic relationships.

ORIGIN OF THREE JAPANESE NATICIDS

Three Japanese naticid species are considered to be migrants from the northeastern Pacific. *Polinices didymoides* (Kanno and Matsuno, 1960) (Pl. 10, fig. 14) from the lower middle Miocene Sankebetsu Formation, central Hokkaido, is morphologically nearly identical with *P. hornii* (Gabb, 1864) (Pl. 10, fig. 15) from the upper Paleocene to upper Eocene of western North America. *Polinices didymoides* is considered to evolve directly from *P. hornii* because there is no species comparable to both in the north Pacific Cenozoic fauna.

The two Miocene species, *Euspira meisensis* (Makiyama, 1926) and *Glossaulax didyma coticazae* (Makiyama, 1926) are also thought to be descended from the northeastern Pacific ancestral stocks. *Euspira meisensis* clearly resembles *E. hotsoni* (Weaver and Palmer, 1922) from the upper Eocene of western North America. *Glossaulax didyma coticazae* is inferred to have evolved from *Glossaulax reclusiana* (Deshayes, 1839), which ranges from middle Eocene to Holocene of the northeastern Pacific. Marincovich (1977) pointed out that *G. reclusiana* is the earliest known species of *Glossaulax*, from which other extinct and living species evolved in the eastern and northwestern Pacific.

SYSTEMATIC PALEONTOLOGY

INTRODUCTION

The supraspecific taxa are arranged in systematic order and the species are in stratigraphic order except for species of *Polinices* Montfort, 1810, which are arranged according to the increasing degree of development of their umbilical calluses, and species of *Glossaulax* Pilsbry, 1929, within which two species groups show clear phylogenetic trends. The arrangement of the species in Text-figure 7, which illustrates stratigraphic ranges of the species, closely conforms to that in the systematics.

The philosophy used in evaluating genus-level classification conforms to that of modern Japanese zoologists, and is less conservative than that used by Marincovich (1977) for northeastern Pacific Naticidae. In general, subgenera used by Marincovich (1977) are raised to full generic rank herein. Similarly, subspecies are used for two Japanese taxa because the large numbers of specimens available for *Glossaulax didyma* (Röding, 1798) allows such distinctions to be made, and because the wide range of geographic variation of *Cernina fluctuata* (Sowerby, 1825) allows me to divide it into geographic subspecies. Certain taxonomic nomina are enclosed in quotation marks. These quotation marks indicate questionable assignments for taxa.

In descriptions of species, terms such as *small*, *moderate*, *large*, *wide*, and *narrow* imply comparison with the other species in the genus or in the subfamily that include the species described.

In discussions of some species, I have quoted extensively in English from the Japanese-language literature that otherwise would be inaccessible to most non-Japanese workers.

Where stratigraphic occurrences are cited for a taxon, fossil localities of the same age are listed from north to south. References to specimens I have illustrated from particular localities are also given along with the stratigraphic occurrence. The arrangement of the localities within each headed table largely conforms to that in the section on stratigraphic occurrence of each species discussion.

I have illustrated specimens of each species from as many localities as possible. Localities mentioned in the text are shown in Text-figure 1. Where several collecting localities are close together I have used numbers to identify them; *e.g.*, KAKEGAWA 1, KAKEGAWA 2, etc. For the benefit of non-Japanese readers, I have cited Japanese prefectural names along with fossil locality names throughout the text, and the prefectures are located and listed alphabetically in Text-figure 1.

TERMINOLOGY

The morphologic terms used in this study (Text-fig. 14) conform to those in text-figure 10 of Marincovich (1977), except that the term "umbilical wall" has been added herein. The umbilical wall (Text-fig. 14) is the exterior shell surface that approximately corresponds to the inner lip and is situated parallel to it. In an umbilicate gastropod, the umbilicus is formed as an opening within the helical spiral of the umbilical wall. When a funicle (Text-fig. 14: slender to thick ridge of callus spiraling into the umbilicus) is present, it is situated upon the umbilical wall. The umbilical wall may be partly or largely concealed by a funicle, so that only an anterior portion of the umbilical wall may be visible.

Characters Used for Naticid Classification

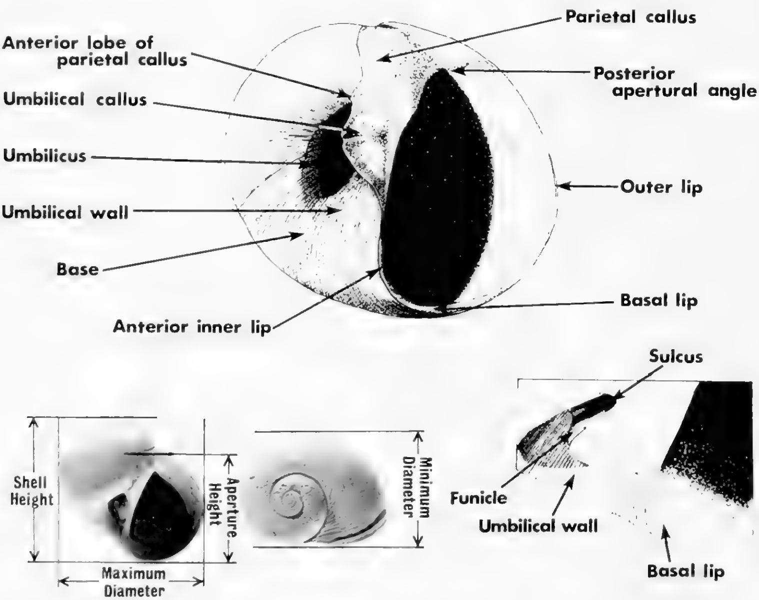
Shell morphology.—Shell morphology is of primary taxonomic importance for naticid specific classification. In polinicine and naticine species, umbilical features, including degree of umbilical opening, shape of the umbilical callus, and configuration of the shell base are especially significant. The configuration of the shell base, which may be altered by the presence or absence of a spiral angulation separating the body-whorl side from the umbilical wall, is accorded much importance in the present study. Naticids frequently show very wide ranges of shell-morphological variation, even in the umbilical features that are commonly used as diagnostic species characters. As discussed in the section on phylogenetic relations, morphological features that are stable characters of one species may be present only as a relatively minor morphologic variation in closely related species. In such cases, the range of morphological variation itself is considered to be an important specific character. External shell sculpture is uncommon in the family except among sinine genera, and is considered to be of only suprageneric importance.

Operculum.—Naticine species have entirely calcareous opercula and polinicines possess corneous ones. Thus, the operculum is of major importance when making the basic distinction between Naticinae and Polinicinae. Nearly all opercula of polinicine species are morphologically identical, and are not taxonomically useful. However, some modern species of *Polinices* Montfort, 1810 have different opercular coloration (Text-fig. 18), which aids in distinguishing species.

As discussed in the systematics, the sculpture of calcareous naticine opercula is taxonomically useful in combination with shell morphology. Although even calcareous opercula are considered to be rare as fossils in other regions, they are surprisingly common along with their shells in Cenozoic strata of Japan (Majima, 1984; Majima and Fukuta, 1986; Majima, 1987a).

Opercula of Japanese species of *Eunaticina* Fischer, 1885 are distinctly different from those of other naticids by having a double-coiled form (Text-fig. 23). In comparison, the operculum of *Eunaticina insculpta* (Carpenter, 1865) from the Pleistocene to Holocene of the northeastern Pacific exhibits a paucispiral form (Marincovich, 1977, pl. 34, fig. 10), like those of other naticids. The operculum of *E. insculpta* is partially calcified (Marincovich, 1977), but those of Japanese species of *Eunaticina* are entirely corneous.

Radular dentition.—Radular dentitions of some



Text-figure 14.—Morphologic terms used in this study, and definitions of the measurements shown in Tables 1–43.

western Pacific naticids and related species are illustrated in Text-figure 15. Generally speaking, naticid radular dentition is morphologically conservative: rachidians of most naticids are tricuspate with a strong central cusp. However, the rachidians of *Bulbus* Brown *in* Smith, 1839, *Tanea* Marwick, 1931, and *Cryptonatica* Dall, 1892 are basically monocuspate.

Among species of *Eunaticina*, *E. papilla* (Gmelin, 1791) has a rachidian which is sculptured with one strong central cusp and several very weak lateral cusps, whereas *E. linnaeana* (Récluz, 1843) possesses a tricuspate rachidian with a strong central cusp. Marincovich (1977, text-fig. 11.e) illustrated the radular dentition of *Eunaticina insculpta* (Carpenter), which greatly differs from those of the two species of *Eunaticina* in Japan in having a multicuspate rachidian. For species of *Eunaticina*, radular dentition is a useful taxonomic character.

Sinum Röding, 1798 has a tricuspate rachidian, with each cusp nearly equally developed. This seems to be a stable generic feature of *Sinum*, although it is also present in the naticine genus *Paratectonatica* Azuma, 1961 (Text-fig. 15.55).

As reviewed above, radular dentition is considered to be of some utility in characterizing a few genera or species, but generally, it is of little taxonomic use in separating Naticidae.

INSTITUTIONAL ABBREVIATIONS

ANSP: Academy of Natural Sciences, Philadelphia, Pennsylvania, U. S. A.
BM(NH): British Museum (Natural History), London, England, U. K.
CC: Department of Geology and Mineralogy, Faculty of Science, University of Kyoto, Kyoto City, Kyoto Prefecture, Japan.
CU: Geological Institute, College of Arts and Science, Chiba University, Chiba City, Chiba Prefecture, Japan.
ESN: Department of Earth Science, Faculty of Science, Nagoya University, Nagoya City, Aichi Prefecture, Japan.
GIYU: Institute of Geology, Faculty of Education, Yokohama National University, Yokohama City, Kanagawa Prefecture, Japan.
GK: Department of Geology, Faculty of Science, Kyushu University, Fukuoka City, Fukuoka Prefecture, Japan.
GSJ: Geological Survey of Japan, Tsukuba City, Ibaraki Prefecture, Japan.
HU: Department of Geology, Faculty of Education, Hirosaki University, Hirosaki City, Aomori Prefecture, Japan.
IGPS: Institute of Geology and Paleontology, Faculty of Science, Tohoku University, Sendai City, Miyagi Prefecture, Japan.
IGUT: Institute of Geoscience, University of Tsukuba, Tsukuba City, Ibaraki Prefecture, Japan.
JC: Department of Geology and Mineralogy, Faculty of Science, University of Kyoto, Kyoto City, Kyoto Prefecture, Japan.
JUE: Department of Geoscience, Joetsu University of Education, Joetsu City, Niigata Prefecture, Japan.
KPM: Kanagawa Prefectural Museum, Yokohama City, Kanagawa Prefecture, Japan.
MCZ: Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, U. S. A.
MFM: Mizunami Fossil Museum, Mizunami City, Gifu Prefecture, Japan.
MU: Department of Earth Science, Mie University, Tsu City, Mie Prefecture, Japan.
NSMT: National Science Museum, Tokyo, Shinzyuku-ku, Tokyo, Japan.
OMNH: Osaka City Museum of Natural History, Osaka City, Osaka Prefecture, Japan.
PKA: Private collection of Mr. K. Araki, Tanba 14, Maizuru City, Kyoto Prefecture, Japan.
PKS: Private collection of Dr. K. Sakurai, Kandasuda-cho 1–15, Chiyoda-ku, Tokyo, Japan.
PNK: Private collection of Dr. N. Kikuchi, Oohama-cho 1–4, Nishinomiya City, Hyogo Prefecture, Japan.
SHM: Saito Ho-on Kai Museum, Sendai City, Miyagi Prefecture, Japan.
TKD: Department of Geology and Mineralogy, Faculty of Science, Tokyo University of Education (now housed in the Institute of Geoscience, University of Tsukuba, Tsukuba City, Ibaraki Prefecture, Japan).
UMUT: University Museum, University of Tokyo, Bunkyo-ku, Tokyo, Japan.
USNM: United States National Museum of Natural History, Washington, DC, U. S. A.
YCM: Yokosuka City Museum, Yokosuka City, Kanagawa Prefecture, Japan.

SYSTEMATICS

Family NATICIDAE Forbes, 1838
Subfamily AMPULLOSPIRINAE Cox, 1930

Discussion.—The supraspecific classification of ampullospirines has been discussed by Cossmann (1925), Stewart (1927), Cox (1930; 1931), Wrigley (1946), Marincovich (1977) and others, but it is still in need of a thorough worldwide revision, as Marincovich (1977) pointed out.

The genus name *Ampullina* Bowdich, 1822 has long been used by many paleontologists for some ampullospirine species, but, as Cox (1930; 1931) pointed out, the specimen illustrated by Bowdich (1822) under the name *Ampullina* (without species name) seems to be *Natica labellata* Lamarck, 1804 (a European Eocene species of *Euspira*). Thus, Dall's (1909) subsequent designation of a type species for *Ampullina* (*Ampullaria depressa* Lamarck, 1804, a distinct ampullospirine species) is probably not valid. Until the specimen illustrated by Bowdich is discovered, *Ampullina* Bowdich, 1822 should be treated as a *nomen nudum*.

The late Cenozoic fauna of the western Pacific, where one species of ampullospirine [*Cernina fluctuata* (Sowerby, 1825)] still survives, is very interesting to many paleontologists, and the following six ampullospirine species are known: *Globularia berauensis* Beets, 1941, from the lower Miocene of Fiji (Ladd, 1977) and upper Miocene of Borneo, Indonesia (Beets, 1941); *Cernina fluctuata* subspp. [see the discussion herein for *Cernina fluctuata nakamurai* (Otuka)]; *Pachycrommium harrisi* (Pannekoek, 1936) (see the discussion of the species herein); *Pachycrommium martini* (Beets, 1941), from the upper Miocene of Borneo, Indonesia (Beets, 1941); *Pachycrommium ? pacificum* Ladd, 1945, from the lower Miocene of Fiji (Ladd, 1945; 1977); and *Waluina edwardi* (Ladd, 1934), from the lower Miocene of Fiji (Ladd, 1934; 1977). Among these, *Cernina fluctuata nakamurai* and *Pachycrommium harrisi* occur as lower middle Miocene fossils in Japan.

Genus **AMPULLINOPSIS** Conrad, 1865

Type species.—*Natica mississippiensis* Conrad, 1848, by monotypy. Oligocene, Mississippi, U. S. A.

Discussion.—Conrad's original figure of the type species of *Ampullinopsis*, *Natica mississippiensis*, is very poor and his original description of the species is very short, so it is difficult to objectively define the genus. Dall (1909, p. 90) gave an additional diagnosis for *N. mississippiensis*, but, as pointed out by Woodring (1959), Dall's specimens included some from the Pacific coast of the United States where *Ampullinopsis* has not been found. Woodring (1959) gave a description for *N. mississippiensis* as follows:

Text-figure 15.—Radular dentitions of the northwestern Pacific naticids and their related species. The illustrations are reproduced from; 1, pl. V, fig. 10b of Sars (1878), as *Amauropsis islandica* (Gmelin, 1791); 2, fig. J-41 of Powell (1951), as *Amauropsis helicoides* (Johnson, 1835); 3, pl. V, fig. 9b of Sars (1878), as *Ampullina smithii* (Brown *in* Smith, 1839); 4, text-fig. 5-E of Thorson (1951), as *Acrybia glacialis*, n. sp.; 5, pl. 13, fig. 7 of Azuma (1961), as *Lunatia yokoyamai* (Kuroda and Habe, 1952); 6, pl. 5, fig. 17 of Odhner (1913), as *Lunatia pallida* (Broderip and Sowerby, 1829); 7, pl. 1, fig. 1 of Inaba (1976), as *Lunatia plicispira* Kuroda, 1961; 8, pl. 12, fig. 7 of Azuma (1961), as *Polinices pyriformis* (Récluz, 1844); 9, pl. 1, fig.5 of Inaba (1976), as *Polinices vavaosi* (Reeve, 1855); 10, text-fig. 51 of Cernohorsky (1971), as *Polinices* (*Polinices*) *flemingiana* (Récluz, 1844); 11, pl. 15, fig. 1 of Azuma (1961), as *Polinices flemingianus* (Récluz, 1844); 12, text-fig. 54 of Cernohorsky (1971), as *Polinices* (*Polinices*) *aurantius* (Röding, 1798); 13, pl. 1, fig. 4 of Inaba (1976), as *Polinices sagamiensis* Pilsbry, 1904; 14, pl. 12, fig. 2 of Azuma (1961), as *Polinices sagamiensis* Pilsbry, 1904; 15, pl. 12, fig. 3 of Azuma (1961), as *Polinices vestitus* Kuroda, 1961; 16, pl. 1, fig. 3 of Inaba (1976), as *Polinices vestitus* Kuroda, 1961; 17, text-fig. 57 of Cernohorsky (1971), as *Polinices* (*Neverita*) *albumen* (Linnaeus, 1758); 18, pl. 12, fig. 1 of Azuma (1961), as *Polinices albumen* (Linnaeus, 1758); 20, pl. 13, fig. 1 of Azuma (1961), as *Neverita didyma* (Röding, 1798); 21, pl. 1, fig. 2 of Inaba (1976), as *Glossaulax didyma hosoyai* (Kira, 1959); 22, pl. 13, fig. 2 of Azuma (1961), as *Neverita vesicalis* (Philippi, 1848); 23, pl. 13, fig. 3 of Azuma (1961), as *Neverita reiniana* Dunker, 1877; 24, pl. 13, fig. 4 of Azuma (1961), as *Neverita hayashii* Azuma, 1961; 25, pl. 12, fig. 4 of Azuma (1961), as *Mammilla mammata* (Röding, 1798); 26, pl. 12, fig. 6 of Azuma (1961), as *Mammilla mikawaensis* Azuma, 1961; 27, pl. 1, fig. 6 of Inaba (1976), as *Mammilla mikawaensis* Azuma, 1961; 28, pl. 1, fig. 7b of Inaba (1976), as *Mammilla opaca* (Récluz, 1851); 29, pl. 15, fig. 2 of Azuma (1961), as *Mammilla opaca* (Récluz, 1851); 30, pl. 12, fig. 5 of Azuma (1961), as *Mammilla simiae* (Deshayes, 1838); 31, text-fig. 59 of Cernohorsky (1971), as *Polinices* (*Mammilla*) *maurus* (Lamarck, 1816); 32, pl. 15, fig. 3 of Azuma (1961), as *Sinum javanicus* (Griffith and Pidgeon, 1834); 33, pl. 2, fig. 1 of Inaba (1976), as *Sinum* (*Sinum*) *javanicum* (Griffith and Pidgeon, 1834); 34, pl. 14, fig. 1 of Azuma (1961), as *Sinum* (*Ectosinum*) *undulatus* (Lischke, 1872); 35, pl. 2, fig. 2 of Inaba (1976), as *Sinum* (*Ectosinum*) *undulatum* (Lischke, 1872); 36, pl. 13, fig. 5 of Azuma (1961), as *Eunaticina papilla* (Gmelin, 1791); 37, pl. 1, fig. 8 of Inaba (1976), as *Eunaticina lamarckiana* (Récluz, 1843); 38, pl. 15, fig. 5 of Azuma (1961), as *Natica spadicea* (Gmelin, 1791); 39, text-fig. 8 of Cernohorsky (1971), as *Natica* (*Natica*) *stellata* Hedley, 1913; 40, pl. 2, fig. 3 of Inaba (1976), as *Natica nipponensis* Kuroda, 1961; 41, pl. 14, fig. 2 of Azuma (1961), as *Natica lactobasis* Kuroda, 1961 [misprint for *lacteobasis*]; 42, pl. 15, fig. 6 of Azuma (1961), as *Natica bibalteata* Sowerby, 1914; 43, pl. 12, fig. 8 of Azuma (1961), as *Natica solida* Blainville, 1825; 44, pl. 14, fig. 3 of Azuma (1961), as *Natica buriasensis* Récluz, 1844 [misprint for *buriasiensis*]; 45, text-fig. 14 of Cernohorsky (1971), as *Natica* (*Natica*) *arachnoidea* (Gmelin, 1791); 47, pl. 14, fig. 4 of Azuma (1961), as *Naticarius alapapilionis* (Röding, 1798); 48, pl. 2, fig. 5 of Inaba (1976), as *Naticarius alapapilionis* (Röding, 1798); 49, pl. 14, fig. 8 of Azuma (1961), as *Naticarius excellens* Azuma, 1961; 50, pl. 14, fig. 5 of Azuma (1961), as *Naticarius concinna* (Dunker, 1859); 51, text-fig. 33 of Cernohorsky (1971) as *Natica* (*Naticarius*) *onca* (Röding, 1798); 52, text-fig. 16 of Powell (1933), as *Notocochlis migratoria* (Powell, 1927); 53, pl. 15, fig. 4 of Azuma (1961), as *Natica lurida* Philippi, 1836; 54, text-fig. 21 of Cernohorsky (1971), as *Natica* (*Natica*) *gualtieriana* Récluz, 1844 [misprint for *gualteriana*]; 55, pl. 15, fig. 7 of Azuma (1961), as *Paratectonatica tigrina* (Röding, 1798); 56, text-fig. 14 of Powell (1933), as *Tanea zelandica* (Quoy and Gaimard, 1832); 57, text-fig. 14 of Kilburn (1976), as *Tanea areolata* (Récluz, 1844); 58, pl. 14, fig. 6 of Azuma (1961), as *Notocochlis tosaensis* (Kuroda, 1961); 59, pl. 14, fig. 9 of Azuma (1961), as *Notocochlis hilaris* (Sowerby, 1914); 60, pl. 2, fig. 7 of Inaba (1976), as *Tanea hilaris* (Sowerby, 1914); 61, pl. 14, fig. 7 of Azuma (1961), as *Notocochlis tabularis* (Kuroda, 1961); 62, pl. 2, fig. 8 of Inaba (1976), as *Tanea tabularis* (Kuroda, 1961); 63, pl. 2, fig. 9 of Inaba (1976), as *Tanea picta magnifluctuata* (Kuroda, 1961); 64, pl. 5, fig. 7 of Odhner (1913), as *Natica clausa* Broderip and Sowerby, 1829; 65, pl. V, fig. 15b of Sars (1878), as *Natica clausa* Broderip and Sowerby, 1829; 66, pl. 3, fig. 20 of Habe (1958), as *Tectonatica janthostoma* (Deshayes, 1839); 67, pl. 14, fig. 10 of Azuma (1961), as *Tectonatica janthostomoides* Kuroda and Habe, 1949; 68, pl. 2, fig. 6b of Inaba (1976), as *Cryptonatica adamsiana* (Dunker, 1859); and 69, pl. 3, fig. 19 of Habe (1958), as *Tectonatica hirasei* (Pilsbry, 1905).

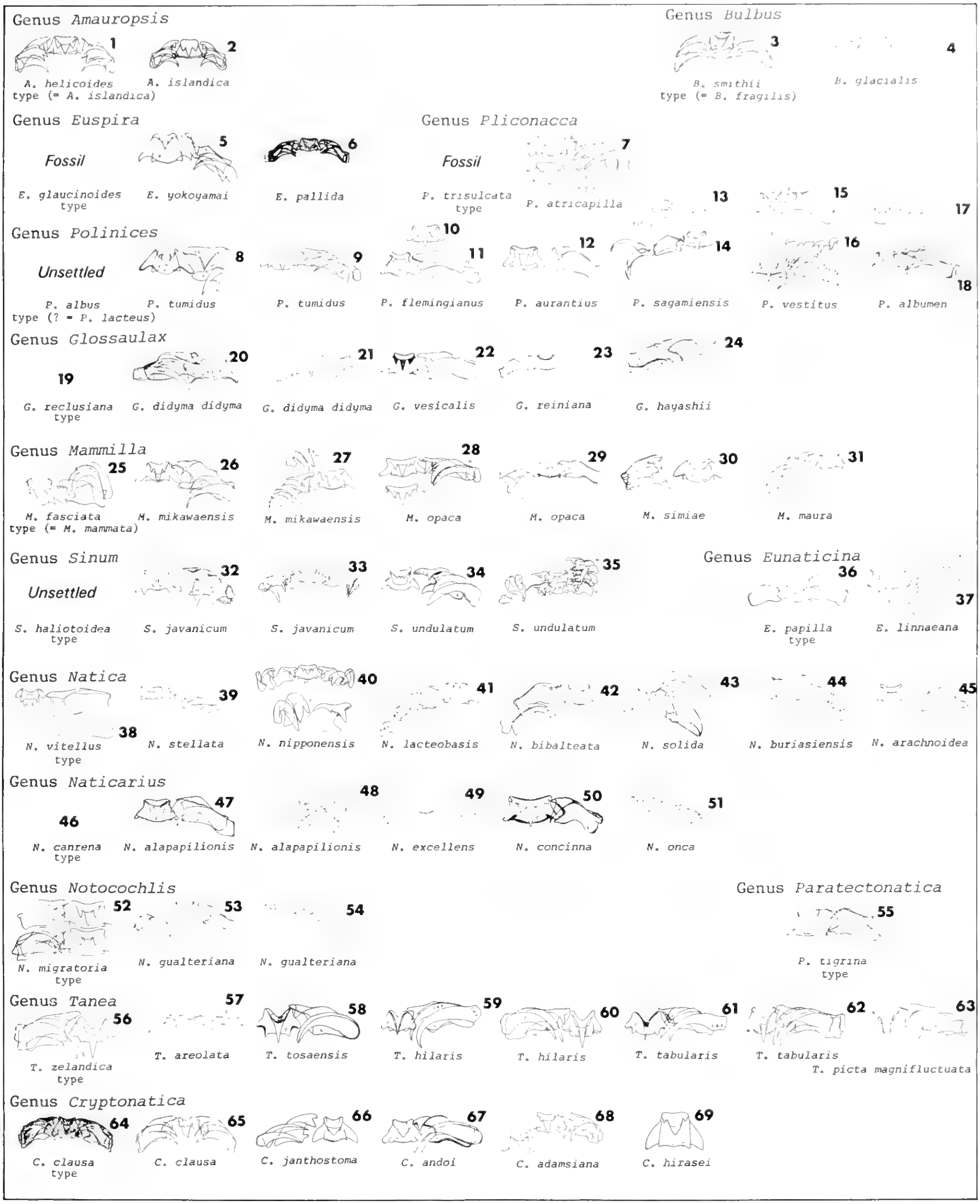

Genus Amauropsis
1
A. helicoides
type (= A. islandica)
2
A. islandica
Genus Bulbus
3
B. smithii
type (= B. fragilis)
4
B. glacialis
Genus Euspira
Fossil
E. glaucinoides
type
5
E. yokoyamai
6
E. pallida
Genus Pliconacca
Fossil
P. trisulcata
type
7
P. atricapilla
13
15
17
Genus Polinices
Unsettled
P. albus
type (? = P. lacteus)
8
P. tumidus
9
P. tumidus
10
11
P. flemingianus
12
P. aurantius
14
P. sagamiensis
16
P. vestitus
18
P. albumen
Genus Glossaulax
19
G. reclusiana
type
20
G. didyma didyma
21
G. didyma didyma
22
G. vesicalis
23
G. reiniana
24
G. hayashii
Genus Mammilla
25
M. fasciata
type (= M. mammata)
26
M. mikawaensis
27
M. mikawaensis
28
M. opaca
29
M. opaca
30
M. simiae
31
M. maura
Genus Sinum
Unsettled
S. haliotoidea
type
32
S. javanicum
33
S. javanicum
34
S. undulatum
35
S. undulatum
Genus Eunaticina
36
E. papilla
type
37
E. linnaeana
Genus Natica
38
N. vitellus
type
39
N. stellata
40
N. nipponensis
41
N. lacteobasis
42
N. bibalteata
43
N. solida
44
N. buriasiensis
45
N. arachnoidea
Genus Naticarius
46
N. canrena
type
47
N. alapapilionis
48
N. alapapilionis
49
N. excellens
50
N. concinna
51
N. onca
Genus Notocochlis
52
N. migratoria
type
53
N. gualteriana
54
N. gualteriana
Genus Paratectonatica
55
P. tigrina
type
Genus Tanea
56
T. zelandica
type
57
T. areolata
58
T. tosaensis
59
T. hilaris
60
T. hilaris
61
T. tabularis
62
T. tabularis
63
T. picta magnifluctuata
Genus Cryptonatica
64
C. clausa
type
65
C. clausa
66
C. janthostoma
67
C. andoi
68
C. adamsiana
69
C. hirasei

Table 1.—Measurements (in mm) and counts of the holotype and of the largest specimen of *Cernina fluctuata nakamurai* (Otuka, 1938) at each locality. Localities are listed in order from north to south.

stratigraphic position	locality	shell height	maximum diameter	minimum diameter	aperture height	number of whorls	specimen measured	number of specimens in lot
lower middle Miocene	OKURA	69.6+	66.8+	53.3+	65.2+	3½+	IGPS 90493*	1
	MAIZURU 1	29.8	24.8+	24.3	25.3	3+	IGUT 16035-1	1
	MAIZURU 2	84.2	77.7	60.2	78.7	5+	PKA unnumbered	1
	SHOBARA 1	83.5+	95.6+	66.7	—	2+	IGUT 15723-1	5
	SHOBARA 1	68.6	70.2	57.0	61.9	4½+	UMUT CM12747 (holotype)	—

* Holotype of *Globularia* (?) *monstrosa* Hatai, 1956.

The outer edge of the sheath of that species is marked by a bending and accentuation of the growth lines rather than by a rim, except near the base of the aperture where a rim is recognizable. The thick lobe generally closes the umbilicus at an early stage, even at a height of 14 mm. Of about 60 specimens examined, one (restored height about 22 mm.) has an incompletely closed umbilicus.

Ampullinopsis species

Ampullinopsis cf. *A. hahazimensis* (Yabe and Hatai). MacNeil, 1964, p. B5, pl. 2, figs. 1, 4, 5 [not *Hahazimania hahazimensis* Yabe and Hatai, 1939 (an indeterminate taxon)].

Discussion.—*Ampullinopsis* cf. *A. hahazimensis* (Yabe and Hatai) of MacNeil (1964) is treated herein as *Ampullinopsis* sp. MacNeil (1964) considered the present unnamed species to be probably conspecific with *Hahazimania hahazimensis* Yabe and Hatai, 1939 (holotype: IGPS 63362 [Pl. 10, fig. 19]), but he also considered the specimens of Yabe and Hatai (1939) to be internal molds. MacNeil mentioned that "until something better than internal molds are found . . . this is just a guess."

Yabe and Hatai (1939) and MacNeil (1964) illustrated axial sections of their specimens. Judging from both sections, Yabe and Hatai's specimen seems to possess an extremely thin shell compared to MacNeil's specimen; that is, the whorls represented by the internal mold of Yabe and Hatai's specimen (pl. 12, fig. 3 of Yabe and Hatai, 1939) are nearly attached to each other whereas those of MacNeil (pl. 2, fig. 5 of MacNeil, 1964) are widely separated from one another by shell material. Thus, the two specimens appear to be different species in having very different shell thicknesses.

The present unnamed species is very similar to *Ampullinopsis crassatina* (Lamarck, 1806), an Oligocene species from Europe (Deshayes, 1824, pp. 171–172, pl. 20, figs. 1, 2; Wrigley, 1946, pp. 97–98, fig. 30), and from Pakistan and Burma (Vredenburg, 1922, pl. 27, figs. 4a–b, pl. 28, figs. 5a–6b). *Ampullinopsis crassatina* was once considered by Dall (1892) and Wrigley (1946) to be very closely related or conspecific with *Natica mississippiensis* Conrad, 1848, the type species of *Ampullinopsis*.

Stratigraphic occurrence.—
Eocene: Miyara Fm., Okinawa Pref. (MacNeil, 1964).

Genus **CERNINA** Gray, 1840

Type species.—*Natica fluctuata* Sowerby, 1825, by monotypy (*fide* Ladd, 1977). Miocene to Holocene, Indo-Western Pacific areas.

Discussion.—*Cernina* is characterized by its globose shell, extremely wide parietal area, sigmoidally curved inner lip, lack of a sheath (terminology in Wrigley, 1946), and an umbilicus closed by a thick anterior inner lip. *Cernina* was considered to be synonymous with *Globularia* Swainson, 1840 by Cox (1931) and Wenz (1941) but it is treated herein as a distinct genus for the following two reasons: (1) *Ampullaria sigaretina* Lamarck, 1804 (Deshayes, 1824, p. 170, pl. 21, figs. 5, 6; Cossmann and Pissarro, 1902, p. 219, pl. 23, fig. 25; Wrigley, 1946, p. 89, fig. 3), the type species of *Globularia*, from the Eocene of Europe, has a slender but distinct sheath, whereas *Natica fluctuata* Sowerby, the type species of *Cernina*, lacks it; (2) the inner lip of *A. sigaretina* is nearly straight (Wrigley, 1946, p. 89), but that of *N. fluctuata* is distinctly sigmoidally curved.

Cernina ranges from Miocene to Holocene, and is represented by two species: *Cernina fluctuata* subspp. (lower Miocene to Holocene, Indo-Western Pacific areas) and *Cernina compressa* (Basterot, 1825) (Miocene of Europe: Cossmann and Peyrot, 1917–1919, pp. 452–454, pl. 12, figs. 27, 28).

Cernina fluctuata nakamurai (Otuka, 1938)
Plate 1, figures 1–4; Text-figure 3.1; Table 1

Globularia (*Cernina*) *nakamurai* Otuka, 1938, pp. 37–38, pl. 3, figs. 19–21; Hatai and Nisiyama, 1952, p. 205.

Globularia (*Globularia*) *nakamurai* Otuka. Kobayashi and Horikoshi, 1958, p. 51, pl. 4, figs. 3a–b; Shikama, 1970, p. 106, pl. 30, fig. 10.

Globularia nakamurai Otuka. Itoigawa and Nishikawa, 1976, pl. 35, fig. 16; Itoigawa, 1978, pl. 3, fig. 5; Sakanoue and Takayasu, 1984, pp. 171–176, pl. 1, figs. 1a–2b; Nakagawa and Takeyama, 1985, pl. 24, fig. 6.

Cernina fluctuata nakamurai (Otuka). Majima and Fukuta, 1986, text-fig. 1.12.
Globularia (?) *monstrosa* Hatai, 1956, pp. 1–2, figs. 1–3.
? *Polinices* ? sp. Shibata and Ina, 1983, p. 59, pl. 8, figs. 18a–b.

Types.—

Globularia (*Cernina*) *nakamurai* Otuka: UMUT CM12747 (holotype: Pl. 1, fig. 3), from the river bed of the Saizyo River, about 250 m north from the Bingo-Shobara National Railway Station, Shobara City, Hiroshima Prefecture, lower middle Miocene Bihoku Group (loc. Shobara 1).

Globularia (?) *monstrosa* Hatai: IGPS 90493 (holotype: Pl. 1, fig. 1), from a coarse-grained sandstone exposed in Okura-mura, Mogami-gun, Yamagata Prefecture, lower middle Miocene Takinosawa Formation (Hatai, 1956).

Description.—Shell globose, very large, spire very low; body whorl greatly inflated, evenly rounded; shell thick, whorls about five; suture moderately impressed. Shell smooth except for weakly developed incremental growth lines. Parietal area very broadly developed and well expanded; parietal callus extremely thin, minutely filling posterior apertural angle, and smoothly merges with inner lip of aperture. Umbilicus entirely closed and covered by a thick anterior inner lip. Anterior inner lip broadly expanded posteriorly, anteriorly reduced in width, and smoothly merges with basal lip that is sharply separated from base with a distinct but weak step. Inner lip distinctly sigmoidally curved; outer lip thin.

Discussion.—Many species of *Cernina* have been described from Neogene strata of the Indo-Western Pacific areas. They are classifiable into four subspecies of *C. fluctuata* as follows:

Cernina fluctuata fluctuata (Sowerby, 1825), lower Miocene of Java, Indonesia [Pannekoek, 1936, as *Ampullina* (*Ampullina*) *lineata*, n. sp.]; upper Miocene of east Borneo [Beets, 1941, as *Globularia fluctuata* (Sowerby)]; upper Miocene of the Philippines (as *Neritilia fernandezi* Kanno, O'hara, and Caagusan, 1982); and upper Miocene or Pliocene of north Borneo [Cox, 1948, as *Globularia fluctuata* (Sowerby)].

Cernina fluctuata carlei (Finlay, 1927), lower Miocene of Kenya [Cox, 1930, as *Cernina callosa* (Sowerby, 1840), not *Natica callosa* Cristofori and Jan, 1832]; lower Miocene of south India [Dey, 1961, as *Globularia* (*Cernina*) *carlei* (Finlay)].

Cernina fluctuata fijiensis (Ladd, 1945), lower Miocene of Fiji [Ladd, 1945; Ladd, 1977, as *Globularia* (*Cernina*) *fijiensis* Ladd].

Cernina fluctuata nakamurai (Otuka, 1938), lower middle Miocene of Japan.

Compared with the first three of these subspecies, *C. fluctuata nakamurai* is characterized by having an extremely large shell and a greatly sigmoidally curved inner lip.

In Japan, *C. fluctuata nakamurai* is morphologically most distinct compared with the other Cenozoic naticids and has been recognized as a distinct tropical element in the early middle Miocene Kadonosawa fauna (Kobayashi and Horikoshi, 1958; Chinzei, 1978).

Stratigraphic occurrence.—

Lower middle Miocene: Takinosawa Fm., Yamagata Pref., locality Okura (Pl. 1, fig. 1); Uchiura Group, Fukui Pref., localities Maizuru 1 (Kobayashi and Horikoshi, 1958) and Maizuru 2 (Pl. 1, fig. 2); Bihoku Group, Hiroshima Pref., localities Shobara 1 (Pl. 1, figs. 3–4) and Shobara 3 (Itoigawa and Nishikawa, 1976); Bihoku Group, Shimane Pref. (Sakanoue and Takayasu, 1984).

Genus **PACHYCROMMIUM** Woodring, 1928

Type species.—*Amaura guppyi* Gabb, 1873, by original designation. Miocene, Dominican Republic.

Discussion.—*Pachycrommium* is characterized by its elongate form, greatly elevated spire, commonly tabulated shoulder, thin and narrow anterior inner lip which is folded back in the basal part, and entirely closed umbilicus.

Euspirocrommium Sacco, 1890 [type species: *Crommium* (*Euspirocrommium*) *degensis* Sacco, 1890, Oligocene, Italy] seems to be indistinguishable from *Pachycrommium*, but Woodring (1928) distinguished them by stating that the type species of *Euspirocrommium*

has a *Phasianella*-like shape and very high spire, and the inner lip is folded back as a thin edge along virtually its entire length, producing a different kind of aperture.

Pseudocrommium Clark *in* Clark and Durham (1946) [type species: *Pseudocrommium carmenensis* Clark *in* Clark and Durham, 1946, Eocene, Bolivar, Colombia] appears to be synonymous with *Pachycrommium*, judging from Clark's description and figures of *Pseudocrommium.*

Crommium Cossmann, 1888 [type species: *Ampullaria willemetii* Deshayes, 1825, Eocene, Europe] is distinguished from *Pachycrommium* by having a globose form, lower spire, and an open umbilicus.

Pachycrommium-like species have been reported in the Oligocene to Pliocene of the tropical to subtropical western Pacific. These specimens are "*Pachycrommium*" *nagaoi* (Hatai and Nisiyama, 1952), from the Oligocene of north Kyushu, Japan; *P.* ? *pacificum* Ladd, 1945, from the lower Miocene of Fiji; *P. harrisi* (Pannekoek, 1936), from the lower Miocene to Pliocene of

Table 2.—Measurements (in mm) and counts of the largest specimen of *Pachycrommium harrisi* (Pannekoek, 1936) at each locality. Localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower middle Miocene	HIGASHI-INNAI 1	30.4+	24.6	21.0	—	3+	IGUT 16033-21	26
	CHICHIBU	36.0	25.9	21.1	21.3	6+	TKD 6165*	1
	MIZUNAMI 5	36.7	26.3	19.7	22.8	4½+	MFM unnumbered	1
	TSUYAMA	31.3	25.2	14.6	22.1	5+	IGUT 16034-2	2

* Holotype of *Pachycrommium japonicum* Kanno, 1958.

the Western Pacific; and *P. martini* (Beets, 1941), from the upper Miocene of Borneo, Indonesia.

Pachycrommium harrisi (Pannekoek, 1936)
Plate 1, figures 6–9; Text-figures 3.1, 16; Table 2

Ampullina (*Ampullospira*) *harrisi* Pannekoek, 1936, p. 58, pl. 3, figs. 38, 39.
Pachycrommium harrisi (Pannekoek). Cox, 1948, pp. 19–20, pl. 1, figs. 4a–b; Majima and Fukuta, 1986, text-fig. 1.13.
Pachycrommium stockwelli Ladd, 1945, p. 359, pl. 51, figs. c, d [not seen]; Ladd, 1977, p. 28, pl. 7, figs. 11, 12.
Pachycrommium japonicum Kanno, 1958, pp. 213–214, pl. 7, figs. 1a–2; Kanno, 1960, pp. 358–359, pl. 48, figs. 9–10b; Masuda, 1967, pl. 1, figs. 22a–b; Shikama, 1970, p. 212, pl. 83, fig. 21; Itoigawa *et al.*, 1981, pl. 33, figs. 14a–b; Itoigawa *et al.*, 1982, p. 200; Masuda *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 256, pl. 128, figs. 1217a–b.
Pachycrommium cf. *japonicum* Kanno. Taguchi, Ono, and Okamoto, 1979, pl. 4, fig. 3.
Babylonia n. sp. Watanabe, Arai, and Hayashi, 1950, pl. 6, fig. 15 [holotype of *P. japonicum* Kanno].

Types.—

Ampullina (*Ampullospira*) *harrisi* Pannekoek: Syntypes preserved in "Rijks Museum van Geologie en Mineralogie" in Leiden, Holland, from lower Miocene Rembang Bed of Java, Indonesia (Pannekoek, 1936).
Pachycrommium stockwelli Ladd: Reg. No. 13053 (holotype) of University of Rochester, Museum of Natural History, from station 110C, Vanua Mabalavu, Fiji, Pliocene Ndalithoni Limestone (Ladd, 1977).
Pachycrommium japonicum Kanno: TKD 6165 (holotype: Pl. 1, fig. 8), from a river cliff, about 300 m downstream of the Shimizu bridge, Tochiya, Chichibu City, Saitama Prefecture, central Japan, lower middle Miocene Hiranita Formation (Kanno, 1958).

Description.—Shell moderate in size, elongate in form, spire greatly elevated; body whorl slightly to moderately inflated, shoulder commonly well tabulated, may be separated from sides of whorls by a distinct angulation, and commonly becoming progressively less tabulate in adult whorls; shell commonly thin; whorls at least six (apices broken in all examined specimens); suture moderately impressed. Shell smooth except for minutely developed incremental growth lines. Parietal area broadly developed; parietal callus commonly very thin, lightly filling posterior apertural angle. Umbilicus entirely closed and covered by a thick but narrow anterior inner lip that merges smoothly with the basal lip. Anterior inner lip and basal lip are distinctly separated from base by a sharp marginal step. Outer lip very thin.

Discussion.—In Japan, *Pachycrommium harrisi* is one of the most distinct Cenozoic naticids. It is easily distinguished from the other Japanese naticids by its peculiar characters, such as its greatly elongate form with a distinctly elevated spire, a narrow but distinct anterior inner lip with a sharp marginal step, and a commonly distinctly tabulated shoulder.

Pachycrommium stockwelli Ladd, 1945, a Pliocene species in Fiji, and *Pachycrommium japonicum* Kanno, 1958, a Miocene species in Japan, are herein made junior synonyms of *P. harrisi* for the first time. *Pachycrommium harrisi* was widely distributed in the lower Miocene (Pannekoek, 1936) to Pliocene (Ladd, 1945; Ladd, 1977) of the western Pacific.

Ladd (1977) differentiated *P. harrisi* from *P. stockwelli* by having a much larger shell and less strongly shouldered whorls. However, shell size is not a useful specific character among many naticids, because it varies among local populations of a single species (Odhner, 1913; Marincovich, 1977; Majima, 1985). Also, the degree of tabulation of the shoulder varies in one local population of *P. harrisi*. Text-figure 16 shows the morphological variation of *P. harrisi* collected from a transported concretion at locality HIGASHI-INNAI 1, Ishikawa Prefecture, in which the shell form and degree of tabulation of the shoulder vary greatly among individuals.

When Cox (1948) reported *P. harrisi* from the upper Miocene in north Borneo, he described the species as "the spire whorls bear 3–4 obscure spiral ridges, which become obsolete on the latter part of the last whorl." This character is not present in Japanese specimens I have seen. *Pachycrommium clarki* (Stewart, 1927), an Eocene species from western North America, possesses spiral costellae grading from weak to nearly non-existent (Marincovich, 1977).

Table 3.—Measurements (in mm) and counts of the holotype of "*Pachycrommium*" *nagaoi* (Hatai and Nisiyama, 1952).

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*
lower Oligocene	KIURAGI	14.3	13.5+	11.9	13.0	3½+	IGPS 36148 (holotype)

Pachycrommium martini (Beets, 1941), from the upper Miocene of Borneo, is very similar to *P. harrisi*, but it differs from the latter by having a strongly developed carination along the outer edge of the tabulated shoulder.

Stratigraphic occurrence.—

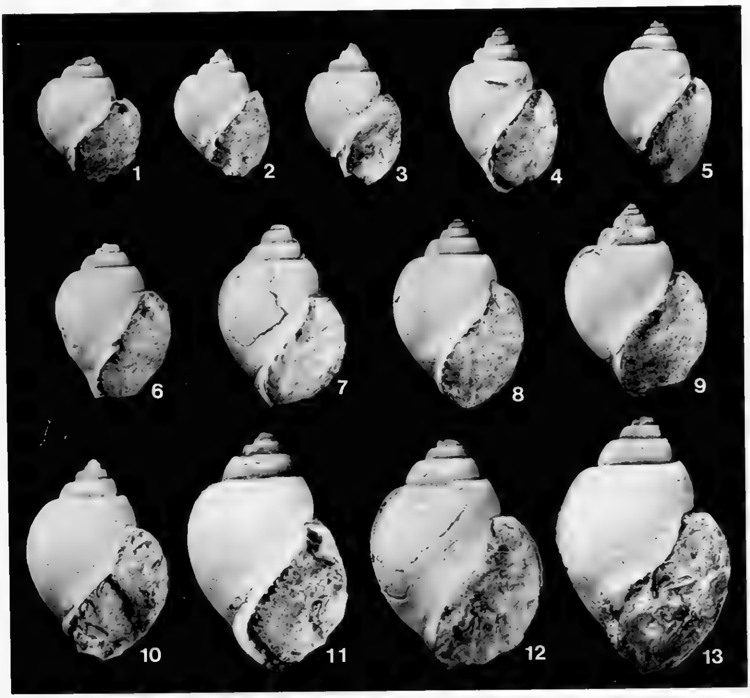
Lower middle Miocene: Higashi-Innai Fm., Ishikawa Pref., locality HIGASHI-INNAI 1 (Pl. 1, fig. 7; Text-fig. 16); Hiranita Fm., Saitama Pref., locality CHICHIBU (Pl. 1, fig. 8); Shukunohora Sandstone, Gifu Pref., locality MIZUNAMI 5 (Pl. 1, fig. 6); Bihoku Group, Okayama Pref., localities TSUYAMA (Pl. 1, fig. 9) and NIIMI (Taguchi, Ono, and Okamoto, 1979).

"Pachycrommium" nagaoi
(Hatai and Nisiyama, 1952)
Plate 1, figure 5; Table 3

Ampullina (*Crommium* ?) sp. Nagao, 1928b, pp. 98–99, pl. 15, figs. 11–15.

Ampullina nagaoi Hatai and Nisiyama, 1952, p. 167; Oyama, Mizuno, and Sakamoto, 1960, pp. 47–48, pl. 6, figs. 1a–d; Masuda and Noda, 1976, pp. 12–13.

Holotype.—IGPS 36148 (Pl. 1, fig. 5), from southern cliff of an isolated hill, about 250 m W of the bridge at Chogiri, Ochi-mura, Higashi-Matsuura-gun, Saga Prefecture, lower Oligocene Kiuragi Formation (Hatai and Nisiyama, 1952).



Text-figure 16.—Individual variation of *Pachycrommium harrisi* (Pannekoek, 1936) from the lower middle Miocene Higashi-Innai Fm., Ishikawa Pref. (loc. HIGASHI-INNAI 1). 1, IGUT 16033-1; 2, IGUT 16033-2; 3, IGUT 16033-3; 4, IGUT 16033-4; 5, IGUT 16033-5; 6, IGUT 16033-6; 7, IGUT 16033-7; 8, IGUT 16033-8; 9, IGUT 16033-9; 10, IGUT 16033-10; 11, IGUT 16033-11; 12, IGUT 16033-12; and 13, IGUT 16033-13, all ×1.4.

Table 4.—Measurements (in mm) and counts of the largest specimen of *Bulbus fragilis* (Leach, 1819) at each locality.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower Miocene	TAIRA 2	33.3	29.4+	23.0+	26.0	4+	GIYU 600-1	2
lower Pleistocene	TOMIKAWA	33.8+	31.4	26.7	24.9+	5	IGUT 15954	1

Discussion.—Since Nagao (1928b) described specimens under the name of *Ampullina* (*Crommium* ?) sp., which were subsequently named as *Ampullina nagaoi* by Hatai and Nisiyama (1952), no additional specimen has been found. Except for the holotype, nearly all of the specimens of *Ampullina* (*Crommium* ?) sp. studied by Nagao (1928b) are poorly preserved. Because the holotype has an elongate shape, an elevated spire, and a thin callus, this species seems to be assigned to *Pachycrommium*. But on the holotype, the umbilical region, which is one of the important characters for generic classification of ampullospirines, is damaged, and therefore its generic assignment is tentative.

Stratigraphic occurrence.—

Lower Oligocene: Kiuragi Fm., Saga Pref., locality KIURAGI (Pl. 1, fig. 5).

Subfamily POLINICINAE Finlay and Marwick, 1937

Discussion.—The Polinicinae is the largest and most diverse subfamily of the northwestern Pacific Naticidae, as it also is in the northeastern Pacific (Marincovich, 1977), and is characterized by its smooth shell surface, commonly nontabulated shoulder, and corneous operculum that commonly entirely covers the aperture.

The oldest occurrence of the subfamily in Japan has been recorded by Kase (1984, p. 156) as *Euspira* sp. from the Lower Cretaceous Hiraiga Formation in Iwate Prefecture, on the Pacific side of northeastern Honshu.

Genus BULBUS Brown *in* Smith, 1839

Type species.—*Bulbus smithii* Brown *in* Smith, 1839 (= *Natica fragilis* Leach, 1819), by monotypy. Lower Miocene (Japan) to Holocene [Arctic, North Pacific, and North Atlantic oceans (Marincovich, 1977)].

Discussion.—*Bulbus* is characterized by its thin shell, sigmoidally curved inner margin of the aperture, and reflexed inner lip, which may cover the slightly open umbilicus. It has a monocuspate rachidian, which is a distinct character of *Bulbus* (Text-figs. 15.3, 15.4).

Bulbus is a distinct cool-water element, because its modern geographic range includes only the Arctic, North Pacific, and North Atlantic oceans (Marincovich, 1977, 1983). The oldest stratigraphic record of the genus is from the early Miocene Honya Mudstone of Fukushima Prefecture, northeastern Japan.

Bulbus fragilis (Leach, 1819)
Plate 1, figures 10–12;
Text-figure 15.3; Table 4

Natica fragilis Leach, 1819, App. 2, p. 62 [not seen]; Philippi, 1852, p. 151.
Bulbus fragilis (Leach). Marincovich, 1977, pp. 335–338, pl. 31, figs. 4–7; Marincovich, 1983, pp. 112–113, pl. 22, fig. 20.
Natica flava Gould, 1839, p. 196 [not seen]; Philippi, 1852, pp. 114–115, pl. 16, fig. 5; Sowerby, 1883, p. 79, pl. 8, fig. 125.
Natica (*Acrybia*) *flava* Gould. Tryon, 1886, p. 52, pl. 22, fig. 30.
Bulbus flavus (Gould). Gould, 1870, pp. 347–348, text-fig. 616; Habe and Ito, 1965a, pp. 31–32, pl. 8, fig. 9; Okutani and Habe, 1975, pp. 80 [unnumbered fig.], 199–200.
Natica (*Amaura*) *flava* Gould. Uchiyama, 1903, p. 10, pl. 28, fig. 46.
Acrybia flava (Gould). Odhner, 1913, pp. 9, 46–47, pl. 4, figs. 26–28.
Bulbus flavus elongatus Habe and Ito, 1965a [June 1], p. 31, pl. 8, fig. 8; Habe and Ito, 1965b [July 31], pp. 17–18 [in Japanese], 31 [in English], pl. 3, fig. 2.
Bulbus smithii Brown *in* Smith, 1839, p. 104, pl. 1, fig. 18 [not seen]; Habe, 1958, p. 12, pl. 2, fig. 18; Abbott, 1974, p. 156, text-fig. 1699.
Ampullina smithii (Brown). Sars, 1878, pp. 155–156, pl. 12, figs. 2a–b, pl. 21, fig. 18 [operculum], pl. 5, figs. 9a–b [radulae], pl. 18, fig. 9 [operculum].
Natica (*Polinices*) *tenuicula* Sowerby, 1915, p. 166, pl. 10, fig. 3.
Bulbus tenuiculus (Sowerby). Kuroda and Habe, 1952, p. 42; Habe, 1961, p. 38, pl. 17, fig. 5.

Types.—

Natica fragilis Leach: type material unknown; type locality Baffin Bay, between Greenland and Canada (Leach, 1819 [*fide* Marincovich, 1977, p. 337]).

Natica flava Gould: type material unknown, presumably lost (Johnson, 1964); type locality unknown, "stomachs of fishes" (Gould, 1839 [*fide* Marincovich, 1977, p. 227]).

Bulbus flavus elongatus Habe and Ito: NSMT Mo49882 (holotype), from Nemuro, Hokkaido, Japan (Habe and Ito, 1965b).

Bulbus smithii Brown: type material unknown; type locality Ardincaple, near Helensburgh, southwestern Scotland (Brown *in* Smith, 1839 [*fide* Marincovich, 1977, p. 337]).

Natica (*Polinices*) *tenuicula* Sowerby: type material unknown; type locality, Nemuro [as "Nomuro"], Hokkaido, Japan (Sowerby, 1915).

Description.—Shell very thin, moderate in size, globose to globose-elongate in form, spire weakly to moderately elevated; body whorl not greatly inflated; suture moderately impressed; whorls five in specimen IGUT 15954, in which nuclear whorls are not clearly differentiated (nuclear whorls of other specimens I have examined are eroded). Spiral sculpture of minute, closely or irregularly spaced costellae; axial sculpture of very weakly developed incremental growth lines that are most distinct below suture. Parietal callus very thin; anterior lobe indistinct. Umbilicus slenderly open, may be nearly closed by a reflexed inner lip; anterior inner lip thin and smoothly merges with parietal callus. At the umbilical area, the inner lip is weakly to strongly reflexed and commonly forms a thin, semicircular umbilical callus. Inner margin of aperture strongly sigmoidally curved; basal lip and outer lip very thin.

Discussion.—The characters of *Bulbus fragilis* are the same as those of the genus. The occurrence of *B. fragilis* from the early Miocene Honya Mudstone (Pl. 1, figs. 10–11) is the oldest stratigraphic record of the species. The earliest previously recorded stratigraphic occurrence was from the early late Miocene Tachilni Formation of southwestern Alaska, U. S. A. (Marincovich, 1983).

Marincovich (1977) fully described the morphological variation of *B. fragilis*, and mentioned that "the range in morphology is from an elongate, higher-spired form with a thin shell, to a more globose, lower-spired form with a thicker shell." The specimen from the lower Pleistocene Tomikawa Formation (Pl. 1, fig. 12) is identified with the former variant of Marincovich (1977).

The Tomikawa specimen seems to be similar to a buccinid, *Volutharpa perryi* (Jay, 1855). *Bulbus fragilis* and *V. perryi* are easily distinguished from each other in morphology of the shell base, because *V. perryi* has a wide and deep siphonal canal and a distinct fasciole, but *B. fragilis* has a simple rounded base. Unfortunately, the Tomikawa specimen lacks its basal part. *Volutharpa perryi* is, however, safely distinguished from the Tomikawa specimen by having thinner parietal and umbilical calluses that smoothly merge with the body whorl, and by having weakly channeled sutures.

Stratigraphic occurrence.—

Lower Miocene: Honya Mudstone, Fukushima Pref., locality TAIRA 2 (Pl. 1, figs. 10–11).

Lower Pleistocene: Tomikawa Fm., Hokkaido, locality TOMIKAWA (Pl. 1, fig. 12).

Genus **EUSPIRA** Agassiz *in* Sowerby, 1838

Type species.—*Natica glaucinoides* Sowerby, 1812, by subsequent designation (Bucquoy, Dautzenberg, and Dollfus, 1883) [not seen: *fide* Kuroda, Habe, and Oyama, 1971; Kilburn, 1976]. Paleogene of France and England.

Discussion.—*Euspira* is characterized by a globose to globose-elongate shell, an open umbilicus, and a slender to indistinct umbilical callus.

Euspira meisensis (Makiyama, 1926)
Plate 2, figures 1–23;
Text-figures 3.3, 10.1; Table 5

Polinices (*Euspira*) *meisensis* Makiyama, 1926, pp. 150–151, pl. 12, fig. 7; Otuka, 1934, p. 627, pl. 49, figs. 76, 77; Masuda, 1956, pl. 26, figs. 8a–b.

Natica (*Euspira*) aff. *meisensis* (Makiyama). Otuka, 1938, p. 37, pl. 3, figs. 25, 28.

Euspira meisensis (Makiyama). Shikama, 1954, pl. 7, figs. 2a–3b; Shibata *in* Itoigawa, Shibata, and Nishimoto, 1974, pp. 148–149, pl. 45, figs. 13a–b, 18–19b; Yoon, 1976, p. 67, pl. 1, figs. 19–22; Itoigawa and Nishikawa, 1976, pl. 35, fig. 17; Itoigawa and Shibata *in* Morishita, 1977, p. 68, pl. 30, fig. 16; Taguchi, Ono, and Okamoto, 1979, pl. 4, fig. 7; Yoon, 1980, p. 75, pl. 8, figs. 7–9; Itoigawa *et al.*, 1981, pl. 34, figs. 10a–b, 14a–b; Itoigawa *et al.*, 1982, pp. 197–198; Masuda *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 256, pl. 128, figs. 1216a–b; Nakagawa and Takeyama, 1985, pl. 19, figs. 7a–b; Majima and Fukuta, 1986, text-fig. 1.3.

Polinices meisensis Makiyama. Masuda, 1967, pl. 1, figs. 24a–b.

Polinices (*Euspira*) *ashiyaensis* Nagao, 1928b, pp. 95–96, pl. 15, figs. 1–1a, 19–21a.

Euspira ashiyaensis (Nagao). Hatai and Nisiyama, 1952, p. 234; Oyama, Mizuno, and Sakamoto, 1960, pp. 48–49, pl. 5, figs. 6a–e; Kamada, 1962, pp. 159–160, pl. 19, figs. 1a–4; Okamoto, 1975, pl. 4A–4, fig. 11; Itoigawa and Shibata *in* Morishita, 1977, p. 68, pl. 30, fig. 13.

Euspira cf. *ashiyaensis* (Nagao). Hashimoto, 1961, p. 90, pl. 10, figs. 15a–18.

Polinices (*Euspira*) *otukai* Masuda, 1956, pp. 162–163, pl. 26, figs. 9a–b.

Ampullina asagaiensis Makiyama. Nemoto and O'hara, 1979b, pl. 2, figs. 13a–b [not *A. asagaiensis* Makiyama, 1934 (an indeterminate taxon)].

Natica sp. Nakagawa and Takeyama, 1985, pl. 19, figs. 5a–b.

Types.—

Polinices (*Euspira*) *meisensis* Makiyama: Geol. Surv. Chosen, Reg. No. 45 (holotype), from Daitokudo, Meisen district, North Korea, lower middle Miocene Heirokudo Formation (Makiyama, 1926). Topotype: Plate 2, figure 11.

Polinices (*Euspira*) *ashiyaensis* Nagao: IGPS 36135 (holotype: Pl. 2, fig. 10), from Taya, Ashiya-machi, Onga-gun, Fukuoka Prefecture, lower Miocene Yamaga Formation of Ashiya Group (Nagao, 1928b).

Polinices (*Euspira*) *otukai* Masuda: IGPS 90421 (holotype: Pl. 2, fig. 1), from Tokunari, Wajima City, Ishikawa Prefecture, lower middle Miocene Higashi-Innai Formation (Masuda, 1956).

Description.—Shell medium to small in size, globose-elongate in form, spire moderately to greatly elevated; body whorl moderately inflated, commonly evenly rounded, may be anteriorly inflated; shoulder slightly flattened; nuclear whorls two, smooth; post-nuclear whorls three-and-one-half in larger specimens,

Table 5.—Measurements (in mm) and counts of the largest specimen of *Euspira meisensis* (Makiyama, 1926) at each locality. Within the lower middle Miocene, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
Oligocene	Asagai 1	23.5	20.7	16.4	16.3	4+	CU 7900118	1
	Asagai 2	30.5	28.3	21.0	20.7	4+	IGUT 15749-1	2
lower Miocene	Ashiya 1	17.7+	16.6	14.0	12.9	3+	IGPS 36135*	1
	Ashiya 3	50.1	43.1	36.2	29.8	4+	IGPS 36137	1
lower middle Miocene	Momijiyama 1	42.6	33.6+	32.4	31.5	5½+	IGUT 15740	1
	Furanui 2	27.7	24.7	21.8	19.1	4½+	IGUT 15738-1	3
	Furanui 5	24.0+	30.6	25.0+	—	—	IGUT 15739-1	8
	Oshamanbe	31.4	28.0	23.3	19.1	5+	IGUT 15742-1	42
	Kadonosawa 1	38.9	32.4	27.8	25.5	5	IGUT 15726-1	8
	Kadonosawa 2	42.0	36.5	30.6	28.6	3½+	IGUT 15727-5	18
	Higashi-Innai 1	25.9	22.5	18.8	18.8	5	IGUT 15730-1	2
	Higashi-Innai 2	16.6	14.4	11.8	11.7	4½	IGUT 15731	2
	Higashi-Innai 2	12.5	10.4	9.1	9.5	3+	IGPS 90421**	—
	Taira 3	17.9	15.0	12.5	12.1	4	IGUT 15748	1
	Yatsuo 1	17.2	15.0	12.1	12.6	4	IGUT 15732-1	5
	Yatsuo 3	14.0	12.2	10.0	11.0	4	IGUT 15729	1
	Maizuru 3	30.8	25.8	25.6	23.3	4½+	IGUT 15753	1
	Maizuru 4	13.9	11.8	8.9	—	4½+	IGUT 15743-2	7
	Tomikusa	26.6	24.7	21.8	21.7	4+	GIYU 572-3	3
	Mizunami 1	30.8	27.8	23.6	—	3+	IGUT 15735	1
	Mizunami 2	20.2	18.4	15.1	16.0	4	IGUT 15733-1	5
	Mizunami 3	30.4	27.5	22.4	—	4+	IGUT 15734-1	6
	Ayugawa	34.8	27.2	25.9	24.8	4½+	GIYU 573-1	24
	Ichishi 1	22.4	21.0	18.6	15.6	4½+	IGUT 15737-1	10
	Tanabe 1	29.2	26.6	23.4	21.3	3+	IGUT 15747-1	5
	Atetsu	9.7	8.7	7.0	8.2	3½+	IGUT 15745-1	2
	Shobara 2	12.4	10.3	9.1	9.6	3+	IGUT 15744-3	4
	Hamada	31.1	31.4	29.4	23.7	3½+	IGUT 15746-1	24
middle middle Miocene	Kokozura	26.7	24.4	20.2	19.9	4+	IGUT 15741-3	10

* Holotype of *Polinices* (*Euspira*) *ashiyaensis* Nagao, 1928b.
** Holotype of *Polinices* (*Euspira*) *otukai* Masuda, 1956.

smooth except for weakly developed incremental growth lines; suture moderately impressed; shell thickness average for genus. Base entirely rounded. Parietal callus weakly to moderately thickened, weakly filling posterior apertural angle; anterior lobe distinct, slightly overhanging umbilicus. Umbilicus moderately to widely open; umbilical callus commonly indistinct, may be minutely developed at center of anterior inner lip. Anterior inner lip thin and straight; basal lip slightly thickened.

Discussion.—*Euspira meisensis* commonly occurs in Oligocene to middle Miocene deposits of Japan and the Korean Peninsula and is characterized by having a globose-elongate form, a thin anterior inner lip lacking a distinct umbilical callus, and an entirely rounded base. The earliest known individuals of *E. meisensis* occur in the Oligocene Iwaki and Asagai formations and some of them are very similar to *Euspira hotsoni* (Weaver and Palmer, 1922), from late Eocene warm-water faunas of western North America (Marincovich, 1977), in having nearly identical umbilical morphologies and non-tabulated shoulders. *Euspira meisensis* is thought to have evolved from *E. hotsoni*.

Previously, *E. meisensis* was considered to be an index fossil for the lower middle Miocene, and *Polinices* (*Euspira*) *ashiyaensis* Nagao, 1928b was thought to be an index fossil for the lower Miocene. But the latter species is herein made a junior synonym of the former, for the first time, on the basis of the following morphological comparison. (1) The shell proportions of *P.* (*E.*) *ashiyaensis* are included in the variation of *E. meisensis*. Nagao (1928b), in his original description of *P.* (*E.*) *ashiyaensis*, mentioned that "the present species differs from *P.* (*Euspira*) *meisensis* Makiyama from the Tertiary of North Korea in having a non-shouldered and posteriorly narrowed whorls and a more elevated spire." However, non-shouldered and posteriorly narrowed whorls, both of which are typically observable in the holotype of *P.* (*E.*) *ashiyaensis* (Pl. 2, fig. 10), are common characters of lower middle Miocene specimens (Pl. 2, figs. 1–6, 11–21), and the spires of lower Miocene specimens are no more elevated than those of the lower middle Miocene specimens. (2) The umbilical characters of the two species are identical in having a thin inner lip commonly lacking a distinct umbilical callus, a moderately to widely open umbilicus, and an entirely rounded base. A lower Miocene specimen with a well preserved umbilical area is illustrated in Plate 2, figure 9.

Polinices (*Euspira*) *otukai* Masuda, 1956 (holotype: Pl. 2, fig. 1) is also herein made a junior synonym of *E. meisensis* (Makiyama). Masuda (1956), in his original description of *P.* (*E.*) *otukai*, distinguished his species from *E. meisensis* by "the obliquely globose shell, small umbilicus, and by the aperture being anteriorly broad and posteriorly narrow." These discriminative characters are, however, included in the morphological variation of *E. meisensis.*

Euspira meisensis is commonly associated with nearshore molluscan assemblages, such as the *Dosinia–Anadara* assemblage (Chinzei and Iwasaki, 1967) and the *Turritella–Glycymeris* assemblage (Shibata, 1978) in early middle Miocene warm-water Kadonosawa faunas, but it is also associated with offshore species at locality MOMIJIYAMA 1 in the Takinoue Formation, central Hokkaido. Kanno and Ogawa (1964) reported the following molluscs from locality MOMIJIYAMA 1 (loc. 46 of Kanno and Ogawa, 1964): *Malletia inermis* (Yokoyama, 1925a), *Macoma calcarea* (Gmelin, 1791), *Turritella shatai* Nomura, 1935a, *Ancistrolepis* cf. *peulepis* Kanehara, 1937, and *Fulgoraria striata* (Yokoyama, 1925c), all offshore and cold-water species. This occurrence represents the northern limit of the geographic distribution of *E. meisensis* in early middle Miocene time.

Stratigraphic occurrence.—

Oligocene: Iwaki Fm., Fukushima Pref. (Kamada, 1962); Asagai Fm., Fukushima Pref., localities ASAGAI 1 (Pl. 2, fig. 7) and ASAGAI 2 (Pl. 2, fig. 8).

Lower Miocene: Yamaga Fm., Yamaguchi Pref. (Okamoto, 1975); Yamaga and Sakamizu fms., Fukuoka Pref., localities ASHIYA 1 (Pl. 2, fig. 10), ASHIYA 2 (Pl. 2, fig. 9), and ASHIYA 3 (Pl. 2, fig. 23); Kadogawa Fm., Miyazaki Pref. (Hashimoto, 1961).

Lower middle Miocene: Takinoue Fm., Hokkaido, locality MOMIJIYAMA 1 (Pl. 2, fig. 12); Furanui Fm., Hokkaido, localities FURANUI 2 (Pl. 2, fig. 13) and FURANUI 5; Kunnui Fm., Hokkaido, locality OSHAMANBE; Kadonosawa Fm., Iwate Pref., localities KADONOSAWA 1 and KADONOSAWA 2 (Pl. 2, fig. 14); Higashi-Innai Fm., Ishikawa Pref., localities HIGASHI-INNAI 1 (Pl. 2, fig. 15) and HIGASHI-INNAI 2 (Pl. 2, fig. 1); Nakayama Fm., Fukushima Pref., locality TAIRA 3 (Pl. 2, fig. 2); Yatsuo Fm., Toyama Pref., localities YATSUO 1 (Pl. 2, fig. 3) and YATSUO 3; Uchiura Group, Fukui Pref., localities MAIZURU 3 and MAIZURU 4 (Pl. 2, fig. 4); Nukuta Fm., Nagano Pref., locality TOMIKUSA (Pl. 2, fig. 16); Togari Fm., Gifu Pref., localities MIZUNAMI 1, MIZUNAMI 2 (Pl. 2, fig. 17), and MIZUNAMI 3; Yamanouchi Fm., Gifu Pref. (Itoigawa and Shibata *in* Morishita, 1977); Kurokawa Fm., Shiga Pref., locality AYUGAWA (Pl. 2, figs. 18–19); Oi Fm., Mie Pref., locality ICHISHI 1 (Pl. 2, fig. 20); Tanabe Group, Wakayama Pref., locality TANABE 1; Bihoku Group, Okayama Pref., locality ATETSU (Pl. 2, fig. 5); Bihoku Group, Hiroshima Pref., locality SHOBARA 2 (Pl. 2, fig. 6); Togane Fm., Shimane Pref., locality HAMADA (Pl. 2, fig. 21).

Middle middle Miocene: Kokozura Fm., Fukushima Pref., locality KOKOZURA (Pl. 2, fig. 22).

Euspira marincovichi, new species
Plate 3, figures 1–4;
Text-figures 10.2, 10.3; Table 6

*Etymology.—*This species is named for Dr. Louie Marincovich, Jr., of the U. S. Geological Survey, Menlo Park, CA, U. S. A., who summarized the Cenozoic Naticidae of the northeastern Pacific in 1977, and kindly gave many critical comments for the present study.

Types.—

Holotype: IGUT 15724 (Pl. 3, fig. 1), from a small outcrop in a tributary of the Shiratori River, about 400 m upstream of the mouth of the tributary, Shiratori, Fukuoka-machi, Ninohe City, Iwate Prefecture, lower middle Miocene Kadonosawa Formation (loc. KADONOSAWA 1).

Paratypes: IGUT 15725-1–15725-43 (Pl. 3, fig. 2), from the type locality of the species; IGUT 15728-1–15728-4 (Pl. 3, figs. 3–4), from an exposure on the

Table 6.—Measurements (in mm) and counts of the holotype and of the largest specimen of *Euspira marincovichi*, n. sp. at each locality. Localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower middle Miocene	KADONOSAWA 1	23.5	22.0	17.3	19.5	4½	IGUT 15725-10*	65
	KADONOSAWA 1	21.9	19.0	14.3	16.8	4½	IGUT 15724 (holotype)	—
	YATSUO 3	28.1	25.5	20.8	21.6	5½	IGUT 15728-2*	4

* Paratype.

Table 7.—Measurements (in mm) and counts of the holotype and of the largest specimen of *Euspira mitsuganoensis* Shibata, 1970 at localities ICHISHI 5 and ICHISHI 6.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower middle Miocene	ICHISHI 5	21.5	21.4	17.7	—	4½+	IGUT 15736-1	2
	ICHISHI 6	17.6	16.3+	14.6	14.1	4+	ESN 30019 (holotype)	1

left bank of the Kubusu River at Kashio, Yatsuo-machi, Toyama Prefecture, lower middle Miocene Joyama Member of the Yatsuo Formation (loc. YATSUO 3).

Description.—Shell small to moderate in size, globose-elongate in form; shell thickness average for genus; nuclear whorls two-and-one-half, smooth, distinctly swollen; postnuclear whorls three in larger specimens, sculptured with very weakly developed incremental growth lines; suture weakly impressed; shoulder minutely concave; body whorl not greatly inflated, commonly slightly but distinctly flattened above periphery. Flattened sides of whorls are more or less separated from minutely concave shoulder with a dull angulation. Parietal callus thick, moderately filling posterior apertural angle; anterior lobe weak, slightly overhanging umbilicus. Umbilicus weakly to moderately open; umbilical wall separated from base by a distinct angulation, or smoothly merged with it, with intermediate gradations between these two end forms. Umbilical callus commonly weakly but distinctly swollen at central part of anterior inner lip, and gradually tapering anteriorly and posteriorly, but umbilical callus may be indistinct. Anterior inner lip thickened.

Discussion.—*Euspira marincovichi* is characterized by its flattened body whorl above the periphery, a thick anterior inner lip, and morphological variation in the sculpture of the basal part. The two end forms of the variation in the basal part are illustrated in Text-figures 10.2 and 10.3; one end form of the basal sculpture shows a distinct angulation circumscribing the umbilicus (Text-fig. 10.3; Pl. 3, fig. 1) and the other possesses an entirely rounded base (Text-fig. 10.2; Pl. 3, fig. 2). There is a continuous range of intermediates between the two end forms.

The specimens of *E. marincovichi* with rounded bases are very similar to *Euspira meisensis* (Makiyama, 1926) (Text-fig. 10.1), but the former species is distinguished from the latter by having a thicker parietal callus, thicker anterior inner lip, and a distinctly flattened body whorl above the periphery. In addition, *E. marincovichi* commonly possesses a small but distinct umbilical callus, whereas *E. meisensis* never has such a distinct callus. Moreover, *E. marincovichi* commonly has a narrower umbilicus than *E. meisensis*.

Euspira pila (Pilsbry, 1911) resembles *E. marincovichi*, and a comparison of their morphology is made in the discussion of the former species.

Stratigraphic occurrence.—

Lower middle Miocene: Kadonosawa Fm., Iwate Pref., locality KADONOSAWA 1 (Pl. 3, figs. 1–2); Joyama Member of Yatsuo Fm., Toyama Pref., locality YATSUO 3 (Pl. 3, figs. 3–4).

Euspira mitsuganoensis Shibata, 1970
Plate 3, figures 5–6;
Text-figure 10.4; Table 7

Euspira mitsuganoensis Shibata, 1970, p. 74, pl. 3, figs. 10a–b; Shibata and Ina, 1983, p. 60, pl. 8, figs. 13, 14.

Holotype.—ESN 30019 (Pl. 3, fig. 6), from the river bed of the Nagano River, about 300 m south from Ashisaka, Iono, Misato-mura, Age-gun, Mie Prefecture, lower middle Miocene Mitsugano Member of the Oi Formation (loc. K35 of Shibata, 1970).

Description.—Shell small in size, globose in form; spire moderately elevated; body whorl moderately inflated, evenly rounded; shell thickness average for genus; whorls about four-and-one-half (apices of all examined specimens eroded); suture moderately impressed. Shell surfaces of all examined specimens are more or less eroded but preserved in small spots, in which incremental growth lines and microscopic spiral striae are observable: the spiral striae are indistinct at the periphery of the body whorl. Parietal callus moderately thickened, weakly filling posterior apertural angle; anterior lobe very strong, overhanging umbilicus. Umbilicus widely open, sharply separated from body-whorl side by a distinct angulation; umbilical callus smooth, weakly developed at posterior corner of umbilicus, smoothly merged with anterior lobe of parietal callus and gradually tapering anteriorly. Anterior inner lip and outer lip thin but gradually thickened anteriorly; basal lip greatly thickened.

Discussion.—*Euspira mitsuganoensis* is characterized by its globose shell, widely open umbilicus and sharp angulation circumscribing the umbilicus (Text-fig. 10.4). In Japan, this species is the morphologically most distinct among the fossil species of *Euspira*.

One end form of the variation of *Euspira marincovichi*, n. sp. has an angulation circumscribing the umbilicus (Text-fig. 10.3), in which it resembles *E. mitsuganoensis*. However, *E. marincovichi* is easily

Table 8.—Measurements (in mm) and counts of the largest specimen of *Euspira pallida* (Broderip and Sowerby, 1829) at each locality. Localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
Pliocene and lower Pleistocene	TESHIO 9	28.2	24.1	—	21.2	4+	IGUT 15593	1
	TOMIKAWA	21.2	17.6	14.2	15.9	5+	IGUT 15774-2	2
	SAWANE 1	11.9+	10.7+	9.4	9.3+	3½	GIYU 533-1	4
	SAWANE 2	14.2+	13.8+	12.5	10.6+	5	GIYU 532-1	4
	CHOSHI 1	28.2+	21.0+	20.5	20.8+	5+	IGUT 15773-4	145
	CHOSHI 2	16.3+	15.1+	12.4	12.1	5	IGUT 15778-1	10
	CHOSHI 3	13.6	11.8	9.8	9.6	4+	IGUT 15777	1

distinguished from *E. mitsuganoensis* by having a more elongate shell form, a narrower umbilicus, and a weak but distinct umbilical callus at the central part of the anterior inner lip.

The habitat of *E. mitsuganoensis* is in striking contrast to those of *E. marincovichi* and *E. meisensis* (Makiyama, 1926). *Euspira mitsuganoensis* is associated with a *Neilonella–Periploma* assemblage in early middle Miocene faunas of the Ichishi basin, which indicates a bathyal zone environment (deeper than 200 m) (Shibata, 1970). In most cases, however, *E. marincovichi* and *E. meisensis* are associated with nearshore molluscs.

Euspira yokoyamai (Kuroda and Habe, 1952) resembles *E. mitsuganoensis*, and morphological comparison of the two species is made in the discussion of the former species.

Stratigraphic occurrence.—

Lower middle Miocene: Shimoda Fm., Aichi Pref. (Shibata and Ina, 1983); Oi Fm., Mie Pref., localities ICHISHI 5 (Pl. 3, fig. 5) and ICHISHI 6 (Pl. 3, fig. 6).

Euspira pallida
(Broderip and Sowerby, 1829)
Plate 3, figures 7–13;
Text-figures 4.5, 11, 15.6; Table 8

Natica pallida Broderip and Sowerby, 1829, p. 372 [not seen: *fide* Oldroyd, 1927, p. 728]; Philippi, 1851, pp. 96–97, pl. 14, fig. 2; Sowerby, 1883, p. 92, pl. 9, fig. 137.

Natica (Neverita) pallida Broderip and Sowerby. Tryon, 1886, p. 37, pl. 9, figs. 76–78, pl. 13, fig. 15, pl. 14, figs. 26–28.

Lunatia pallida (Broderip and Sowerby). Odhner, 1913, pp. 8, 31–40, pl. 3, figs. 15, 19–37, pl. 4, figs. 1–8, pl. 5, figs. 16–18 [radulae]; Okutani, 1964, pp. 393–394, pl. 1, fig. 19, pl. 5, fig. 8; Okutani, 1966, p. 16, pl. 2, fig. 6; Ishikawa, 1969, pl. 3, fig. 7; Oyama, 1969, p. 76; ? Ishikawa, 1970, p. 133, pl. 9, fig. 1; Matsui, 1985, p. 173, pl. 22, fig. 9.

Not *Lunatia pallida* (Broderip and Sowerby). Shuto, 1964, pp. 288–289, pl. 43, figs. 4, 6–8, 11, 13 [= *Euspira yokoyamai* (Kuroda and Habe, 1952)].

Polinices (Euspira) pallida (Broderip and Sowerby). Dall, 1921, p. 164, pl. 14, fig. 5; Oldroyd, 1927, p. 728, pl. 97, fig. 9.

Euspira pallida (Broderip and Sowerby). Kuroda and Habe, 1952, p. 57; Kotaka, 1962, pp. 135–136, pl. 33, figs. 19, 20; Okutani and Habe, 1975, pp. 80 [unnumbered fig.], 171; Noda *et al.*, 1983, p. 7, pl. 3, figs. 4a–b.

Not *Euspira* cf. *E. pallida* (Broderip and Sowerby). MacNeil, 1960, p. 57, pl. 2, figs. 20, 26 [= *Euspira yokoyamai* (Kuroda and Habe, 1952)].

Polinices pallidus (Broderip and Sowerby). MacGinitie, 1959, p. 91, pl. 12, fig. 10.

Not *Pollinices* [*sic*] *pallidus* (Broderip and Sowerby). Yokoyama, 1920, p. 77, pl. 4, figs. 1a–b [= *Euspira yokoyamai* Kuroda and Habe, 1952)].

Not *Polinices pallidus* (Broderip and Sowerby). Yokoyama, 1928c, p. 124, pl. 19, fig. 3 [= *Euspira yokoyamai* (Kuroda and Habe, 1952)].

Eunatica pallida (Broderip and Sowerby). Habe and Ito, 1965a, p. 30, pl. 8, fig. 3; Okutani, 1968, p. 29.

Polinices (Euspira) pallidus (Broderip and Sowerby). Marincovich, 1977, pp. 278–281, pl. 25, figs. 1–6, 8.

Natica (Lunatia) pallida Broderip and Sowerby. Simonarson, 1981, pp. 34–35, pl. 2, fig. 4.

Uberella yokoyamai (Kuroda and Habe). Ozaki, 1958, pp. 144–145, pl. 15, fig. 8, pl. 19, fig. 7 [not *U. yokoyamai* (Kuroda and Habe, 1952)].

Type.—Type material unknown, presumably in BM(NH); type locality, Icy Cape [Arctic coast of Alaska] (Broderip and Sowerby, 1829: *fide* Marincovich, 1977).

Description.—Shell medium in size, globose to globose-elongate in form, spire weakly to moderately elevated; suture moderately impressed; whorls about five (apices of all examined specimens eroded); body whorl weakly inflated, commonly evenly rounded; shoulder may be weakly and narrowly tabulated. Axial sculpture of very weakly developed growth lines that are most distinct below suture and on base; spiral sculpture of microscopic, sparse striae that are commonly best developed at subsutural area. Shell thickness thin to moderate. Parietal callus weak to moderate in thickness, weakly filling posterior apertural angle; anterior lobe moderately to strongly developed, weakly overhanging umbilicus. Umbilicus moderately open to nearly closed; umbilical callus commonly indistinct, but may be weakly developed; if an umbilical callus is present, it is semicircular in form (Text-fig. 11 [arrow **a**]). Outer lip thin; anterior inner lip thin to thick; basal lip moderately thickened.

Discussion.—*Euspira pallida* contains a very wide range of morphological variation, especially in its um-

Table 9.—Measurements (in mm) and counts of the largest specimen of *Euspira pila* (Pilsbry, 1911) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
Pliocene and lower Pleistocene	TESHIO 2	17.0	15.1+	14.0	—	3½+	IGUT 16069	1
	TESHIO 5	35.7	29.0+	24.7	25.2	5½+	IGUT 16070-1	2
	TESHIO 7	20.0+	17.8+	16.2	—	4+	IGUT 16073-1	5
	TESHIO 8	16.3+	12.6+	13.6	—	4+	IGUT 16072	1
	KUROMATSUNAI 1	17.7	13.6	12.5	13.4	4+	IGUT 15761-1	10
	KUROMATSUNAI 2	20.9+	16.9+	14.0	15.8+	5	IGUT 15762-1	14
	SETANA	7.0	6.2	5.4	5.2	3¼	IGUT 15768-1	3
	TOMIKAWA	21.2	17.9	14.7	15.2	5	IGUT 15764-2	5
	CHIKAGAWA 1	58.5	43.4+	33.1	37.7	6½	IGPS 90442*	73
	CHIKAGAWA 2	16.0	12.9+	10.5	10.5	5	GIYU 510-1	7
	DAISHAKA	23.3	18.9	16.3	16.1	5½	IGUT 15765	1
	KITAKANEGASAWA	11.3	9.3	8.1	7.0+	4½	IGUT 15769-1	3
	TOFUIWA	9.0+	7.6+	6.4	6.1+	4	IGUT 15766-1	2
	MANGANJI 1	16.2	13.0	11.3	10.8	5	GIYU 545-1	22
	MANGANJI 2	13.1+	10.7	9.1	9.1+	5	GIYU 546-1	6
	SAWANE 4	16.1	13.8	11.5	12.5	5	GIYU 574	1
	HAIZUME 1	14.8+	13.2+	11.5	—	5	JUE 15239	6
	HAIZUME 2	26.7+	24.0+	21.8+	—	6½	JUE 15238	7
	FUTATSUNUMA 1	19.4	16.5	13.6	14.8	5½	IGUT 15804	1
	ISURUGI	16.8+	13.8+	13.6	12.1+	5	IGUT 15771-1	3
	OMMA 1	22.4+	20.6	17.4	15.1+	5	IGUT 15756-1	4
	OMMA 2	11.1+	10.4	9.0	8.0+	3½	IGUT 15760-1	2
	OMMA 4	40.3	36.3	32.4	26.5	6½	IGUT 15754-1	45
	OMMA 5	23.7+	19.0+	18.8	—	5	IGUT 15757-1	8
	OMMA 6	28.2+	22.5+	21.2	18.9+	3½+	IGUT 15755-1	6
upper Pleistocene	ANDEN	37.6	29.8+	26.9	25.8	4½+	IGUT 15767-1	13
	WAKIMOTO	26.0	22.6	18.5	19.0	6	GIYU 542-1	9
	SEMATA	22.2	19.3	15.6	14.8	5½	IGUT 15805-1	5

* Holotype of *Euspira pila shimokitaensis* Hatai, Masuda, and Suzuki, 1961.

bilical part (Text-fig. 11); that is, one extreme form has a wide umbilicus, and a simple and thin anterior inner lip lacking a distinct umbilical callus (Text-figs. 11.2c, 11.5c, 11.6c, 11.7c), whereas the other extreme form possesses a relatively thick anterior inner lip and an umbilicus nearly closed by a weak but distinct semicircular umbilical callus (the semicircular umbilical callus may be indistinct in some specimens with closed umbilici) (Text-figs. 11.1a, 11.2a, 11.3a, 11.4a, 11.5a, 11.6a, 11.7a). The two extreme forms are completely interconnected by intermediate forms (Text-figs. 11.1b, 11.2b, 11.3b, 11.4b, 11.5b, 11.6b, 11.7b). The shell proportions also vary, from globose to globose-elongate; generally speaking, the globose form has a wide umbilicus and the globose-elongate form possesses a slender umbilicus. These morphological variations are observable in both lower Pleistocene (Text-figs. 11.1a–11.4c) and Holocene (Text-figs. 11.5a–11.7c) specimens in Japan, and have been previously described by Odhner (1913) and Marincovich (1977) among boreal specimens.

Euspira pallida occurs in the Pliocene and early Pleistocene cold-water Omma-Manganji faunas in the northern half of Japan (Text-fig. 4.5). *Euspira pallida* is, therefore, one of the important elements of the Omma-Manganji fauna.

Euspira pila (Pilsbry, 1911) and *E. yokoyamai* (Kuroda and Habe, 1952) are very similar to *E. pallida*. Detailed comparisons among them are made in the discussions of the former two species.

Stratigraphic occurrence.—

Pliocene and lower Pleistocene: Yuchi Fm., Hokkaido, locality TESHIO 9 (Pl. 3, fig. 7); Tomikawa Fm., Hokkaido, locality TOMIKAWA (Pl. 3, fig. 8); Wakimoto Fm., Akita Pref. (Matsui, 1985); Sawane Fm., Niigata Pref., localities SAWANE 1 and SAWANE 2 (Pl. 3, fig. 9); Iioka Fm., Chiba Pref., localities CHOSHI 1 (Pl. 3, figs. 10–12, Text-fig. 11.1a–11.4c), CHOSHI 2, and CHOSHI 3.

Euspira pila (Pilsbry, 1911)
Plate 4, figures 1–12, 16–20;
Text-figures 4.6, 12.1; Table 9

Polinices pila Pilsbry, 1911, pp. 32–33.
Polynices [*sic*] *ovata pila* [*sic: Polinices pila* Pilsbry, 1911; *Natica ovata* Sowerby, 1914] Pilsbry. Otuka, 1939, p. 30, pl. 2, figs. 8, 9.

Euspira pila (Pilsbry). Kuroda and Habe, 1952, p. 57; Habe, 1958, pp. 12–13, pl. 5, fig. 8; Hatai, Masuda, and Suzuki, 1961, pl. 3, fig. 20; Okutani and Habe, 1975, pp. 80 [unnumbered figs.], 228; Kanno *et al.*, 1980, pl. 4, figs. 3a–b.
Lunatia pila (Pilsbry). Habe, 1961, p. 38, pl. 17, fig. 6; Habe and Ito, 1965a, p. 32, pl. 8, fig. 13; Kaseno and Matsuura, 1965, pl. 2, fig. 29; Oyama, 1969, p. 76; Habe and Kosuge, 1970, p. 48, pl. 18, fig. 27; Ogasawara, 1977, pl. 19, figs. 6a–7b; Ogasawara *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 330, pl. 165, fig. 1562; Matsuura, 1985, pl. 40, fig. 8.
Not *Eunatica pila* (Pilsbry). Nemoto and O'hara, 1979a, pl. 1, figs. 10a–b [= *Cryptonatica clausa* (Broderip and Sowerby, 1829)].
Natica ovata Sowerby, 1914, p. 35, pl. 2, fig. 3.
Euspira pila ovata (Sowerby). Kanehara, 1942, pl. 3(2), figs. 1a–b; Kuroda and Habe, 1952, p. 57.
Euspira pila shimokitaensis Hatai, Masuda, and Suzuki, 1961, pp. 27–28, pl. 4, figs. 8a–b; Masuda *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 312, pl. 156, figs. 1459a–b.
Cryptonatica janthostomoides (Kuroda and Habe) [not *C. janthostomoides* (Kuroda and Habe, 1949)]. Ogasawara, 1977, pl. 19, figs. 5a–b; Ogasawara *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 330, pl. 165, fig. 1561.

Types.—

Polinices pila Pilsbry: Syntypes, ANSP 97973, and No. 1706 of Mr. Hirase's collection; type locality, Akkeshi, Kushiro, Hokkaido (Pilsbry, 1911).
Natica ovata Sowerby: type material unknown; type locality, Hidaka, Hokkaido (Sowerby, 1914).
Euspira pila shimokitaensis Hatai, Masuda, and Suzuki: IGPS 90442 (holotype: Pl. 4, fig. 17), from the river cliff of the Chika River, about 400 m upstream of its mouth, Chikagawa, Mutsu City, Aomori Prefecture, lower Pleistocene Sunagomata Formation (loc. CHIKAGAWA 1).

Description.—Shell small to very large in size, globose-elongate in form, spire moderately to greatly elevated; shell thickness average; nuclear whorls one-and-one-half, smooth, surface commonly eroded; postnuclear whorls four; body whorl not greatly inflated, evenly rounded except for slightly concave shoulder; suture moderately impressed. Axial sculpture of weakly developed incremental growth lines; spiral sculpture of microscopic, dense striae that may be indistinct in younger whorls. Base entirely rounded. Parietal callus thin, but gradually thickened anteriorly and posteriorly, moderately filling posterior apertural angle; anterior lobe weak but distinct, weakly overhanging umbilicus. Umbilicus narrowly to moderately open; umbilical callus commonly weakly developed but distinct, located anteriorly, tapering anteriorly and posteriorly, may be semicircular in form; funicle weak to lacking. Anterior inner lip and basal lip moderately thickened.

Discussion.—*Euspira pila* is characterized by having a globose-elongate shell, a weak but distinct umbilical callus, and an entirely rounded base.

In 1961, Hatai, Masuda, and Suzuki proposed a new subspecies *Euspira pila shimokitaensis* (holotype: Pl. 4, fig. 17) from the lower Pleistocene Sunagomata Formation, Aomori Prefecture (loc. CHIKAGAWA 1). Hatai, Masuda, and Suzuki compared *E. pila shimokitaensis* with *E. pila* as follows:

> The present one is closely related to *Euspira pila* (Pilsbry) . . . in the shape of funicle, parietal callus and umbilicus, but can be distinguished therefrom by its highly spired shell. That is to say, the specimens referable to *pila* collected from the present region commonly have about 0.8 in width/length, while the present one has about 0.72.

Although Hatai, Masuda, and Suzuki stressed the higher spire as a subspecific character, the holotype of *E. pila shimokitaensis* lacks the apertural part except for anterior inner and basal lips (Pl. 4, fig. 17). Therefore, the ratio of width/height of the holotype is seemingly less than the true ratio. The shell proportions of the holotype of *E. pila shimokitaensis* fall within the morphological variation of *E. pila*. *Euspira pila shimokitaensis* is, therefore, a junior synonym of *E. pila*.

Some morphological variations of *Euspira pila* possess the distinctly developed semicircular umbilical callus seen in some species of *Cryptonatica* Dall, 1892, but the umbilical callus of *E. pila* is commonly smaller and situated more anteriorly than that of species of *Cryptonatica*. In addition, the anterior lobe of the parietal callus of *E. pila* is relatively heavier than those of species of *Cryptonatica*. Among species of *Cryptonatica* in Japan, *C. adamsiana* (Dunker, 1859) (Pl. 14, figs. 1–17) is similar to *E. pila* in having a small umbilical callus. However, *C. adamsiana* has a flattened shoulder and a weaker anterior lobe of the parietal callus than that seen in *E. pila*.

Euspira pila resembles both *Euspira meisensis* (Makiyama, 1926) and *E. marincovichi*, n. sp., but *E. pila* is distinguished from *E. meisensis* by having a small but distinct umbilical callus, and from *E. marincovichi* by having a thin parietal callus and an entirely rounded base.

A variant of *E. pallida* (Broderip and Sowerby, 1829) with a semicircular umbilical callus closely resembles *E. pila*, but is distinguished from the latter species by having a more closed umbilicus and a more globose shell.

Euspira pila is one of the characteristic naticids of the cold-water Omma-Manganji fauna, and commonly occurs in shallow-water facies of Pliocene and lower Pleistocene deposits in northeastern Honshu and Hokkaido (Text-fig. 4.6).

Stratigraphic occurrence.—

Pliocene and lower Pleistocene: Yuchi Fm., Hokkaido, localities TESHIO 2, TESHIO 5 (Pl. 4, fig. 16), TESHIO 7, and TESHIO 8; Nakanokawa Fm., Hokkaido, localities KUROMATSUNAI 1 and KUROMATSUNAI 2 (Pl. 4, fig. 1); Chinkope Fm., Hokkaido, locality SETANA;

Table 10.—Measurements (in mm) and counts of the largest specimen of *Euspira yokoyamai* (Kuroda and Habe, 1952) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
Pliocene and lower Pleistocene	KITAKANEGASAWA	9.9	10.3	8.2	7.5	4	IGUT 15788	1
	KIMITSU 1	14.9	14.8	11.9	11.2	4½	IGUT 15786-1	2
	NOJIMA 1	15.5	14.6	11.7	10.7	4+	GIYU 582-1	8
	KAKEGAWA 18	14.8+	14.6	12.3	—	4½+	GIYU 581	1
	TONOHAMA 1	9.2+	8.2+	7.1	7.0+	4	IGUT 15785	1
	MIYAZAKI 1	18.8+	18.8	15.0	14.9+	5	GIYU 567-1	2
	MIYAZAKI 2	17.0	15.3	12.5	13.2	4½	IGUT 15781-1	28
	MIYAZAKI 3	15.7	15.2	12.1	12.4	4½+	GIYU 579	1
	MIYAZAKI 4	17.8+	16.9+	14.7	—	4+	IGUT 15782	3
	MIYAZAKI 8	12.6	11.9	9.4	10.3	4½	GIYU 578-1	2
	MIYAZAKI 9	12.0+	11.5	9.0	9.2+	4	IGUT 15784-1	2
	MIYAZAKI 10	17.0+	16.6+	13.8	—	4½+	GIYU 580-1	6
	SHINZATO 1	15.2	14.5	12.0	12.3	4½	IGUT 15789-1	6
	SHINZATO 2	15.6	14.8	12.1	11.5	4½	IGUT 15790-1	5
	SHINZATO 3	12.2	11.0	9.3	8.8	4½	IGUT 15795-1	3
	SHINZATO 4	12.6	11.1	9.4	9.7	4+	IGUT 15792-1	2
	SHINZATO 5	12.5	11.0	9.1	9.5	3½	IGUT 15791-1	9
	SHINZATO 6	12.8	11.8	9.7	10.0	4½	IGUT 15796-1	5
	SHINZATO 9	13.0	12.2	10.8	—	4½	IGUT 15798	1
upper Pleistocene	SEMATA	13.2+	11.7+	10.2	10.4+	4	IGUT 15787	1

Tomikawa Fm., Hokkaido, locality TOMIKAWA (Pl. 4, fig. 2); Sunagomata Fm., Aomori Pref., locality CHIKAGAWA 1 (Pl. 4, figs. 17–18) and CHIKAGAWA 2 (Pl. 4, fig. 3): Daishaka Fm., Aomori Pref., locality DAISHAKA (Pl. 4, fig. 4); Narusawa Fm., Aomori Pref., locality KITAKANEGASAWA (Pl. 4, fig. 5); Sasaoka Fm., Akita Pref., locality TOFUIWA (Pl. 4, fig. 6); Sasaoka Fm., Akita Pref., localities MANGANJI 1 (Pl. 4, fig. 7) and MANGANJI 2; Sawane Fm., Niigata Pref., locality SAWANE 4 (Pl. 4, fig. 8); Haizume Fm., Niigata Pref., localities HAIZUME 1 and HAIZUME 2; Yamadahama Fm., Fukushima Pref., locality FUTATSUNUMA 1 (Pl. 4, fig. 9); Natsukawa Fm., Toyama Pref., locality ISURUGI (Pl. 4, fig. 10); Omma Fm., Ishikawa Pref., localities OMMA 1, OMMA 2, OMMA 4 (Pl. 4, fig. 19), OMMA 5, and OMMA 6.

Upper Pleistocene: Shibikawa Fm., Akita Pref., localities ANDEN (Pl. 4, fig. 11) and WAKIMOTO; Semata Fm., Chiba Pref., locality SEMATA (Pl. 4, fig. 12).

Euspira yokoyamai
(Kuroda and Habe, 1952)
Plate 3, figures 14–22;
Text-figures 5.1, 12.2, 15.5; Table 10

Pollinices [*sic*] *pallidus* (Broderip and Sowerby). Yokoyama, 1920, p. 77, pl. 4, figs. 1a–b [not *Euspira pallida* (Broderip and Sowerby, 1829)].

Polinices pallidus (Broderip and Sowerby). Yokoyama, 1928c, p. 124, pl. 19, fig. 3 [not *Euspira pallida* (Broderip and Sowerby, 1829)].

Euspira cf. *E. pallida* (Broderip and Sowerby). MacNeil, 1960, p. 57, pl. 2, figs. 20, 26 [not *E. pallida* (Broderip and Sowerby, 1829)].

Lunatia pallida (Broderip and Sowerby). Shuto, 1964, pp. 288–289, pl. 43, figs. 4, 6–8, 11, 13 [not *Euspira pallida* (Broderip and Sowerby, 1829)].

Gennaeosinum (?) *yokoyamai* Kuroda and Habe, 1952, pp. 12, 59.

Uberella yokoyamai (Kuroda and Habe). Taki and Oyama, 1954, p. 17, pl. 5, figs. 1a–b; Oyama, 1973, p. 31, pl. 7, figs. 11a–b; Mori and Osada, 1979, pl. 2, fig. 10.

Not *Uberella yokoyamai* (Kuroda and Habe). Ozaki, 1958, pp. 144–145, pl. 15, fig. 8, pl. 19, fig. 7 [= *Euspira pallida* (Broderip and Sowerby, 1829)].

Lunatia yokoyamai (Kuroda and Habe). Oyama, 1969, p. 76, pl. 4, figs. 1a–b.

Euspira yokoyamai (Kuroda and Habe). Kuroda, Habe, and Oyama, 1971, p. 186 [in Japanese], pp. 121–122 [in English], pl. 109, fig. 4.

Natica sp. aff. *N. stellatus* Hedley. MacNeil, 1960, p. 55, pl. 8, figs. 6, 7 [not *N. stellatus* Hedley, 1913].

Lectotype.—UMUT CM20231 (missing: Oyama, 1973; Ichikawa, 1983), designated by Oyama (1973), from Koshiba, Kanazawa-Shiba-machi, Kanazawa-ku, Yokohama City, Kanagawa Prefecture, lower Pleistocene Koshiba Formation.

Description.—Shell small and globose; spire low; shell thickness average; body whorl greatly to moderately inflated, commonly evenly rounded; suture deeply to shallowly incised, may be circumscribed by a somewhat sharp angulation; whorls five in larger specimens (boundary between nuclear and postnuclear whorls is indistinct because the apical surfaces of all examined specimens are eroded); sculpture of very weakly developed incremental growth lines that are most distinct below suture and on base. Parietal callus thin, slightly filling posterior apertural angle; anterior lobe distinct,

Table 11.—Measurements (in mm) and counts of the holotype of "*Euspira*" *aritensis* Shuto and Ueda, 1967.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*
middle Oligocene	ARITA 1	5.7	5.6	4.7	4.8	4½	GK L7974 (holotype)

overhanging umbilicus. Umbilicus moderately to narrowly open; umbilical callus nearly lacking. Anterior inner lip moderate in thickness, smoothly merges with anterior lobe of parietal callus; outer lip thin; basal lip moderately thickened, slightly reflexed.

Discussion.—*Euspira yokoyamai* is characterized by its globose shell, incised suture, and simple anterior inner lip without any umbilical callus. Pliocene specimens seem to be slightly different from Holocene specimens. The Holocene specimens have distinctly incised sutures and moderately open umbilici whereas the sutural incisions of the Pliocene fossils are weak and their umbilici are relatively more closed.

Compared with *Euspira pallida* (Broderip and Sowerby, 1829), the species most similar to *E. yokoyamai*, *E. yokoyamai* has a narrower range of variation in its umbilical morphologies and shell form. The different ranges of morphological variation of the two species are one of the distinct characters used to discriminate them; that is, *E. yokoyamai* never has a semicircular umbilical callus, a closed umbilicus, or a globose-elongate form, which are observable in morphological variation of *E. pallida*. The end form of the variation of *E. pallida*, which has a simple anterior inner lip and an open umbilicus (Text-figs. 11.1c, 11.2c, 11.3c, 11.4c, 11.5c, 11.6c, 11.7c), greatly resembles *E. yokoyamai*, but this end variant of *E. pallida* never possesses incised sutures. As mentioned above, Pliocene individuals of *E. yokoyamai* possess more weakly incised sutures than Holocene specimens. This is interpreted to be a character intermediate between *E. pallida* and *E. yokoyamai*. *Euspira yokoyamai* is considered to have evolved from *E. pallida* in early Pliocene time.

Euspira mitsuganoensis Shibata, 1970 resembles *E. yokoyamai*, but the former species differs from the latter by having a distinctly angular base and a wider umbilicus. *Euspira yokoyamai* possesses an entirely rounded base and a moderately to narrowly open umbilicus.

Euspira yokoyamai is an endemic species in early Pliocene to Holocene warm-water faunas of Japan, and is one of the important elements of the Pliocene and lower Pleistocene warm-water Kakegawa fauna, in which it has been previously misidentified with *E. pallida*, a characteristic element of the cold-water Omma-Manganji fauna, by MacNeil (1960: as *Euspira* cf. *E. pallida*) and Shuto (1964). Ozaki (1958) reported *E. yokoyamai* from the lower Pleistocene Iioka Formation that yields the Omma-Manganji fauna, but the specimens from the Iioka (Pl. 3, figs. 10–12; Text-fig. 11.1a–11.4c) are identified with *E. pallida*. Ozaki (1958) misidentified *E. pallida* with *E. yokoyamai*.

Stratigraphic occurrence.—

Pliocene and lower Pleistocene: Narusawa Fm., Aomori Pref., locality KITAKANEGASAWA (Pl. 3, fig. 16); Mandano Fm., Chiba Pref., locality KIMITSU 1 (Pl. 3, fig. 15); Nojima Fm., Kanagawa Pref., locality NOJIMA 1 (Pl. 3, fig. 17); Koshiba Fm., Kanagawa Pref. [Yokoyama, 1920; as "*Pollinices* [*sic*] *pallidus* (Broderip and Sowerby)"]; Tenno Member of Lower Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 18 (Pl. 3, fig. 18); Ananai Fm. Kochi Pref., locality TONOHAMA 1; Tsuma Member of Koyu Fm., Miyazaki Pref., locality MIYAZAKI 8; Takanabe Member of Koyu Fm., localities MIYAZAKI 1, MIYAZAKI 2 (Pl. 3, fig. 19), MIYAZAKI 3 (Pl. 3, fig. 20), MIYAZAKI 4, MIYAZAKI 9, and MIYAZAKI 10; Yonabaru Fm., Okinawa Pref. [MacNeil, 1960; as "*Euspira* cf. *E. pallida* (Broderip and Sowerby, 1829)"]; Shinzato Fm., Okinawa Pref., localities SHINZATO 1 (Pl. 3, fig. 21), SHINZATO 2 (Pl. 3, fig. 22), SHINZATO 3, SHINZATO 4, SHINZATO 5, SHINZATO 6, and SHINZATO 9.

Upper Pleistocene: unnamed Fm., Ishikawa Pref. [Yokoyama, 1928c; as "*Polinices pallidus* (Broderip and Sowerby)"]; Semata Fm., Chiba Pref., locality SEMATA; Lower Shimoda Fm., Kanagawa Pref. (Mori and Osada, 1979).

"Euspira" aritensis Shuto and Ueda, 1967
Plate 3, figure 23; Table 11

Euspira aritensis Shuto and Ueda, 1967, pp. 34–36, pl. 2, figs. 4–7.

Holotype.—GK L7974 (Pl. 3, fig. 23), from roadcut north of Obo, Arita-machi, Nishi-Matsuura-gun, Saga Prefecture, middle Oligocene Kishima Formation (Shuto and Ueda, 1967).

Discussion.—The original specimens of "*Euspira*" *aritensis* are very small, less than about 8 mm in maximum diameter, but Shuto and Ueda (1967) considered the specimens to be adults because they have five whorls. Five whorls represent the full adult stage in other species of *Euspira*.

The present species is tentatively placed in *Euspira* because of its globose shell and open umbilicus, although the umbilical parts of the specimens are imperfect.

Though Shuto and Ueda (1967) mentioned that "there is no comparable species in Japan and East Asia," *Euspira sultani* (Martin, 1914) from the Eocene of Java, Indonesia, is very similar to "*E.*" *aritensis*.

Stratigraphic occurrence.—
Middle Oligocene: Kishima Fm., Saga Pref., locality ARITA 1 (Pl. 3, fig. 23).

Genus POLINICES Montfort, 1810

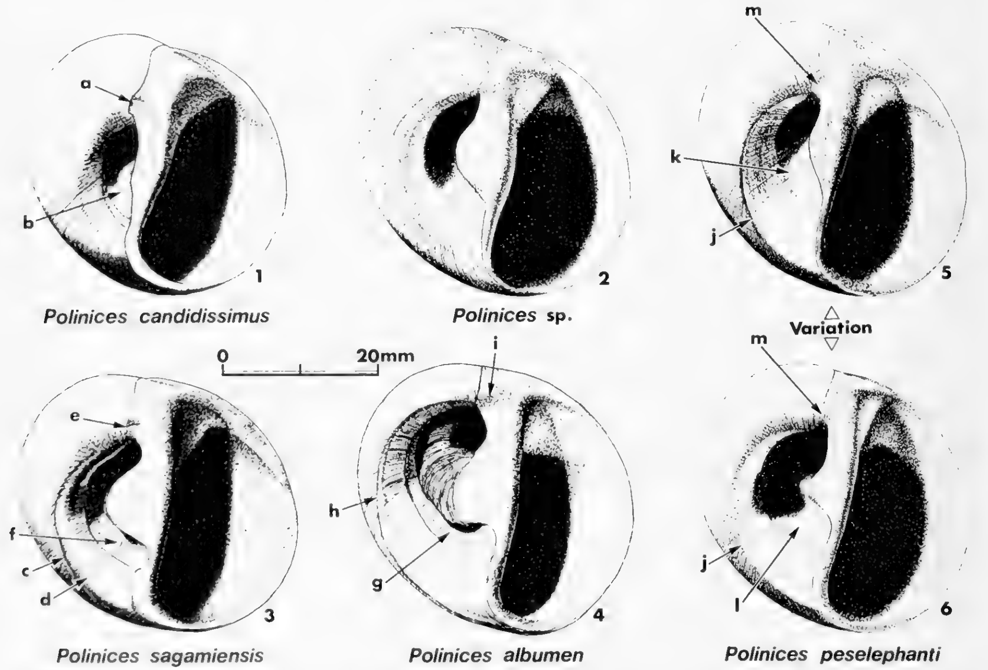
Type species.—*Polinices albus* Montfort, 1810 [? = *Nerita mammilla* Linnaeus, 1758 ? = *Natica lacteus* Guilding, 1834 (Text-fig. 18.1a–c)], by original designation, ? living in West Indies.

Discussion.—*Polinices* is characterized by its stout shell, globose to globose-elongate form, massive umbilical callus, and by commonly having a shallow transverse groove or a dimple at the juncture between parietal callus and umbilical callus (Text-fig. 17 [arrows **a**, **e**, **i**, **m**]).

The status of the type species is unsettled, because: (1) Montfort's (1810) original indication for *Polinices albus* Montfort, 1810, the type species by original designation, is very poor, and no one has yet identified *P. albus* with any valid species; (2) it is not clear whether Montfort (1810) considered *Nerita mammilla* Linnaeus, 1758 to be synonymous with *Polinices albus* or to be an another example of *Polinices*.

There seems to be no easy way to judge the status of the type species of *Polinices*, but on the assumption that *P. albus* is synonymous with *N. mammilla*, the following discussions compiled from previous studies may be helpful.

"The original presentation by Linné in 1758 of *Nerita mammilla* covered different though allied species from both the East and West Indies. Of these most authors have chosen the Oriental shell of Rumphius to carry the name. But the Linnean shell should be interpreted as *N. lactea* Guilding, or a related form, because four out of five citations belong to the West Indian form, which besides is described as from 'Barbados' and as 'umbilicata'." (Hedley, 1924, p. 161). "Woodring (1957) places *Polinices albus* in the synonymy of the Caribbean *Natica brunnea* Link, 1807 (= *Albula hepatica* Röding, 1798). The species *Polin-*



Text-figure 17.—Basal views of (1) *Polinices candidissimus* (Le Guillou, 1842), (2) *P.* sp., (3) *P. sagamiensis* Pilsbry, 1904, (4) *P. albumen* (Linnaeus, 1758), and (5, 6) *P. peselephanti* (Link, 1807). Species of *Polinices* commonly have a shallow transverse groove or a dimple (arrows **a**, **e**, **i** and **m**) at the juncture between parietal callus and umbilical callus, and a distinct spiral groove (arrows **b**, **f**, **g** and **l**) on the umbilical wall. *Polinices albumen* and *P. peselephanti* have a spiral angulation separating the body-whorl side from the umbilical wall, where growth lines are sharply bent (arrows **h** and **j**). *Polinices sagamiensis* also has bending growth lines whereas its base is rounded (arrow **d**) and the flexure points of the growth lines are located on a spiral striation (arrow **c**) slightly outside of the bottom (arrow **d**) of the base.

Table 12.—Measurements (in mm) and counts of the holotype of *Polinices didymoides* Kanno and Matsuno, 1960.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*
lower middle Miocene	CHIKUBETSU 1	48.7	49.2	40.0	39.6	4+	TKD 5510 (holotype)

ices hepaticus (Röding) is a tan or orange-brown species" (Cernohorsky, 1971, p. 191), "whereas *P. albus* was described (and named) as white" (Marincovich, 1977, p. 246). Therefore, if *P. albus* is considered to be synonymous with *N. mammilla* Linnaeus, the type species of *Polinices* might be identified with the Caribbean, white, and umbilicate species, *P. lacteus* (Guilding, 1834) (Text-fig. 18.1a–c). Cernohorsky (1971, p. 191) mentioned that "*Polinices albus* is most probably synonymous with *Nerita mammilla* Linnaeus, a dubious taxon which may be an earlier name for *Polinices lacteus* (Guilding) from the West Indies."

Oyama (1969) classified the modern Japanese species of *Polinices* into the following three groups [the species classified in each group are modified in part from those of Oyama (1969), reflecting my opinion]:

Group **A**: shell nearly globose, height almost equal to width; umbilicus slenderly open; umbilical callus not well developed. *Polinices candidissimus* (Le Guillou, 1842) (Text-fig. 17.1).

Group **B**: shell ovate to greatly depressed; umbilicus widely open, U-shaped due to being largely covered by a well developed semicircular umbilical callus; callus clearly divided into parietal and umbilical calluses by a deep and wide sulcus. *Polinices peselephanti* (Link, 1807) (Text-figs. 17.5, 17.6), *P. vestitus* Kuroda, 1961, *P. sagamiensis* Pilsbry, 1904 (Text-fig. 17.3), *P. albumen* (Linnaeus, 1758) (Text-fig. 17.4), and *P.* sp. (Text-fig. 17.2).

Group **C**: shell globose-elongate, spire largely elevated; umbilicus largely to entirely covered by a greatly developed umbilical callus; parietal callus smoothly merges with umbilical callus. *Polinices flemingianus* (Récluz, 1844) (Text-fig. 18.3a–c), *P. mellosus* (Hedley, 1924) (Text-fig. 18.4a–c), *P. tumidus* (Swainson, 1840) (Text-fig. 18.2a–c), and *P. aurantius* (Röding. 1798).

In species of the above three groups, a shallow transverse groove or dimple is commonly recognized at the juncture between the parietal and umbilical calluses (Text-fig. 17 [arrows **a**, **e**, **i**, **m**]).

In addition to the above three groups, a fourth group is based on a fossil species, the lower middle Miocene *Polinices didymoides* Kanno and Matsuno, 1960 (Pl. 10, fig. 14), as follows.

Group **D**: shell globose; umbilicus narrowly open; umbilical callus slender, evenly tapering anteriorly; no shallow transverse groove or dimple at juncture between umbilical and parietal calluses, where instead the callosity is weakly elevated.

These four groups are arranged according to the increasing degree of development of their umbilical calluses, *i.e.*, **D** ➡ **A** ➡ **B** ➡ **C**, in which order the species of *Polinices* described below are arranged.

Polinices didymoides
Kanno and Matsuno, 1960
Plate 10, figure 14; Table 12

Polinices didymoides Kanno and Matsuno, 1960, p. 43, pl. 5, figs. 7a–b.

Holotype.—TKD 5510 (Pl. 10, fig. 14), from the upper stream of the Chipotsunai River, a tributary of the Kotanbetsu River, northwestern Hokkaido, the lower member of the lower middle Miocene Sankebetsu Formation (loc. 732 of Kanno and Matsuno, 1960).

Description.—Shell relatively large for genus, globose, spire weakly elevated; suture moderately impressed; body whorl greatly inflated, evenly rounded; whorls about five (apex eroded), sculptured with incremental, regularly arranged but irregularly developed growth lines that are well developed below suture and on base; shell moderately thick. Parietal callus moderately thickened, moderately filling posterior apertural angle; anterior lobe very weak. Umbilicus minutely open (its depth undetermined due to being filled with very hard matrix); umbilical callus slender, smooth, regularly tapering anteriorly, and smoothly merges with parietal callus, where the callus is weakly elevated. Anterior inner lip greatly thickened; basal lip missing.

Discussion.—There is no other verified specimen of *Polinices didymoides* except for the holotype (Pl. 10, fig. 14). O'hara (1966, table 2), and O'hara and Kanno (1973, p. 129) listed *P. didymoides* from the lower middle Miocene Shin-Uryu Formation, northwestern Hokkaido, but these occurrences need confirmation.

It is interesting that *P. didymoides* is very similar to *Polinices hornii* (Gabb, 1864) (Pl. 10, fig. 15), from the upper Paleocene to upper Eocene of western North America. However, the two species are slightly different in size, degree of umbilical opening, and inferred environmental preference. The largest specimen of *P. hornii* attains 31.2 mm in height and 31.1 mm in diameter (Marincovich, 1977), but the holotype of *P. didymoides* is 48.7 mm in height and 48.2 mm in maximum diameter (Table 12). Marincovich (1977, p. 262) mentioned that "all of the largest specimens" of *P. hornii* "are imperforate", but the holotype of *P. didymoides* has a narrow umbilicus. Marincovich (1977)

Table 13.—Measurements (in mm) and counts of the largest specimen of *Polinices candidissimus* (Le Guillou, 1842) at each locality. Localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
Pliocene and lower Pleistocene	NOJIMA 1	15.8	24.0	20.7	19.6	4+	GIYU 589-1	26
	NOJIMA 3	15.9	16.7	13.7	13.5	4+	GIYU 594-1	5
	NOJIMA 4	13.3	13.9	10.4	11.3	3+	GIYU 595	1
	YONABARU 3	26.3	28.6	21.5	22.1	3½+	IGUT 16078	1

considered *P. hornii* to be an indicator of a tropical climate, but *P. didymoides* is associated with molluscs indicating "rather warm to temperate thermal conditions" (Kanno and Matsuno, 1960).

There is no other species morphologically similar to both *P. hornii* and *P. didymoides* among Cenozoic naticid faunas of the northern Pacific. *Polinices didymoides* is, therefore, considered to have evolved from an ancestral stock in western North America.

Stratigraphic occurrence.—

Lower middle Miocene: Sankebetsu Fm., Hokkaido, locality CHIKUBETSU 1 (Pl. 10, fig. 14).

Polinices candidissimus
(Le Guillou, 1842)
Plate 8, figures 13–16;
Text-figure 17.1; Table 13

Natica candidissima Le Guillou, 1842, p. 105; Reeve, 1855, pl. 8, fig. 28; Sowerby, 1883, p. 85, pl. 3, fig. 26; Tryon, 1886, p. 46, pl. 16, fig. 49, pl. 19, fig. 95.
Not *Natica candidissima* Récluz, 1851, p. 87, pl. 2, fig. 3 [homonym; living, Bahia, Brazil].
Polinices candidissimus (Le Guillon) [*sic*]. Kuroda, Habe, and Oyama, 1971, p. 183 [in Japanese], p. 120 [in English], pl. 18, fig. 4.
Natica jukesii Reeve, 1855, pl. 19, figs. 84a–b; Sowerby, 1883, p. 88, pl. 5, fig. 55.
Natica (*Polinices*) *jukesii* Reeve. Martin, 1905, p. 265, pl. 39, figs. 638, 639.
Uber jukesii (Reeve). Hedley, 1924, p. 156.
Polinices ? *jukesii* (Reeve). Kuroda and Habe, 1952, p. 78.
Polinices jukesi [*sic*] (Reeve). Oyama, 1969, p. 78.
Polinices cf. *P. flemingianus* (Récluz). MacNeil, 1960, pp. 53–54, pl. 8, fig. 3 [not *P. flemingianus* (Récluz, 1844)].
Neverita (*Glossaulax*) *reiniana* Dunker. Shikama and Masujima, 1969, table 3(1) [without description and illustration; not *N.* (*G.*) *reiniana* Dunker, 1877].

Types.—

Natica candidissima Le Guillou: type material unknown; type locality, Moluccas, Indonesia (Reeve, 1855).

Natica jukesii Reeve: type material unknown; type locality, north Australia (Reeve, 1855).

Description.—Shell small to medium in size and globose in form, spire weakly to moderately elevated; body whorl greatly inflated, evenly rounded; suture weakly impressed; nuclear whorls one-and-three-fourths, smooth; postnuclear whorls four in larger specimens; axial sculpture of incremental, weakly developed growth lines that are most distinct below suture; spiral sculpture of very minute, closely spaced, minutely wavy costellae that are commonly indistinct in fossil specimens. Parietal callus moderately to greatly thickened and moderately filling posterior apertural angle; anterior lobe distinct, bearing a transverse groove or depression just above the lobe (Text-fig. 17 [arrow **a**]). Umbilicus moderately to widely open, deep; umbilical callus not well developed, smooth, tapering anteriorly, may be weakly expanded at its anterior end; funicle commonly very weak; umbilical wall smoothly merges with the body-whorl side without angulation, bearing a shallow but wide spiral groove (Text-fig. 17 [arrow **b**]) along funicle. Anterior inner lip and basal lip moderately to greatly thickened.

Discussion.—*Polinices candidissimus* is characterized by its globose form, moderately to widely open umbilicus, and weakly developed umbilical callus. In Japan, it is the morphologically most distinctive species among Pliocene to Holocene species of *Polinices.*

Although *P. candidissimus* and *Glossaulax reiniana* (Dunker, 1877) (Text-fig. 20.5, Pl. 6, figs. 19–25) are classified into different genera, they are closely similar in shell form, in callus morphology, and in having a distinct spiral groove along the funicle. However, *G. reiniana* differs from *P. candidissimus* by having its transverse umbilical callus groove situated on a slightly more posterior portion of the umbilical callus (Text-fig. 20.5). Though *P. candidissimus* possesses a transverse callus groove (or depression), the groove is always situated just above the anterior lobe of the parietal callus (Text-fig. 17 [arrow **a**]). Modern specimens of the two species have distinctly different shell colors. The whorls of *P. candidissimus* are white but those of *G. reiniana* are pale brown with a yellowish subsutural band. On one modern specimen of *P. candidissimus* I have seen, a thin, pale brownish periostracum covers the whole shell except for the callus (Pl. 8, fig. 16), although the shell beneath is white.

Polinices candidissimus occurs in the Pliocene Yonabaru and Shinzato formations in Okinawa Prefecture, where it was misidentified as *Polinices flemingianus* (Récluz, 1844) by MacNeil (1960, as *Polinices* cf. *P.*

Table 14.—Measurements (in mm) and counts of the largest specimen of *Polinices sagamiensis* Pilsbry, 1904 at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of speci-mens in lot*
Pliocene and lower Pleistocene	NOJIMA 1	39.8	43.3+	35.5	33.2	2+	GIYU 596-1	3
	KAKEGAWA 1	53.8	50.6	43.0	43.5	3+	IGUT 15721-5	5
	KAKEGAWA 2	47.9	47.4+	38.4	38.8	5+	IGUT 15806-2	4
	KAKEGAWA 17	42.9	40.2	31.3	33.1	4+	IGUT 15807	1
	TONOHAMA 2	29.3	29.2	23.3	25.0	3+	IGUT 15808	1
upper Pleistocene	HIRADOKO	25.4	29.1	22.4	21.0	5	IGUT 15809-1	2
	SAKURAI	38.7	41.7	31.6	30.0	5½	IGUT 16081-1	4

flemingianus). *Polinices flemingianus* (Text-fig. 18.3a–c) differs from *P. candidissimus* by having an elongate shell and a distinctly developed umbilical callus.

Stratigraphic occurrence.—

Pliocene and lower Pleistocene: Nojima Fm., Kanagawa Pref., localities NOJIMA 1 (Pl. 8, fig. 14), NOJIMA 3, and NOJIMA 4 (Pl. 8, fig. 13); Yonabaru Fm., Okinawa Pref., locality YONABARU 3 (Pl. 8, fig. 15); Shinzato Fm., Okinawa Pref. [MacNeil, 1960; as *Polinices* cf. *P. flemingianus* (Récluz, 1844)].

Polinices sagamiensis Pilsbry, 1904
Plate 4, figures 23–27;
Text-figures 4.2, 15.13, 15.14, 17.3; Table 14

Polinices sagamiensis Pilsbry, 1904, pp. 23–24, pl. 4, figs. 37, 37a; Makiyama, 1927, pp. 74–75, pl. 3, figs. 1, 2; Yokoyama, 1928b, p. 63, pl. 6, fig. 2; Kuroda and Habe, 1952, p. 78; Kira, 1954, p. 35, pl. 17, fig. 15; Kawamoto, 1956, p. 27, pl. 10, fig. 95; Kira, 1959, p. 41, pl. 17, fig. 15; Azuma, 1961, p. 197, pl. 21, fig. 2 [radula]; Hayasaka, 1961, p. 75, pl. 9, figs. 12a–b; Shikama, 1964, text-fig. 191.6; Oyama, 1969, text-fig. 4; Habe and Kosuge, 1970, p. 48, pl. 18, fig. 29; Kuroda, Habe, and Oyama, 1971, pp. 182–183 [in Japanese], p. 120 [in English], pl. 18, figs. 7, 8; Oyama, 1973, pp. 31–32, pl. 7, figs. 7a–b; Okutani and Habe, 1975, pp. 81 [unnumbered figs.], 172; Inaba, 1976, p. 87, pl. 1, fig. 4 [radula]; Matsuura, 1977, pl. 6, fig. 31; Majima, 1985, pl. 17, figs. Na–b.

Polynices [*sic*] *sagamiensis* Pilsbry. Hirase, 1934, p. 60, pl. 91, fig. 8; Otuka, 1935, p. 866, pl. 53, fig. 36.

Not *Polinices sagamiensis* Pilsbry. Itoigawa and Shibata *in* Morishita, 1977, p. 68, pl. 30, fig. 18 [= *Glossaulax hagenoshitensis* (Shuto, 1964)].

Not *Polinices* (*Neverita*) *sagamiensis* Pilsbry. Shuto, 1964, pp. 281–282, pl. 42, figs. 2, ?8, ?14 [= *Glossaulax hagenoshitensis* (Shuto, 1964): figs. 8 and 14 show imperfect specimens].

Polinices (*Mammillaria*) *sagamiensis* Pilsbry. Taki and Oyama, 1954, p. 17, pl. 24, fig. 12.

Polinices powisianus (Récluz) [not *P. powisianus* (Récluz, 1844)]. Yokoyama, 1922, pp. 83–84, pl. 4, fig. 12; Kira, 1959, p. 41, pl. 17, fig. 16.

Polinices cf. *P. albumen* (Linnaeus). MacNeil, 1960, p. 53, pl. 2, fig. 23, pl. 12, fig. 26 [not *P. albumen* (Linnaeus, 1758)].

Holotype.—ANSP 85956, from Hayama, on Sagami Bay, about four miles from Kamakura, Pacific side of central Japan (Pilsbry, 1904).

Description.—Shell large in size, globose to globose-elongate in form, spire moderately elevated; suture weakly impressed; shell thickness average for genus; body whorl greatly to moderately inflated; shoulder commonly flattened but may be slightly concave; nuclear whorls one-and-one-half, smooth; postnuclear whorls about three-and-one-half in larger specimens. Spiral sculpture of microscopic, minutely wavy, closely spaced costellae that are commonly indistinct in fossil specimens; axial sculpture of incremental growth lines that are most distinct below suture and on base. One spiral striation (Text-fig. 17 [arrow **c**]) runs along slightly outside of the bottom of the base (Text-fig. 17 [arrow **d**]), where the growth lines are slightly but distinctly bent. Parietal callus heavily thickened, greatly filling posterior apertural angle; anterior lobe distinct, weakly overhanging umbilicus, and shallowly and narrowly incised just above the lobe (Text-fig. 17 [arrow **e**]). Umbilicus moderately open, deep, U-shaped; umbilical callus large, semicircular in form, with a strong funicle; sulcus deeply to shallowly channeled; umbilical wall smoothly merges with body-whorl side except for one spiral striation (Text-fig. 17 [arrow **c**]) described above, and shallowly but widely incised by a spiral groove (Text-fig. 17 [arrow **f**]) which occupies about one half of umbilical wall. Outer lip weakly thickened; anterior inner lip and basal lip greatly thickened but the anterior inner lip shallowly to deeply excavated by the spiral groove on the umbilical wall.

Discussion.—*Polinices sagamiensis* is characterized by its globose to globose-elongate form, distinct spiral groove (Text-fig. 17 [arrow **f**]) on the umbilical wall, and rounded base bearing a spiral striation (Text-fig. 17 [arrow **c**]), which consists of the flexures of the growth lines. A spiral area located between the umbilical spiral groove and the basal spiral striation makes a "strong cord around the umbilical crescent", as originally described by Pilsbry (1904).

Polinices sagamiensis is closely allied to *Polinices albumen* (Linnaeus, 1758), *P. peselephanti* (Link, 1807), *P. vestitus* Kuroda, 1961, and *P.* sp. (Text-fig. 17.2), all of which are classified into the Group **B** mentioned

Table 15.—Measurements (in mm) and counts of the largest specimen of *Polinices peselephanti* (Link, 1807) at each locality.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of speci-mens in lot*
upper Pleistocene	KIKAI 1	30.0	30.5	23.4	26.5	5	GIYU 524	1
	KIKAI 2	32.0	34.3	25.9	28.3	5	GIYU 523-1	6

in the discussion of the genus *Polinices*. A comparison of their characteristics is as follows:

Polinices albumen (Text-fig. 17.4) is characterized by its laterally compressed shell and very large umbilical callus with a very strong funicle. The shell of *P. albumen* closely resembles that of *P. sagamiensis* in having a shallow but wide spiral groove on the umbilical wall (Text-fig. 17 [arrow **g**]) and a basal spiral striation (Text-fig. 17 [arrow **h**]) consisting of flexures of the growth lines. However, *P. albumen* has a depressed shell, angulate base, larger umbilical callus, and a weaker depression (Text-fig. 17 [arrow **i**]) at the anterior lobe of the parietal callus than does *P. sagamiensis*.

Polinices peselephanti (Text-figs. 17.5, 17.6) is characterized by having a spiral angulation (Text-fig. 17 [arrow **j**]) separating the body-whorl side from the umbilical wall, a weaker spiral groove on the umbilical wall (Text-fig. 17 [arrows **k** and **l**]), and a relatively weakly developed umbilical callus. *Polinices peselephanti* has two end morphs for the shape of its umbilical callus. One end morph (Text-fig. 17.5) has a weakly developed umbilical callus like that of *P. candidissimus* (Text-figure 17.1) and the other (Text-fig. 17.6) has a moderately developed semicircular umbilical callus comparable to that of *P. sagamiensis* (Text-fig. 17.3). Generally, the former end morph has a weaker umbilical groove (Text-fig. 17 [arrow **k**]) than the latter (Text-fig. 17 [arrow **l**]). The growth lines are sharply bent at the bottom part of the shell and the bends coincide exactly with the spiral angulation separating the body-whorl side from the umbilical wall (Text-fig. 17 [arrow **j**]). This is the most important character for discriminating *P. peselephanti* from *P. sagamiensis*. Although the growth lines of the latter species are also bent, their flexure points are on a spiral striation (Text-fig. 17 [arrow **c**]) located slightly outside of the bottom (Text-fig. 17 [arrow **d**]) of the rounded base.

Polinices vestitus is characterized by a reddish-brown periostracum covering the whorls, a weakly developed spiral groove on the umbilical wall, and an indistinct basal spiral striation consisting of the bending of the growth lines. Besides the characteristics just mentioned, Kuroda (1961) characterized *P. vestitus* as having a shell that "is of somewhat earthenware" in appearance, "not porcelainous as in many *Polinices* (s.s.)."

Polinices sp. (Text-fig. 17.2) is characterized by irregularly but distinctly developed spiral costellae, and a smoothly rounded base without any spiral striation and angulation. There is no valid species name which is applicable to the present unnamed species. However, specimens available for study are few in number, so the present species remains unnamed.

Stratigraphic occurrence.—

Pliocene and lower Pleistocene: Nojima Fm., Kanagawa Pref., locality NOJIMA 1; Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 1 (Pl. 4, figs. 23, 26), KAKEGAWA 2, and KAKEGAWA 17 (Pl. 4, fig. 24); Ananai Fm., Kochi Pref., locality TONOHAMA 2 (Pl. 4. fig. 25); Yonabaru Fm., Okinawa Pref. [MacNeil, 1960, as "*Polinices* cf. *P. albumen* (Linnaeus, 1758)"]; Chinen Sandstone, Okinawa Pref. [MacNeil, 1960: as "*Polinices* cf. *P. albumen* (Linnaeus, 1758)"].

Upper Pleistocene: Hiradoko Fm., Ishikawa Pref., locality HIRADOKO; Sakurai Fm., Chiba Pref., locality SAKURAI; Toshima Sand of Toyohashi Group, Aichi Pref. (Hayasaka, 1961).

Polinices peselephanti (Link, 1807)
Plate 4, figures 21–22;
Text-figures 17.5, 17.6; Table 15

Natica peselephanti Link, 1807, p. 140 [not seen].
Polinices (*Neverita*) *peselephanti* (Link). Cernohorsky, 1972, p. 99, pl. 26, fig. 5; Kilburn, 1976, pp. 857–859, text-figs. 16a–c.
Natica powisiana Récluz, 1844, pp. 210–211; Philippi, 1852, p. 46, pl. 7, fig. 4; Reeve, 1855, pl. 6, figs. 22a–b; Sowerby, 1883, p. 83, pl. 3, fig. 32.
Natica (*Neverita*) *powisiana* Récluz. Uchiyama, 1902c, p. 429, pl. 27, fig. 30–32.
Natica (*Polinices*) *powisiana* Récluz. Martin, 1905, pp. 263–265 [in part ?], pl. 39, figs. 633, 633a, ?634, 635–637a; Fischer, 1927, p. 47 [in part ?]. pl. 212, figs. 8, 9, ?10.
Uber powisianum (Récluz). Hedley, 1924, p. 160.
Polinices powisianus (Récluz). Habe and Kosuge, 1965, p. 36, pl. 12, fig. 21; Oyama, 1969, p. 78; Cernohorsky, 1972, p. 99, pl. 26, fig. 1; Okutani and Habe, 1975, pp. 81 [unnumbered figs.], 179.
Not *Polinices powisianus* (Récluz) [= *Polinices sagamiensis* Pilsbry, 1904]. Yokoyama, 1922, p. 83, pl. 4, fig. 12; Kira, 1959, p. 41, pl. 17, fig. 16.
Mammillaria powisiana (Récluz). Wilson and Gillett, 1980, p. 38, pl. 18, figs. 5, 5a.
Natica columnaris Récluz, 1850, p. 394–395; Reeve, 1855, pl. 5, figs. 19a–b; Sowerby, 1883, p. 78, pl. 3, fig. 37; Tryon, 1886, p. 47, pl. 20, fig. 4.
Polinices columnaris (Récluz), Shikama, 1964, text-fig. 191.5.

Table 16.—Measurements (in mm) and counts of the holotype and of the largest specimen of *Polinices mizunamiensis* Itoigawa, 1960 at each locality. Localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of speci-mens in lot*
lower middle Miocene	HIGASHI-INNAI 1	8.5	8.3	6.6	7.1	3+	IGUT 15981	1
	YATSUO 2	15.1	14.0	11.4	11.7	4+	IGUT 15983-1	3
	YATSUO 3	12.7	12.2	10.0	10.4	4½+	IGUT 15982-1	4
	MIZUNAMI 5	13.0	12.2	9.6	11.0	4+	IGUT 15984-1	4
	MIZUNAMI 5	12.9	10.5	8.1	10.7	5	ESN 20059 (holotype)	—

Types.—

Natica peselephanti Link: type material unknown; type locality unknown [= Tranquebar, India (Chemnitz, 1781): *fide* Kilburn, 1976].

Natica powisiana Récluz: type material unknown; type locality, Molluccas, Indonesia (Récluz, 1844).

Natica columnaris Récluz: type material unknown; type locality, Manila, Philippines (Récluz, 1850).

Description.—Shell large in size, globose to globose-elongate in form, spire weakly to moderately elevated; body whorl greatly inflated; shoulder slightly concave; shell thickness slightly thin for genus; nuclear whorls one-and-one-half, smooth; postnuclear whorls four in larger specimens (Holocene). Axial sculpture of very weakly developed incremental growth lines that are most distinct below suture and on base; spiral sculpture of microscopic, minutely wavy, dense costellae. Parietal callus moderately to greatly thickened, moderately filling posterior apertural angle; anterior lobe distinct, overhanging umbilicus, slightly dimpled from callus surface (Text-fig. 17 [arrow **m**]). Umbilicus widely open, U-shaped, circumscribed by a clearly to obscurely developed basal spiral angulation (Text-fig. 17 [arrow **j**]) where the growth lines are sharply bent; sulcus wide, shallow to deep; umbilical callus smooth, variation in form represented by the following two end morphs: the callus of one end morph (Text-fig. 17.6) is semicircular, moderately developed, with a distinct funicle circumscribed by a shallow but distinct spiral groove (Text-fig. 17 [arrow **l**]) on the umbilical wall, whereas the callus of the other end morph (Text-fig. 17.5) is weak, gently tapering anteriorly and posteriorly, lacking both a distinct funicle and the distinct spiral umbilical groove (Text-fig. 17 [arrow **k**). The two end morphs are separated by a continuous range of intermediate forms. Outer lip slightly thickened; anterior inner lip and basal lip moderately thickened but the former lip may be slightly excavated by a spiral groove on the umbilical wall.

Discussion.—A comparison of the characters of *P. peselephanti* with those of allied species is given in the discussion of *P. sagamiensis* Pilsbry, 1904.

Some workers have illustrated fossil specimens with a very large umbilical callus nearly covering the umbilicus under the name of *powisiana* (Martin, 1905, pl. 39, fig. 634; Fischer, 1927, pl. 212, fig. 10), from Neogene deposits of the East Indies. However, I have not observed such a variant among either fossil or modern specimens of *P. peselephanti.*

Stratigraphic occurrence.—

Upper Pleistocene: Ryukyu Limestone, Kagoshima Pref., localities KIKAI 1 and KIKAI 2 (Pl. 4, fig. 22).

Polinices mizunamiensis Itoigawa, 1960
Plate 8, figures 17–21;
Text-figures 3.2, 19.2; Table 16

Polinices mizunamiensis Itoigawa, 1960, pp. 283–284, pl. 4, figs. 10a–c; Itoigawa *in* Itoigawa, Shibata, and Nishimoto, 1974, p. 148, pl. 45, figs. 9a–b; Itoigawa *et al.*, 1981, pl. 34, figs. 9a–b; Itoigawa *et al.*, 1982, pp. 195–196.

Neverita coticazae (Makiyama). Itoigawa *in* Itoigawa, Shibata, and Nishimoto, 1974, p. 148 [in part], pl. 45, fig. 5 [not *Glossaulax didyma coticazae* (Makiyama, 1926); not figs. 10a–b = *G. didyma coticazae* (Makiyama)].

Holotype.—ESN 20059 (Pl. 8, fig. 20), from a river cliff at Shukunohora, Hiyoshi-machi, Mizunami City, Gifu Prefecture, lower middle Miocene Shukunohora Sandstone of Mizunami Group (loc. S41 of Itoigawa, 1960).

Description.—Shell very small, elongate to globose-elongate, spire moderately to greatly elevated; body whorl not greatly inflated, shoulder minutely concave; suture moderately impressed; nuclear whorls two-and-one-half, smooth; postnuclear whorls about three-and-one-half in larger specimens, sculptured with incremental growth lines; shell thickness relatively thin for genus; base commonly rounded, but may be spirally slightly angulated. Parietal callus thick, greatly filling posterior apertural angle; anterior lobe distinct to weak, overhanging umbilicus. Umbilicus widely to moderately open; umbilical callus moderately developed, tapering anteriorly or abruptly pinched off at its anterior end, commonly smoothly merges with anterior lobe of parietal callus, where the callosity may be traversed by a very shallow depression; sulcus weak to nearly lacking; funicle moderately developed, along which a shallow and narrow spiral groove is commonly developed on the umbilical wall. Umbilical wall is sculptured with incremental growth lines that are most distinct within the spiral groove. Anterior inner lip and basal lip moderately thickened.

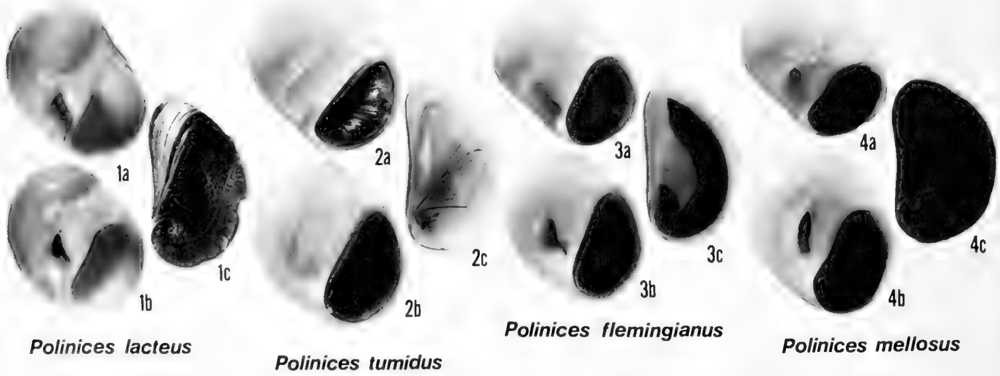
Discussion.—*Polinices mizunamiensis* is characterized by its very small, elongate and perforate shell with two-and-one-half nuclear whorls. Because of its elongate shell, *P. mizunamiensis* is placed in Group **C** mentioned in the discussion of the genus *Polinices.*

It is well known that some species of *Polinices* with elongate shells (Group **C**) exhibit entirely overlapping morphological variations. Marincovich (1977, pp. 248–251) discussed the difficulty of dealing taxonomically with the *Polinices uber* (Valenciennes, 1832) species-group, which includes *P. uber, P. intemeratus* (Philippi, 1851), *P. panamaensis* (Récluz, 1844), and *P. otis* (Broderip and Sowerby, 1829), all living in the tropical eastern Pacific, and mentioned that "these species exhibit overlapping variations in form and umbilical morphology." This is also a problem in some modern western Pacific species of *Polinices* that are very similar to *P. mizunamiensis.* Kuroda and Kikuchi (1972) discussed the taxonomic relations of three western Pacific species of *Polinices*, including *Polinices tumidus* (Swainson, 1840) [cited as *P. pyriformis* (Récluz, 1844), a junior synonym of *P. tumidus* (Swainson, 1840), in Kuroda and Kikuchi (1972)], *P. flemingianus* (Récluz, 1844), and *P. mellosus* (Hedley, 1924). The discussion of Kuroda and Kikuchi (1972), roughly translated from Japanese into English, follows:

When Kikuchi traveled to Yaeyama, in the Ryukyu Islands, he collected a large number of *Polinices tumidus*-like specimens from Kabira Bay, Ishigaki-jima. Those specimens exhibit a wide range of continuous variations in their shell shapes, degree of umbilical opening, and coloration (from pure white to pale yellow). Based on shell morphologies, it seems impossible to divide the specimens into distinct species-level taxa. However, the specimens possess the three different colors of corneous opercula, which are: (1) uniformly orange brown [Text-fig. 18.2c], (2) orange brown with a wide blackish brown band [Text-fig. 18.3c], and (3) uniformly blackish brown [Text-fig. 18.4c]. These three types of corneous opercula can be observed in *Polinices tumidus, P. flemingianus* and *P. mellosus*, respectively. Of these, the shell of *P. tumidus* is slightly different from those of the latter two species in its coloration and in the degree of umbilical opening. The shell of *P. tumidus* is always pure white with a pale black apex, whereas the shells (including apexes) of the other two species vary from pure white to pale yellow. *Polinices tumidus* always possesses a closed umbilicus, whereas the umbilici of *P. flemingianus* and *P. mellosus* range from perforate to imperforate. Based on the nature of their shells, a discrimination between *P. flemingianus* and *P. mellosus* beggars all description.

In addition to the differences mentioned by Kuroda and Kikuchi (1972), *P. tumidus* is distinguishable from both *P. flemingianus* and *P. mellosus* by having a protoconch with about two-and-one-half whorls and a small nucleus (Text-fig. 19.1). The latter two species possess protoconchs with about one-and-one-half whorls and larger nuclei (Text-figs. 19.3, 19.4).

Polinices mizunamiensis is very similar to these three species of *Polinices*, but it differs from *P. tumidus* by its always-open umbilicus, and from both *P. flemingianus* and *P. mellosus* by having a protoconch with about two-and-one-half whorls and a smaller nucleus (Text-fig. 19.2). In other words, the shell form and the umbilical features of *P. mizunamiensis* are very similar to the perforate variants of both *P. flemingianus* (Text-fig. 18.3a–b) and *P. mellosus* (Text-fig. 18.4a–b),



Text-figure 18.—Shells and opercula of (1a–c) *Polinices lacteus* (Guilding, 1834) [? = *Polinices albus* Montfort, 1810, the type species of the genus *Polinices* Montfort, 1810], collected from Boca Chica, Florida Keys, U. S. A. (Holocene), (2a–c) *P. tumidus* (Swainson, 1840), (3a–c) *P. flemingianus* (Récluz, 1844), and (4a–c) *P. mellosus* (Hedley, 1924). 2a–4c were collected from Kabira Bay, Ishigaki-jima, Okinawa Pref. (Holocene). 1a–b (shell), ×1.0, 1c (operculum), ×1.4, NSMT Mo42105; 2a–b (shell), ×1.1, 2c (operculum), ×1.5, IGUT 16091; 3a–b (shell), ×1.2, 3c (operculum), ×2.0, PNK unnumbered; 4a–b (shell), ×1.3, 4c (operculum), ×2.2, IGUT 16092.

Table 17.—Measurements (in mm) and counts of the lectotype of the largest specimen of *Neverita eocenica* (Nagao, 1928a) at localities NAGASAKI 1 and NAGASAKI 3.

stratigraphic position	locality	shell height	maximum diameter	minimum diameter	aperture height	number of whorls	specimen measured	number of specimens in lot
lower Eocene	NAGASAKI 1	10.8+	9.8+	8.7	9.6+	4+	IGPS 35699 (lectotype)	1
	NAGASAKI 3	15.1	13.3+	13.2	11.1	3+	IGUT 15951-4	64

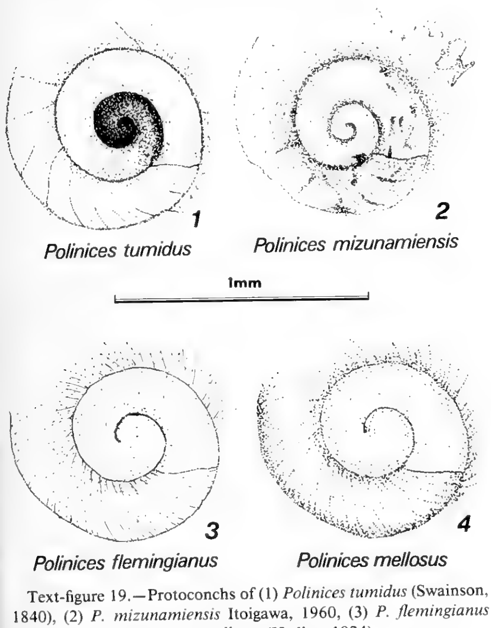
whereas its protoconch (Text-fig. 19.2) is very similar to that of *P. tumidus* (Text-fig. 19.1). Though the operculum of *P. mizunamiensis* is unknown, *P. mizunamiensis* is considered to be a distinct species level taxon, judging from morphological comparison with the three allied species, *P. tumidus*, *P. flemingianus*, and *P. mellosus*.

Stratigraphic occurrence.—

Lower middle Miocene: Higashi-Innai Fm., Ishikawa Pref., locality HIGASHI-INNAI 1; Kashio Member of Yatsuo Fm., Toyama Pref., locality YATSUO 2 (Pl. 8, fig. 18); Joyama Member of Yatsuo Fm., Toyama Pref., locality YATSUO 3 (Pl. 8, fig. 17); Shukunohora Sandstone, Gifu Pref., locality MIZUNAMI 5 (Pl. 8, figs. 19–21).

Genus **NEVERITA** Risso, 1826

Type species.—*Neverita josephinia* Risso, 1826, by monotypy. Eocene to Holocene, Europe.



Text-figure 19.—Protoconchs of (1) *Polinices tumidus* (Swainson, 1840), (2) *P. mizunamiensis* Itoigawa, 1960, (3) *P. flemingianus* (Récluz, 1844), and (4) *P. mellosus* (Hedley, 1924).

Discussion.—*Neverita* is characterized by its globose to weakly depressed shell and massive umbilical callus that is not divided into two lobes by a transverse groove. Species of *Neverita* have *Glossaulax*-like shells but their umbilical calluses are massive.

Neverita eocenica (Nagao, 1928a)

Plate 4, figures 13–15; Table 17

Polynices [*sic*] (*Neverita*) *eocenica* Nagao, 1928a, pp. 118–119, pl. 18, figs. 2a–3.

Neverita eocenica (Nagao). Hatai and Nisiyama, 1952, pp. 235–236; Majima, 1988, text-fig. 3.1a–3.3b.

Polinices (*Glossaulax*) *eocenica* Nagao. Oyama, Mizuno, and Sakamoto, 1960, p. 50, pl. 5, figs. 8a–b.

Lectotype.—IGPS 35699 (Pl. 4, fig. 13), designated by Hatai and Nisiyama (1952, pp. 235–236), from sea cliff W of a 48 m high hill, about 250 m north of Takesaki, Koyagi-jima (Hatai and Nisiyama, 1952), Koyagi-machi, Nishi-Sonogi-gun, Nagasaki Prefecture, lower Eocene Futagojima Formation.

Description.—Shell globose, very small, spire weakly elevated; body whorl not greatly inflated, slightly but distinctly flattened above periphery; whorls four or more (apices of all examined specimens eroded), sculptured with incremental growth lines that are most distinct below suture and on base; shell not greatly thickened. Parietal callus heavy, greatly filling posterior apertural angle; anterior lobe indistinct. Umbilicus narrowly open; umbilical wall smoothly merges with the body-whorl side without any angulation, ornamented with distinct growth lines; umbilical callus greatly thickened, largely filling umbilicus except for anterior and left sides of umbilicus, and smoothly merges with parietal callus; callus may be sculptured with a very weakly developed transverse groove or depression. Anterior inner lip and basal lip thin.

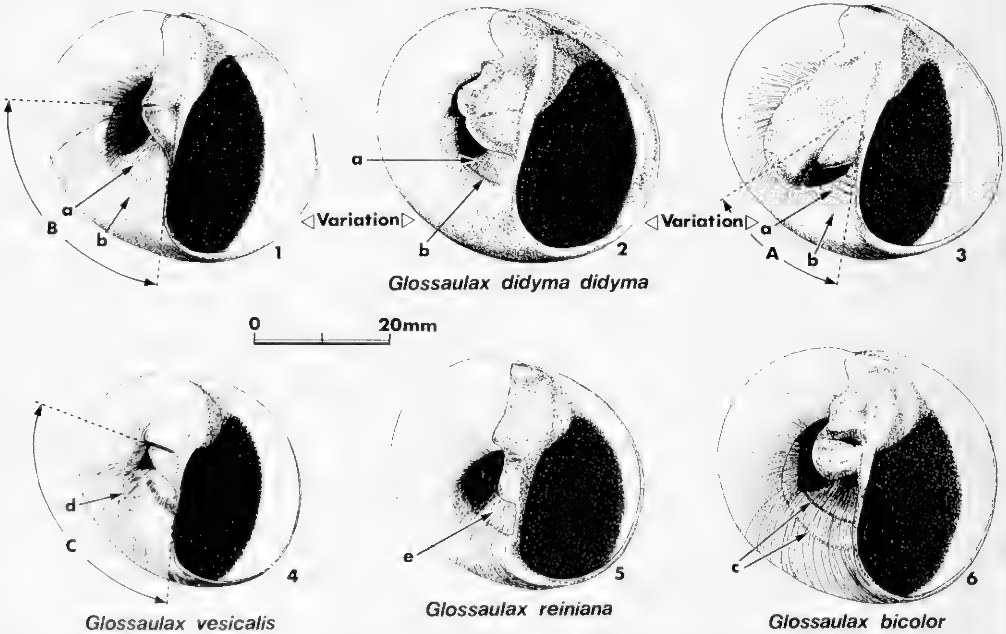
Discussion.—*Neverita eocenica* is characterized by its small shell, globose form with flattened sides above the periphery, and a heavily developed umbilical callus largely filling the umbilicus.

In his original description, Nagao (1928a) described the umbilical parts of *N. eocenica* as "umbilicus deep, almost covered by a solid, large, broad callus, whose end is rounded and thickened but not grooved." Though the transverse callus groove is not observable in the holotype (Pl. 4, fig. 13), a few individuals from locality NAGASAKI 3, Nagasaki Prefecture, clearly show a faint transverse callus groove or depression (Pl. 4, figs. 14b, 15b). This feature is considered to be an intraspecific variation of *N. eocenica.*

A similar variation of the transverse groove has also been recorded in *Neverita globosa* Gabb, 1869, from the upper Paleocene to upper Eocene of western North America by Givens and Kennedy (1976) and Marincovich (1977). Marincovich (1977, p. 315) mentioned that "a few individuals of *N.* (*N.*) *globosa* show a faint transverse callus groove when examined in strong oblique light" (see Givens and Kennedy, 1976, pl. 2, figs. 7, 11, 14). Marincovich (1977) argued that *N. globosa* may be the ancestral stock from which *Glossaulax* Pilsbry, 1929, evolved because of the following three reasons: (1) the incipient development of the umbilical callus groove of *N. globosa* is interpreted as a forerunner of *Glossaulax*, which is characterized by presence of the distinct umbilical callus groove; (2) the stratigraphic distribution of *N. globosa* (upper Paleocene to upper Eocene) partly overlaps that of the earliest known species of *Glossaulax, G. reclusiana* (Deshayes, 1839) (middle Eocene to Holocene); and (3) *N. globosa* and *G. reclusiana* lived in the same region at the same time (western North America during the middle to late Eocene).

I consider *N. eocenica* to be very closely related to *N. globosa*, and to be a member of the ancestral stock of *Glossaulax*. However, *N. eocenica* might not be the direct ancestor of species of *Glossaulax* in Japan. In the northwestern Pacific, *Glossaulax* first appeared in the early middle Miocene [*Glossaulax didyma coticazae* (Makiyama, 1926)], and there is a wide stratigraphic gap between *N. eocenica* and *G. didyma coticazae.* The ancestor of species of *Glossaulax* in Japan, therefore, is thought to be *G. reclusiana*, the earliest evolved species of *Glossaulax.*

Neverita eocenica is also very closely related to *Neverita wanneri* (Martin, 1914, p. 172, pl. 6, figs. 156, 157) from the upper Eocene of Java, Indonesia. *Neverita wanneri* differs slightly from *N. eocenica* by having a larger shell (up to 30 mm; Martin, 1914) and a slightly angulate base.



Text-figure 20.—Basal views of (1–3) *Glossaulax didyma didyma* (Röding, 1798), (4) *G. vesicalis* (Philippi, 1848), (5) *G. reiniana* (Dunker, 1877), and (6) *G. bicolor* (Philippi, 1848). Umbilical characters of *G. didyma didyma*: a shallowly but widely incised spiral groove (arrow **a**) on the umbilical wall and a shallowly incised transverse callus groove crossing to the inner margin of the aperture at an acute (angle **A**) to a right angle (angle **B**). *Glossaulax vesicalis*: a weakly angular base (arrow **d**) and a minutely to strongly incised umbilical callus groove crossing to the inner margin of the aperture at an obtuse angle (angle **C**). *Glossaulax reiniana*: a greatly incised spiral groove (arrow **e**) on the umbilical wall. *Glossaulax bicolor*: an umbilical wall bearing two spiral steps (arrow **c**) and an entirely rounded base.

Table 18.—Measurements (in mm) and counts of the holotype and of the largest specimen of *Glossaulax didyma coticazae* (Makiyama, 1926) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of speci-mens in lot*
lower middle Miocene	North Korea*	26.5	27.0	22.7	20.6	4+	CC 100231 (holotype)	—
	FURANUI 4	20.8	21.2	17.0	16.8	4+	IGUT 15835	1
	KADONOSAWA 1	23.4	20.7+	17.7	19.3	5½	IGUT 15844-1	95
	KADONOSAWA 2	27.4	30.0	26.5	21.0	5+	IGUT 15847-1	3
	KADONOSAWA 3	18.3	19.7	15.4	15.3	3+	IGUT 15846-4	5
	YANAGAWA	40.3+	41.6	36.1	32.8	4+	SHM 6110	1
	HIGASHI-INNAI 1	19.5	19.4	16.2	16.8	5+	IGUT 15838-1	5
	TAIRA 1	18.9	21.3	16.0	13.8	2½+	IGUT 15836-1	2
	YATSUO 3	25.3	27.1	22.1	19.8	5+	IGUT 15852-1	4
	YATSUO 4	17.6+	16.8+	13.9	—	4+	IGUT 15853-1	7
	MIZUNAMI 5	10.4	11.1	8.4	8.4	4+	IGUT 15950-1	2
	TSUYAMA	15.0	16.2	12.5	13.0	3+	IGUT 15858-1	2
	NIIMI	10.8	11.7	10.1	9.7	3+	IGUT 15854-1	2
	HAMADA	15.3+	17.7+	17.3	12.0+	2+	IGUT 15855-1	7
middle middle Miocene to upper Miocene	SHIZUKUISHI	19.0	23.2	20.2	16.2	4+	GSJ F12556	6
	SENNAN	39.0+	41.8	40.3	32.3+	5+	SHM 21708	1
	TANAGURA 1	37.8	31.6	26.4	25.2	5½+	IGUT 15842-1	2
	TANAGURA 2	38.1+	31.9+	29.7+	25.7+	4½+	IGUT 15839-7	52
	TANAGURA 3	32.4	28.4	27.4	24.0	4+	UMUT CM25918**	1
	SHIOBARA	23.1	23.1	18.8	19.0	4+	IGUT 15851	1
	KOKOZURA	15.0	16.6	13.4	12.6	5	IGUT 15387	1
	SAKAE	25.5	29.0	25.0	23.4	4+	JC 610093***	1
lower Pliocene	GOROKU	42.4	42.1	37.0	—	5+	IGPS 15967	25
	SHIGARAMI 1	33.1+	32.6+	28.8	—	4½+	GIYU 521	1

* Kinshodo, Cisshu-gun, Kankyo-Hokudo, North Korea.
** Lectotype, herein designated, of *Natica kiritaniana* Yokoyama, 1931.
*** Lectotype, herein designated, of *Neritaeformis (Neverita) fissuratus* Kuroda, 1931.

Stratigraphic occurrence.—
Lower Eocene: Futagojima Fm., Nagasaki Pref., localities NAGASAKI 1 (Pl. 4, fig. 13) and NAGASAKI 3 (Pl. 4, figs. 14–15).

Genus **GLOSSAULAX** Pilsbry, 1929

Type species.—Natica reclusiana Deshayes, 1839, by original designation. Middle Eocene to Holocene, eastern Pacific (Marincovich, 1977).

Discussion.—Glossaulax is characterized by the presence of a weakly to strongly incised transverse groove on the moderately to heavily developed umbilical callus. Species of *Glossaulax* are now distributed in the temperate to tropical Eastern and Western Pacific (Marincovich, 1977), and the Indian Ocean (Kilburn, 1976; Richards, 1981; Smythe, 1982).

Many species of *Euspira* Agassiz *in* Sowerby, 1838 and *Polinices* Montfort, 1810 have a weakly incised depression or groove on their calluses, which are always situated at the juncture between parietal and umbilical calluses (Text-fig. 17 [arrows **a**, **e**, **i** and **m**). In *Glossaulax*, the transverse callus groove is situated at the center of the umbilical callus.

Neverita Risso, 1826 very closely resembles *Glossaulax*, but differs by having a massive umbilical callus without a transverse groove. As mentioned in the discussion of *Neverita eocenica* (Nagao, 1928a), *Glossaulax* is thought to have evolved from *Neverita globosa* Gabb, 1869 of western North America (Givens and Kennedy, 1976; Marincovich, 1977).

Umbilical characters are of primary importance for the classification of species of *Glossaulax*. Text-figure 20 shows basal views of the Holocene species of *Glossaulax* in Japan. Among them, *G. didyma didyma* (Röding, 1798), *G. vesicalis* (Philippi, 1848), and *G. reiniana* (Dunker, 1877) occur as fossils.

Glossaulax didyma coticazae
(Makiyama, 1926)
Plate 5, figures 1–25, Plate 6, figures 1–3;
Text-figures 3.4, 9.1; Table 18

Polinices (Neverita) coticazae Makiyama, 1926, p. 150, pl. 12, fig. 8; Nomura, 1939, p. 255, pl. 13, figs. 13a–14b.
Neverita coticazae (Makiyama). Kamada, 1962, pp. 157–158, pl. 18, figs. 21a–22; Masuda and Takegawa, 1965, pl. 2, fig. 21; Masuda, 1967, pp. 5–6, pl. 1, figs. 25a–26b; Itoigawa *in* Itoigawa, Shibata, and Nishimoto, 1974, p. 148 [in part], pl. 45, figs. 10a–b [not fig. 5 = *Polinices mizunamiensis* Itoigawa, 1960]; Taguchi, Ono, and Okamoto, 1979, pl. 4, figs. 4, 5; Yoon, 1980, p. 75, pl. 8, figs. 12, 13.

Polinices coticazae Makiyama. ? Kanno and Ogawa, 1964, pl. 2, fig. 12.
Glossaulax coticazae (Makiyama). Itoigawa and Shibata *in* Morishita, 1977, p. 68, pl. 30, fig. 15.
Neverita (*Glossaulax*) *coticazae* (Makiyama). Itoigawa *et al.*, 1981, pl. 34, figs. 2a–b; Itoigawa *et al.*, 1982, pp. 196–197.
Glossaulax didyma coticazae (Makiyama). Majima and Fukuta, 1986, text-fig. 1.4; Majima, 1988, pp. 15–18, text-figs. 4.1, 5.1a–5.18b, 6.16–6.17b, 7.1a–7.8b.
Neritaeformis (*Neverita*) *fissuratus* Kuroda, 1931, pp. 75–76, pl. 10, figs. 74, 75.
Neverita fissurata (Kuroda). Hatai and Nisiyama, 1952, p. 224.
Natica kiritaniana Yokoyama, 1931, pp. 201–202, pl. 12, figs. 2a–c.
Polinices (*Neverita*) *kiritaniana* (Yokoyama). Nomura and Zinbo, 1935, p. 190, pl. 15, fig. 31; Nomura and Hatai, 1936, p. 147; Fujie and Uozumi, 1957, pp. 503–504, pl. 24, figs. 9a–b.
Polinices kiritaniana (Yokoyama). Nomura and Onishi, 1940, p. 185, pl. 18, figs. 3a–b; Hatai and Nisiyama, 1952, p. 221.
Neverita kiritaniana (Yokoyama). ? Tanaka, 1960, unnumbered pl., figs. 24a–b; Shikama, 1970, p. 106, pl. 30, fig. 14; Iwasaki, 1970, pp. 416–418, pl. 2, figs. 10–12, text-fig. 19; ? Ogasawara, 1976, pp. 63–64, pl. 15, fig. 10; ? Ogasawara and Nomura, 1980, pl. 12, figs. 3a–c; Masuda *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 270, pl. 135, figs. 1267, 1268.
Polinices (*Neverita*) *kiritaniana* var. *gorokuensis* Nomura, 1938, pp. 273–274, pl. 36, figs. 8a–9b.
Neverita kiritaniana gorokuensis (Nomura). Hatai and Nisiyama, 1952, pp. 234–235.
Neverita gorokuensis (Nomura). Masuda *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 294, pl. 147, fig. 1383.
Neverita sp. Suehiro, 1979, pp. 89–90, pl. 16, figs. 1a–b.
Polinices (*Neverita*) *didyma* (Bolten) [*sic*]. Nomura and Hatai, 1936, pp. 146–147, pl. 17, figs. 3, 4 [not *Glossaulax didyma didyma* (Röding, 1798).
Neverita (*Glossaulax*) cf. *didyma* (Röding). Amano, 1983, p. 33 [not *Glossaulax didyma didyma* (Röding, 1798)].
Neverita (*Glossaulax*) *didyma* (Röding). Amano, Kanno, and Mizuno, 1985, pl. 2, fig. 14 [not *Glossaulax didyma didyma* (Röding, 1798)].
Glossaulax didyma (Röding). Majima, 1987b, pp. 59–64 [in part], figs. 1a–4b [not *G. didyma didyma* (Röding, 1798); not figs. 3.1a–3.6b, 4.1a–4.6b, 5, 6.1a–6.8b = *G. didyma didyma* (Röding, 1798)].
Neverita aff. *hosoyai* Kuroda [*sic*]. Shikama, 1973, pl. 16, fig. 18 [not *N. hosoyai* Kira, 1959].
Polinices cf. *hyugensis* Shuto. Suehiro, 1979, p. 89, pl. 16, figs. 2a–b [not *Glossaulax hyugensis* (Shuto, 1964)].
Polinices sp. Nakagawa and Takeyama, 1985, pl. 19, figs. 6a–b.

Types.—

Polinices (*Neverita*) *coticazae* Makiyama: CC 100231 (holotype: Pl. 5, fig. 1), from Kinshodo, Meisen district, North Korea, lower middle Miocene Mankodo Formation.

Neritaeformis (*Neverita*) *fissuratus* Kuroda: JC 610093 (lectotype, designated herein: Pl. 5, fig. 19), from Sakai-zawa, Sakae-mura, Kamiminochi-gun, Nagano Prefecture, upper Miocene Aoki Formation.

Natica kiritaniana Yokoyama: UMUT CM25918 (lectotype, designated herein: Pl. 5, fig. 16), from Nishigoto, Hanawa-machi, Higashi-Shirakawa-gun, Fukushima Prefecture, middle middle Miocene Kubota Formation.

Polinices (*Neverita*) *kiritaniana* var. *gorokuensis* Nomura: SHM 2261 (lectotype, designated by Hatai and Nisiyama, 1952, pp. 234–235), from Goroku cliff, Sendai City, Miyagi Prefecture, lower Pliocene Tatsunokuchi Formation.

Description.—Shell small to moderate in size, globose to elongate in form, spire moderately to greatly elevated; shell weakly to moderately thickened; body whorl not greatly inflated, commonly evenly rounded, but sides of body whorl and shoulder may be minutely flattened; suture moderately impressed; nuclear whorls two-and-one-half, smooth; postnuclear whorls three-and-one-half in larger specimens. Axial sculpture of very weakly developed incremental growth lines; spiral sculpture of very minute, closely spaced, minutely wavy costellae that are not commonly preserved. Parietal callus moderately to greatly thickened, moderately filling posterior apertural angle; anterior lobe weak to indistinct, commonly smoothly merges with umbilical callus. Umbilicus moderately to narrowly open; umbilical callus moderate in size, subtrigonal to subquadrate in form, commonly attached to posterior side of umbilicus, and divided into two subtrigonal callus lobes by a strongly to moderately incised transverse groove; posterior callus lobe larger and wider than anterior one; umbilical wall circumscribed by a smoothly rounded base, and narrowly but distinctly incised by a spiral groove along a weak funicle. Anterior inner lip and basal lip commonly thickened.

Discussion.—*Glossaulax didyma coticazae* is characterized by its globose to elongate shell, distinctly incised transverse callus groove, and subtrigonal to subquadrate umbilical callus that is attached to the posterior side of the umbilicus. Generally, individuals in association with the lower middle Miocene warm-water Kadonosawa faunas show a tendency to be globose in form, small in size and relatively thin shelled (Pl. 5, figs. 1–11). On the other hand, those in the middle middle Miocene to upper Miocene cold-water Shiobara faunas show a tendency to be globose to elongate in form, moderate in size and thick shelled (Pl. 5, figs. 12–19).

Neritaeformis (*Neverita*) *fissuratus* Kuroda, 1931, *Natica kiritaniana* Yokoyama, 1931, and *Polinices* (*Neverita*) *kiritaniana* var. *gorokuensis* Nomura, 1938 are synonymous with *G. didyma coticazae*, as discussed below.

In 1931, Kuroda proposed *Neritaeformis* (*Neverita*) *fissuratus* as a new species from the upper Miocene Aoki Formation, Nagano Prefecture. The lectotype of *N.* (*N.*) *fissuratus*, designated herein, has a subtrigonal umbilical callus detached from the posterior side of the umbilicus (Pl. 5, fig. 19), and is nearly identical to end form A [Text-fig. 20.1: see discussion of morphological variation of *G. didyma didyma* (Röding, 1798) herein]. *Neritaeformis* (*Neverita*) *fissuratus* is synonymous with *G. didyma coticazae* but not with *G. didyma didyma*. *Glossaulax didyma coticazae*, as discussed in the section on phylogenetic relations, gradually evolved to *G. didyma didyma* in Pliocene time. The lectotype of *N.* (*N.*) *fissuratus*, therefore, appears to be a forerunner of *G. didyma didyma* in the morphological variation of the Miocene species *G. didyma coticazae*.

In 1931, Yokoyama proposed *Natica kiritaniana* as a new species (Pl. 5, fig. 16: lectotype, designated herein) from the middle middle Miocene Kubota Formation, Fukushima Prefecture. It has been accepted by many workers as a distinct species characterized by having a greatly elevated spire. However, as noted by Nomura and Hatai (1936, p. 147) and Kamada (1962, p. 158), the degree of variation in regard to the shell form of *Natica kiritaniana* from the Kubota Formation (Pl. 5, figs. 14–16) grades into that of the type specimens of *G. didyma coticazae* from the lower middle Miocene Mankodo Formation, North Korea (Pl. 5, figs. 1–2). *Natica kiritaniana* is, therefore, synonymous with *G. didyma coticazae*.

In 1938, Nomura proposed *Polinices* (*Neverita*) *kiritaniana* var. *gorokuensis* from the lower Pliocene Tatsunokuchi Formation, Miyagi Prefecture. The topotypes shown in Plate 5, figures 20–25 and Plate 6, figures 1–2, are very similar to some Miocene individuals bearing the greatly elevated spires that characterize *G. didyma coticazae*. Each Pliocene population, as mentioned in the section on phylogenetic relations, has been assigned to a subspecies herein (*G. didyma coticazae* or *G. didyma didyma*), based on its dominant morphology. *Polinices kiritaniana* var. *gorokuensis* Nomura is, therefore, synonymous with *G. didyma coticazae*.

Stratigraphic occurrence.—

Lower middle Miocene: ? Takinoue Fm., Hokkaido (Kanno and Ogawa, 1964); Furanui Fm., Hokkaido, locality FURANUI 4 (Pl. 5, fig. 3); Kadonosawa Fm., Iwate Pref., localities KADONOSAWA 1 (Pl. 5, fig. 4), KADONOSAWA 2, and KADONOSAWA 3 (Pl. 5, fig. 5); Kozai Fm., Miyagi Pref. (Nomura, 1939); Yanagawa Fm., Fukushima Pref., locality YANAGAWA (Pl. 5, fig. 6); Higashi-Innai Fm., Ishikawa Pref., locality HIGASHI-INNAI 1 (Pl. 5, fig. 7); Numanouchi Fm., Fukushima Pref., locality TAIRA 1; Yatsuo Fm., Toyama Pref., localities YATSUO 3 (Pl. 5, fig. 8) and YATSUO 4; Uchiura Group, Fukui Pref. (Nakagawa and Takeyama, 1985; as "*Polinices* sp."); Shukunohora Sandstone, Gifu Pref., locality MIZUNAMI 5 (Pl. 5, fig. 9); Bihoku Group, Okayama Pref., localities TSUYAMA (Pl. 5, fig. 10) and NIIMI (Pl. 5, fig. 11); Togane Fm., Shimane Pref., locality HAMADA.

Middle middle Miocene to upper Miocene: Togeshita Fm., Hokkaido [Amano, 1983, as "*Neverita* (*Glossaulax*) cf. *didyma* (Röding, 1798)"]; Yamatsuda Fm., Iwate Pref., locality SHIZUKUISHI (Pl. 5, fig. 12); Kanagase Fm., Miyagi Pref., locality SENNAN (Pl. 5, fig. 13); Kubota Fm., Fukushima Pref., localities TANAGURA 1 (Pl. 5, fig. 15), TANAGURA 2 (Pl. 5, fig. 14), and TANAGURA 3 (Pl. 5, fig. 16); Kanomatazawa Fm., Fukushima Pref., locality SHIOBARA (Pl. 5, fig. 17); Kokozura Fm., Fukushima Pref., locality KOKOZURA (Pl. 5, fig. 18); Aoki Fm., Nagano Pref., locality SAKAE (Pl. 5, fig. 19); Fujina Fm., Shimane Pref. (Suehiro, 1979, as "*Neverita* sp." and "*Polinices* cfr. *hyugensis* Shuto, 1964"); Zushi Fm., Kanagawa Pref. (Shikama, 1973, as "*Neverita* aff. *hosoyai* Kuroda").

Lower Pliocene: Tatsunokuchi Fm., Miyagi Pref., locality GOROKU (Pl. 5, figs. 20–25, Pl. 6, figs. 1–2); Nodani Fm., Niigata Pref. [Amano, Kanno, and Mizuno, 1985; as "*Neverita* (*Glossaulax*) *didyma* (Röding, 1798)"]; Shigarami Fm., Nagano Pref., locality SHIGARAMI 1 (Pl. 6, fig. 3).

Glossaulax didyma didyma
(Röding, 1798)
Plate 6, figures 4–18, Plate 7, figures 1–5;
Text-figures 5.6, 9.4, 9.5, 9.6, 15.20, 15.21,
20.1, 20.2, 20.3, 21, 22; Table 19

Albula didyma Röding, 1798, p. 20.
Natica didyma Bolten [*sic*]. Philippi, 1852, pp. 6–7, pl. 1, figs. 1-4.
Natica didyma (Röding). Sowerby, 1883, p. 77, pl. 1, fig. 4, pl. 2, fig. 14.
Polinices didyma (Bolten) [*sic*]. Pilsbry and Vanatta, 1908, p. 556, pl. 29, fig. 9.
Polinices (*Neverita*) *didyma* (Bolten) [*sic*]. Taki, 1934, pp. 224–234, text-figs. 1–4 [radula and soft parts].
Polynices [*sic*] *didyma* (Röding). Hirase, 1934, p. 60, pl. 91, fig. 9; Richards, 1981, p. 44, pl. 17, figs. 133, 133a.
Neritaeformis (*Neverita*) *didyma* (Bolten) [*sic*]. Kinoshita and Isahaya, 1934, p. 7, pl. 3, fig. 26.
Neverita didyma (Bolten) [*sic*]. Yen, 1936, pp. 203–204, pl. 17, figs. 27, 27a.
Polinices (*Neverita*) *didymus* (Röding). Altena, 1941, pp. 63–65.
Neverita didyma (Röding). Kuroda and Habe, 1952, p. 72; Ozaki, Fukuta, and Ando, 1957, pp. 164–165, pl. 28, fig. 4; Azuma, 1961, p. 198, pl. 13, fig. 1 [radula]; Hase, 1965, pl. 6, fig. 10; Ogasawara, 1981, pl. 2, figs. 15a–c.
Neverita (*Glossaulax*) *didyma* (Röding). Kira, 1954, p. 35, pl. 17, fig. 22; Kira, 1959, p. 42, pl. 17, fig. 22; Hayasaka, 1961, pp. 75–76, pl. 9, figs. 19a–b; Oyama, 1961b, unnumbered pl. [*Neverita* (1)], figs. 3, 4; Habe and Ito, 1965a, pp. 32–33, pl. 9, figs. 1, 2; Takahashi and Okamoto, 1969, p. 40, pl. 5, fig. 13; Habe and Kosuge, 1970, p. 48, pl. 18, fig. 24; Okutani and Habe, 1975, pp. 17 [living specimen], 81 [unnumbered figs.], 234–235; Yoo, 1976, p. 66, pl. 10, figs. 11–13; Matsuura, 1977, pl. 1, fig. 30, pl. 16, fig. 9; Fujiyama *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 354, pl. 177, fig. 1719; Matsuura, 1985, pl. 42, fig. 2.
Polinices (*Neverita*) *didyma* (Röding). Taki and Oyama, 1954, p. 17, pl. 6, figs. 5a–b.

Table 19.—Measurements (in mm) and counts of the largest specimen of *Glossaulax didyma didyma* (Röding, 1798) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
upper Pliocene	FUTATSUNUMA 1	21.9	25.3	20.3	18.2	5½	IGUT 15886-1	3
	NAKATSU	44.0	40.7	32.8+	31.5	5½+	IGUT 11101-1	3
	KAKEGAWA 8	39.4	46.5	38.2	31.4	4+	IGUT 15876-2	30
	KAKEGAWA 9	32.2+	42.9	31.9	—	2+	IGUT 15878-1	8
	KAKEGAWA 13	43.4+	54.4+	47.2	31.5+	5+	IGUT 15877	1
	MIYAZAKI 1	28.4+	32.7+	31.6+	21.3+	3½+	IGUT 15879-1	11
upper Pliocene or lower Pleistocene	GOJOME 1	40.3+	35.8+	29.9+	31.2+	3+	IGUT 15889-2	2
	GOJOME 3	43.5+	49.5+	43.5	32.6+	5½+	IGUT 15890	1
	MANGANJI 1	24.1+	28.8+	28.4+	20.0+	4+	GIYU 543	8
lower Pleistocene	CHIKAGAWA 1	40.6+	29.0+	32.7+	34.9+	4½+	IGUT 15884-1	5
	OMMA 1	11.1	12.7	10.3	9.3	5	IGUT 15887	1
	OMMA 7	10.4	13.7	10.6	9.2	4½	IGUT 15888-1	2
	KAKEGAWA 3	33.1+	29.2+	28.4	—	5+	IGUT 15875-6	42
	KAKEGAWA 5	49.2	46.7	38.8	39.1	5½+	GIYU 599-7	310
	KAKEGAWA 21	33.6	31.8+	27.7	31.5	3½+	IGUT 15891	1
	HANEJI 2	13.5+	14.8	13.4	—	1½+	IGUT 16077-1	2
	HANEJI 4	26.0	29.6	23.6	20.5	4½+	IGUT 16076	1
upper Pleistocene	ANDEN	41.4	52.1	41.6	34.5	5	IGUT 15880-1	9
	HIRADOKO	50.4	62.2	54.3	44.0	6½	IGUT 15881-1	2
	SEMATA	59.7	70.5	59.0	43.7	6½	IGUT 15882-1	5
	ATSUMI	22.0	24.0	21.2	18.0	5½	IGUT 15883-1	3

Neverita (*Glossaulax*) "*didyma* (Röding)". Oyama, 1969, p. 77.

Glossaulax didyma (Röding). Kuroda, Habe, and Oyama, 1971, p. 184 [in Japanese], pp. 120–121 [in English], pl. 18, figs. 5, 6; Majima, 1987b, pp. 59–64 [in part], figs. 3.1a–3.6b, 4.1a–4.6b, 5, 6.1a–6.8b [not figs. 2.1a-2.4b = *Glossaulax didyma coticazae* (Makiyama, 1926)].

Polinices (*Glossaulax*) *didyma* (Röding). Cernohorsky, 1972, p. 100, pl. 26, fig. 3; Kilburn, 1976, p. 860.

Neverita (*Glossaulax*) *didyma* (Röding) var. Oyama, 1973, p. 32, pl. 7, figs. 1a–b.

Neverita (*Glossaulax*) *didyma didyma* (Röding). Horikoshi, 1977, pp. 1–9, text-figs. 3, 14a–c.

Polinices didyma (Röding). Kilburn and Rippey, 1982, p. 71, pl. 16, fig. 5.

Not *Polinices didyma* (Röding). Yamada, 1963, unnumbered pl., figs. 25a–b [= *Glossaulax reiniana* (Dunker, 1877)].

Nevertita [*sic*] (*Glossaulax*) *didyma* (Röding). Matsui, 1985, p. 173, pl. 22, fig. 11.

Glossaulax didyma didyma (Röding). Majima, 1988, pp. 15–18, text-figs. 4.1–4.3, 6.1a–6.15b, 7.9a–7.15b.

Not *Polinices* (*Neverita*) *didymus* (Bolten) [*sic*]. Nomura and Hatai, 1936, pp. 146–147, pl. 17, figs. 3, 4 [= *Glossaulax didyma coticazae* (Makiyama, 1926)].

Not *Neverita* (*Glossaulax*) cf. *didyma* (Röding). Amano, 1983, p. 33 [= *Glossaulax didyma coticazae* (Makiyama, 1926)].

Natica papyracea Philippi, 1845, p. 45, pl. 12, fig. 14.

Natica papyracea von dem Busch [*sic*]. Philippi, 1852, pp. 43–44, pl. 5, fig. 4, pp. 87–88, pl. 13, fig. 4.

Neverita (*Glossaulax*) *papyracea* (Philippi). Horikoshi, 1977, pp. 1–9, text-figs. 1a–b, 4, 15a–b, 19.

Natica ampla Philippi, 1848, p. 156; Philippi, 1852, pp. 41–42, pl. 6, fig. 2.

Natica (*Neverita*) *ampla* Philippi. Tryon, 1886, pp. 32–33 [in part], pl. 10, figs. 81, 82, 85, 86, pl. 11, fig. 93, pl. 12, fig. 6 [not pl. 10, fig. 83, pl. 11, fig. 92 = *Glossaulax vesicalis* (Philippi, 1848); not pl. 11, fig. 91 = *Glossaulax bicolor* (Philippi, 1848)]; Uchiyama, 1902b, pp. 395–396, pl. 26, figs. 25, 26; Uchiyama, 1903, pl. 29, fig. 6 [radulae].

Natica ampla Reeve [*sic*]. Tokunaga, 1906, p. 18, pl. 1, figs. 32a–c.

Polinices (*Neverita*) *ampla* (Philippi). Yokoyama, 1920, p. 77 [in part], pl. 5, figs. 5a–b [not pl. 5, figs. 6a–b = *Glossaulax reiniana* (Dunker, 1877)].

Neverita ampla (Philippi). Yen, 1936, pp. 205–206 [in part], pl. 17, fig. 28a [not pl. 17, fig. 28 = *Glossaulax reiniana* (Dunker, 1877)].

Neverita (*Glossaulax*) *ampla* (Philippi). Oyama, 1961b, unnumbered pl. [*Neverita* (1)], figs. 7, 8; Horikoshi, 1977, pp. 1–9, text-fig. 20 [not text-figs. 9a–b, 16 = *Glossaulax bicolor* (Philippi, 1848)].

Neverita (*Glossaulax*) "*ampla* (Philippi)". Oyama, 1969, p. 77.

Not *Polinices didyma ampla* (Philippi). Pilsbry and Vanatta, 1908, pp. 556–557, pl. 29, fig. 8 [= *Glossaulax bicolor* (Philippi, 1848)].

Natica problematica Reeve, 1855, pl. 6, figs. 21a–b.

Neverita problematica (Reeve). Yen, 1942, p. 211, pl. 16, fig. 96 [syntype].

Natica robusta Dunker, 1859, p. 232; Dunker, 1861, pp. 13–14, pl. 2, fig. 24.

Neverita (*Glossaulax*) *didyma robusta* (Dunker). Oyama, 1972, p. 43, pl. 3, figs. 2, 3.

Neverita (*Glossaulax*) *hosoyai* Kuroda and Kira MS [*sic*]. Kira, 1959, p. 42.

Neverita (*Glossaulax*) *hosoyai* Kira. Habe, 1961, p. 38, pl. 17, fig. 13; Oyama, 1961b, unnumbered pl. [*Neverita* (1)], figs. 5, 6; Okutani and Habe, 1975, pp. 81 [unnumbered fig.], 268.

Glossaulax didyma hosoyai (Kira). Inaba, 1976, p. 87, pl. 1, fig. 2 [radula].

Neverita (*Glossaulax*) *didyma hosoyai* Kira. Horikoshi, 1977, pp. 1–9, text-figs. 2, 11a–d, 12a–c, 13.

Not *Neverita* aff. *hosoyai* Kuroda [*sic*]. Shikama, 1973, pl. 16, fig. 18 [= *Glossaulax didyma coticazae* (Makiyama, 1926)].

Polinices didyma bicolor (Philippi). Pilsbry and Vanatta, 1908, p. 557, pl. 29, figs. 4, 5 [not *Glossaulax bicolor* (Philippi, 1848)].

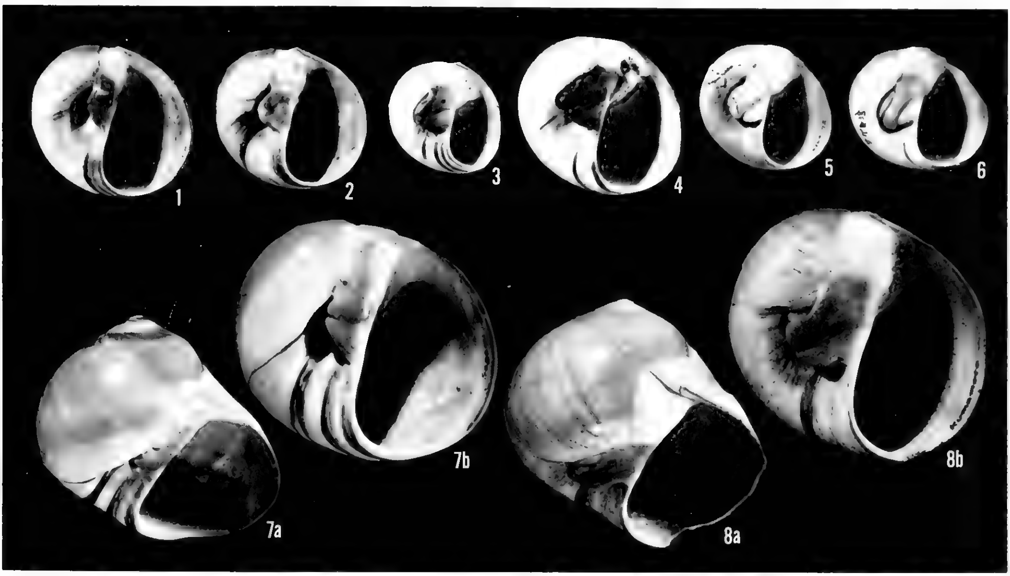
Neverita reiniana Dunker [not *Glossaulax reiniana* (Dunker, 1877)]. Ozaki, 1958, pp. 143–144, unnumbered text-fig. on page 144;

Ogasawara *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 330, pl. 165, figs. 1560, 1563, 1564.
Neverita (*Glossaulax*) *reiniana* Dunker [not *Glossaulax reiniana* (Dunker, 1877)]. Ogasawara, 1977, pl. 19, figs. 1–2b, 10a–b [not pl. 19, figs. 3a–b = *Glossaulax reiniana* (Dunker, 1877)]; Mori and Osada, 1979, pl. 2, fig. 8.
Neverita (*Glossaulax*) *petiveriana* (Récluz). Shuto, 1969, p. 85, pl. 5, figs. 12, 14, text-fig. 21.1, 21.2 [not *N.* (*G.*) *petiveriana* (Récluz, 1846)].
Neverita petiveriana (Récluz). Popenoe and Kleinpell, 1978, pl. 4, figs. 48, 49 [not *N. petiveriana* (Récluz, 1846)].
Natica vitellus spadicea (Gmelin). Hayasaka and Oki, 1971, p. 9, pl. 1, figs. 13a–b [not *N. vitellus spadicea* (Gmelin, 1791)].
Natica sp. Dickerson, 1922, pl. 4, fig. 2.

Types.—

Albula didyma Röding: type material unknown; type locality unknown [? Tranquebar, India (Pilsbry and Vanatta, 1908)].
Natica papyracea Philippi: type material unknown; type locality unknown (Philippi, 1852).
Natica ampla Philippi: type material unknown; type locality unknown (Philippi, 1852).
Natica problematica Reeve: type material preserved in the BM(NH) (Yen, 1942, p. 211); type locality, China (Reeve, 1855).
Natica robusta Dunker: type material unknown; type locality, Dejima, Nagasaki Prefecture, Japan (Pilsbry and Vanatta, 1908).
Neverita (*Glossaulax*) *hosoyai* Kira: OMNH Mo4579 (lectotype, designated herein: fig. 3.2a–b of Majima, 1987b), from off Chosi, Chiba Prefecture, Pacific side of central Honshu, Holocene.

Description.—Shell large, moderately to greatly thickened and weakly depressed globose to globose-elongate in form, spire weakly to moderately elevated; body whorl greatly inflated, shoulder weakly flattened to minutely concave; nuclear whorls two, smooth; postnuclear whorls four-and-one-half in larger specimens; suture moderately impressed; spiral sculpture of minute, closely spaced, minutely wavy costellae that become gradually distinct from base to suture of the body whorl; axial sculpture of incremental growth lines that are most distinct below suture and on base. Parietal callus moderately to heavily thickened, thickly filling posterior apertural angle; anterior lobe distinct to indistinct. Umbilicus widely to narrowly open, may be nearly closed. Umbilical morphology varies widely and is represented by two end forms (Text-figs. 20.1, 20.3) of the variation and all their intermediates (Text-fig. 20.2): one end form (Text-fig. 20.1) shows a widely open umbilicus, with a small and subtrigonal umbilical callus and with a distinct anterior lobe of the parietal callus, and the other end form (Text-fig. 20.3) exhibits a large and heavy umbilical callus, by which the um-



Text-figure 21.—Morphological variation of Holocene *Glossaulax didyma didyma* (Röding, 1798). 1–6, IGUT 16093 (1, IGUT 16093-1; 2, IGUT 16093-2; 3, IGUT 16093-3; 4, IGUT 16093-4; 5, IGUT 16093-5; and 6, IGUT 16093-6), ×0.5, Sagami Bay, Pacific side of central Honshu; 7a–b, IGUT 16096-2, ×0.8, Enoshima, Sagami Bay, Kanagawa Pref., Pacific side of central Honshu; 8a–b, IGUT 16097, ×0.8, Ariake Bay, Kumamoto Pref., central Kyushu.

bilicus is largely closed and the anterior lobe of the parietal callus is nearly covered. Umbilical callus divided into two lobes by a weakly incised transverse groove; posterior callus lobe commonly larger than the anterior one (Text-figs. 20.2, 20.3), but may be the same size in the end form with the widely open umbilicus (Text-fig. 20.1). Umbilical wall commonly smoothly merges with the body-whorl side, but may be circumscribed by a minutely developed spiral angulation, and sculptured with a wide but very shallow spiral depression (Text-fig. 20 [arrow **a**]) along funicle, but it may be indistinct. Anterior inner lip and basal lip minutely to greatly thickened.

Discussion.—Glossaulax didyma didyma is strongly characterized by the presence of the two end forms of morphological variation in the degree of development of the umbilical callus: one end form previously called *G. didyma* [end form **A**: Text-figs. 20.1, 21.1, 21.7a–b], shows a widely open umbilicus and a subtrigonal small umbilical callus, and the other end form, previously called *G. hosoyai* (Kira, 1959), exhibits an umbilicus largely closed by a heavily developed umbilical callus [end form **B**: Text-figs. 20.3, 21.6, 21.8a–b]. The two end forms **A** and **B** are connected by a continuous series of intermediates that show a very wide variety of umbilical callus shape (Text-figs. 20.2, 21.2–21.5).

In some localities, either end form **A** or **B** occurs abundantly in association with their intermediates. In Pliocene and early Pleistocene time, for example, only the end form **A** occurs in strata along the Sea of Japan coast of Honshu, which yield the cold-water Omma-Manganji faunas (Pl. 6, figs. 15–16), whereas both end forms **A** and **B** commonly occur together in strata along the Pacific coast of southwestern Japan, which yield the warm-water Kakegawa faunas (Pl. 6, figs. 5–14, 17–18) in which the Lower Kakegawa Formation at locality KAKEGAWA 5, Shizuoka Prefecture abundantly yields end form **B** (Pl. 7, figs. 1–5).

Horikoshi (1977) examined modern species of *Glossaulax* in Japan and subdivided the present species, as follows:

(1) *Glossaulax didyma didyma* (Röding) (in the sense of Horikoshi, 1977) is an Indian Ocean subspecies and *Glossaulax didyma hosoyai* (Kira, 1959) is a geographical subspecies in Japanese waters [end form **B** in this study], both of which are characterized by having a large umbilical callus with a transverse callus groove that joins the inner margin of the aperture at an acute angle (Text-fig. 20 [angle **A**]).

(2) *Glossaulax papyracea* (Philippi, 1845) is the commonest species of *Glossaulax* in Japan [end form **A** in this study] and has been taxonomically confused by Japanese malacologists with *G. didyma didyma* (in the sense of Horikoshi, 1977), an Indian Ocean subspecies. *Glossaulax papyracea* is characterized by having a relatively small-sized umbilical callus with a transverse callus groove that is nearly normal to the inner margin of the aperture (Text-fig. 20 [angle **B**]).

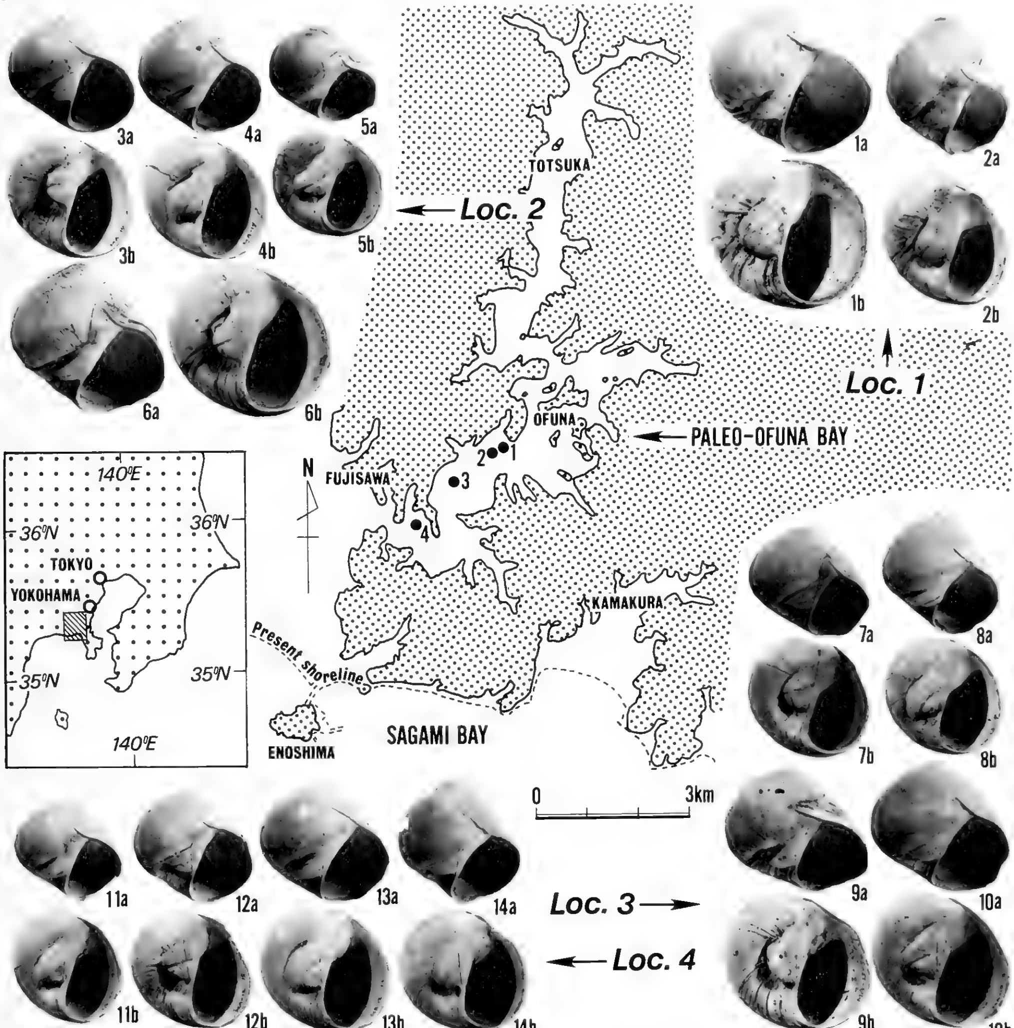
(3) *Glossaulax papyracea* is easily distinguished from both *G. didyma didyma* (in the sense of Horikoshi, 1977) and *G. didyma hosoyai* by the difference in the angle between the transverse callus groove and the inner margin of the aperture.

Horikoshi's taxonomic conclusions, noted above, are mainly based upon a morphological comparison between specimens from Indo-Western Pacific waters and figures illustrated by Philippi (1852).

According to Horikoshi (1977), the two end forms **A** and **B** in this study are different species. However, I cannot agree with Horikoshi's taxonomic conclusions, because there are numerous fossil and modern specimens that show any intermediate state of callus groove angle between the two end forms **A** and **B**, and because both end forms commonly occur together in association with all the intermediate forms. Furthermore, a specimen illustrated by Philippi (1852, pl. 1, fig. 2) as *Natica didyma*, which Horikoshi considered to be the typical form of *G. didyma* from the Indian Ocean, has a transverse callus groove that is normal to the inner margin of the aperture, although Horikoshi firmly believed it to have an acute angle. Therefore, I believe that there is no reason to segregate end forms **A** and **B** as discrete species-level taxa.

Taki (1934; 1948) considered the two end forms **A** and **B** to live in different habitats; that is, end form **A** supposedly lives in an inner bay environment that is shallower than that inhabited by end form **B**. Further, Horikoshi (1977) considered his *G. didyma hosoyai* [end form **B** in this study] to live in an open sea environment. However, the abundant occurrence of end form **B** from the Paleo-Ofuna Bay (5,000–6,500 y.B.P.) of Matsushima and Ohshima (1974) is inconsistent with these conclusions. The Paleo-Ofuna Bay (Text-fig. 22) is situated along the Kashio River, Kanagawa Prefecture, Pacific (east) side of central Honshu. Matsushima and Ohshima (1974) estimated its maximum length at 13 km, its maximum width at 1.5 km, and the minimum width of its entrance at 0.6 km. In the Paleo-Ofuna Bay, end form **B** occurs in the sandy and muddy facies in association with assemblages B and C of Matsushima and Ohshima (1974). The B assemblage consists mainly of species now living in littoral to sublittoral sandy bottoms in the embayment, such as *Meretrix lusoria* (Röding, 1798), *Phacosoma japonicus* (Reeve, 1850), *Mactra veneriformis* Reeve, 1852, *Macoma incongrua* Martens, 1865, and *Umbonium (Suchium) moniliferum* (Lamarck, 1822). The C assemblage consists mainly of species now living in sublittoral muddy bottoms in the embayment, such as *Dosinella penicillata* (Reeve, 1850), *Paphia undulata* (Born, 1778), and *Anodontia stearnsiana* Oyama *in* Taki and Oyama, 1954. Therefore, end form **B** is considered to have lived under the influence of the strong coastal waters in the Paleo-Ofuna Bay (Text-fig. 22). This indicates that end form **B** also lives in shallow waters in the inner bay environment where only end form **A** has been previously considered to live.

Glossaulax bicolor (Philippi, 1848) (Text-fig. 20.6), living in the Holocene warm waters of Japan, is similar to end form **A** (Text-fig. 20.1) of *G. didyma didyma*, but the former species is easily distinguished from the latter because: (1) the anterior callus lobe of the um-



Text-figure 22.—*Glossaulax didyma didyma* (Röding, 1798) from Paleo-Ofuna Bay (Matsushima and Ohshima, 1974). All the specimens illustrated (×0.8) are preserved in KPM (unnumbered). The specimens of 1a–2b, 3a–6b, 7a–10b, and 11a–14b were collected, respectively, from localities 1 (loc. 8 of Matsushima, 1984), 2 (loc. 9 of Matsushima, 1984), 3 (loc. 16 of Matsushima, 1984), and 4 (loc. 34 of Matsushima, 1984) illustrated in this figure.

Table 20.—Measurements (in mm) and counts of the holotype and of the largest specimen of *Glossaulax didyma dainichiensis*, n. subsp. at each locality.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
upper Pliocene	KAKEGAWA 1	41.6	54.6	46.1	35.7	4½+	IGUT 15826-1*	106
	KAKEGAWA 1	25.3	34.5	29.2	22.0	5½	IGUT 15825 (holotype)	—
	KAKEGAWA 2	35.9+	50.0+	43.0	29.0+	4½+	IGUT 15827-7*	56
	KAKEGAWA 6	16.4	30.4	23.6	21.8	5	IGUT 15833	1
	KAKEGAWA 10	35.9	42.2	34.1	30.7	4½+	IGUT 15828-1*	47
	KAKEGAWA 11	33.4	40.5+	38.8	27.0	4+	IGUT 15831-1	17
	KAKEGAWA 12	27.2	30.6	25.1	—	5½	IGUT 15830-1	5
	KAKEGAWA 15	18.8	22.3+	18.3	—	4+	IGUT 15834-1	3
	KAKEGAWA 16	20.0	22.4	19.6	16.1	4+	IGUT 15832-1	7
	KAKEGAWA 17	47.9+	48.4	41.6	37.7+	5+	IGUT 15829-1	3

* Paratype.

bilical callus is always larger than its posterior one; (2) its transverse callus groove is deeper than that of *G. didyma didyma*; and (3) its umbilical wall is sculptured with double flights [very weak spiral steps (Text-fig. 20 [arrow **c**]); *i.e.*, umbilical wall incised by two shallow grooves (narrow and wide)], but *G. didyma didyma* shows a single step (Text-fig. 20 [arrow **b**]).

Glossaulax reclusiana (Deshayes, 1839) and *G. pabloensis* (Clark, 1915) [= *G. andersoni* (Clark, 1918) in the sense of Marincovich, 1977. See synonym list of *Neverita* (*Glossaulax*) *andersoni* in Marincovich, 1977, p. 328 (Marincovich, oral commun., 1985)], both species from western North America, very closely resemble end form **B** of *G. didyma didyma*. Some specimens of end form **B** (Pl. 7, figs. 1–5) are difficult to distinguish from the two American species. However, neither American species includes end form **A** of *G. didyma didyma* in its range of morphological variation.

Stratigraphic occurrence.—

Upper Pliocene: Yamadahama Fm., Fukushima Pref., locality FUTATSUNUMA 1 (Pl. 6, fig. 4); Kanzawa Fm., Kanagawa Pref., locality NAKATSU (Pl. 6, figs. 5–6); Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 13 (Pl. 6, fig. 7); Tenno Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 8 (Pl. 6, figs. 8–9) and KAKEGAWA 9 (Pl. 6, figs. 10–11); Takanabe Member of Koyu Fm., Miyazaki Pref., locality MIYAZAKI 1 (Pl. 6, figs. 13–14).

Upper Pliocene or lower Pleistocene: Sasaoka Fm., Akita Pref., localities GOJOME 1, GOJOME 3 (Pl. 6, fig. 15), and MANGANJI 1.

Lower Pleistocene: Sunagomata Fm., Aomori Pref., locality CHIKAGAWA 1 (Pl. 6, fig. 16); Omma Fm., Ishikawa Pref., localities OMMA 1 and OMMA 7; Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 5 (Pl. 7, figs. 1–5); Hosoya Member of Upper Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 3 (Pl. 6, figs. 17–18) and KAKEGAWA 21; Nakoshi Sandstone, Okinawa Pref., localities HANEJI 2 and HANEJI 4 (Pl. 6, fig. 12).

Upper Pleistocene: Shibikawa Fm., Akita Pref., locality ANDEN; Hiradoko Fm., Ishikawa Pref., locality HIRADOKO; Semata Fm., Chiba Pref., locality SEMATA; Katori Fm., Chiba Pref. (Ozaki, 1958, as "*Neverita reiniana* Dunker, 1877"); Naganuma Fm., Kanagawa Pref. (Yokoyama, 1920); Ninomiya Group, Kanagawa Pref. [Mori and Osada, 1979, as "*Neverita* (*Glossaulax*) *reiniana* Dunker, 1877"]; Toshima Sand of Toyohashi Group, Aichi Pref., locality ATSUMI; Kogashira Fm., Kagoshima Pref. [Hayasaka and Oki, 1971, as "*Natica vitellus spadicea* (Gmelin, 1791)"].

Glossaulax didyma dainichiensis,
new subspecies
Plate 7, figures 6–16;
Text-figures 5.5, 9.2; Table 20

Glossaulax didyma, n. subsp. Majima, 1988, pp. 15–18, text-figs. 4.4, 8.1a–8.11b.

Types.—

Holotype: IGUT 15825 (Pl. 7, fig. 15), from Dainichi, Fukuroi City, Shizuoka Prefecture, upper Pliocene Dainichi Member of the Lower Kakegawa Formation (loc. KAKEGAWA 1).

Paratypes: IGUT 15826-1–15826-106 (Pl. 7, figs. 6–11, 14, 16), from the same locality as the holotype; IGUT 15827-1–15827-56 (Pl. 7, fig. 13), from Dainichi, Fukuroi City, Shizuoka Prefecture, upper Pliocene Dainichi Member of the Lower Kakegawa Formation (loc. KAKEGAWA 2); IGUT 15828-1–15828-47 from Kami-Iida, Mori-machi, Suchi-gun, Shizuoka Prefecture, upper Pliocene Dainichi Member of the Lower Kakegawa Formation (loc. KAKEGAWA 10).

Description.—Shell medium to large in size, globose to depressed in form, spire moderately to very weakly elevated; body whorl moderately to greatly inflated, may bear flattened shoulder; shell thin; nuclear whorls two, surface weathered; postnuclear whorls three-and-one-half in larger specimens, smooth except for incremental growth lines that are most distinct below suture and on base; suture weakly impressed. Parietal callus commonly thin, may be moderately thickened, and slightly to moderately filling posterior apertural angle; anterior lobe weak to distinct. Umbilicus weakly to moderately open; umbilical wall separated from body-whorl side by an obscure angulation, sculptured with weak growth lines and with a weakly incised but wide spiral groove along the weak to strong funicle; groove occupies one-half of umbilical wall, commonly ornamented with weak spiral costellae; umbilical callus moderate to large in size, subtrigonal to subquadrate in form, commonly attached to posterior side of umbilicus, and divided into two lobes by a very strongly to moderately incised transverse groove. In individuals with a subquadrate umbilical callus, anterior callus lobe is larger than posterior one, and their shells are commonly thin and depressed, but in those with a subtrigonal umbilical callus, posterior callus lobe is equal to or larger than the anterior one, and their shells are commonly globose and relatively more thickened. The umbilical calluses of the latter individuals may be greatly developed. The end morphs are connected by a continuous set of intermediates. Anterior inner lip and basal lip slightly thickened.

Discussion.—Glossaulax didyma dainichiensis displays a characteristically broad range of morphological variation. Some variants (Pl. 7, figs. 6–11) of *G. didyma dainichiensis* are morphologically nearly identical with the end forms **A** and **B** and their intermediates of *G. didyma didyma.* In addition to these, another variant, which strongly characterizes *G. didyma dainichiensis,* is observable. This third variant (Pl. 7, figs. 13–16) shows a depressed and thinner shell bearing a subquadrate umbilical callus that is divided into two lobes by a strongly incised groove. In the umbilical callus of this variant, the anterior callus lobe is larger than the posterior one; also, the transverse callus groove does not normally cross to the inner margin of the aperture, but does so at an obtuse angle (Pl. 7, figs. 12–16; Text-fig. 9 [angle **A**]). All the variants above are connected by a continuous set of intermediates at some localities where *G. didyma dainichiensis* occurs abundantly (locs. KAKEGAWA 1, KAKEGAWA 2, and KAKEGAWA 10).

As discussed in the section on phylogenetic relations, *G. didyma dainichiensis* was a local subspecies for a short time in the late Pliocene and is considered to be a transitional subspecies between the *G. didyma coticazae* (Makiyama, 1926) – *G. didyma didyma* (Röding, 1798) lineage and *G. vesicalis* (Philippi, 1848). It shows substantial morphological overlap with *G. didyma coticazae, G. didyma didyma,* and *G. vesicalis,* as follows:

(1) As described above, *G. didyma dainichiensis* has variants that are morphologically nearly identical with the end forms **A** and **B** of *G. didyma didyma.* The transverse callus groove of some individuals of *G. didyma dainichiensis* is strongly incised, which is an important feature of *G. didyma coticazae.*

(2) The depressed form of *G. didyma dainichiensis* is very similar to *Glossaulax vesicalis* (Philippi) in having a thin shell, strongly incised transverse callus groove, and an obtuse angle between the transverse callus groove and the inner lip of the aperture. Further, it closely resembles the earliest known individuals of *G. vesicalis* in having a depressed shell. Plate 7, figures 18–20 show the earliest known individuals (early Pleistocene) of *G. vesicalis,* which are slightly different from its late Pleistocene and Holocene specimens (Pl. 7, figs. 17, 21–24) in degree of elevation of the spire. The late Pleistocene to Holocene *G. vesicalis* has a moderately elevated spire.

The weakly elevated spires of the earliest known individuals of *G. vesicalis* are interpreted to reflect a subspecies, *G. didyma dainichiensis,* that is transitional between the *G. didyma coticazae* – *G. didyma didyma* lineage and *G. vesicalis.*

Stratigraphic occurrence.—

Upper Pliocene: Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 1 (Pl. 7, figs. 6–11, 14–16), KAKEGAWA 2 (Pl. 7, fig. 13), KAKEGAWA 6 (Pl. 7, fig. 12), KAKEGAWA 10, KAKEGAWA 11, KAKEGAWA 12, KAKEGAWA 15, KAKEGAWA 16, and KAKEGAWA 17.

Glossaulax vesicalis (Philippi, 1848)
Plate 7, figures 17–24;
Text-figures 5.5, 9.3, 15.22, 20.4; Table 21

Natica vesicalis Philippi, 1848, p. 159; Philippi, 1852, pp. 40–41, pl. 6, fig. 1.
Polinices didyma vesicalis (Philippi). Pilsbry and Vanatta, 1908, pp. 557–558, pl. 29, figs. 6, 7.
Neverita vesicalis (Philippi). Kuroda and Habe, 1952, p. 72; Azuma, 1961, p. 198, pl. 13, fig. 12 [radula].
Neverita (Glossaulax) vesicalis (Philippi). Habe, 1961, p. 39, pl. 18, fig. 10; Oyama, 1961b, unnumbered pl. [*Neverita* (2)], figs. 5–8; Oyama, 1969, p. 77; Habe and Kosuge, 1970, p. 48, pl. 18, fig. 26; Okutani and Habe, 1975, pp. 81 [unnumbered figs.], 256; Horikoshi, 1977, pp. 1–9, text-figs. 8a–d, 18, 21.
Glossaulax vesicalis (Philippi). Majima, 1987b, pp. 70–72, figs. 10.1a–10.7b; Majima, 1988, p. 18, text-figs. 4.5, 8.12a–8.19b.
Natica incisa Philippi, 1852, pp. 81–82, pl. 12, fig. 8.
Neverita (Glossaulax) incisa (Philippi). Horikoshi, 1977, pp. 1–9, text-figs. 5, 22.

Types.—

Natica vesicalis Philippi: type material unknown; type locality, Canton, China (Philippi, 1848).
Natica incisa Philippi: type material unknown; type locality, China (Philippi, 1852).

Table 21.—Measurements (in mm) and counts of the largest specimen of *Glossaulax vesicalis* (Philippi, 1848) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower Pleistocene	CHIKAGAWA 1	32.3	38.7+	30.4+	24.3	4+	IGUT 15872-1	7
	OMMA 8	24.1+	30.9+	25.7	—	4+	GIYU 535	1
	MIYAZAKI 5	20.8	30.0	23.8	17.9	4+	IGUT 15870	1
upper Pleistocene	HIRADOKO	22.3	26.2+	21.0	18.4	4+	IGUT 15871-1	2
	SEMATA	23.4	25.2	19.5	19.7	5	IGUT 15873-2	7
	KIKAI 1	24.5	28.5	22.0	20.4	5	GIYU 525	1

Description.—Shell small to moderate in size, very thin, globose to weakly depressed in form, spire moderately to very weakly elevated; body whorl greatly inflated, commonly evenly rounded, may bear a flattened to slightly concave shoulder; nuclear whorls one-and-one-half, smooth; postnuclear whorls three-and-one-half in larger specimens. Spiral sculpture of minute, closely spaced, minutely wavy costellae; axial sculpture of incremental growth lines that are most distinct below suture and on base. Parietal callus thin, lightly filling posterior apertural angle; anterior lobe weak to distinct. Umbilicus widely open; umbilical wall smooth except for incremental growth lines, may be ornamented with a very weakly incised but wide (occupying about one-half of umbilical wall) spiral groove along a very weakly developed funicle, and separated from body-whorl side with an obscure spiral angulation (Text-fig. 20 [arrow **d**]). The groove of the umbilical wall, if it is present, is ornamented with many weakly developed spiral costellae. Umbilical callus small, thin, commonly attached to posterior side of umbilicus, divided into two lobes by a weakly to strongly incised transverse groove that commonly crosses to the inner apertural margin at an obtuse angle (Text-fig. 20 [angle **C**]); anterior callus lobe subtriangular, being commonly larger than the posterior one, but they may be equal in size; posterior callus lobe smoothly merges with anterior lobe of the parietal callus, together in some specimens making up a strong wedge-shaped lobe. Anterior inner lip and basal lip thin.

Discussion.—*Glossaulax vesicalis* is characterized by its very thin shell and weakly developed umbilical callus bearing a weakly to strongly incised transverse callus groove that commonly crosses to the inner margin of the aperture at an obtuse angle (Text-fig. 20 [angle **C**]).

The spires of early Pleistocene specimens of *G. vesicalis* (Pl. 7, figs. 18–20) are very weakly elevated, but those of late Pleistocene and Holocene specimens are moderately elevated (Pl. 7, figs. 17, 21–24).

Stratigraphic occurrence.—

Lower Pleistocene: Sunagomata Fm., Aomori Pref., locality CHIKAGAWA 1 (Pl. 7, fig. 18); Omma Fm., Ishikawa Pref., locality OMMA 8 (Plate 7, fig. 19); Takanabe Member of Koyu Fm., locality MIYAZAKI 5 (Pl. 7, fig. 20).

Upper Pleistocene: Hiradoko Fm., Ishikawa Pref., locality HIRADOKO (Pl. 7, fig. 22); Semata Fm., Chiba Pref., locality SEMATA (Pl. 7, fig. 23); Ryukyu Limestone, Kagoshima Pref., locality KIKAI 1 (Pl. 7, fig. 24).

Glossaulax reiniana (Dunker, 1877)
Plate 6, figures 19–25;
Text-figures 15.23, 20.5; Table 22

Neverita reiniana Dunker, 1877, p. 71; Dunker, 1882, p. 62, pl. 4, figs. 15, 16; Kuroda and Habe, 1952, p. 72; Azuma, 1961, p. 198, pl. 13, fig. 3 [radula]; Itoigawa and Ogawa, 1973, pl. 5, fig. 24.

Not *Neverita reiniana* Dunker. Ozaki, 1958, pp. 143–144, unnumbered text-fig. on p. 144 [= *Glossaulax didyma didyma* (Röding, 1798)]; Ogasawara *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 330, pl. 165, figs. 1560, 1563, 1564 [= *Glossaulax didyma didyma* (Röding, 1798)]; Shimamoto, 1984, pl. 3, figs. 7a–b [= *Cryptonatica janthostoma* (Deshayes, 1839)].

Polinices (*Neverita*) *reiniana* (Dunker) var. Taki and Oyama, 1954, p. 17, pl. 6, figs. 6a–b.

Neverita (*Glossaulax*) *reiniana* Dunker. Habe, 1961, p. 38, pl. 17, fig. 11; Hayasaka, 1961, p. 76, pl. 9, figs. 18a–b; Oyama, 1961b, unnumbered pl. [*Neverita* (1)], figs. 1, 2; Oyama, 1969, p. 77; Habe and Kosuge, 1970, p. 48, pl. 18, fig. 25; Oyama, 1973, p. 32, pl. 7, figs. 2a–b; Okutani and Habe, 1975, pp. 81 [unnumbered fig.], 250; Ogasawara, 1977, pl. 19, figs. 3a–b [not figs. 1–2b, 10a–b = *Glossaulax didyma didyma* (Röding, 1798)]; Matsuura, 1977, pl. 16, fig. 8; Horikoshi, 1977, pp. 1–9, text-fig. 10; Uyeno and Matsushima, 1979, pl. 8, fig. 3; Matsuura, 1985, pl. 32, fig. 4.

Not *Neverita* (*Glossaulax*) *reiniana* Dunker. Kaseno and Matsuura, 1965, pl. 2, figs. 32, 33 [= *Glossaulax hagenoshitensis* (Shuto, 1964)]; Mori and Osada, 1979, pl. 2, fig. 8 [= *Glossaulax didyma didyma* (Röding, 1798)]; Kotaka and Hashibuan, 1983, pl. 2, figs. 15a–b [calcareous operculum; ? = *Natica vitellus* (Linnaeus, 1758)].

Glossaulax reiniana (Dunker). Kuroda, Habe, and Oyama, 1971, pp. 184–185 [in Japanese], p. 121 [in English], pl. 18, fig. 2; Majima, 1985, pl. 17, figs. Oa–b; Majima, 1987b, pp. 69–70, figs. 9.1a–9.3b; Majima, 1988, pp. 18–20, text-fig. 9.2.

Not *Polinices* (*Glossaulax*) aff. *reiniana* (Dunker). Shuto, 1964, pp. 285–286, pl. 42, fig. 1, text-fig. 3(2) [= *Glossaulax hyugensis* (Shuto, 1964)].

Polinices (*Neverita*) *ampla* (Philippi). Yokoyama, 1920, p. 77 [in part], pl. 5, figs. 6a–b [not *P.* (*N.*) *ampla* (Philippi, 1848); not pl. 5, figs. 5a–b = *Glossaulax didyma didyma* (Röding, 1798)].

Neverita ampla (Philippi). Yen, 1936, pp. 205–206 [in part], pl. 17,

Table 22.—Measurements (in mm) and counts of the largest specimen of *Glossaulax reiniana* (Dunker, 1877) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
upper Pliocene and lower Pleistocene	OMMA 1	20.6	23.7	18.5	16.6	5+	IGUT 15865-1	23
	OMMA 2	10.7	12.6	10.2	9.0	4½+	IGUT 15866	1
	OMMA 5	33.8+	37.0	31.3	24.7+	6	IGUT 15864-1	12
	KAKEGAWA 1	16.2	18.7	15.0	—	4½+	IGUT 15862	1
	KAKEGAWA 3	25.1	25.1	20.2	—	5½	IGUT 15859-4	14
	KAKEGAWA 15	29.3	31.6	24.4	22.7	5½	IGUT 15861	1
	KAKEGAWA 17	18.3	18.4	16.1	14.7	5	IGUT 15860-1	10
upper Pleistocene	ANDEN	21.0	23.9	19.5	18.0	5½	IGUT 15885-1	3
	HIRADOKO	15.6	17.0	13.9	13.3	5	IGUT 15868-1	8
	SAKURAI	46.7	47.1	37.1	34.8	6½	IGUT 15863-1	15
	ATSUMI	18.7	21.2	16.7	15.9	5½	IGUT 15869	1

fig. 28 [not *N. ampla* (Philippi, 1848); not pl. 17, fig. 28a = *Glossaulax didyma didyma* (Röding, 1798)].

Polinices didyma (Röding). Yamada, 1963, unnumbered pl., figs. 25a–b [not *Glossaulax didyma didyma* (Röding, 1798)].

Natica vitellus spadicea (Gmelin). Hayasaka, 1961, pp. 76–77, pl. 9, figs. 23a–b [not *N. vitellus spadicea* (Gmelin, 1791)].

Natica stellatus Hedley. Yamada, 1963, unnumbered pl., figs. 26a–b [not *N. stellatus* Hedley, 1913].

Types.—Type material unknown; type locality, Japan (from the title of Dunker (1877) as "*Mollusca nonnulla nova maris Japonici*").

Description.—Shell moderate in size and thickness, globose in form, spire weakly to moderately elevated; body whorl greatly inflated, evenly rounded, but may bear weakly concave shoulder; nuclear whorls one-and-one-half, smooth; postnuclear whorls four in larger specimens, sculptured with minute, closely spaced, minutely wavy spiral costellae and with incremental growth lines that are most distinct on the subsutural part. Parietal callus moderately thickened, moderately filling posterior apertural angle; anterior lobe very distinct. Umbilicus moderately open, deep, revealing early conch whorls; umbilical wall circumscribed by an obscure spiral angulation on base, and strongly incised by a spiral groove (Text-fig. 20 [arrow **e**]) along a distinctly developed funicle; groove occupies about one-half of the umbilical wall, and is ornamented with distinct growth lines and many spiral lirae; umbilical callus small, rectangular in form, smoothly merges with anterior lobe of parietal callus, and divided into two lobes by a very weakly developed transverse groove, which is situated slightly posteriorly. Anterior callus lobe is larger than posterior one. Anterior inner lip and basal lip greatly thickened, but former lip is deeply excavated by the spiral groove on the umbilical wall.

Discussion.—*Glossaulax reiniana* is characterized by an umbilical wall deeply incised by a spiral groove (Text-fig. 20 [arrow **e**]), a very distinct anterior lobe of the parietal callus, a weakly developed umbilical callus, and a distinct funicle. It is morphologically the most distinct among all species of *Glossaulax* in Japan in having a distinctly grooved umbilical wall.

Stratigraphic occurrence.—

Upper Pliocene and lower Pleistocene: Omma Fm., Ishikawa Pref., localities OMMA 1 (Pl. 6, fig. 19), OMMA 2, and OMMA 5; Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 1, KAKEGAWA 15 (Pl. 6, fig. 20), and KAKEGAWA 17 (Pl. 6, fig. 21); Hosoya Member of Upper Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 3 (Pl. 6, fig. 22).

Upper Pleistocene: Shibikawa Fm., Akita Pref., locality ANDEN; Hiradoko Fm., Ishikawa Pref., locality HIRADOKO (Pl. 6, fig. 23); Sakurai Fm., Chiba Pref., locality SAKURAI (Pl. 6, fig. 24); Naganuma Fm., Kanagawa Pref. [Yokoyama, 1920, as "*Polinices* (*Neverita*) *ampla* (Philippi, 1848)"; Uyeno and Matsushima, 1979]; Toshima Sand of Toyohashi Group, Aichi Pref., locality ATSUMI (Pl. 6, fig. 25); Sakishima Fm., Mie Pref. [Yamada, 1963, as "*Polinices didyma* (Röding, 1798)"; Itoigawa and Ogawa, 1973].

Glossaulax hyugensis (Shuto, 1964)
Plate 8, figures 1–3; Text-figures 4.3, 8

Polinices (*Glossaulax*) *hyugensis* Shuto, 1964, pp. 282–284, pl. 42, figs. 3, 5, 13, 15, pl. 43, figs. 9, 10, 12, text-figs. 1(2), 2.

Polinices hyugensis Shuto. Aoki and Baba, 1984, p. 74, text-fig. 7.

Glossaulax hyugensis (Shuto). Majima, 1985, pp. 129–131, pl. 17, figs. Aa–Bb, pl. 18, figs. Aa–Kb, text-figs. 3, 4, 6, 7, 9; Majima, 1987b, pp. 66–68, figs. 8.1a–b, 8.3a–8.4b.

Not *Polinices* cfr. *hyugensis* Shuto. Suehiro, 1979, p. 89, pl. 16, figs. 2a–b [= *Glossaulax didyma coticazae* (Makiyama, 1926)].

Polinices (*Glossaulax*) aff. *reiniana* (Dunker). Shuto, 1964, pp. 285–286, pl. 42, fig. 1, text-fig. 3(2) [not *Glossaulax reiniana* (Dunker, 1877)].

Holotype.—GK L8009, from roadcut at Hagenoshita, Takanabe-machi, Koyu-gun, Miyazaki Prefecture (loc. MIYAZAKI 1), upper Pliocene Takanabe Member of Koyu Formation.

Discussion.—Form **1U** of *G. hyugensis* (Pl. 8, fig. 3;

Text-fig. 8) closely resembles end form **A** of *G. didyma didyma* (Röding, 1798) (Text-fig. 20.1) in having similar callus morphologies. However, form **1U** of *G. hyugensis* is readily distinguished from end form **A** of *G. didyma didyma* by having a nearly flat umbilical wall and a spirally angulate base. End form **A** of *G. didyma didyma* has an umbilical wall incised by a very shallow but wide spiral groove (Text-fig. 20 [arrow **a**]), and commonly has a rounded base without any distinct angulation. Further, form **1U** of *G. hyugensis* has a subquadrate to semicircular umbilical callus, a weak transverse callus groove, and commonly an anterior umbilical callus lobe larger than the posterior one. In end form **A** of *G. didyma didyma*, the umbilical callus commonly is subtrigonal in form; the transverse callus groove is moderately incised; and the anterior umbilical callus lobe is equal to or smaller than the posterior one. Form **1U** of *G. hyugensis* and end form **A** of *G. didyma didyma* occur together at locality MIYAZAKI 1 of the Koyu Formation, Miyazaki Prefecture, where they are easily distinguishable (form **1U** of *G. hyugensis*, Pl. 8, fig. 3; end form **A** of *G. didyma didyma*, Pl. 6, fig. 13).

Stratigraphic occurrence.—

Lower Pliocene: Tano Member of Higashimorogata Fm. (Shuto, 1964); Kawabaru Member of Koyu Fm. (Shuto, 1964).

Upper Pliocene: Tenno Member of Lower Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 9; Nobori Fm., Kochi Pref., locality TONOHAMA 1; Ananai Fm., Kochi Pref., locality TONOHAMA 2; Takanabe Member of Koyu Fm., Miyazaki Pref., localities MIYAZAKI 1 (Pl. 8, figs. 1–3), MIYAZAKI 2, and MIYAZAKI 3.

Glossaulax nodai Majima, 1985
Plate 8, figures 11–12; Text-figures 4.3, 8

Glossaulax nodai Majima, 1985, p. 131, pl. 18, figs. La–Ob, text-figs. 5–7, 9; Majima, 1987b, p. 69, figs. 8.2a–b, 8.5a–b.

Holotype.—IGUT 15695 (Pl. 8, fig. 12), from small tunnel cut, about 300 m east from Tonoya, Kakegawa City, Shizuoka Prefecture (loc. KAKEGAWA 13), upper Pliocene Dainichi Member of Lower Kakegawa Formation.

Discussion.—Majima (1985) predicted that the juvenile form of *G. nodai* would possess a subtrigonal umbilical callus like that of its adult. A juvenile specimen of *G. nodai* collected from locality MIYAZAKI 5, Takanabe Member of the Koyu Formation, Miyazaki Prefecture, where an adult specimen of *G. nodai* occurs (Majima, 1985, pl. 18, figs. Ma–b), has a subtrigonal umbilical callus (Pl. 8, fig. 11). *Glossaulax nodai*, therefore, maintains a constant umbilical callus form throughout its post-larval growth.

Stratigraphic occurrence.—

Upper Pliocene and lower Pleistocene: Nojima Fm., Kanagawa Pref., locality NOJIMA 1; Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 13 (Pl. 8, fig. 12) and KAKEGAWA 17; Takanabe Member of Koyu Fm., Miyazaki Pref., locality MIYAZAKI 5 (Pl. 8, fig. 11).

Glossaulax hagenoshitensis (Shuto, 1964)
Plate 8, figures 4–10; Text-figures 5.2, 8

Polinices (*Neverita*) *sagamiensis* Pilsbry. Shuto, 1964, pp. 281–282, pl. 42, fig. 2 [not *Polinices sagamiensis* Pilsbry, 1904; figs. 8, 14 show imperfect specimens].
Polinices sagamiensis Pilsbry. Itoigawa and Shibata *in* Morishita, 1977, p. 68, pl. 30, fig. 18 [not *P. sagamiensis* Pilsbry, 1904].
Polinices (*Glossaulax*) *hagenoshitensis* Shuto, 1964, pp. 284–285, pl. 42, fig. 10, text-fig. 1(1).
Glossaulax hagenoshitensis (Shuto). Majima, 1985, pp. 131–134, pl. 17, figs. Ca–Kc, Ma–c, pl. 18, figs. Pa–Qc, pl. 19, figs. Aa–Mc, text-figs. 3–9; Majima, 1987b, pp. 68–69, figs. 8.6a–8.11c.
Neverita (*Glossaulax*) *reiniana* Dunker. Kaseno and Matsuura, 1965, pl. 2, figs. 32, 33 [not *Glossaulax reiniana* (Dunker, 1877)].
Glossaulax didyma (Röding). Kuroda *et al.*, 1981, p. 67 [list], pl. 1, figs. 10A–C [not *G. didyma didyma* (Röding, 1798)].

Holotype.—GK L8003, from roadcut at Hagenoshita, Takanabe-machi, Koyu-gun, Miyazaki Prefecture (loc. MIYAZAKI 1), upper Pliocene Takanabe Member of Koyu Formation.

Discussion.—Kuroda *et al.* (1981) illustrated a specimen as *Glossaulax didyma* (Röding, 1798) from the lower Pleistocene Byobudani Formation, Joetsu City, Niigata Prefecture, on the northwest side of central Honshu facing the Sea of Japan. Their figures and an additional specimen from the Byobudani Formation (Pl. 8, fig. 10) are identified with form 3Tb of *G. hagenoshitensis*. This occurrence suggests that *G. hagenoshitensis* is not rare in the cold-water Omma-Manganji faunas distributed along the northwest side of Honshu facing the Sea of Japan.

Stratigraphic occurrence.—

Upper Pliocene and lower Pleistocene: Byobudani Fm., Niigata Pref., locality JOETSU (Pl. 8, fig. 10); Omma Fm., Ishikawa Pref., localities OMMA 1, OMMA 2, and OMMA 3; Nojima Fm., Kanagawa Pref., locality NOJIMA 1; Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 1, KAKEGAWA 2, KAKEGAWA 10 (Pl. 8, figs. 7–9), KAKEGAWA 11, KAKEGAWA 12, KAKEGAWA 13, KAKEGAWA 14, KAKEGAWA 15, KAKEGAWA 16, and KAKEGAWA 17; Tenno Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 8 and KAKEGAWA 9; Hosoya Member of Upper Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 3; Nobori Fm., Kochi Pref., locality TONOHAMA 1; Ananai Fm., Kochi Pref., locality TONOHAMA 3; Takanabe Member of Koyu Fm., Miyazaki Pref., lo-

Table 23.—Measurements (in mm) and counts of the holotype of *Pliconacca nomii* (Nagao, 1928b).

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*
upper Eocene	NAGASAKI 2	20.2	22.3	16.8	17.2	4+	IGPS 36151 (holotype)

calities MIYAZAKI 1 (Pl. 8, figs. 4–6), MIYAZAKI 2, MIYAZAKI 3, and MIYAZAKI 4.

Genus **PLICONACCA** Cossmann and Martin *in* Martin, 1914

Type species.—Natica (*Pliconacca*) *trisulcata* Martin, 1914, by monotypy. Upper Eocene, Java, Indonesia.

Discussion.—Pliconacca is characterized by the presence of two or three transverse callus grooves or depressions. The following five species have been previously reported as *Pliconacca*: *Natica* (*Pliconacca*) *trisulcata* Martin, 1914 (p. 171, pl. 6, figs. 149, 149a), from the upper Eocene of Java, Indonesia; *Polinices* (*Pliconacca*) *arata* (Gabb, 1860) of Palmer, 1937 (pp. 123–124, pl. 13, figs. 5, 10, 12, 15, 17, 18, pl. 80, fig. 15), from the middle Eocene of North America; *Natica* (*Pliconacca*) *nanoharae* Beets, 1942 (pp. 251–252, pl. 26, figs. 40–45), from the Neogene of East Borneo; *Polinices* (*Pliconacca*) *nomii* Nagao, 1928b of Oyama, Mizuno, and Sakamoto, 1960 (pp. 50–51, pl. 5, figs. 9a–b), from the upper Eocene Okinoshima Formation, Nagasaki Prefecture, Japan; and *Pliconacca martini* Ladd, 1977 (p. 30, pl. 8, figs. 8, 9), from the upper Miocene Suva Formation, Viti Levu, Fiji. These five species are divisible into two groups on the basis of the subsutural sculpture: one group is sculptured with axial wrinkles that are prominent on all or early conch whorls (*Pliconacca trisulcata* and *P. martini*); the other group has no distinct sculpture on the subsutural part except for incremental growth lines (*P. arata*, *P. nanoharae*, and *P. nomii*). The following species, which have been previously classified into other genera, are also classifiable into the first group of *Pliconacca*: *Natica* (*Lunatia*) *atricapilla* Martin, 1884 (pp. 167–168, pl. 8, fig. 162), from the lower Miocene of Java (Martin, 1919), Indonesia; *Uberella cicatrix* Marwick, 1931 (p. 100, pl. 8, figs. 149–150), from the upper Oligocene to lower Miocene of New Zealand; *Lunatia plicispira* Kuroda, 1961 (pp. 130–131, pl. 18, fig. 11), from Tosa Bay, Kochi Prefecture, Japan (Holocene); and *Naticarinus* [*sic*] *okinawaensis* Noda, 1980 (p. 16, pl. 7, figs. 19a–20), from the upper Pliocene Shinzato Formation, Okinawa Prefecture, Japan. Among them, *L. plicispira* and *N. okinawaensis* are herein considered to be synonymous with *P. atricapilla*.

Besides the species of *Pliconacca* mentioned above, the following three species may be referred to *Pliconacca*: *Polinices weisbordi* Palmer, 1937 (pp. 122–123, pl. 12, figs. 7, 10), from the upper Eocene of North America; *Natica denticulifera* Marwick, 1924 (pp. 552–553, pl. 55, fig. 9), from the Pliocene to Holocene of New Zealand; and *Natica ovovata* Sowerby, 1850 of Wrigley, 1949 (p. 21, fig. 39). Palmer (1937) in describing the umbilical callus of *P. weisbordi* said that "across the upper portion of the umbilical callus are two slash-like grooves." Marwick (1924), in describing the umbilical callus of *N. denticulifera* said that "lower outside corner of callus marks apex of a triangular shallow depression with a small denticle on each side" and Marwick (1931) mentioned that "probably *U. cicatrix* is directly ancestral to the Pliocene to Recent *U. denticulifera* (Marw.)." *Uberella cicatrix* is a distinct species of *Pliconacca* as mentioned above. Wrigley (1949) noted the grooves on the callosity of *N. ovovata*, saying that "the parietal callus is broad, thick, and sharply separated from the rear plug by duplicated grooves."

Pliconacca nomii (Nagao, 1928b)
Plate 1, figure 17; Table 23

Polinices (*Neverita*) *nomii* Nagao, 1928b, pp. 96–97, pl. 15, figs. 16–16c; Oyama, 1961a, p. 77 (413).
Neverita nomii (Nagao). Hatai and Nisiyama, 1952, p. 235.
Polinices (*Pliconacca*) *nomii* Nagao. Oyama, Mizuno, and Sakamoto, 1960, pp. 50–51, pl. 5, figs. 9a–b; Itoigawa and Shibata *in* Morishita, 1977, p. 68, pl. 30, fig. 14.

Holotype.—IGPS 36151 (Pl. 1, fig. 17), from near the top of the 92 m high hill, about 300 m west of Abo, Koyagi-jima, Koyagi-machi, Nishi-Sonogi-gun, Nagasaki Prefecture (Hatai and Nisiyama, 1952, p. 235), upper Eocene Futagojima Formation.

Discussion.—Pliconacca nomii is characterized by its large shell, attaining 20.2 mm in height, smooth shell surface, depressed conical form, and large and thick callosity bearing two transverse grooves. *Pliconacca nomii* is known from its holotype only. In his original description, Nagao (1928b) said "callosity thick, . . . two grooved, at its lower part, but the posterior groove very indistinct." The present species is, therefore, assigned to the genus *Pliconacca*, as first pointed out by Oyama (1961a).

As mentioned in the discussion of the genus, *Pliconacca* is divisible into two groups based on the subsutural ornamentation: one group is ornamented with axial wrinkles on all or early conch whorls, whereas the other is smooth except for incremental growth lines. The growth lines of *P. nomii* have been described by

Table 24.—Measurements (in mm) and counts of the largest specimen of *Pliconacca atricapilla* (Martin, 1884) at each locality. Localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
upper Pliocene and lower Pleistocene	KAKEGAWA 24	22.2	17.8+	15.8	—	4½+	GIYU 584	1
	SHINZATO 1	18.2+	15.8+	13.0	12.9+	5	IGUT 15800	3
	SHINZATO 2	20.0	17.4+	14.5	15.5	4+	IGUT 15054-2	2
	SHINZATO 3	28.8+	26.5+	22.4	19.9	6	IGUT 10498	10
	SHINZATO 3	19.5+	16.4	14.5	14.5+	4½+	IGUT 10499*	—
	SHINZATO 4	15.2	13.1	10.7	11.3	4+	IGUT 10595-1	2
	SHINZATO 5	6.0	5.4	4.3	4.8	3+	IGUT 15802	4

* Holotype of *Naticarinus* [*sic*] *okinawaensis* Noda, 1980 .

Nagao (1928b) as "Line of growth crowded, oblique, but usually fine." *Pliconacca nomii* is, therefore, assigned to the second group of species of *Pliconacca*.

Pliconacca nanoharae (Beets, 1942) from the Neogene of East Borneo, a member of the second group of *Pliconacca*, differs from *P. nomii* by having a globose and an extremely small shell attaining only 2 mm in height (Beets, 1942).

Stratigraphic occurrence.—

Upper Eocene: Okinoshima Fm., Nagasaki Pref., locality NAGASAKI 2 (Pl. 1, fig. 17).

Pliconacca atricapilla (Martin, 1884)
Plate 1, figures 13–16; Text-figure 15.7; Table 24

Natica (*Lunatia*) *atricapilla* Martin, 1884, pp. 167–168, pl. 8, fig. 162.

Natica atricapilla Martin. Martin, 1919, p. 99; Vlerk, 1931, p. 257.

Lunatia plicispira Kuroda (MS). Azuma, 1960, p. 23 [without description or comparison], pl. 3, fig. 8 [*nomen nudum*].

Lunatia plicispira Kuroda, 1961, pp. 130–131 [in English], 134–135 [in Japanese], pl. 18, fig. 11; Azuma, 1961, p. 199, pl. 13, fig. 6 [radula]; Okutani, 1964, p. 394, pl. 1, fig. 21; Oyama, 1969, p. 76; Inaba, 1976, p. 87, pl. 1, fig. 1 [radula].

Euspira plicispira (Kuroda). Kuroda, Habe, and Oyama, 1971, p. 185 [in Japanese], p. 121 [in English], pl. 18, fig. 3.

Natica aff. *stellatus* Hedley. Noda, 1980, pp. 15–16, pl. 7, fig. 18 [not *N. stellatus* Hedley, 1913].

Naticarinus [*sic*] *okinawaensis* Noda, 1980, p. 16, pl. 7, figs. 19a–20.

"*Naticarius*" *okinawaensis* Noda. Aoki and Baba, 1984, p. 73, text-fig. 5.

Types.—

Natica (*Lunatia*) *atricapilla* Martin: type material preserved in the National Museum of Geology and Mineralogy in Leiden; type locality, depth 104–112 m in bore hole B, Ngembak, lower Miocene of Java, Indonesia (Martin, 1883–1887).

Lunatia plicispira Kuroda: holotype preserved in the Teramachi collection of Toba Aquarium, Mie Prefecture; type locality, Tosa Bay, Kochi Prefecture, Pacific side of southwest Japan, Holocene (Kuroda, 1961).

Naticarius okinawaensis Noda: IGUT 10499 (holotype: Pl. 1, fig. 15), from cliff about 1 km northeast of Ihara, Sashiki-mura, Shimajiri-gun, Okinawa Prefecture, Japan (loc. 334 of Noda, 1980; loc. SHINZATO 3), upper Pliocene Shinzato Formation.

Description.—Shell large in size for genus, elongate in form, spire greatly to moderately elevated; shell thickness somewhat thin to moderate; body whorl not greatly inflated, evenly rounded, but may bear a somewhat flattened shoulder; suture distinctly impressed; nuclear whorls one-and-one-half, smooth; postnuclear whorls four-and-one-half in largest specimen; axial sculpture of incremental growth lines that are most distinct at base, and of distinct wrinkles extending from suture halfway to periphery, becoming indistinguishable from growth lines near aperture in larger specimens; spiral sculpture of microscopic, minutely wavy, dense costellae. Parietal callus moderate in thickness, moderately filling posterior apertural angle where a burly but short spiral keel may be developed; anterior lobe distinct. Umbilicus weakly to moderately open, may be closed, circumscribed by a fairly angulate basal spiral striation where the growth lines are very weakly bent; umbilical callus very weak, gradually tapering anteriorly or abruptly pinched off anteriorly, smoothly merges with anterior lobe of parietal callus where two or three short spiral folds are commonly gently developed but may be indistinct. Outer lip thin; anterior inner lip and basal lip moderately thickened.

Discussion.—*Pliconacca atricapilla* is characterized by having an elongate shell, subsutural wrinkles, and two or three gently developed spiral folds at the juncture between the parietal and umbilical calluses.

Lunatia plicispira Kuroda, 1961 and *Naticarius okinawaensis* Noda, 1980 are considered to be synonymous with *P. atricapilla* (Martin, 1884). The three species share the characters mentioned above. The characteristic presence of gentle folds on their calluses has not been mentioned by previous authors. However, the specimens illustrated by Martin (1884, pl. 8,

Table 25.—Measurements (in mm) and counts of the holotype of *Mammilla insignis* (Nagao, 1928b).

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*
middle Oligocene	ARITA 2	13.2	14.2	10.6	11.4	4+	IGPS 36155 (holotype)

fig. 162) and Noda (1980, pl. 7, fig. 19a; Pl. 1, fig. 15) clearly show the very-weakly developed callus folds. Although the holotype of *L. plicispira* illustrated by Kuroda (1961, pl. 18, fig. 11) seems to exhibit no callus fold, many modern specimens I have seen possess very-weakly developed callus folds (Pl. 1, fig. 16d). In some modern and fossil specimens, the callus folds are indistinct.

Pliconacca atricapilla first appeared in the lower Miocene of Java, Indonesia (Martin, 1919) and is considered to be a descendant of either *Pliconacca trisulcata* (Martin, 1914) from the upper Eocene of Java, Indonesia, or *Pliconacca cicatrix* (Marwick, 1931) from the upper Oligocene to lower Miocene of New Zealand. The latter two species possess distinct umbilical callus folds (grooves), and subsutural wrinkles that are prominent on the early conch whorls.

Pliconacca trisulcata differs from *P. atricapilla* by having a globose shell and three distinct transverse grooves on the umbilical callus. *Pliconacca cicatrix* is distinguished from *P. atricapilla* by having a very low spire and a small shell, attaining only 6.4 mm in height (Marwick, 1931, p. 100). *Pliconacca martini* Ladd, 1977, from the lower Miocene of Fiji differs from *P. atricapilla* by having a distinct callus ornamentation ("two or three broad grooves" as mentioned by Ladd, 1977, p. 30).

Martin (1884) described the coloration of *P. atricapilla* as having dark spiral bands at the subsutural and umbilical parts. Similar dark bands are subtle features of a few specimens from the upper Pliocene Shinzato Formation of Okinawa Prefecture, but are not present in other fossil and modern specimens I have seen. The coloration mentioned above may be one of the geographic or chronological variations of *P. atricapilla*. Another noticeable variation of *P. atricapilla* is observed in the degree of its umbilical opening. Some specimens exhibit widely open umbilici (Pl. 1, fig. 14), whereas others show nearly closed ones (Pl. 1, fig. 15).

In modern waters, *P. atricapilla* is known to live on fine sandy bottoms at depths of 50–450 m, from Sagami Bay to Tosa Bay, Pacific side of central to southwestern Japan (Kuroda, Habe, and Oyama, 1971) and has a corneous operculum that fits the aperture.

Stratigraphic occurrence.—

Upper Pliocene and lower Pleistocene: Hijikata Member of Upper Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 24 (Pl. 1, fig. 13); Nobori Fm., Kochi Pref. (Aoki and Baba, 1984); Shinzato Fm., Okinawa Pref., localities SHINZATO 1 (Pl. 1, fig. 14), SHINZATO 2, SHINZATO 3 (Pl. 1, fig. 15), SHINZATO 4, and SHINZATO 5.

Genus MAMMILLA Schumacher, 1817

Type species.—*Mammilla fasciata* Schumacher, 1817 (=*Albula mammata* Röding, 1798), by monotypy. Holocene, western Pacific.

Discussion.—*Mammilla* is characterized by its thin and elongate shell, nearly smooth external surface, large aperture, anteriorly inflated body whorl, transverse depression just below the anterior lobe of the parietal callus, and slender umbilical callus.

The shell morphologies of many species of *Mammilla* are extremely similar, so taxonomy for Japanese fossil species of *Mammilla* is very difficult. Fossils lack coloration, operculum, and radulae, all of which are important characters for the classification of species of *Mammilla*.

Mammilla insignis (Nagao, 1928b)
Plate 9, figure 9; Table 25

Polinices (Neverita) insignis Nagao, 1928b, pp. 97–98, pl. 15, figs. 17–18.
Neverita insignis (Nagao). Hatai and Nisiyama, 1952, p. 234.
Mammilla insignis (Nagao). Oyama, Mizuno, and Sakamoto, 1960, p. 51, pl. 6, figs. 3a–c.

Holotype.—IGPS 36155 (Pl. 9, fig. 9), from Obo, Arita-machi, Nishi-Matsuura-gun, Saga Prefecture, middle Oligocene Kishima Formation (Oyama, Mizuno, and Sakamoto, 1960).

Discussion.—The description of the present species represented only by the holotype, is fully given by Nagao (1928b). Though Kanno [1955, p. 32 (list), pl. 6, figs. 18a–b] reported the present species under the name of *Neverita insignis* (Nagao) from the upper Oligocene to lower Miocene deposits of Tsushima, Nagasaki Prefecture, his specimen is too poor to be identified precisely. Oyama, Mizuno, and Sakamoto (1960) classified the present species as *Mammilla*, with which I agree owing to its large aperture, anteriorly inflated body whorl, and small umbilical callus, which is separated from the parietal callus by a distinct transverse groove (Pl. 9, fig. 9).

Stratigraphic occurrence.—

Middle Oligocene: Kishima Fm., Saga Pref., locality ARITA 2 (Pl. 9, fig. 9).

Table 26.—Measurements (in mm) and counts of the largest specimen of *Mammilla* sp. at each locality. Localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
upper Pliocene and lower Pleistocene	CHIKAGAWA 2	16.7+	12.3	8.8	12.8	5	IGUT 16039	1
	NOJIMA 3	14.0	13.2	9.8	12.4	3+	GIYU 618	1
	KAKEGAWA 3	17.4+	14.3	12.4	15.1+	4½+	IGUT 16040	1
	KAKEGAWA 5	13.3	11.7	9.2	12.2	5½	IGUT 16041	1
	TONOHAMA 1	15.0+	12.7	10.6	12.1+	4+	IGUT 16042-1	2
	TONOHAMA 2	15.3	13.1	9.4	13.6	5½	IGUT 16043-1	2
	MIYAZAKI 1	17.4	14.9	11.2	15.4	4½+	IGUT 16044-1	40
	SHINZATO 8	18.6	16.2	12.4	15.3	5½	IGUT 16045-2	2
	HANEJI 3	17.4	14.8	10.5	15.4	5½	IGUT 16082	1

Mammilla species
Plate 9, figures 1–8; Table 26

Discussion.—A large number of specimens of *Mammilla* have been recorded from the upper Pliocene and Pleistocene deposits of Japan, and have been identified with the following species: *Sigaretus* (*Eunaticina*) *oblongus* Reeve, 1864 of Yokoyama (1922) from the Imba Formation, Chiba Prefecture; *Sinum oblongum yuguchiensis* Iwai, 1959 of Iwai (1959) from the Higashimeya Formation, Aomori Prefecture; *Mammilla melanostoma* (Gmelin, 1791) of MacNeil (1960) from the Shinzato and Chinen formations, Okinawa Prefecture; *Mammilla kurodai* Taki, 1943 of Hayasaka (1961) from the Toshima Sand of the Toyohashi Group, Aichi Prefecture; *Mammilla melanostoma* (Gmelin, 1791) and *M. maura* (Bruguière, 1816) of Shuto (1964) from the Miyazaki Group, Miyazaki Prefecture; *Mammilla yokoyamai* T. Makino [MS] *in* Oyama (1958) and *M.* sp. of Kaseno and Matsuura (1965) from the Omma Formation, Ishikawa Prefecture; and *Mammilla* sp. of Mori and Osada (1979) from the Shimoda Formation, Kanagawa Prefecture.

Higo (1973) listed the following ten species from modern Japanese waters under the genus *Mammilla*: *Mammilla kurodai* Taki, 1943; *M. mikawaensis* Azuma, 1961; *M. opaca* (Récluz, 1851); *M. maura* (Bruguière, 1816); *M. simiae* (Deshayes, 1838); *M. mammata* (Röding, 1798); *M. yokoyamai* T. Makino [MS] *in* Oyama (1958) (fossil); *M. sebae* (Récluz, 1851); *M. melanostomoides* (Quoy and Gaimard, 1832); and *M. priamus* (Récluz, 1851). The modern species have been basically distinguished on the basis of coloration, operculum, radula, and slight differences of shell morphologies. Unfortunately, the fossil specimens I have seen all lack the coloration, operculum, and radula. Thus, the specific identifications of fossils are tentative herein, and all the upper Pliocene and Pleistocene fossil specimens of *Mammilla* studied herein are treated as *Mammilla* sp.

Stratigraphic occurrence.—

Upper Pliocene and lower Pleistocene: Sunagomata Fm., Aomori Pref., locality CHIKAGAWA 2 (Pl. 9, fig. 1); Higashimeya Fm., Aomori Pref. (Iwai, 1959 as *Sinum oblongum yuguchiensis*, n. sp.); Omma Fm., Ishikawa Pref. (Kaseno and Matsuura, 1965, as *Mammilla yokoyamai* T. Makino [MS] *in* Oyama (1958), and *M.* sp.); Nojima Fm., Kanagawa Pref., locality NOJIMA 3 (Pl. 9, fig. 2); Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 5; Hosoya Member of Upper Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 3 (Pl. 9, fig. 3); Nobori Fm., Kochi Pref., locality TONOHAMA 1 (Pl. 9, fig. 4); Ananai Fm., Kochi Pref., locality TONOHAMA 2 (Pl. 9, fig. 5); Takanabe Member of Koyu Fm., Miyazaki Pref., locality MIYAZAKI 1 (Pl. 9, fig. 7); Shinzato Fm., Okinawa Pref., locality SHINZATO 8 (Pl. 9, fig. 6); Nakoshi Sand, Okinawa Pref., locality HANEJI 3 (Pl. 9, fig. 8).

Upper Pleistocene: Imba Fm., Chiba Pref. [Yokoyama, 1922 as *Sigaretus* (*Eunaticina*) *oblongus* Reeve, 1864]; Shimoda Fm., Kanagawa Pref. (Mori and Osada, 1979 as *Mammilla* sp.); Toshima Sand of Toyohashi Group, Aichi Pref. (Hayasaka, 1961 as *Mammilla kurodai* Taki, 1943).

Subfamily **SININAE** Woodring, 1928

Discussion.—The subfamily Sininae is characterized by distinct spiral ornamentation on the postnuclear whorls and by a narrower umbilical callus. Among Cenozoic fossil sinines in Japan, the three genera *Sigatica* Meyer and Aldrich, 1886, *Eunaticina* Fischer, 1885, and *Sinum* Röding, 1798 are recognized.

The umbilical characters of Sininae are similar to those of the polinicine genus *Mammilla* in having a commonly slender umbilicus and a narrower umbilical callus. They may be phylogenetically close.

Genus **SIGATICA** Meyer and Aldrich, 1886

Type species.—*Sigaretus* (*Sigatica*) *boettgeri* Meyer and Aldrich, 1886, by monotypy. Eocene, Mississippi and Alabama, U. S. A.

Table 27.—Measurements (in mm) and counts of the holotype of *Sigatica kurodai* Itoigawa and Shibata, 1976

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*
lower middle Miocene	MIZUNAMI 5	6.0	5.4	4.5	5.1	4½	MFM 10073 (holotype)

Discussion.—*Sigatica* is characterized by its globose and small shell (commonly attaining less than 10 mm in height), wide and deep umbilicus, very thin and narrower umbilical callus that tapers anteriorly, and by having very shallowly incised spiral grooves below suture and/or base.

Sigatica is known from the Paleogene of Europe, the lower Eocene to Holocene of North America, and the lower middle Miocene and Holocene of Japan. The following species have been described as *Sigatica*: *Sigatica hantoniensis* (Pilkington, 1804), from the Paleogene of Europe (Wrigley, 1949, ? a naticine species: according to Wrigley, 1949, the species has a calcareous operculum); *S. ovovata* (Sowerby, 1850), from the Paleogene of Europe (Wrigley, 1949, a species of *Pliconacca* [see the discussion of the genus *Pliconacca* Cossmann and Martin *in* Martin, 1914]); *S. abducta* (Deshayes, 1864), from the Paleogene of England (Wrigley, 1949); *S. clarkeana* (Aldrich, 1887), from the lower Eocene of Alabama, U. S. A. (Harris, 1899); *S. boettgeri* (Meyer and Aldrich, 1886), from the middle Eocene of Mississippi and Alabama, U. S. A. (Palmer, 1937); *S. semisulcata* (Gray, 1839), from the Holocene of South Carolina to the West Indies (Abbott, 1974); *S. semisulcata bathyora* (Woodring, 1928), from the middle Miocene of the Dominican Republic (Woodring, 1928); *S. carolinensis* (Dall, 1889), from the Pliocene of Florida (Dall, 1892) and the Holocene of North Carolina to south Florida and the West Indies (Abbott, 1974); *S. bathyraphe* (Pilsbry, 1911), from the Holocene of the Pacific side of Japan; and *S. kurodai* Itoigawa and Shibata, 1976, from the lower middle Miocene of Japan.

Sigatica kurodai Itoigawa and Shibata, 1976
Plate 1, figure 18; Table 27

Sigatica kurodai Itoigawa and Shibata, 1976, pp. 12–13, pl. 3, figs. 9a–b; Itoigawa *et al.*, 1981, pl. 34, figs. 3a–b, 6a–b; Itoigawa *et al.*, 1982, pp. 198–199.

Sigatica sp. Itoigawa, 1960, p. 284, pl. 4, figs. 12a–b; Itoigawa *in* Itoigawa, Shibata, and Nishimoto, 1974, p. 149, pl. 45, fig. 12.

Holotype.—MFM 10073 (Pl. 1, fig. 18), from locality S41 of Itoigawa (1960), Shukunohora, Hiyoshi-machi, Mizunami City, Gifu Prefecture, lower middle Miocene Shukunohora Sandstone.

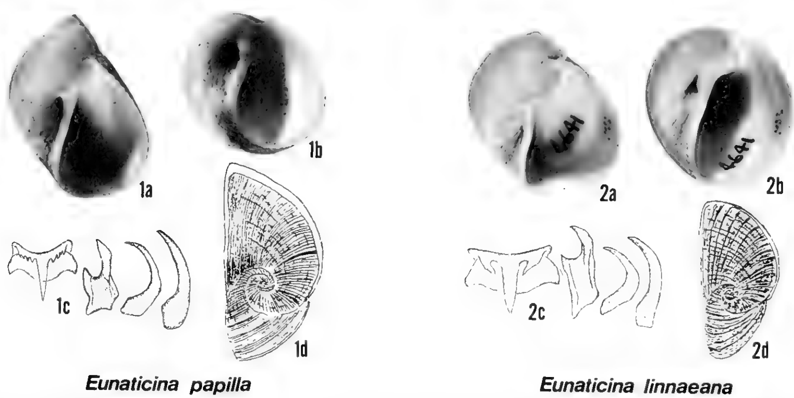
Discussion.—Itoigawa and Shibata (1976) compared the present species with *Sigatica bathyraphe* (Pilsbry, 1911) as follows: "This shell resembles *Sigatica bathyraphe* (Pilsbry, 1911). But the former has the shell with stronger sculpture and a more round body whorl."

Stratigraphic occurrence.—

Lower middle Miocene: Shukunohora Sandstone, Gifu Pref., locality MIZUNAMI 5 (Pl. 1, fig. 18).

Genus **EUNATICINA** Fischer, 1885

Type species.—*Nerita papilla* Gmelin, 1791 (Text-fig. 23.1a–d), by original designation. Miocene to Holocene, Indo-Western Pacific area.



Text-figure 23.—Shells, radulae, and opercula of (1a–d) *Eunaticina papilla* (Gmelin, 1791) and (2a–d) *E. linnaeana* (Récluz, 1843). 1a–b, IGUT 11103, ×1.8, off Mikawa-Isshiki Fishing Port, Aichi Pref. (Holocene); 2a–b, OMNH Mo4641, ×1.2, off Kii Peninsula, Pacific side of central Japan (Holocene). 1c and 2c, radulae, ×125; 1d and 2d, opercula, ×2.4, modified from Arakawa and Kira (1957).

Table 28.—Measurements (in mm) and counts of the specimen of *Eunaticina papilla* (Gmelin, 1791) at locality KAKEGAWA 8.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
upper Pliocene	KAKEGAWA 8	16.0	13.4	9.4	13.3	3½+	IGUT 16046	1

Discussion.—*Eunaticina* is characterized by a globose to globose-elongate shell, open umbilicus, and spiral costae entirely covering the last two whorls in adults.

Eunaticina appears to be closely related to *Sigatica* Meyer and Aldrich, 1886 and *Sigaretotrema* Sacco, 1890, which share several important characters: globose or globose-elongate shell, spiral costae (grooves), and an open umbilicus. Oyama (1969) considered the three genera to be taxa intermediate between Polinicinae and Sininae.

The following species have been included in *Eunaticina*: *Eunaticina papilla* (Gmelin, 1791), discussed in this study; *E. linnaeana* (Récluz, 1843), discussed in this study; *E. modoerensis* (Altena, 1941), Pliocene of Java, Indonesia (? a junior synonym of *E. linnaeana*); *E. dingeldeii* (Iredale, 1931), living in Australian waters (? a junior synonym of *E. linnaeana*, by Kilburn, 1976); *E. regia* (Guppy, 1873), Miocene of Jamaica, West Indies (Woodring, 1928, p. 387); *E. insculpta* (Carpenter, 1865), Pliocene to Holocene of Pacific side of Central to North America (Marincovich, 1977, pp. 359–361); and *E. cincta* (Hutton, 1885), Pleistocene to ? Holocene of New Zealand (Marwick, 1924, p. 572–573; Powell, 1979, p. 158).

Eunaticina papilla (Gmelin, 1791)
Plate 10, figure 16;
Text-figures 15.36, 23.1a–d; Table 28

Nerita papilla Gmelin, 1791, p. 3675 [not seen].
Sigaretus papilla (Gmelin). Reeve, 1864, pl. 4, figs. 19a–b; Weinkauff, 1883, pp. 38–39, pl. 9, figs. 4, 6, pl. 10, fig. 8; Tokunaga, 1906, p. 19, pl. 1, fig. 34.
Not *Sigaretus papilla* (Gmelin). Uchiyama, 1903, p. 11, pl. 28, figs. 59, 60 [= *Eunaticina linnaeana* (Récluz, 1843)].
Sigaretus (*Eunaticina*) *papilla* (Gmelin). Tryon, 1886, p. 58, pl. 25, figs. 78, 79, 87, 88; Yokoyama, 1922, p. 84, pl. 5, fig. 8.
Sigaretus (*Eunaticina*) *papilla* Chemn. [*sic*]. Martin, 1905, p. 269, pl. 40, figs. 647, 648.
Sigaretus papilla Chemn. [*sic*]. Tesch, 1920, p. 68, pl. 132, figs. 204a–b.
Sinum papilla (Gmelin). Kuroda and Habe, 1952, p. 85.
Eunaticina papilla (Gmelin). Taki and Oyama, 1954, p. 17, pl. 25, fig. 8; Azuma, 1961, p. 199, pl. 13, fig. 5 [radula]; Habe, 1961, p. 40, pl. 18, fig. 14; Hayasaka, 1961, pp. 77–78, pl. 9, figs. 21a–b; Oyama, 1969, p. 80, text-figs. 6 [operculum], 7 [radula]; Habe and Kosuge, 1970, p. 45, pl. 18, fig. 3; Kuroda, Habe, and Oyama, 1971, pp. 188–189 [in Japanese], p. 123 [in English], pl. 109, fig. 10; Oyama, 1973, p. 32, pl. 7, figs. 5a–b; Okutani and Habe, 1975, p. 83 [unnumbered figs.], p. 245; Popenoe and Kleinpell, 1978, pl. 4, figs. 50, 51; Mori and Osada, 1979, pl. 2, fig. 11; Fujiyama *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 354, pl. 177, fig. 1721; Kanno, O'hara, and Caagusan, 1982, p. 104, pl. 17, figs. 11a–b; Akamatsu and Kitagawa, 1983, pl. 3, fig. 9; Majima and Fukuta, 1986, text-fig. 1.10.
Not *Eunaticina papilla* (Gmelin) [= *Eunaticina linnaeana* (Récluz, 1843)]. Nomura, 1935b, p. 205, pl. 9, figs. 27a, 27b; Cernohorsky, 1971, pp. 201–202, text-fig. 69; Cernohorsky, 1972, p. 102, pl. 27, fig. 5; Matsuura, 1977, pl. 6, fig. 28.
Not *Sinum* (*Eunaticina*) *papillum* (Gmelin). Otuka, 1935, p. 867, pl. 54, fig. 64 [= *Eunaticina linnaeana* (Récluz, 1843)].
Not *Sinum* (*Eunaticina*) *papilla* (Gmelin). Altena, 1941, pp. 82–84, text-figs. 23a–b [= *Eunaticina linnaeana* (Récluz, 1843)].
Eunaticina linnaeana (Récluz). Kilburn, 1976, pp. 870–871 [in part], text-figs. 21 [right-side figure], 26b [radula] [not *E. linnaeana* (Récluz, 1843); not fig. 21 (left-side figure), = *E. linnaeana* (Récluz)].

Type.—Type material unknown; type locality, Tranquebar, India (*fide* Weinkauff, 1883).

Description.—Shell small, globose-elongate, spire elevated, body whorl not greatly inflated; suture shallowly channeled; shell thin; whorls three-and-one-half (apex eroded). Spiral sculpture of flat-topped costae separated by much narrower, sharply incised grooves; costae are indistinct in early conch whorls, may be narrower below suture; axial sculpture of incremental growth lines. Parietal callus thin, lightly filling posterior apertural angle; anterior lobe distinct. Umbilicus moderately open. Anterior inner lip weakly thickened, not forming a distinct umbilical callus, separated from parietal callus by a shallow dimple. Basal lip not thickened.

Discussion.—*Eunaticina papilla* is characterized by its globose-elongate form, elevated spire, and spiral costae that entirely cover the later conch whorls in the adult.

Until Arakawa and Kira (1957) exhaustively studied the shells, opercula, radulae, habitats, and anatomy of the two forms [globose-elongate form (Text-fig. 23.1a–b) and globose form (Text-fig. 23.2a–b)] of *Eunaticina* in Japan, these two forms of *Eunaticina* had been doubtfully considered to be either a variation of one species or to be two different species. Arakawa and Kira treated the two forms of *Eunaticina* as follows:

Globose-elongate form (Text-fig. 23.1a–b) is *Eunaticina papilla* [as "*Sinum* (*Eunaticina*) *pyilla* [*sic*] (Gmelin)" in Arakawa and Kira, 1957: misprint for *papilla*] and globose form (Text-fig. 23.2a–b) is *Eunaticina linnaeana* (Récluz, 1843) [as *Sinum* (*Eunaticina*) *lamarckianum* (Récluz, 1843) in Arakawa and Kira, 1957]. There is no intermediate form between them, but these two species are identical in whorl sculpture, and in coloration of the nuclear whorls (brown) and periostracum (pale yellow). The opercula of the two species are corneous, very similar and peculiar in form among naticids (Text-figs. 23.1d, 23.2d). The lengths of both opercula attain about half of the axial length of the aperture. The operculum of *E. papilla* is wide and nearly semicircular in form (Text-fig. 23.1d) but that of *E. linnaeana* is relatively slender (Text-fig. 23.2d), whereas the apertural form of the former species is more slender than that of the latter. The radular dentitions of the two species are quite distinct; that is, the rachidian of *E. papilla* has a prominent central cusp and four weakly developed lateral cusps on both sides (Text-fig. 23.1c), whereas that of *E. linnaeana* is tricuspate with a strong central cusp (Text-fig. 23.2c). *Eunaticina papilla* is now living in 20 to 40 m depth but *E. linnaeana* in tidal flat to 20 m. Male and female are recognized in both the forms, but no sexual dimorphism is observable in shells of either species. From the observations described above, Arakawa and Kira (1957) concluded that the two forms of *Eunaticina* in Japan are different species.

Kilburn (1976) discussed shell differences between *E. papilla* and *E. linnaeana*. The radular dentition of *E. linnaeana* figured by Kilburn (1976, text-fig. 26b) is, however, identical to those of *E. papilla* illustrated by Arakawa and Kira (1957) (Text-fig. 23.1c) and by Azuma (1961) (Text-fig. 15.36). Furthermore, one of the two shells illustrated by Kilburn [1976, text-fig. 21 (right-side figure)] as *E. linnaeana* looks similar to that of *E. papilla*. Kilburn (1976) probably confused, in part, *E. papilla* with *E. linnaeana*.

Stratigraphic occurrence.—

Upper Pliocene: Tenno Member of Lower Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 8 (Pl. 10, fig. 16).

Lower Pleistocene: Semata Fm., Chiba Pref. (Yokoyama, 1922; Oyama, 1973); Shimoda Fm., Kanagawa Pref. (Mori and Osada, 1979); Toshima Sand of Toyohashi Group, Aichi Pref. (Hayasaka, 1961).

Eunaticina linnaeana (Récluz, 1843)
Text-figures 15.37, 23.2a–d

Sigaretus linnaeanus Récluz, 1843, pp. 6, 8, pl. 1, figs. 4a–b [not seen].
Sigaretus (*Naticina*) *linnaeanus* Récluz. Weinkauff, 1883, pp. 37–38, pl. 9, figs. 2, 5.
Sigaretus (*Eunaticina*) *linneanus* [*sic*] Récluz. Tryon, 1886, p. 59, pl. 25, figs. 89, 90.
Eunaticina linnaeana (Récluz). Kilburn, 1976, pp. 870–871 [in part], text-fig. 21 [left-side figure] [not text-figs. 21 (right-side figure), 26b (radula) = *Eunaticina papilla* (Gmelin, 1791)].
Sigaretus lamarckianus Récluz, 1843, p. 6, 7 [in part], pl. 1, figs. 5a–b [not pl. 3, fig. 2 = *Sinum cuvierianum*] [not seen, *fide* Kilburn, 1976]; Weinkauff, 1883, pp. 40–41, pl. 9, figs. 8, 11.
Sinum lamarckianum (Récluz). Kuroda and Habe, 1952, p. 85.
Eunaticina lamarckiana (Récluz). Kira, 1959, p. 39, pl. 17, fig. 2. Oyama, 1969, p. 80; Inaba, 1976, p. 88, pl. 1, fig. 8 [radula].
Sigaretus papilla (Gmelin). Uchiyama, 1903, p. 11, pl. 28, figs. 59, 60 [not *Eunaticina papilla* (Gmelin, 1791)].
Eunaticina papilla (Gmelin) [not *E. papilla* (Gmelin, 1791)]. Nomura, 1935b, p. 205, pl. 9, figs. 27a, 27b; Cernohorsky, 1971, pp. 201–202, text-fig. 69; Cernohorsky, 1972, p. 102, pl. 27, fig. 5; Matsuura, 1977, pl. 6, fig. 28.
Sinum (*Eunaticina*) *papillum* (Gmelin). Otuka, 1935, p. 867, pl. 54, fig. 64 [not *Eunaticina papilla* (Gmelin, 1791)].
Sinum (*Eunaticina*) *papilla* (Gmelin). Altena, 1941, pp. 82–84, text-figs. 23a–b [not *Eunaticina papilla* (Gmelin, 1791)].

Types.—

Sigaretus linnaeanus Récluz: type material unknown; type locality, Malaysia (*fide* Kilburn, 1976).
Sigaretus lamarckianus Récluz: type material unknown; type locality, Philippines (*fide* Kilburn, 1976).

Discussion.—Fossil specimens of *Eunaticina linnaeana* were not available for this study. The discussion of this species is included herein with the discussion of *Eunaticina papilla* (Gmelin, 1791).

Stratigraphic occurrence.—

Upper Pleistocene: Hiradoko Fm., Ishikawa Pref. (Otuka, 1935; Matsuura, 1977).

Genus **SINUM** Röding, 1798

Type species.—*Helix haliotoidea* Linnaeus, 1758, by subsequent desgnation [Dall, 1915, p. 109 (not seen)].

Discussion.—*Sinum* is characterized by its greatly depressed to globose conical shell, flattened base, greatly enlarged body whorl with very large aperture, closely spaced spiral costae entirely covering all the postnuclear whorls, minutely developed parietal and umbilical calluses, and commonly closed umbilicus.

The status of the type species seems to be unsettled. Woodring (1928, p. 389) discussed the type species of *Sinum* as follows:

> There is some question as to just what species the type of *Sinum* is. Two species are listed under this genus in the Museum Boltenianum, *S. fuscum* and *S. haliotoideum*, in the synonymy of both of which "*Helix haliotoidea* Gmelin" is cited with references added by Gmelin in the twelfth edition of the Systema Naturae. Dall's type designation apparently refers to the species cited by Roeding as "*S. haliotoideum*," for which only one figure ("Knorr Vergn, 6. t. 39. fig. 5") is cited. This figure is a ventral view of a medium-sized, greatly flattened, imperforate "*Sigaretus*." It probably can not be determined whether it is the same species as *Helix haliotoidea* Linné, a dorsal view of the type of which was figured by Hanley (Ipsa Linnaei Conchylia, pp. 390–391, pl. 4, fig. 7, 1855: "*haliotidea*" by error). At all events both these figures represent shells that are congeneric.

Cernohorsky (1972, p. 102) had the following comments on *Helix haliotoidea* Linnaeus, 1758 and *Sinum fuscum* Röding, 1798, in his description of *Sinum zonale* (Quoy and Gaimard, 1833):

Table 29.—Measurements (in mm) and counts of the holotype and of the largest specimen of *Sinum ineptum* (Yokoyama, 1924) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower middle Miocene	FURANUI 3	18.1	18.4+	17.0	17.0	4+	IGUT 15811-1	2
	KADONOSAWA 1	26.4	24.9+	19.9	21.8	5	IGUT 15812-2	8
	KADONOSAWA 1	16.7	19.1	14.4+	15.4	3+	UMUT CM12079*	—
	KADONOSAWA 2	23.7	24.8+	20.0	20.8	4+	IGUT 15953-1	4
	KADONOSAWA 4	30.2	32.4	23.9	26.8	3+	IGUT 16036	1
	TAIRA 1	21.7+	22.0+	19.9	18.9+	3+	IGUT 15814-1	5
	MIZUNAMI 4	22.5	27.5	22.0	22.9	—	MFM unnumbered	1
	TANABE 2	15.3	21.9	16.2	12.3	—	UMUT CM24624 (holotype)	1
middle middle Miocene to upper Miocene	TANAGURA 1	19.4	21.5	16.9	16.9	4+	IGUT 15845-1	3
	TANAGURA 2	13.8	16.5	13.0	12.2	4+	IGUT 15816	1
	KOKOZURA	18.7	21.7	16.4	16.3	3+	IGUT 15813-1	5

* Holotype of *Sinum yabei* Otuka, 1934.

Helix haliotoidea Linnaeus, 1758, originally reported from the Mediterranean and American Seas is an unknown identity, and *Sinum fuscum* Roeding, 1798, is a composite species which also includes *S. zonale*. *Sigaretus laevigatus* Lamarck, 1822, however, could be an earlier name for *S. zonale*.

Sinum ineptum (Yokoyama, 1924)
Plate 9, figures 10–20; Text-figure 3.5; Table 29

Sigaretus ineptus Yokoyama, 1924, pp. 53–54, pl. 6, fig. 16.
Sinum ineptum (Yokoyama). Hatai and Nisiyama, 1952, p. 244; Masuda, 1967, pl. 1, figs. 23a–b; Yoon, 1980, p. 75, pl. 8, figs. 10, 11; Masuda *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 256, pl. 128, figs. 1219a–b.
Sinum yabei Otuka, 1934, pp. 627–628, pl. 49, figs. 74, 75; Nomura and Hatai, 1936, pp. 145–146, pl. 17, figs. 9, 10; Otuka, 1937, p. 28, pl. 3, figs. 6, 7; Hatai and Nisiyama, 1952, p. 244; Aoki, 1959, p. 277, pl. 3, figs. 32a–b; Kamada, 1962, p. 161, pl. 19, figs. 6a–8b; Masuda and Takegawa, 1965, pl. 2, figs. 20a–b; Shikama, 1970, p. 106, pl. 30, figs. 18a–b; Iwasaki, 1970, p. 418, pl. 1, figs. 15a–b; Itoigawa *in* Itoigawa, Shibata, and Nishimoto, 1974, p. 149, pl. 45, figs. 20a–21b; Yamagishi *et al.*, 1975, pl. 1, fig. 12; Ogasawara, 1976, p. 64, pl. 13, fig. 16, pl. 15, fig. 11; Itoigawa and Shibata *in* Morishita, 1977, p. 68, pl. 30, fig. 17; Taguchi, Ono, and Okamoto, 1979, pl. 4, fig. 6; Suehiro, 1979, p. 88, pl. 15, figs. 10a–c; ?Ogasawara and Nomura, 1980, pl. 12, fig. 1; Itoigawa *et al.*, 1981, pl. 34, figs. 15a–b; Itoigawa *et al.*, 1982, p. 199–200; Masuda *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 274, pl. 137, figs. 1286a–b; Nakagawa and Takeyama, 1985, pl. 22, figs. 1a–b.

Types.—

Sigaretus ineptus Yokoyama: UMUT CM24624 (holotype: Pl. 9, fig. 17), from Fujishima, Shirahama-machi, Tanabe City, Wakayama Prefecture, lower middle Miocene Tanabe Group.

Sinum yabei Otuka: UMUT CM12079 (holotype: Pl. 9, fig. 12), from Shiratori, Fukuoka-machi, Ninohe City, Iwate Prefecture, lower middle Miocene Kadonosawa Formation.

Description.—Shell small, thin, weakly to moderately elongate in form, spire weakly to moderately elevated; base flattened; body whorl greatly inflated, not evenly rounded; shoulder commonly flattened, may be slightly but broadly convex; suture moderately impressed; nuclear whorls two-and-one-half, smooth; postnuclear whorls two-and-one-half. Spiral sculpture of low, flat-topped costae separated by interspaces of commonly lesser but rarely greater width; interspaces may be sculptured with a single minute costella, uncommonly with more than two; axial sculpture of incremental growth lines that are most distinct at base, and give costae minutely wavy appearance. Parietal area narrow; parietal callus very thin, very minutely filling posterior apertural angle; anterior lobe weakly developed. Umbilicus minutely open; umbilical callus very narrow, flattened, weakly reflexed. Anterior inner lip slightly thickened, smoothly merging with umbilical callus; basal lip and outer lip thin.

Discussion.—*Sinum ineptum* is characterized by having a weakly to moderately elongate shell and a flattened shoulder. It varies in shell form; that is, some specimens possess conical elongate forms (Pl. 9, figs. 12–13, 15–16, 18) whereas others have a weakly depressed shape [Pl. 9, figs. 17 (slightly deformed), 19]. These two end forms are entirely interconnected by intermediate forms. Although the holotype of *S. ineptum* (Pl. 9, fig. 17) is axially slightly deformed and its base is not well preserved, its shell outline safely falls within the variation known for Miocene specimens.

Stratigraphic occurrence.—

Lower middle Miocene: Chikubetsu Fm., Hokkaido (Ogasawara *et al.*, 1982); Furanui Fm., Hokkaido, locality FURANUI 3 (Pl. 9, figs. 10–11); Takahoko Fm., Aomori Pref. (Aoki, 1959); Kadonosawa Fm., Iwate Pref., localities KADONOSAWA 1 (Pl. 9, figs. 12–13), KADONOSAWA 2, and KADONOSAWA 4 (Pl. 9, fig. 16); Higashi-Innai Fm., Ishikawa Pref. (Masuda, 1967);

Table 30.—Measurements (in mm) and counts of the largest specimen of *Sinum javanicum* (Griffith and Pidgeon, 1834) at each locality. Within the upper Pleistocene, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
upper Pliocene	KAKEGAWA 1	20.6	30.1+	24.2	16.5	4	IGUT 15818-1	5
	KAKEGAWA 2	35.3	46.3	35.0	32.2	4+	IGUT 15819	1
	KAKEGAWA 10	26.1	36.4+	30.3+	—	4+	IGUT 15820-1	3
upper Pleistocene	HIRADOKO	17.0	30.3	21.1	14.8	4	IGUT 15821	1
	SAKURAI	27.0	37.2	28.7	23.4	4½	IGUT 15822-1	3

Numanouchi Fm., Fukushima Pref., locality TAIRA 1 (Pl. 9, fig. 14); Uchiura Group, Fukui Pref. (Nakagawa and Takeyama, 1985); Nataki Fm., Gifu Pref., locality MIZUNAMI 4 (Pl. 9, fig. 15); Tanabe Group, Wakayama Pref., locality TANABE 2 (Pl. 9, fig. 17); Bihoku Group, Okayama Pref. (Taguchi, Ono, and Okamoto, 1979); Togane Fm., Shimane Pref. (Otuka, 1937).

Middle middle Miocene to upper Miocene: Kanagase Fm., Miyagi Pref. (Masuda and Takegawa, 1965); Kubota Fm., Fukushima Pref., localities TANAGURA 1 (Pl. 9, fig. 18) and TANAGURA 2 (Pl. 9, fig. 19); Kokozura Fm., Fukushima Pref., locality KOKOZURA (Pl. 9, fig. 20); Aimagawa Fm., Gumma Pref. (Yamagishi *et al.*, 1975); Saikawa Fm., Ishikawa Pref. (Ogasawara, 1976); Fujina Fm., Shimane Pref. (Suehiro, 1979; ?Ogasawara and Nomura, 1980).

Sinum javanicum (Griffith and Pidgeon, 1834)
Plate 9, figures 22–23;
Text-figures 15.32, 15.33; Table 30

Cryptosoma javanicum Griffith and Pidgeon, 1834, p. 596, pl. 41, fig. 1 [not seen].
Sigaretus javanicus (Griffith and Pidgeon). Reeve, 1864, pl. 2, figs. 8a–b; Weinkauff, 1883, pp. 8–9, pl. 1, figs. 4–6, pl. 3, fig. 12.
Sinum javanicum (Griffith and Pidgeon). Hirase, 1934, p. 60, pl. 91, fig. 10; Kuroda and Habe, 1952, p. 85; Azuma, 1961, p. 199, pl. 15, fig. 3 [radula]; Hayasaka, 1961, p. 78, pl. 10, figs. 1a–c; Habe and Kosuge, 1965, p. 36, pl. 12, fig. 15; Habe and Kosuge, 1970, p. 45, pl. 18, fig. 4; Kuroda, Habe, and Oyama, 1971, p. 187 [in Japanese], pp. 122–123 [in English], pl. 109, figs. 6, 7; Okutani and Habe, 1975, pp. 83 [unnumbered figs.], 260–261; Matsuura, 1977, pl. 7, fig. 1; Aoki and Baba, 1983, p. 50, text-figs. 13a–b; Majima and Fukuta, 1986, text-fig. 1.11.
Sinum javanicus (Griffith and Pidgeon). Kira, 1954, p. 35, pl. 17, fig. 6; Kira, 1959, pp. 39–40, pl. 17, fig. 6; Takahashi and Okamoto, 1969, p. 40, pl. 5, fig. 15.
Sinum (*Sinum*) *javanicus* (Griffith and Pidgeon). Oyama, 1958, unnumbered pl. [*Sinum*], figs. 14–17.
Sinum (*Sinum*) *javanicum* (Griffith and Pidgeon). Oyama, 1969, p. 81; Inaba, 1976, p. 88, pl. 2, fig. 1 [radula].

Type.—Type material unknown; type locality, Java, Indonesia (Reeve, 1864; Kuroda, Habe, and Oyama, 1971).

Description.—Shell large, weakly depressed, spire weakly elevated; body whorl greatly inflated, shoulder broadly but weakly convex; base flattened; nuclear whorls two-and-one-half, smooth; postnuclear whorls two-and-one-half; suture moderately impressed and very weakly channeled. Spiral sculpture of low, flat-topped costae, separated by narrower interspaces that may bear a single minute costella; axial sculpture of incremental growth lines that are most distinct at base, and give costae and costellae a lightly wavy appearance. Parietal callus very thin, lightly filling posterior apertural angle; anterior lobe very weak. Umbilicus commonly closed, may be minutely open; umbilical callus very weak, slender, indistinct from inner lip, weakly reflexed. Anterior inner lip and outer lip thin.

Discussion.—*Sinum javanicum* is characterized by a large shell, weakly elevated spire, distinctly developed spiral costae and a commonly closed umbilicus.

Sinum javanicum lives in the modern warm waters around the Japanese Islands and first appeared in the upper Pliocene Dainichi Member of the Lower Kakegawa Formation (Pl. 9, fig. 22) in association with the warm-water Kakegawa fauna.

Stratigraphic occurrence.—

Upper Pliocene: Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 1, KAKEGAWA 2 (Pl. 9, fig. 22), and KAKEGAWA 10.

Upper Pleistocene: Hiradoko Fm., Ishikawa Pref., locality HIRADOKO; Sakurai Fm., Chiba Pref., locality SAKURAI (Pl. 9, fig. 23); Toshima Sand of Toyohashi Group, Aichi Pref. (Hayasaka, 1961).

"Sinum" festiva (Yokoyama, 1925b)
Plate 9, figure 21; Table 31

Sigaretus festivus Yokoyama, 1925b, p. 8, pl. 1, fig. 6.
Eunaticina festiva (Yokoyama). Hatai and Nisiyama, 1952, p. 244.

Holotype.—UMUT CM22564 (Pl. 9, fig. 21), from a short distance north of Shimosoyama, Shigarami, Togakushi-mura, Kamiminochi-gun, Nagano Prefecture, lower Pliocene Shigarami Formation.

Discussion.—The holotype is conical in form, with a flat base and a closed umbilicus, based upon which Yokoyama (1925b) assigned the species to the Sininae. However, its shell surface is almost totally eroded, so it is impossible to determine whether it is *Sinum* or not. Shell-surface sculpture is the best criterion for the

Table 31.—Measurements (in mm) and counts of the holotype of "*Sinum*" *festiva* (Yokoyama, 1925b).

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*
lower Pliocene	SHIGARAMI 3	25.4	29.9	23.7	20.6	4+	UMUT CM22564 (holotype)

classification of sinine species. In shell outline, this species is very similar to *Sinum ineptum* (Yokoyama, 1924) and they may be conspecific, but to confirm it, additional well-preserved topotypes are necessary.

Stratigraphic occurrence.—

Lower Pliocene: Shigarami Fm., Nagano Pref., locality SHIGARAMI 3 (Pl. 9, fig. 21).

Subfamily **NATICINAE** Forbes, 1838

Discussion.—The naticine species group is easily distinguished from other naticids by having an entirely calcareous operculum. The shells of species in this subfamily are similar to those of the Polinicinae but commonly differ by the presence of a semicircular umbilical callus with a distinct funicle and a more tabulated shoulder. In some genera of this subfamily, however, they are not easy to distinguish from *Euspira* Agassiz *in* Sowerby, 1838, one of the polinicine genera, on the basis of shell form alone; for example, *Nacca* Risso, 1826 (p. 148; type species, *Natica fulminea* Gmelin, 1791, living, West Africa) and *Magnatica* Marwick, 1924 (p. 553; type species, *Polinices planispirus* Suter, 1917 [not *Natica planispira* Phillips, 1836, = *Natica* (*Magnatica*) *suteri* Marwick, 1924, Miocene, New Zealand]) do not have distinct semicircular umbilical calluses and well tabulated shoulders, whereas they have entirely calcareous opercula. The calcareous operculum of *N.* (*M.*) *suteri*, a fossil species, has been recorded by Graham (1965).

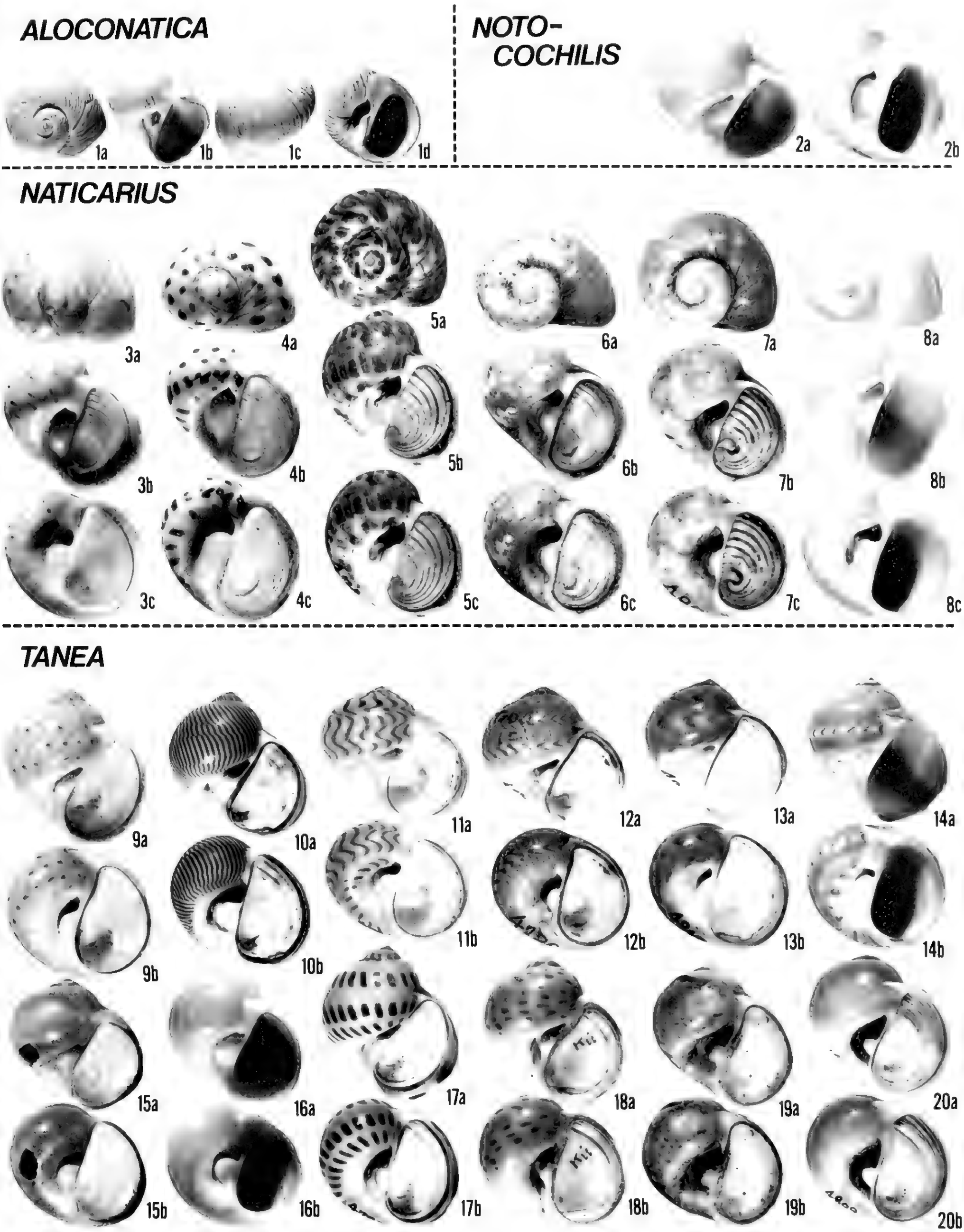
This subfamily has been diverse in world waters throughout the Cenozoic as has been the Polinicinae, but its conservatism in shell form is conspicuous even among naticids, and makes the worldwide supraspecific taxonomy within this subfamily difficult. In 1969, Oyama published a preliminary systematic revision of Japanese living Naticidae, in which he classified the Japanese modern species of Naticinae into six genera, including *Natica* Scopoli, 1777, *Naticarius* Duméril, 1806, *Notocochlis* Powell, 1933, *Paratectonatica* Azuma, 1961, *Cryptonatica* Dall, 1892, and *Tanea* Marwick, 1931, on the basis of the combination of morphologies of the shell, operculum, and the radular dentition. The generic classification adopted herein is mainly based upon Oyama's study, which seems to be more useful than those of the other workers for at least the western Pacific Naticinae species group. Oyama's diagnoses of genera of the Japanese Naticinae are briefly summarized as follows:

Natica Scopoli, 1777 (Pl. 10, figs. 1–13): Shell smooth but may bear subsutural axial wrinkles; umbilicus rather narrow; umbilical callus not well developed; operculum smooth except for one to three marginal grooves, inner margin distinctly crenulated or serrated; rachidian tricuspate, with a strong central cusp (Text-fig. 15.38–15.45).

Naticarius Duméril, 1806 (Pl. 12, figs. 17–18; Text-fig. 24.3a–24.8c): Whorl sculpture of distinct axial wrinkles below sutures; umbilicus not greatly open; umbilical callus large, half-heart-shaped, situated anteriorly; sulcus greatly developed; operculum wholly covered by numerous spiral grooves or costae; rachidian tricuspate, with a strong central cusp (Text-fig. 15.47–15.51).

Notocochlis Powell, 1933 (Pl. 12, figs. 21–22; Text-fig. 24.2a–b): Shell and radular (Text-fig. 15.52–15.54) features similar to those of *Naticarius* but umbilicus more closed and operculum smooth except for one marginal shallow groove.

Text-figure 24.—The type species of (1a–d) *Aloconatica* Shikama, 1971, (2a–b) *Notocochilis* Powell, 1933, (3a–c) *Naticarius* Duméril, 1806, and (9a–b) *Tanea* Marwick, 1931, and Japanese Holocene species of (4a–8c) *Naticarius* and (10a–20b) *Tanea*. All are Holocene specimens. 1a–c, *Aloconatica kushime* Shikama, 1971, KPM S2474 (holotype of the species) ×1.3, Enshu-Nada, Pacific side of central Honshu; 2a–b, *Notocochlis migratoria* (Powell, 1927), IGUT 16118, ×1.6, "eelgrass" (*Zostera*) sandflat, off Akatarere Point, Paua, Parengarenga Harbour, northern New Zealand; 3a–c, *Naticarius canrena* (Linnaeus, 1758), KPM S2479, ×1.2, Little Duck Key, Florida, U. S. A.; 4a–c, *N. onca* (Röding, 1798), KPM 761-722, ×1.5, Ishigaki-jima, Okinawa Pref.; 5a–c, *N. concinnus* (Dunker, 1859), OMNH Mo4742, ×1.4, Mukai-jima, Hiroshima Pref.; 6a–c, *N. alapapilionis* (Röding, 1798), GIYU 625, ×1.2, Kashiwajima, Kochi Pref.; 7a–c, *N. excellens* Azuma, 1961, OMNH Mo4822, ×1.5, Tosa Bay (30 fm.), Kochi Pref.; 8a–c, *N. orientalis* (Gmelin, 1791), PKS unnumbered, ×0.8, Amami-Ooshima, Kagoshima Pref.; 9a–b, *Tanea zelandica* (Quoy and Gaimard, 1832), IGUT 16119, ×1.7, Waikamae Beach, West Wellington, New Zealand; 10a–b, *T. lineata* (Röding, 1798), NSMT Mo64470, ×0.7, Taiwan (unknown in detail); 11a–b, *T. undulata* (Röding, 1798), OMNH Mo4783, ×1.2, Okinawa Pref. (unknown in detail); 12a–b, *T. euzona* (Récluz, 1844), OMNH Mo4726, ×1.4, Tosa Bay (100 fm.), Kochi Pref.; 13a–b, *T. lemniscata* (Philippi, 1851), OMNH Mo4846, ×1.8, off Mikawa-Isshiki Fishing Port, Aichi Pref.; 14a–b, *T. picta* (Récluz, 1844), PKS unnumbered, ×1.1, Wakayama Pref. (unknown in detail); 15a–b, *T. areolata* (Récluz, 1844), PKS unnumbered, ×1.8, Amami-Ooshima, Kagoshima Pref.; 16a–b, *T. areolata* (Récluz, 1844), KPM 761-715, ×1.5, Amami-Ooshima, Kagoshima Pref.; 17a–b, *T. tosaensis* (Kuroda, 1961), OMNH Mo4797, ×1.0, Tosa Bay (100 fm.), Kochi Pref.; 18a–b, *T. hilaris* (Sowerby, 1914), NSMT Mo64468, ×1.2, off Kii Peninsula, Pacific side of southwestern Honshu; 19a–b, *T. shoichiroi* (Kuroda, 1961), OMNH Mo4722, ×1.6, off Mikawa-Isshiki Fishing Port, Aichi Pref.; 20a–b, *T. tabularis* (Kuroda, 1961), OMNH Mo4809, ×1.2, off Mikawa-Isshiki Fishing Port, Aichi Pref.


ALOCONATICA
NOTO-
COCHILIS
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NATICARIUS
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Table 32.—Measurements (in mm) and counts of the largest specimen of *Natica vitellus* (Linnaeus, 1758) at each locality. Localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
upper Pliocene and lower Pleistocene	Kakegawa 1	33.1	32.5	25.5	27.0	5½	IGUT 15068-1	11
	Kakegawa 2	21.1	21.6	20.0	17.6	4+	IGUT 15070-1	4
	Kakegawa 10	27.2	24.3+	20.5	—	4+	IGUT 15072-3	7
	Kakegawa 11	15.9	15.8	13.1	12.9	4½	IGUT 15074-1	2
	Kakegawa 17	23.9+	23.8+	19.6	20.3+	5	IGUT 15077-1	4
	Tonohama 2	20.8	21.9	16.7	17.0	5	IGUT 15246-1	12
	Miyazaki 1	23.3+	18.9+	21.3	—	5	IGUT 15090-1	3
	Miyazaki 2	21.5+	21.0+	18.8	19.8+	4+	IGUT 15093	1
	Shinzato 6	21.5	22.9	17.4	16.3	4½+	IGUT 16080	1
	Kume 1	16.4	17.4	14.0	14.1	4¾	GIYU 619	1
	Kume 2	25.4+	27.4+	20.0	18.8+	5½	GIYU 620-1	2
	Kume 3	15.9	15.1	13.4	13.1	5	GIYU 621-1	2

Paratectonatica Azuma, 1961 (Pl. 14, fig. 18): Shell smooth; umbilicus narrowly open; umbilical callus small; operculum smooth except for two marginal grooves; rachidian tricuspate, each cusp of which is nearly equally developed (Text-fig. 15.55).

Cryptonatica Dall, 1892 (Pl. 11, figs. 1–22, Pl. 12, figs. 1–16, Pl. 13, figs. 1–23, Pl. 14, figs. 1–17; Text-fig. 25): Shell smooth; umbilicus commonly closed, may be slightly open around semicircular umbilical callus; operculum commonly smooth, may bear one or two marginal grooves; rachidian basically monocuspate, may be weakly crenulated, commonly with a very small lateral cusp on both sides (Text-fig. 15.64–15.69).

Tanea Marwick, 1931 (Pl. 12, figs. 23–24, Pl. 13, figs. 24–28, Pl. 14, figs. 19–25; Text-fig. 24.9a–24.20b): Whorls entirely smooth; umbilicus more or less narrow; umbilical callus commonly large, rounded; operculum smooth except for one or two marginal grooves; rachidian entirely monocuspate, strongly pointed (Text-fig. 15.56–15.63).

Genus **NATICA** Scopoli, 1777

Type species.—Nerita vitellus Linnaeus, 1758, by subsequent designation (Anton, 1839). Miocene to Holocene, tropical Western Pacific.

Discussion.—Natica is characterized by a globose shell, deeply open umbilicus, weakly developed umbilical callus, and a smooth operculum except for a few marginal grooves. The operculum is distinctly crenulated at its inner margin.

There has been debate over selection of a subsequent designator of the type species of *Natica*. Harris (1897) has been cited as the the subsequent designator by many workers including Woodring (1928; 1957), Grant and Gale (1931), Finlay and Marwick (1937), Wenz (1941), Oyama (1969), Cernohorsky (1971), and Kilburn (1976). Marincovich (1977), however, cited Anton (1839) as the subsequent designator, which is a much earlier date than that of Harris. In 1957, Woodring mentioned that

> Anton's designation . . . is of doubtful validity, as it is a designation for *Natica* Lamarck.

Additionally, Cernohorsky (1971) pointed out that

> Anton signalled his type designation by using "VERSALBUCHSTABEN" for species so designated. In the selection on *Natica* Lamarck (*non* Scopoli), Anton listed six species a–f, and none of these species have been singled out as the type; all six names are printed in italics; there was thus no type designation made by Anton.

Marincovich (1977) answered the above questions and concluded that Anton

> listed six species under *Natica*, and none of them is capitalized, although *N. mamillaris* is listed first and printed in ordinary letters and the other five species are 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 [1961], rule 67g). A much later designation of *N. vitellus* as type species of *Natica* (Harris, 1897) is, therefore, redundant.

Natica vitellus (Linnaeus, 1758)
Plate 10, figures 1–12;
Text-figures 4.1, 15.38; Table 32

Nerita vitellus Linnaeus, 1758, p. 776.

Natica vitellus (Linnaeus). Hedley, 1913, pp. 299–300; Tesch, 1920, pp. 70–71, pl. 132, figs. 207a–b; Powell, 1933, text-fig. 20 [operculum]; Altena, 1941, p. 69–70; Kuroda and Habe, 1952, p. 71; Kira, 1954, p. 35, pl. 17, fig. 17; Kira, 1959, p. 41, pl. 17, fig. 17; Habe and Kosuge, 1965, p. 36, pl. 12, fig. 16; Oyama, 1969, p. 83; Habe and Kosuge, 1970, p. 47, pl. 18, fig. 20; Cernohorsky, 1972, p. 94, pl. 24, fig. 5; Majima, 1984, pp. 366–368, pl. 69, figs. 12a [shell], 12b [operculum]; Majima and Fukuta, 1986, text-fig. 1.6.

Not *Natica vitellus* (Linnaeus) [= *Natica stellatus* Hedley, 1913]. Philippi, 1852, pp. 12–13, pl. 1, figs. 10, 11; Reeve, 1855, pl. 10, figs. 39a–b; Sowerby, 1883, pp. 93–94, pl. 4, fig. 41; Wenz, 1941, text-fig. 2974.

Natica (*Natica*) *vitellus* (Linnaeus). Martin, 1905, p. 261 [in part], pl. 39, figs. 624, 624a [not fig. 625 = *Natica stellatus* Hedley, 1913]; Nomura, 1935b, pp. 200–201, pl. 9, figs. 33, 33b; Cernohorsky, 1971, pp. 173–176, text-figs. 2, 3, 4 [operculum], 5.

Not *Natica* (*Natica*) *vitellus* (Linnaeus). [= *Natica stellatus* Hedley, 1913] Tryon, 1886, p. 29, pl. 8, fig. 60; Uchiyama, 1902b, p. 395, pl. 26, figs. 19, 20.

Natica cf. *N. vitellus* (Linnaeus). MacNeil, 1960, pp. 54–55, pl. 2, fig. 22, pl. 8, fig. 8, pl. 12, figs. 20, 24.

Natica vitellus vitellus (Linnaeus). Okutani and Habe, 1975, pp. 82 [unnumbered fig.], 239.

Nerita ruffa Born, 1778, p. 413 [not seen].

Natica (*Nerita*) [*sic: Nerita* Linnaeus, 1758; *Natica* Scopoli, 1777] *ruffa* (Born). Philippi, 1852, pp. 14–15, pl. 2, figs. 1, 2.

Natica ruffa (Born). Reeve, 1855, pl. 16, figs. 70a–b; Sowerby, 1883, p. 80, pl. 4, fig. 42; Tesch, 1920, pp. 69–70, pl. 133, figs. 208a–b; Altena, 1941, pp. 73–75; Cox, 1948, pp. 18–19, pl. 1, figs. 3a–c; Kuroda and Habe, 1952, p. 71.

Natica (*Natica*) *ruffa* (Born). Tryon, 1886, pp. 29–30, pl. 9, figs. 62, 63; Uchiyama, 1902b, p. 395, pl. 26, figs. 21, 22; Martin, 1905, pp. 260–261, pl. 39, figs. 621–622a, 623–623a [operculum]; Nomura, 1935b, p. 200, pl. 9, figs. 29a–30; Shuto, 1969, pp. 79–80, pl. 5, figs. 13, 15–18, pl. 6, figs. 5, 14; Kanno, O'hara, and Caagusan, 1982, pp. 102–103, pl. 17, figs. 9a–10b.

Nerita spadicea Gmelin, 1791, p. 3672 [not seen].

Natica spadicea (Gmelin). Reeve, 1855, pl. 3, figs. 9a–b; Sowerby, 1883, p. 81, pl. 2, fig. 20; Dickerson, 1922, pl. 4, figs. 3a, 3c [operculum] [not fig. 3b = *Polinices* sp. indet.]; Kira, 1959, p. 41, pl. 17, fig. 20; Azuma, 1961, p. 200, pl. 15, fig. 5 [radula].

Natica vitellus spadicea (Gmelin). Kuroda and Habe, 1952, p. 71; Kira, 1954, p. 35, pl. 17, fig. 20; Kuroda, Habe, and Oyama, 1971, p. 175 [in Japanese], p. 116 [in English], pl. 19, fig. 3.

Natica "*spadicea* (Gmelin)". Oyama, 1969, p. 83.

Types.—

Nerita vitellus Linnaeus: type material unknown; type locality, Asiatic Ocean (Linnaeus, 1758).

Nerita ruffa Born: type material unknown; type locality, Mauritius (Philippi, 1852).

Nerita spadicea Gmelin: type material unknown; type locality unknown.

Description.—Shell medium in size, globose to globose-elongate in form, spire moderately to very weakly elevated; shell thickness average for genus; body whorl greatly inflated, evenly rounded, but may be minutely concave at shoulder; nuclear whorls two-and-one-half to three, smooth; postnuclear whorls about three in adults; suture distinctly impressed, may be weakly canaliculated. Spiral sculpture of minute, closely spaced, minutely wavy costellae; axial sculpture of incremental growth lines that are most distinct at base, and of weak wrinkles just below the suture; growth lines commonly developing irregularly into a very weak keel on body whorl of adults. Parietal callus thick, moderately filling posterior apertural angle; anterior lobe distinct. Umbilicus deeply open, separated from base by an obscure spiral angulation; umbilical callus small but distinct, subtriangular to subquadrate in form, smoothly merges into parietal callus, commonly covering posterior side of umbilicus, and may be divided into two lobes by an obscure transverse groove or a concavity on its adaxial side; anterior callus lobe always smaller than posterior one. Anterior inner lip greatly to moderately thickened; basal lip greatly thickened; outer lip not greatly thickened; posterior part of outer lip weakly convex.

Operculum semicircular in form, solid, calcified paucispiral; internal sculpture of weakly developed spiral costellae and incremental growth lines; external sculpture of two or three strong spiral grooves along outer margin, and of granulated calcified pad at central area; inner margin irregularly but distinctly crenulated.

Discussion.—*Natica vitellus* is characterized by its small but distinct subtriangular to subquadrate umbilical callus, deep umbilicus, and bi- to trisulcate operculum.

Hanley (1855, *fide* Hedley, 1913, pp. 299–300) clarified that *Nerita vitellus* of Linnaeus (1758) is not the *Natica vitellus* of his previous workers, but is the *Nerita ruffa* of Born (1778). Hedley (1913) mentioned that "the shell universally but erroneously called *Natica vitellus* must now take the name of *Natica stellatus* Martyn" [*non binom.: fide* Cernohorsky, 1971, p. 176]. The figures erroneously assigned to *N. vitellus* are listed in the synonym list of *N. vitellus* in this study. *Natica stellatus* Hedley, 1913 (Pl. 10, fig. 13) is distinguished from *N. vitellus* by having a tongue-like umbilical callus extending greatly along the posterior margin of the umbilicus.

The suture and the operculum display characteristic variations. Some shells possess weakly channeled sutures (Pl. 10, fig. 12) and others are not channeled. Bi- or trisulcate opercula are recognized in both fossil and modern specimens.

Natica vitellus is now distributed throughout the tropical western Pacific, north from Fiji (Cernohorsky, 1971) and south from Sagami Bay, Pacific side of central Japan (Kuroda, Habe, and Oyama, 1971), and is traced back to the Miocene (Altena, 1941). In Cenozoic strata of Japan, it occurs commonly in upper Pliocene and lower Pleistocene deposits on the Pacific side of southwestern Japan in association with the warm-water Kakegawa faunas.

Stratigraphic occurrence.—

Upper Pliocene and lower Pleistocene: Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 1 (Pl. 10, fig. 7), KAKEGAWA 2, KAKEGAWA 10 (Pl. 10, figs. 8, 12), KAKEGAWA 11 (Pl. 10, fig. 1), and KAKEGAWA 17 (Pl. 10, fig. 2); Ananai Fm., Kochi Pref., locality TONOHAMA 2 (Pl. 10, fig. 3); Takanabe Member of Koyu Fm., Miyazaki Pref., lo-

Table 33.—Measurements (in mm) and counts of the largest specimen of *Naticarius concinnus* (Dunker, 1859) at each locality.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower Pleistocene	HANEJI 2	10.3	11.0	8.9	8.5	4½	IGUT 16083-1	3
upper Pleistocene	SAKURAI	14.5	13.5	10.8	10.7	5	IGUT 16049-1	3

calities MIYAZAKI 1 (Pl. 10, fig. 4) and MIYAZAKI 2 (Pl. 10, fig. 5); Shinzato Fm., Okinawa Pref., locality SHINZATO 6 (Pl. 10, fig. 9); Higa Fm., Okinawa Pref., locality KUME 1; Fusakina Fm., Okinawa Pref., localities KUME 2 (Pl. 10, fig. 6) and KUME 3.

Genus **NATICARIUS** Duméril, 1806

Type species.—*Nerita canrena* Linnaeus, 1758 (Text-fig. 24.3a–c), by subsequent monotypy (Froriep, 1806, p. 165). Living, West Indies and southeastern U. S. A.

Discussion.—*Naticarius* is characterized by distinctly developed axial wrinkles below the suture, well developed semicircular to half-heart-shaped umbilical callus with a strong funicle, tabulated shoulder, and a multisulcate operculum. Text-figure 24.4a–24.8c shows the modern species of *Naticarius* in Japan.

There are three interpretations concerning the nomenclatorial status of *Naticarius* and its type species. Among them, I prefer the second interpretation.

The first interpretation is that *Naticarius*, one of Duméril's (1806) names, should be regarded as a substitutive name for *Natica* Lamarck, 1799, not for *Natica* Scopoli, 1777. Duméril's *Naticarius* has no nominal species. Thus, *Nerita canrena* Linnaeus, which is the only nominal species cited in *Natica* Lamarck, 1799, is considered to be the type species of *Naticarius* by monotypy (*Naticarius* Duméril, 1806: type species, *Nerita canrena* Linnaeus, 1758, by monotypy). This interpretation has been adopted by Iredale (1916), Woodring (1928), Finlay and Marwick (1937), Wenz (1941), and Marincovich (1977).

The second interpretation is that Duméril's name is regarded as an entirely new name dating from his usage without any nominal species. Froriep's (1806) inclusion of *Nerita canrena* as a single example for *Naticarius* is thus considered to be a type designation by subsequent monotypy [*Naticarius* Duméril, 1806: type species, *Nerita canrena* Linnaeus, 1758, by subsequent monotypy (Froriep, 1806)]. This intepretation has been adopted by Woodring (1957), Oyama (1969), Cernohorsky (1971), and Kilburn (1976). Cernohorsky mentioned that

> there is no evidence in the text that *Naticarius* has been proposed as a replacement name for either *Natica* Scopoli or *Natica* Lamarck, and the citation lacks any reference to previous authors.

The third interpretation was maintained by Kuroda, Habe, and Oyama (1971). They stated that Duméril (1806) is not a valid publication according to the definition within the International Code of Zoological Nomenclature (1961), and that its translation by Froriep (1806) is valid (*Naticarius* Froriep, 1806: type species, *Nerita canrena* Linnaeus, 1758, by monotypy).

Naticarius concinnus (Dunker, 1859)
Plate 12, figures 17–18;
Text–figures 15.50, 24.5a–c; Table 33

Natica concinna Dunker, 1859, p. 232; Dunker, 1861, p. 14, pl. 2, fig. 21; Dunker, 1882, p. 60; Hirase, 1934, p. 59, pl. 90, fig. 6; Kuroda and Habe, 1952, p. 70.

Natica (*Naticarius*) *concinna* Dunker. Kawamoto, 1956, p. 28, pl. 10, fig. 94.

Naticarius concinnus (Dunker). Habe, 1961, p. 39, pl. 18, fig. 2; Oyama, 1969, p. 84; Kuroda, Habe, and Oyama, 1971, p. 178 [in Japanese], p. 117 [in English], pl. 19. fig. 7; Habe and Kosuge, 1970, p. 46, pl. 18, fig. 11; Okutani and Habe, 1975, pp. 82 [unnumbered figs.], 263; Inaba, 1976, p. 88, pl. 2, fig. 4 [radula]; Aoki and Baba, 1983, p. 50, text-fig. 12.

Naticarius concinna (Dunker). Azuma, 1961, p. 201, pl. 14, fig. 5 [radula].

Natica (*Natica*) *colliei* Récluz. Uchiyama, 1902a, p. 356, pl. 25, figs. 12–14 [not *N.* (*N.*) *colliei* Récluz, 1844, living, Australia].

Type.—Type material unknown; type locality, Dejima, Nagasaki Prefecture, Japan (Dunker, 1859).

Description.—Shell small, globose to globose-elongate, spire moderately elevated; body whorl greatly inflated, evenly rounded, but may bear weakly flattened shoulder; shell thickness average for genus; nuclear whorls one-and-one-half, smooth; postnuclear whorls about three in adults; suture weakly impressed. Spiral sculpture of microscopic, closely spaced, minutely wavy striations; axial sculpture of incremental growth lines and of well developed axial wrinkles below suture. Parietal callus moderately thickened, moderately filling posterior apertural angle; anterior lobe distinct. Umbilicus deeply open around umbilical callus; umbilical callus moderate to small in size for genus, separated from parietal callus by a deep sulcus; funicle distinct. Anterior inner lip and basal lip not greatly thickened. No fossil operculum known.

Discussion.—*Naticarius concinnus* is characterized by a small shell and a relatively small umbilical callus.

Three specimens from the upper Pleistocene Sakurai Formation, Chiba Prefecture, central Japan, preserve slightly the original shell coloration; that is, one broad but spotted light brown band is just below the periphery, and a narrow spotted light brown band is below the suture and also may be just above the periphery.

The fossil coloration agrees with that of modern specimens. No fossil operculum is known but those of modern specimens are multisulcate (Pl. 12, fig. 18; Text-fig. 24.5b–c).

Naticarius alapapilionis (Röding, 1798) (Text-fig. 24.6a–c), living in the tropical western Pacific, differs from the present species by having a broadly tabulated shoulder and a well developed basal lip.

Stratigraphic occurrence.—

Lower Pleistocene: Nakoshi Sand, Okinawa Pref., locality HANEJI 2.

Upper Pleistocene: Sakurai Fm., Chiba Pref., locality SAKURAI (Pl. 12, fig. 17).

Genus **NOTOCOCHLIS** Powell, 1933

Type species.—*Cochlis migratoria* Powell, 1927 (Text-figs. 15.52, 24.2a–b), by original designation. Living, New Zealand and Australian waters (Powell, 1979, p. 154).

Discussion.—The shell of *Notocochlis* is very similar to that of *Naticarius* Duméril, 1806 in all aspects, but its operculum greatly differs from the latter by having an almost smooth external surface, except for a weakly developed marginal groove (Pl. 12, figs. 21–22). *Naticarius* has a multisulcate operculum (Pl. 12, fig. 18; Text-fig. 24.3a–24.8c). *Notocochlis* is, therefore, characterized by the combination of a *Naticarius*-like shell and an almost smooth operculum. The shell of *Notocochlis* is slightly different from *Naticarius* in having a more closed umbilicus and a less tabulated shoulder.

Cernohorsky (1971) considered *Notocochlis* to be a synonym of *Natica* Scopoli, 1777, and Kilburn (1976, p. 844) stated that *Notocochlis* "does not really appear to be validly separable from *Natica* s.s." *Notocochlis*, however, differs from *Natica* by having a distinct sulcus and a well developed semicircular umbilical callus. Species in the *Natica* species group never have those characters.

Notocochlis gualteriana (Récluz, 1844)
Plate 12, figure 21; Text-figures 15.53, 15.54

Natica gualteriana Récluz, 1844, p. 208; Philippi, 1852, pp. 71–72, pl. 11, fig. 8; Reeve, 1855, pl. 25, figs. 114a–b; Sowerby, 1883, pp. 81–82, pl. 9, fig. 152; Hedley, 1913, pp. 298-299; Salvat and Rives, 1980, p. 300, text-fig. 158; Kilburn and Rippey, 1982, p. 70, pl. 16, fig. 3.

Notocochlis gualtieriana [*sic*] (Récluz). Habe, 1961, p. 39, pl. 18, fig. 4.

Natica (*Natica*) *gualtieriana* [*sic*] Récluz. Cernohorsky, 1971, pp. 180–182, text-figs. 21 [radulae], 22-23 [operculum], 24, 25.

Natica gualtieriana [*sic*] Récluz. Cernohorsky, 1972, p. 95, pl. 24, fig. 9.

Cryptonatica gualtieriana [*sic*] (Récluz). Okutani and Habe, 1975, pp. 82 [unnumbered figs.], 267.

Natica (*Natica*) *gualteriana* Récluz. Kilburn, 1976, pp. 835–837.

Natica tesellata Philippi, 1848, p. 158; Philippi, 1852, pp. 48–49, pl. 7, fig. 7; Kuroda and Habe, 1952, p. 71.

Natica (*Natica*) *marochiensis* (Gmelin) [not *Notocochlis marochiensis* (Gmelin, 1791), living, West Indies]. Martin, 1905, pp. 258–259, pl. 38, figs. 616–617a; Ladd, 1934, pp. 209–210, pl. 36, figs. 2, 3.

Natica marochiensis (Gmelin) [not *Notocochlis marochiensis* (Gmelin, 1791)]. Tesch, 1920, pp. 68–69, pl. 132, figs. 205a–b; Altena, 1941, pp. 79–81; Popenoe and Kleinpell, 1978, pl. 5, figs. 59, 62.

Naticarius marochiensis (Gmelin) [not *Notocochlis marochiensis* (Gmelin, 1791)]. MacNeil, 1960, p. 55, pl. 15, figs. 21, 22; Shuto, 1969, pp. 77–79, pl. 6, figs. 1–4, 6–9; Ladd, 1977, pp. 30–31, pl. 9, figs. 3–6, 7–8 [operculum], 9, 10.

Natica marochiensis var. *lurida* Philippi. Cossmann, 1910, pp. 59–60, pl. 4, figs. 11, 12 [not *Natica lurida* Philippi, 1836, ? living, Atlantic waters].

Natica (*Natica*) *marochiensis* var. *lurida* Philippi. Uchiyama, 1902a, p. 356, pl. 25, figs. 10, 11 [not *N. lurida* Philippi, 1836].

Natica lurida Philippi [not *N. lurida* Philippi, 1836]. Oyama, 1969, p. 85, text-fig. 12; Azuma, 1961, p. 200, pl. 15, fig. 4 [radula].

Tectonatica lurida (Philippi). Habe and Kosuge, 1970, p. 46, pl. 18, fig. 16 [not *Natica lurida* Philippi, 1836].

Cryptonatica lurida (Philippi). Kuroda, Habe, and Oyama, 1971, p. 174 [in Japanese], pp. 115–116 [in English], pl. 19, fig. 14 [not *Natica lurida* Philippi, 1836].

Natica colliei Récluz. Yokoyama, 1928b, pp. 63–64, pl. 6, fig. 1 [not *N. colliei* Récluz, 1844, living, Australia].

Natica rufilabris Reeve [not *N. rufilabris* Reeve, 1855, living, Bahia, Brazil]. Hirase, 1934, p. 59, pl. 90, fig. 13; Hatai, 1941, p. 106, pl. 34, figs. 25, 26; Kuroda and Habe, 1952, p. 71.

Tectonatica adamsiana (Dunker). Habe and Kosuge, 1970, p. 47, pl. 18, fig. 17 [not *Cryptonatica adamsiana* (Dunker, 1859)].

Types.—

Natica gualteriana Récluz: type material unknown; type locality, "Sual, province of Pangasinan, island of Luzon; found at five to seven fathoms, on sand" (Récluz, 1844), Philippines.

Natica tessellata Philippi: type material unknown; type locality, "Die Freundschafts-Inseln" (Philippi, 1852) = Tonga Islands.

Discussion.—No fossil specimens are available for this study. MacNeil (1960) reported the present species as *Natica marochiensis* (Gmelin) [not *Notocochlis marochiensis* (Gmelin, 1791)], from the lower Pleistocene Nakoshi Sand, Okinawa Prefecture.

Cernohorsky (1971) fully discussed the confused taxonomic history of the present species. The present species has been confused, for a long time, with *Notocochlis marochiensis* (Gmelin, 1791) (Pl. 12, fig. 22), a species of the West Indies. The two species are very similar to each other, but Cernohorsky (1971) compared them as follows:

> *Natica marochiensis* has a more globose shell, the spire whorls are more elevated and the nuclear whorls are purple in color, but always white in *gualtieriana*. The columellar edge of the operculum and a narrow zone adjacent to the edge are always scabrous in *N. marochiensis* . . . , but smooth in *N. gualtieriana*.

Stratigraphic occurrence.—

Lower Pleistocene: Nakoshi Sand, Okinawa Pref. [MacNeil, 1960, as "*Natica marochiensis* (Gmelin, 1791)"].

Table 34.—Measurements (in mm) and counts of the holotype and of the largest specimen of *Tanea minoensis* (Itoigawa, 1960) at each locality. Localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower middle Miocene	OKUSHIRI	18.0+	16.8	13.0	14.0+	4+	IGUT 16065	1
	YATSUO 3	14.2+	9.8+	11.0	—	4½+	IGUT 16037-1	3
	MIZUNAMI 5	23.8+	23.7	18.8	20.6+	4½+	ESN 20061 (holotype)	1
	AYUGAWA	14.9+	15.2	12.4	11.1+	3+	GIYU 617	1

Genus TANEA Marwick, 1931

Type species.—*Natica zelandica* Quoy and Gaimard, 1832 (Text-figs. 15.56, 24.9a–b), by original designation. Living, New Zealand.

Discussion.—*Tanea* is characterized by its smooth whorls, relatively thin shell, smooth operculum except for one or two marginal grooves, and greatly pointed monocuspate rachidian. Among these characters, the greatly pointed monocuspate rachidian most characterizes species of *Tanea* (Text-fig. 15.56–15.63). The shells of *Tanea* are very similar to those of *Naticarius* Duméril, 1806 and *Notocochlis* Powell, 1933, but are separable from them by having a relatively thin shell and smooth whorls except for fine growth lines.

Tanea is one of the most diverse naticid genera within the Indo-Pacific seas. Oyama (1969) listed ten species classifiable into *Tanea* from Japanese modern waters and Kilburn (1976, p. 853) pointed out that "relatively few species have so far been referred to *Tanea*, but this number will no doubt be greatly increased by future radula studies." Text-figure 24.10a–24.20b shows the modern species of *Tanea* in Japan.

Tanea minoensis (Itoigawa, 1960)
Plate 13, figures 24–28;
Text-figure 3.2; Table 34

Natica (*Naticarius*) *minoensis* Itoigawa, 1960, p. 284, pl. 4, figs. 11a–b.
Naticarius minoensis (Itoigawa). Itoigawa *et al.*, 1981, pl. 34, figs. 7a–b; Itoigawa *et al.*, 1982, pp. 194–195.

Holotype.—ESN 20061 (Pl. 13, fig. 27), from a river cliff at Shukunohora, Hiyoshi-machi, Mizunami City, Gifu Prefecture, lower middle Miocene Shukunohora Sandstone (loc. S41 of Itoigawa, 1960; loc. MIZUNAMI 5).

Description.—Shell moderate in size, globose-elongate in form, spire moderately to greatly elevated; body whorl not greatly inflated; shoulder distinctly tabulated, nearly smooth, separated from whorl sides by an obscure angulation; shell thick for genus; nuclear whorls one-and-one-half, smooth; postnuclear whorls three in adults, smooth except for minutely developed incremental growth lines that are most distinct below suture and on base; suture moderately impressed. Parietal callus moderate in thickness, moderately filling posterior apertural angle; anterior lobe distinct. Umbilicus deeply open, separated from base by a distinct spiral ridge that is made by bending of the growth line; umbilical callus moderate in size, semicircular in form, with a strongly to moderately developed funicle; sulcus broad and deep. Anterior inner lip not greatly thickened; basal lip thick, weakly reflexed. Operculum unknown.

Discussion.—*Tanea minoensis* is characterized by having a smooth shell, distinct spiral ridge circumscribing the umbilicus, and a distinctly tabulated shoulder with a nearly smooth surface.

Though the present species has been classified into *Naticarius* Duméril, 1806 by Itoigawa (1960, as a subgenus of *Natica* Scopoli, 1777) and Itoigawa *et al.* (1981; 1982), I classify it as a species of *Tanea* because of its smooth whorls without any subsutural wrinkle and its close relation with *Natica rostalina* Jenkins, 1863 from the Miocene to Pliocene of the East Indies (Jenkins, 1863, p. 56, pl. 6, fig. 8; Cossmann, 1910, pp. 55–57, pl. 4, figs. 1, 2; Martin, 1905, p. 256, pl. 38, fig. 611). *Natica rostalina* possesses a smooth shell and a flat operculum except for one marginal shallow groove (Jenkins, 1863), from both of which, *N. rostalina* is referable to a species of *Tanea*. *Natica rostalina* is very closely related to *T. minoensis* in having a distinct spiral ridge circumscribing the umbilicus and a distinctly tabulated shoulder with a smooth surface. The close relation of the two species evidently indicates that *minoensis* is a species of *Tanea*. *Natica rostalina* slightly differs from *T. minoensis* by having a smaller umbilical callus.

Tanea lineata (Röding, 1798) (Text-fig. 24.10a–b), living in the tropical western Pacific, and *Tanea tabularis* (Kuroda, 1961) (Text-fig. 24.20a–b), living in warm waters of Japan, are similar to *T. minoensis* but the former two species differ from the latter by having a low but wide rib circumscribing the umbilicus. *Tanea lemniscata* (Philippi, 1851) (Text-fig. 24.13a–b), living in the tropical western Pacific, is another similar species that differs from *T. minoensis* by having a slender umbilical callus.

Table 35.—Measurements (in mm) and counts of the largest specimen of *Tanea tabularis* (Kuroda, 1961) at each locality

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
upper Pliocene	KAKEGAWA 1	13.5	13.0	10.3	10.0	5½	IGUT 16047-1	3
	KAKEGAWA 10	11.1	10.2	8.1	8.7	4½+	IGUT 16048-1	2
upper Pleistocene	KIKAI 1	22.1	22.5	17.6	17.0	4+	GIYU 527	1

Previously, the present species has been known only from the Mizunami Group, central Japan, but as cited in the stratigraphic occurrence below, it is distributed widely in the lower middle Miocene strata of Japan in association with warm-water Kadonosawa faunas.

Stratigraphic occurrence.—

Lower middle Miocene: Tsurikake Fm., Hokkaido, locality OKUSHIRI (Pl. 13, fig. 24); Yatsuo Fm., Toyama Pref., locality YATSUO 3 (Pl. 12, figs. 25, 26); Shukunohora Sandstone, Gifu Pref., locality MIZUNAMI 5 (Pl. 13, fig. 27); Kurokawa Fm., Shiga Pref., locality AYUGAWA (Pl. 13, fig. 28).

Tanea tabularis (Kuroda, 1961)
Plate 14, figures 20–22;
Text-figures 15.61, 15.62, 24.20a–b; Table 35

Natica (*Naticarius*) *tabularis* Kuroda, 1961, pp. 126–127 [in English], 133 [in Japanese], pl. 18, fig. 3.
Notocochlis tabularis (Kuroda). Azuma, 1961, p. 202, pl. 14, fig. 17 [radula]; Habe, 1961, p. 39, pl. 18, fig. 5; Habe and Kosuge, 1970, p. 47, pl. 18, fig. 22.
Natica (*Notocochlis*) *tabularis* Kuroda. Shikama and Horikoshi, 1963, text-fig. 65.
Tanea tabularis (Kuroda). Oyama, 1969, p. 87; Okutani and Habe, 1975, pp. 82 [unnumbered fig.], 215; Inaba, 1976, p. 88, pl. 2, fig. 8 [radula].

Holotype.—? Private collection of the late Dr. T. Kuroda (pl. 18, fig. 3 in Kuroda, 1961); type locality, "off Daioh-zaki Cape, the entrance of Ise Bay, Pacific side of central Honshu, about 60–100 meters in depth" (Kuroda, 1961).

Description.—Shell globose, moderate in size, spire moderately elevated; body whorl moderately inflated; shoulder distinctly tabulated, may be minutely concave; whorls more than five-and-one-half, protoconch indistinct in fossil specimens I have seen; sculpture of incremental growth lines that are most distinct below suture and on base; suture weakly impressed; shell thickness average for genus. Parietal callus moderate in thickness, weakly filling posterior apertural angle; anterior lobe weak, slightly overhanging umbilicus. Umbilicus deep, widely open around a small semicircular to tongue-like umbilical callus, circumscribed by a low but wide spiral rib at base; umbilical callus possessing a distinct funicle, separated from parietal callus by a shallowly but widely excavated sulcus. Anterior inner lip thin; basal lip not greatly thickened. No fossil operculum known.

Discussion.—*Tanea tabularis* is characterized by a distinctly tabulated shoulder and by basal sculpture consisting of a wide but low spiral rib circumscribing the umbilicus. The operculum described by Kuroda (1961) (Pl. 14, fig. 22; Text-fig. 24.20a–b) and the radulae illustrated by Azuma (1961) and Inaba (1976) (Text-figs. 15.61, 15.62) evidently indicate that *tabularis* is a species of *Tanea*, whereas the coloration of this species, which is dull corneous brown with a white basal part, is exceptionally simple among the species of *Tanea*. *Tanea lineata* (Röding, 1798) (Text-fig. 24.10a–b) is the most similar species in having a wide but low spiral rib circumscribing the umbilicus and a very wide sulcus, but differs slightly from *T. tabularis* by having a larger umbilical callus and a weakly tabulated shoulder. *Tanea undulata* (Röding, 1798) (Pl. 14, figs. 23–25; Text-fig. 24.11a–b) and *T. areolata* (Récluz, 1844) (Pl. 12, figs. 23–24; Text-fig. 24.15a–24.16b), living in the Indo-Western Pacific warm waters, differ from *T. tabularis* by having a larger umbilical callus, more slender sulcus, and an entirely rounded base without any rib. According to Kuroda (1961) and Habe (1961), *T. tabularis* is now distributed in the warm waters of the Pacific side of southwestern Japan. The present species is considered to be endemic in Japanese warm waters and first appeared in the upper Pliocene Dainichi Member of the Lower Kakegawa Formation, Pacific side of central Honshu.

Stratigraphic occurrence.—

Upper Pliocene: Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 1 (Pl. 14, fig. 20) and KAKEGAWA 10.

Upper Pleistocene: Ryukyu Limestone, Kagoshima Pref., locality KIKAI 1 (Pl. 14, fig. 21).

Tanea undulata (Röding, 1798)
Plate 14, figures 23–25;
Text-figure 24.11a–b; Table 36

Cochlis undulata Röding, 1798, p. 147.
Notocochlis undulata (Röding). Habe and Kosuge, 1965, p. 35, pl. 12, fig. 13.
Natica undulata (Röding). Cernohorsky, 1974, p. 168, text-fig. 38 [syntype].
Tanea undulata (Röding). Okutani and Habe, 1975, pp. 82 [unnumbered fig.], 279.

Table 36.—Measurements (in mm) and counts of the specimens of *Tanea undulata* (Röding, 1798) at localities HANEJI 1 and HANEJI 3.

stratigraphic position	locality	shell height	maximum diameter	minimum diameter	aperture height	number of whorls	specimen measured	number of specimens in lot
lower Pleistocene	HANEJI 1	11.6+	12.8	10.8	9.5	4+	IGUT 16084	1
	HANEJI 3	14.9+	15.0	11.6	—	5	IGUT 16085	1

Natica zebra Lamarck, 1822, p. 203 [not seen]; Philippi, 1852, p. 18, pl. 2, figs. 13, 14; Reeve, 1855, pl. 13, figs. 53a–b; Sowerby, 1883, p. 79, pl. 7, fig. 92; Hirase, 1934, p. 59, pl. 90, fig. 4; Oostingh, 1935, pp. 46–47, pl. 5, figs. 55a–b; Kuroda and Habe, 1952, p. 71; Shuto, 1969, pp. 80–81, pl. 6, figs. 10, 11; Cernohorsky, 1971, p. 203.

Natica (Natica) zebra Lamarck. Tryon, 1886, p. 16, pl. 2, fig. 32; Uchiyama, 1902a, p. 354, pl. 25, fig. 1; Martin, 1905, p. 258, pl. 38, figs. 615–615b.

Natica (Naticarius) zebra Lamarck. Kira, 1954, p. 35, pl. 17, fig. 5.

Notocochlis zebra (Lamarck). Kira, 1959, p. 39, pl. 17, fig. 5; Habe and Kosuge, 1970, p. 46, pl. 18, fig. 9.

Tanea zebra (Lamarck). Oyama, 1969, p. 87.

Naticarius cf. *N. andoi* (Nomura). MacNeil, 1960, p. 56, pl. 10, figs. 17, 29, pl. 12, fig. 25 [not *Cryptonatica andoi* (Nomura, 1935b)].

Types.—

Cochlis undulata Röding: Syntype preserved in the University Museum in Copenhagen (Cernohorsky, 1974, text-fig. 38); type locality unknown.

Natica zebra Lamarck: Syntype is the same as that of the above species; type locality unknown.

Description.—Shell small in size, slightly depressed globose, spire weakly elevated; body whorl greatly inflated; shoulder minutely concave but not tabulated; suture weakly impressed; whorls five (protoconch not clearly set off), smooth except for minutely developed incremental growth lines that are most distinct below sutures. Parietal callus moderate in thickness, weakly filling posterior apertural angle; anterior lobe distinct, weakly overhanging umbilicus. Umbilicus deep but narrow, open around umbilical callus; sulcus deep; umbilical callus large, subtrigonal with a rounded apex and a sharp edge; funicle distinct. Anterior inner lip not greatly thickened. No fossil operculum known.

Discussion.—Both *Cochlis undulata* Röding, 1798 and *Natica zebra* Lamarck, 1822 were described based upon the same figure of "*zebra in familia neritarum*" of Chemnitz (1781, pl. 187, figs. 1885–1886) (Cernohorsky, 1974). *Cochlis undulata* Röding is, therefore, the prior name for *N. zebra* Lamarck. Although the radula of this species has not been studied, the shell is classifiable into *Tanea* because of the combination of the two characters: the smooth shell surface except for weak growth lines and the smooth operculum with a few marginal grooves (Pl. 14, fig. 25; Text-fig. 24.11a–b). The modern form is most characterized by the coloration of a white base with many orange-brown flames.

The present species is now distributed in the tropical western Pacific and the Indian Ocean (Cernohorsky, 1974). Fossil specimens have been reported from the Neogene formations in Java (Martin, 1905, and Oostingh, 1935), Philippines (Shuto, 1969), and Okinawa [MacNeil, 1960, as "*Naticarius* cf. *N. andoi* (Nomura, 1935b)"].

Tanea picta magnifluctuata (Kuroda, 1961) and *T. tosaensis* (Kuroda, 1961) (Pl. 14, fig. 19; Text-fig. 24.17a–b) differ from *T. undulata* by having a more elevated spire and more tabulated shoulder. *Tanea lineata* (Röding, 1798) (Text-fig. 24.10a–b) is separable from *T. undulata* by having a more elevated spire, more tabulated shoulder, and a wide but low spiral rib circumscribing the umbilicus. *Tanea hilaris* (Sowerby, 1914) (Text-fig. 24.18a–b), living in warm waters of southwestern Japan, and *T. shoichiroi* (Kuroda, 1961) (Text-fig. 24.19a–b), living in the Daio-zaki Cape, entrance of the Ise Bay, Pacific side of central Japan, are distinguishable from *T. undulata* by having weakly channeled sutures and a smaller umbilical callus. *Tanea lemniscata* (Philippi, 1851) (Text-fig. 24.13a–b) is distinguished by having a more depressed umbilical callus.

Stratigraphic occurrence.—

Lower Pleistocene: Haneji Fm., Okinawa Pref., localities HANEJI 1 (Pl. 14, fig. 23) and HANEJI 3 (Pl. 14, fig. 24); Chinen Sand, Okinawa Pref. [MacNeil, 1960, as "*Naticarius* cf. *N. andoi* (Nomura, 1935b)"].

Upper Pleistocene: Ryukyu Limestone, Okinawa Pref. [MacNeil, 1960, as "*Naticarius* cf. *N. andoi* (Nomura, 1935b)"].

Tanea areolata (Récluz, 1844)
Plate 12, figures 23–24;
Text-figures 15.57, 24.15a–24.16b; Table 37

Natica areolata Récluz, 1844, p. 206; Philippi, 1852, pp. 67–68, pl. 11, fig. 2; Cernohorsky, 1972, pp. 95–96, pl. 24, fig. 10.

Natica (Natica) areolata Récluz. Tryon, 1886, p. 25, pl. 6, fig. 23; Cernohorsky, 1971, p. 182, text-figs. 26 [operculum], 28–30.

Tanea areolata (Récluz). Oyama, 1969, p. 87, pl. 5, figs. 8a–b [figs. 8a–b, as *Naticarius areolatus*]; Kilburn, 1976, p. 853, fig. 14 [radula].

Type.—Type material unknown; type locality, Island of Capul: found on the reefs, Philippines, and Amboina (Récluz, 1844).

Description.—Shell globose, spire moderately elevated, body whorl moderately inflated, nearly evenly rounded, but shoulder weakly concave; shell thickness and size average for genus; base entirely rounded; whorls

Table 37.—Measurements (in mm) and counts of the specimen of *Tanea areolata* (Récluz, 1844) at locality KIKAI 1.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
upper Pleistocene	KIKAI 1	14.3	13.3	10.3	11.0	4+	GIYU 527	1

more than four (apex weathered), smooth except for microscopic, incremental growth lines that are most distinct below suture; suture weakly impressed. Parietal callus moderate in thickness, lightly filling posterior apertural angle; anterior lobe moderately developed, weakly overhanging umbilicus. Umbilicus narrowly open along most of umbilical callus margin; umbilical callus smooth, subtrigonal, with a sharp edge and a weakly angulated apex; funicle distinct; sulcus narrow but deeply excavated. Basal lip not greatly thickened. No fossil operculum known.

Discussion.—Kilburn (1976) illustrated the radular dentition of *Tanea areolata*, which shows the monocuspate rachidian characterizing species of *Tanea* (Text-fig. 15.57). Cernohorsky (1972) described the shell coloration of *T. areolata* as "white in colour, ornamented with broad, arrow-shaped or curved, orange-brown axial markings which are arranged in 3 spiral zones on body whorl and separated by narrow white lines" (see Pl. 12, fig. 24 and Text-fig. 24.15a–24.16b). The coloration is the best marker of the present species, but it is lacking in fossil specimens available for study.

Tanea areolata is characterized by having a moderately elevated spire, entirely rounded base, narrowly open umbilicus, and a subtrigonal umbilical callus with a weakly pointed apex. The shell of *Tanea picta magnifluctuata* (Kuroda, 1961) closely resembles that of *T. areolata*, but is slightly different from the latter species by having a more elevated spire, which is the only discriminative point in shell morphology. *Tanea tosaensis* (Kuroda, 1961) (Pl. 14, fig. 19; Text-fig. 24.17a–b), living in the warm waters of Japan, and *T. lemniscata* (Philippi, 1851) (Text-fig. 24.13a–b) differ from *T. areolata* by having a smaller umbilical callus. *Tanea undulata* (Röding, 1798) (Pl. 14, figs. 23–25; Text-fig. 24.11a–b), living in the tropical western Pacific, differs from *T. areolata* by having a more depressed shell form with a lower spire. *Tanea lineata* (Röding, 1798) (Text-fig. 24.10a–b) is distinguishable from *T. areolata* by having a weak but wide spiral rib circumscribing the umbilicus.

Stratigraphic occurrence.—

Upper Pleistocene: Ryukyu Limestone, Kagoshima Pref., locality KIKAI 1 (Pl. 12, fig. 23).

Genus **ALOCONATICA** Shikama, 1971

Type species.—*Aloconatica kushime* Shikama, 1971 (Text-fig. 24.1a–d), by original designation. Living, Enshu-Nada, Pacific side of central Japan.

Discussion.—*Aloconatica* is characterized by the combination of distinct axial grooves on the whorls, which commonly entirely cover the body whorl in juveniles, and an operculum bearing two marginal costae. The operculum of *Aloconatica kushime* Shikama, the type species, is unknown, but a closely related species, *Aloconatica niasensis* (Wissema, 1947), possesses an operculum bearing two marginal costae (Majima, 1984, p. 366, pl. 69, fig. 11b).

Stigmaulax Mörch, 1852, *Naticarius* Duméril, 1806, and *Quantonatica* Iredale, 1936 are similar to *Aloconatica* in the sculpture of the shell surface, but *Stigmaulax* is distinguishable from *Aloconatica* by having an operculum bearing a strong central rib, *Naticarius* is separable by having an operculum with many spiral grooves or costae (Text-fig. 24.3a–24.8c), and *Quantonatica* is different by having an operculum bearing many weak spiral ribs. The operculum of *Quantonatica subcostata* (Tenison-Woods, 1878), which lives in Australian waters, and is the type species of *Quantonatica*, has been illustrated by Pritchard and Gatliff (1900), Hedley (1901), and Cotton (1955). *Natica* Scopoli, 1777, *Tanea* Marwick, 1931, *Notocochlis* Powell, 1933, and *Cryptonatica* Dall, 1892 have opercula similar to that of *Aloconatica*, but they never possess the distinct axial grooves entirely covering the body whorl.

Aloconatica niasensis (Wissema, 1947)
Plate 12, figures 19–20; Table 38

Naticarius (Naticarius) niasensis Wissema, 1947, pp. 139–140, pl. 6, figs. 133–135.
Naticarius cf. *N. niasensis* Wissema. MacNeil, 1960, pp. 56–57, pl. 8, figs. 2, 4, 5, pl. 12, figs. 16, 18.
"*Naticarius*" sp. Majima, 1984, p. 366, pl. 69, figs. 10, 11a, 11b [operculum].

Holotype.—Preserved in the Rijks Museum van Geologie en Mineralogie at Leiden, Holland (Wissema, 1947, pl. 6, figs. 133–135); type locality, locality 100 of Wissema (1947).

Description.—Shell moderate in size, globose in form and moderate in thickness; spire moderately elevated; body whorl moderately inflated, evenly rounded; shoulder not tabulated; suture distinctly impressed, commonly weakly channeled; whorls more than four (apexes eroded); base entirely rounded without any angulation. Spiral sculpture of minute, closely spaced but irregularly developed costellae; axial sculpture of incremental growth lines, and of strong grooves running over body whorl especially in juveniles, com-

Table 38.—Measurements (in mm) and counts of the largest specimen of *Aloconatica niasensis* (Wissema, 1947) at each locality.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower Pliocene	YONABARU 2	14.6	14.5	10.9	12.4	3½+	IGUT 15067-2	4
upper Pliocene	SHINZATO 1	17.6	16.3	12.9	13.3	3+	IGUT 16075	1
	SHINZATO 2	18.5	18.4	14.1	14.4	4+	IGUT 16050	1
	SHINZATO 4	13.3	13.3	10.3	10.8	4+	IGUT 16051	1
	SHINZATO 5	15.7	16.2	12.5	13.4	4+	IGUT 16052	1
	SHINZATO 7	10.6	10.4	9.4	9.2	3½+	IGUT 16053	1

monly dying out centrally in adults; axial grooves may also be indistinct on basal part of body whorl in some adults. Parietal callus moderate in thickness, moderately filling posterior apertural angle; anterior lobe weak. Umbilicus deeply open; umbilical callus small, depressed, semicircular in form; funicle weak; sulcus shallowly but broadly excavated. Anterior inner lip and basal lip not greatly thickened.

Operculum half-heart in shape. Outer surface: spiral sculpture of two distinct costae along the outer margin, of which the inner one is spirally subdivided into two costae by a shallow groove, and of closely spaced costellae occupying inner side of the costae; costellae separated from inner costae by a shallow spiral groove; axial sculpture of minutely developed, incremental growth lines; central area covered by a thin calcified pad. Inner surface smooth except for minutely developed, incremental growth lines. Inner margin weakly crenulated; outer margin nearly smooth except for one groove running along outer edge.

Discussion.—Aloconatica niasensis is characterized by strong axial grooves covering the body whorl in juveniles and by an operculum ornamented mainly with two spiral costae along the outer margin. The operculum of the present species has been reported by Majima (1984, p. 366, pl. 69, fig. 11b, as "*Naticarius*" sp.). Though the work of Wissema (1947) has been cited as a "doctor's thesis", it was published within the meaning of article 8 of the International Code of Zoological Nomenclature (1961). The new species proposed in Wissema (1947) are, therefore, valid.

As pointed out by MacNeil (1960), this species shows an ontogenetic variation in development of axial grooves; namely, in adults, the grooves die out centrally leaving a broad central band which is sculptured only by faint spiral costellae. In the original description of this species, Wissema (1947) described the axial grooves of the holotype by saying that "deeply incised wrinkles run across the whorl surface, only a little less distinct on the middle of the body whorl, which zone gets broader towards the outer lip." MacNeil (1960) considered the holotype to be a juvenile. The holotype seems to possess a more elevated spire than the fossil specimens from Okinawa, but I consider it to be an intraspecific variation of the present species.

Stratigraphic occurrence.—

Lower Pliocene: Yonabaru Fm., Okinawa Pref., locality YONABARU 2.

Upper Pliocene: Shinzato Fm., Okinawa Pref., localities SHINZATO 1 (Pl. 12, fig. 19), SHINZATO 2, SHINZATO 4, SHINZATO 5, and SHINZATO 7 (Pl. 12, fig. 20).

Genus **CRYPTONATICA** Dall, 1892

Type species.—Natica clausa Broderip and Sowerby, 1829, by subsequent designation (Dall, 1909, p. 85). Upper Oligocene or lowest Miocene (Allison and Marincovich, 1981) to Holocene, northern Pacific and circumboreal.

Discussion.—Cryptonatica is characterized by its semicircular umbilical callus entirely or largely filling the umbilicus, and smooth operculum that may be sculptured with a few (less than three) grooves along its outer margin.

There have been two different views on the taxonomic relation between *Tectonatica* Sacco, 1890 and *Cryptonatica* Dall, 1892. Some authors have considered *Cryptonatica* to be a junior synonym of *Tectonatica* (Cossmann, 1925; Woodring, 1928; Grant and Gale, 1931; Finlay and Marwick, 1937; Wenz, 1941; Wrigley, 1949; Cernohorsky, 1971 [with question]), whereas some other authors have considered the two genera to be distinct (Powell, 1951; Woodring, 1957; Oyama, 1969; Marincovich, 1977). I agree with the second opinion and I believe that there is no species referred to *Tectonatica* in the northern Pacific, as mentioned below.

Among the authors who support the second view, Oyama (1969) and Marincovich (1977) have had different opinions on the classification of the northern Pacific species of *Cryptonatica*. Oyama (1969, p. 86) argued that the following species, which had been classified into *Tectonatica* Sacco, 1890 by Japanese malacologists, should be assigned to *Cryptonatica*: *Cryp-*

tonatica janthostomoides (Kuroda and Habe, 1949), *C. janthostoma* (Deshayes, 1839), *C. russa* (Gould, 1859), *C. hirasei* (Pilsbry, 1905), *C. ranjii* (Kuroda, 1961), *C. figurata* (Sowerby, 1914), and *C. clausiformis* (Oyama, 1951). His rationale for this assignment was that the typical form of *Tectonatica* (type species: *Natica tectula* Sacco, 1890, Miocene to Pliocene, Italy) is more allied to that of *Natica* s.s. (type species: *Nerita vitellus* Linnaeus, 1758) than are the northern Pacific species of *Cryptonatica*. On the other hand, Marincovich (1977) considered *C. janthostomoides* and *C. janthostoma* to be species of *Tectonatica*, and *C. clausa* to be a species of *Cryptonatica*. Marincovich (1977, p. 405) mentioned that "*Tectonatica* differs from *Cryptonatica* by having an open umbilicus, whereas the umbilicus of *Cryptonatica* is entirely closed by the semicircular umbilical callus."

Of the two opinions argued, respectively, by Oyama (1969) and Marincovich (1977), I agree with Oyama's (1969) opinion for the following two reasons.

(1) The degree of the umbilical opening in *C. janthostomoides* and *C. janthostoma* is very variable (Text-figs. 13, 25). Juveniles of the two species commonly or rarely possess entirely closed umbilici whereas the adults show narrowly to widely open umbilici. Therefore, the northern Pacific species of *Cryptonatica* cannot be clearly divided into two groups on the basis of the degree of umbilical opening.

(2) The northern Pacific species of *Cryptonatica* are more closely related to each other than they are to *N. tectula*, the type species of *Tectonatica*. This is because the umbilical and opercular characters of *N. tectula* distinctly differ from those of the northern Pacific species of *Cryptonatica*. The umbilical callus of *N. tectula* is subquadrate (Sorgenfrei, 1958, pl. 38, figs. 122a–c) to semicircular (Pavia, 1980, pl. 7, figs. 9a–c, 13) in form, and covers the posterior side of the umbilicus, whereas those of the northern Pacific species of *Cryptonatica* are always semicircular in form and the specimens with open umbilici never have an umbilical callus that is attached to the posterior side of the umbilicus, where the umbilicus is the deepest (Text-fig. 13 [arrows **a**, **b**]). The operculum of *N. tectula* (Pavia, 1980, pl. 7, figs. 10a–12b) is weakly crenulated at its inner margin. This character is not observable in the northern Pacific species of *Cryptonatica*. Therefore, if the northern Pacific species of *Cryptonatica* can be divided into two groups, neither should be assigned to *Tectonatica*.

I believe there is no reason to divide the northern Pacific species of *Cryptonatica* into two genera [the above reason (1)], or to apply *Tectonatica* to all or some of them [the above reason (2)].

Recently, Petit (1986) pointed out that Cossmann (1896) designated the type species of *Cryptonatica* [*Natica* (*Cryptonatica*) *floridana* Dall, 1892, by subsequent designation] prior to Dall's (1909) designation that has been accepted by subsequent authors as the type designation of *Cryptonatica* [*Natica clausa* Broderip and Sowerby, 1829, by subsequent designation (adopted herein)]. He mentioned that "Cossmann (1896: 238) in a review of Dall's 1892 publication designated *N.* (*C.*) *floridana* Dall as the type of *Cryptonatica*, an action overlooked by all subsequent authors, including Cossmann himself." If Cossmann's designation is valid, *Cryptonatica* may not be applicable to the northern Pacific species above.

Cryptonatica clausa
(Broderip and Sowerby, 1829)
Plate 11, figures 3–22;
Text-figures 4.4, 13.1a–b, 15.64, 15.65; Table 39

Natica clausa Broderip and Sowerby, 1829, p. 372 [not seen, *fide* Oldroyd, 1927, p. 724]; Philippi, 1852, pp. 98–99, pl. 14, fig. 5; Reeve, 1855, pl. 20, figs. 88a–b, pl. 25, fig. 113; Gould, 1870, pp. 342–343, text-fig. 612: Sars, 1878, pp. 159–160, pl. 12, figs. 1a–b [shell], 1c [operculum], pl. 21, figs. 12a–b [shell], pl. 5, figs. 15a–b [radula], pl. 18, fig. 12 [operculum]; Sowerby, 1883, p. 96, pl. 4, fig. 48; Odhner, 1913, pp. 7, 14–23, pl. 3, figs. 1–3, 5–14, 16–17, pl. 5, figs. 7–14 [radulae]; MacGinitie, 1959, pp. 90–91, pl. 1, fig. 10, pl. 12, fig. 8; Kuroda and Habe, 1952, p. 70.

Natica (*Natica*) *clausa* Broderip and Sowerby. Tryon, 1886, pp. 30–31 [in part], pl. 9, figs. 65, 67, 69, 73 [not fig. 68 = *Cryptonatica janthostoma* (Deshayes, 1839)].

Not *Natica* (*Natica*) *clausa* Broderip and Sowerby. Uchiyama, 1902b, p. 395, pl. 26, figs. 23, 24 [= *Cryptonatica andoi* (Nomura, 1935b)].

Natica (*Cryptonatica*) *clausa* Broderip and Sowerby. Dall, 1921, p. 163, pl. 14, fig. 11; Oldroyd, 1927, p. 724, pl. 97, fig. 2; MacNeil, 1957, p. 109, pl. 13, figs. 12, 13, pl. 15, fig. 9; Marincovich, 1977, pp. 410–418, pl. 41, figs. 7–10, pl. 42, figs. 1–6, text-fig. 8; Allison and Marincovich, 1981, pl. 3, figs. 9, 10; Marincovich, 1983, p. 113, pl. 22, fig. 21.

Natica (*Tectonatica*) *clausa* Broderip and Sowerby. Grant and Gale, 1931, pp. 797–798, text-fig. 11; Kinoshita and Isahaya, 1934, p. 7, pl. 4, fig. 28; Kotaka, 1962, pp. 134–135, pl. 33, fig. 17; Shikama, 1964, p. 112, pl. 61, fig. 8; Abbott, 1974, p. 159, text-fig. 1718.

Tectonatica clausa (Broderip and Sowerby). Okutani, 1964, pp. 395–396, pl. 1, fig. 18, pl. 5, fig. 7; Habe and Ito, 1965a, p. 30, pl. 8, fig. 4; Okutani, 1966, p. 17, pl. 2, fig. 5, text-fig. 8 [radula]; Okutani, 1968, p. 30; Habe and Kosuge, 1970, p. 46, pl. 18, fig. 14.

Cryptonatica clausa (Broderip and Sowerby). Addicott, 1966b, pl. 1, fig. 13; Okutani and Habe, 1975, pp. 82 [unnumbered fig.], 247; Habe and Ito, 1976, p. 79; Kanno *et al.*, 1980, pl. 4, figs. 2a–b; Noda, Amano, and Majima, 1984, pl. 5, fig. 10; Majima, 1984, pp. 363–365, pl. 69, figs. 1a–5b, pl. 70, figs. 1–4b; Noda and Amano, 1985, pl. 3, fig. 12; Matsui, 1985, p. 173, pl. 22, fig. 10; Majima and Fukuta, 1986, text-figs. 1.9, 3.1–3.2, 3.7, 3.9; Majima, 1987a, p. 64, text-figs. 4.1–4.3.

Natica russa Gould, 1859, pp. 43–44; Kuroda and Habe, 1952, p. 71.

Natica (*Cryptonatica*) *russa* Gould. Dall, 1921, p. 163; Oldroyd, 1927, p. 725.

Natica (*Tectonatica*) *russa* Gould. Grant and Gale, 1931, p. 798–799; Kotaka, 1962, p. 135, pl. 33, fig. 18; Chinzei, 1959, pp. 110–111, pl. 10, fig. 8.

Table 39.—Measurements (in mm) and counts of the largest specimen of *Cryptonatica clausa* (Broderip and Sowerby, 1829) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower middle Miocene	MOMIJIYAMA 1	39.0	36.7	33.0	25.6	5+	IGUT 15957-1	8
	MOMIJIYAMA 2	22.3	21.3	17.8	17.3	4+	IGUT 15958	1
	FURANUI 1	35.2	32.0	28.5	21.9	5½+	IGUT 15956-1	13
Pliocene and lower Pleistocene	TESHIO 2	26.6	23.7	18.9	—	5	IGUT 16055-1	27
	TESHIO 4	27.4+	25.4+	21.8	20.2	4½+	IGUT 16056-1	2
	TESHIO 5	34.3+	30.9	26.0	22.4+	5+	IGUT 16058-1	8
	TESHIO 7	37.2	32.7	29.6	25.0	5+	IGUT 16062-1	13
	ATSUGA	30.7	26.1+	25.0	22.5	3+	IGUT 15606-1	2
	KUROMATSUNAI 1	16.6	15.9	13.2	12.7	4+	IGUT 15960-8	17
	KUROMATSUNAI 2	20.2	—	—	—	4+	IGUT 15064-1	11
	TOMIKAWA	31.3+	29.3+	25.6	—	1½+	IGUT 15961-1	10
	CHIKAGAWA 1	35.6+	31.7+	28.0	—	6½	IGUT 15962-1	51
	CHIKAGAWA 2	19.8	16.4+	14.3	13.8	5	IGUT 15963-2	30
	DAISHAKA	24.3	19.7	16.5	12.5	4+	SHM 6151*	1
	NAMIOKA	33.2+	35.3	30.1	—	5+	IGUT 15964-1	4
	HIGASHIMEYA	36.7	28.2	24.3	—	5½+	HU unnumbered	1
	OCHIAI	33.8	28.3+	24.8	22.6	5½+	IGUT 15575-5	6
	FUTATSUI 1	9.6+	8.7+	7.3	—	1+	IGUT 15965	1
	FUTATSUI 2	40.5	36.8	30.8	—	5+	IGUT 15966-1	3
	GOJOME 2	8.8	8.1	6.4	7.4	4+	IGUT 15967	1
	GOJOME 4	24.4	21.0	18.6	19.0	5+	IGUT 15968-1	3
	TOFUIWA	13.4	12.6	10.3	10.3	4+	IGUT 15969-2	5
	SAWANE 1	33.6+	24.8+	26.0	—	5+	GIYU 533	2
	SAWANE 2	26.8	19.6+	20.3+	—	5+	GIYU 532-1	10
	CHOSHI 1	14.1+	13.0	11.2	10.2	1½+	IGUT 15970-1	30
	NOJIMA 2	23.7	20.6+	16.5	17.3	5½+	GIYU 603	1

* Holotype of *Natica tugaruana* Nomura and Hatai, 1935.

Tectonatica russa (Gould). Sakagami *et al.*, 1966, pl. 1, figs. 11, 20; Habe, 1961, p. 39, pl. 18, fig. 8; Habe and Ito, 1965a, p. 31, pl. 8, fig. 6; Habe and Kosuge, 1970, p. 47, pl. 18, fig. 19; Ogasawara and Naito, 1983, pl. 8, figs. 6a–b, 8–9b.

Not *Tectonatica russa* (Gould). Habe, 1958, pp. 13–14, pl. 5, fig. 7 [= *Cryptonatica wakkanaiensis* Habe and Ito, 1976, living, Wakkanai, Hokkaido, northern Japan].

Cryptonatica russa (Gould). Oyama, 1969, p. 86; Okutani and Habe, 1975, pp. 83 [unnumbered fig.], 192.

Cryptonatica aleutica Dall, 1919, p. 352; Woodring and Bramlette, 1950, pl. 10, fig. 1; Habe and Ito, 1976, p 79.

Natica (*Cryptonatica*) *aleutica* (Dall). Dall, 1921, p. 164, pl. 14, fig. 10; Oldroyd, 1927, p. 726.

Natica aleutica (Dall). Kuroda and Habe, 1952, p. 70; Kosuge, 1972, pl. 6, fig. 7.

Natica (*Tectonatica*) *tugaruana* Nomura and Hatai, 1935, pp. 128–129, pl. 9, fig. 9; Iwai, 1959, p. 49, pl. 1, figs. 18a–b; Iwai, 1965, pp. 52–53, pl. 20, figs. 1a–b.

Natica (*Cryptonatica*) *clausa tugaruana* Nomura and Hatai. Otuka, 1939, p. 30, pl. 2, figs. a–d.

Natica (*Tectonatica*) *clausa tugaruana* Nomura and Hatai. Itoigawa, 1958, p. 261, pl. 2, fig. 5.

Natica tugaruana Nomura and Hatai. Hatai, Masuda, and Suzuki, 1961, pl. 4, fig. 6; Takayasu, 1961, pl. 3, fig. 6; Takayasu, 1962, pl. 1, fig. 27.

Tectonatica tugaruana (Nomura and Hatai). Chinzei, 1973, pl. 14, figs. 9a–b.

Cryptonatica tugaruana (Nomura and Hatai). Masuda *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 312, pl. 156, figs. 1458a–b.

Tectonatica clausiformis Oyama, 1951, pp. 2, 4 [footnote].

Natica clausiformis (Oyama). Shikama and Horikoshi, 1963, p. 42, text-fig. 65.

Cryptonatica clausiformis (Oyama). Oyama, 1969, p. 86, text-fig. 14.

Cryptonatica zenryumaruae Habe and Ito, 1976, pp. 79–82, text-fig. 4.

Natica (*Cryptonatica*) *janthostoma* Deshayes. Oldroyd, 1927, pl. 97, fig. 5 [not *Cryptonatica janthostoma* (Deshayes, 1839); not p. 123 = *Cryptonatica janthostoma* (Deshayes)].

Tectonatica janthostoma (Deshayes). Sawada, 1962, pp. 49–50, pl. 5, figs. 13, 14 [not *Cryptonatica janthostoma* (Deshayes, 1839)].

Natica severa Gould. Takayasu, 1961, pl. 3, fig. 7 [not *N. severa* Gould, 1859].

Eunatica pila (Pilsbry). Nemoto and O'hara, 1979a, pl. 1, figs. 10a–b [not *Euspira pila* (Pilsbry, 1911)].

Types.—

Natica clausa Broderip and Sowerby: type material unknown, presumably in BM(NH) (Marincovich, 1977); type locality unknown (Marincovich, 1977), Arctic (Oldroyd, 1927).

Natica russa Gould: type material unknown (Johnson, 1964); type locality, Arctic Ocean (Gould, 1859).

Cryptonatica aleutica Dall: USNM 217156 (lectotype, designated by Marincovich, 1977, as "USNM 217516": plate 6, figure 7 in Kosuge, 1972 and plate

41, figure 7 in Marincovich, 1977), from St. George Island, Pribilof Islands, Alaska, 30 fms (Marincovich, 1977).

Natica (Tectonatica) tugaruana Nomura and Hatai: SHM 6151 (holotype: Pl. 11, fig. 11), from Tsurugasaka, Aomori City, Aomori Prefecture, Pliocene Daishaka Formation (Nomura and Hatai, 1935).

Tectonatica clausiformis Oyama: type material unknown; type locality, Oki, Shimane Prefecture (Oyama, 1951).

Cryptonatica zenryumaruae Habe and Ito: NSMT Mo51530 (holotype: Pl. 11, fig. 19), from off Cape Soya, northernmost part of Hokkaido, at sandy bottom of 40–50 m deep (Habe and Ito, 1976).

Description.—Shell small to moderate in size, thin to thick, globose to globose-elongate, spire moderately to greatly elevated; body whorl not greatly inflated, shoulder weakly to minutely concave just below suture; suture weakly impressed; nuclear whorls two, smooth; postnuclear whorls four in largest specimen (IGUT 15962-1, loc. CHIKAGAWA 1, Aomori Prefecture). Spiral sculpture of microscopic, closely spaced, minutely wavy striae; axial sculpture of weakly developed, incremental growth lines that are most distinct below suture and on base. Parietal callus moderate in thickness, weakly to moderately filling posterior apertural angle; anterior lobe commonly lacking, but may be minutely developed if a very shallow sulcus is present. Umbilicus entirely closed by a semicircular umbilical callus which blends smoothly into underlying whorl or is raised slightly above it. Umbilical callus commonly smoothly merges into parietal callus but may be indistinctly separated from the latter callus by a minutely incised sulcus. Anterior inner lip and basal lip slightly thickened.

Operculum weakly concave; outer surface smooth except for a semicircular pad at central part which coincides morphologically with the umbilical callus; inner surface weakly sculptured with incremental growth lines; inner and outer margins smooth.

Discussion.—*Cryptonatica clausa* is characterized by its entirely closed umbilicus, indistinct anterior lobe of parietal callus, and smooth outer surface of the operculum. Fossil shells of *C. clausa* bearing opercula have been recorded by Majima (1984; 1987a) and Majima and Fukuta (1986).

Odhner (1913) exhaustively documented the variation of *C. clausa* in its size, shell form, and radular dentition. Marincovich (1977) discussed the morphological variation of *C. clausa* in the eastern Pacific area and listed many synonymous species. Both Odhner and Marincovich have observed that the adult shell of *C. clausa* attains its maximum size in Arctic seas, whereas it gradually decreases in size toward the south along with an increase in habitat depth.

In Japan, *C. clausa* also varies greatly in size (Table 39) and form (Pl. 11, figs. 3–22). The form varies from globose to elongate. The Japanese specimens with elongate shells have been previously named *Natica tugaruana* (holotype: Pl. 11, fig. 11) by Nomura and Hatai (1935) for fossils, and *Cryptonatica zenryumaruae* (holotype: Pl. 11, fig. 19) by Habe and Ito (1976) for Recent forms. *Natica tugaruana* and *Cryptonatica zenryumaruae* are synonymous with *C. clausa*, because there is no critical boundary in shell form among all the examined specimens.

Allison and Marincovich (1981) have reported *C. clausa* from the late Oligocene to earliest Miocene fauna of the Narrow Cape Formation on Sitkinak Island, western Gulf of Alaska, which is the oldest published occurrence of the species, and indicates that the ancestral stock of *C. clausa* was around the Arctic area. Throughout its history, *C. clausa* has been common in cold waters of the eastern Pacific area (Marincovich, 1977). In Japan, *C. clausa* first appeared in the lower middle Miocene Takinoue (Pl. 11, figs. 4–5) and Furanui (Pl. 11, figs. 6–7) formations in Hokkaido, and is common in the Pliocene and lower Pleistocene cold-water Omma-Manganji faunas in northern Japan (Text-fig. 4.4).

Stratigraphic occurrence.—

Lower middle Miocene: Takinoue Fm., Hokkaido, localities MOMIJIYAMA 1 (Pl. 11, fig. 4) and MOMIJIYAMA 2 (Pl. 11, fig. 5); Furanui Fm., Hokkaido, locality FURANUI 1 (Pl. 11, figs. 6–7).

Pliocene and lower Pleistocene: Yuchi Fm., Hokkaido, localities TESHIO 2, TESHIO 4, TESHIO 5 (Pl. 11, fig. 8), and TESHIO 7; Atsuga Fm., Hokkaido, locality ATSUGA; Nakanokawa Fm., Hokkaido, localities KUROMATSUNAI 1 and KUROMATSUNAI 2; Tomikawa Fm., Hokkaido, locality TOMIKAWA (Pl. 11, fig. 9); Sunagomata Fm., Aomori Pref., localities CHIKAGAWA 1 (Pl. 11, fig. 10) and CHIKAGAWA 2; Daishaka Fm., Aomori Pref., localities DAISHAKA (Pl. 11, fig. 11) and NAMIOKA; Higashimeya Fm., Aomori Pref., locality HIGASHIMEYA (Pl. 11, fig. 12); Kubo Fm., Iwate Pref., locality OCHIAI (Pl. 11, fig. 13); Kobinaizawa Fm., Akita Pref., localities FUTATSUI 1 and FUTATSUI 2 (Pl. 11, fig. 14); Sasaoka Fm., Akita Pref., localities GOJOME 2, GOJOME 4 (Pl. 11, fig. 15), and TOFUIWA (Pl. 11, fig. 16); Kannonji Fm., Yamagata Pref. (Ogasawara and Naito, 1983); Sawane Fm., Niigata Pref., localities SAWANE 1 (Pl. 11, fig. 17) and SAWANE 2; Nishiyama Fm., Niigata Pref. (Itoigawa, 1958); Yamadahama Fm., Fukushima Pref. [Nemoto and O'hara, 1979a, as "*Eunaticina pila* (Pilsbry, 1911)"]; Iioka Fm., Chiba Pref., locality CHOSHI 1 (Pl. 11, fig. 3); Nojima Fm., Kanagawa Pref., locality NOJIMA 2 (Pl. 11, fig. 18).

Table 40.—Measurements (in mm) and counts of the largest specimen of *Cryptonatica ichishiana* (Shibata, 1970) at each locality. Localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower middle Miocene	YATSUO 3	17.7	15.9	13.7	11.5	5	IGUT 15577	6
	ICHISHI 2	14.3	12.8	10.8	9.3	4½+	IGUT 15066-2	38
	ICHISHI 3	13.4	12.2	10.6	9.1	4+	IGUT 15975-1	2
	ICHISHI 4	15.7	14.2	11.7	9.7	4+	IGUT 15976-1	2
	ICHISHI 5	12.0	10.2	9.7	—	4+	IGUT 15977-1	3

Cryptonatica ichishiana (Shibata, 1970)
Plate 11, figures 1–2; Table 40

Tectonatica ichishiana Shibata, 1970, pp. 73–74, pl. 3, figs. 9a–b, 13; ? Shibata and Ina, 1983, p. 59, pl. 8, figs. 11a–b.
Cryptonatica ichishiana (Shibata). Majima, 1984, pp. 365–366, pl. 69, figs. 7–9; Majima and Fukuta, 1986, text-fig. 3.8.

Holotype.—ESN 30018, from Ashisaka, Iono, Misato-mura, Age-gun, Mie Prefecture, lower middle Miocene Oi Formation (loc. K36 of Shibata, 1970).

Description.—Shell small, relatively thin, globose-elongate, spire commonly greatly elevated; body whorl commonly anteriorly inflated; shoulder weakly flattened, may be minutely concave; suture moderately to distinctly impressed, may be weakly channeled; whorls about five in largest specimen (IGUT 15577, loc. YATSUO 3, Toyama Pref.; apices of all examined specimens are minutely to largely eroded), sculptured with minute, closely spaced, minutely wavy, spiral striae, and with incremental growth lines. Parietal callus thin, weakly filling posterior apertural angle; anterior lobe indistinct or minutely developed. Umbilicus always closed by a weakly to moderately developed umbilical callus; umbilical callus semicircular, minutely separated from parietal callus by a very shallow sulcus, and weakly raised above underlying whorl. Anterior inner lip and basal lip slightly thickened.

Operculum thin; external surface smooth or sculptured with two very weak lineations along outer margin; internal surface unknown.

Discussion.—*Cryptonatica ichishiana* is characterized by a high spire, anteriorly inflated body whorl, umbilicus closed by a semicircular umbilical callus, and a smooth operculum that may bear two weak lineations along the outer margin. Two opercula of *C. ichishiana* have been recorded by Majima (1984), and they exhibit slightly different sculpture on the outer surfaces. One operculum is sculptured with two very weak lineations along the outer margin whereas the other possesses a smooth surface. *Cryptonatica ichishiana* is very similar to *Cryptonatica clausa* (Broderip and Sowerby, 1829), but the operculum of *C. clausa* never has any lineation.

Cryptonatica oregonensis (Conrad, 1865), from the middle to lower Miocene of western North America (Marincovich, 1977), closely resembles the present species in having an elevated spire and a semicircular umbilical callus covering the umbilicus. Marincovich (1977) described the opercula found associated with the shells of *C. oregonensis* by saying that "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." *Cryptonatica ichishiana*, therefore, slightly differs from *C. oregonensis* in the sculpture of the operculum.

Stratigraphic occurrence.—

Lower middle Miocene: Joyama Member of Yatsuo Fm., Toyama Pref., locality YATSUO 3 (Pl. 11, fig. 1); ? Shimoda Fm., Aichi Pref. (Shibata and Ina, 1983); Mitsugano Member of Oi Fm., Mie Pref., localities ICHISHI 2, ICHISHI 3, ICHISHI 4 (Pl. 11, fig. 2), and ICHISHI 5.

Cryptonatica janthostoma (Deshayes, 1839)
Plate 12, figures 1–16;
Text-figures 3.6, 13.2a–c, 15.66, 25.1–25.9; Table 41

Natica janthostoma Deshayes, 1839, p. 361 [not seen, *fide* Oldroyd, 1927, p. 725]; Philippi, 1852, pp. 53–54, pl. 8, fig. 8; Reeve, 1855, pl. 18, figs. 79a–b; Sowerby, 1883, p. 82, pl. 4, fig. 52; Kuroda and Habe, 1952, p. 71.
Not *Natica janthostoma* Deshayes [= *Cryptonatica andoi* (Nomura, 1935b)]. Yokoyama, 1920, pp. 76–77, pl. 5, figs. 3, 4; Hirase, 1934, p. 59, pl. 90, fig. 14; Yen, 1936, pp. 202–203, pl. 16, figs. 26, 26a.
Natica (*Cryptonatica*) *janthostoma* Deshayes. Dall, 1921, p. 164, pl. 14, fig. 12; Oldroyd, 1927, p. 725 [not pl. 97, fig. 5 = *Cryptonatica clausa* (Broderip and Sowerby, 1829)].
Natica (*Tectonatica*) *janthostoma* Deshayes. Kinoshita and Isahaya, 1934, p. 7, pl. 4, fig. 27; Shikama and Horikoshi, 1963, p. 42, text-fig. 65; Marincovich, 1977, pp. 405–408, pl. 40, figs. 10–13, pl. 41, figs. 2–5; Marincovich, 1983, p. 114, pl. 22, fig. 22.
Not *Natica* (*Tectonatica*) *janthostoma* Deshayes. Taki, 1937, pp. 88–89, text-figs. 5, 6 [= *Cryptonatica andoi* (Nomura, 1935b)].
Natica (*Cryptonatica*) aff. *janthostoma* Deshayes. MacNeil, Mertie, and Pilsbry, 1943, p. 84, pl. 11, figs. 12, 14.
Tectonatica janthostoma (Deshayes). Kuroda and Habe, 1949, p. 71, text-figs. 1a–b; Habe, 1958, p. 13, pl. 1, fig. 23, pl. 3, fig. 20 [radula]; Habe, 1961, p. 39, pl. 18, fig. 9; Habe and Ito, 1965a, p. 32, pl. 8, figs. 10, 11.
Not *Tectonatica janthostoma* (Deshayes). Sawada, 1962, pp. 49–50,

Table 41.—Measurements (in mm) and counts of the largest specimen of *Cryptonatica janthostoma* (Deshayes, 1839) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
lower middle Miocene	CHIKUBETSU 2	35.5	27.4	24.3	27.9	4½+	TKD 5511*	2
	CHIKUBETSU 3	42.8	38.8	32.5	28.9	5+	IGUT 16068	1
	ASAHI	27.5	23.8	21.1	18.5	4+	IGUT 15978-1	2
middle middle Miocene to upper Miocene	YONBANGAWA	34.8	26.4+	24.9	27.7	5+	IGUT 15979	1
	TANAGURA 2	13.4+	12.0+	10.7	—	4½	IGUT 15980	1
Pliocene and lower Pleistocene	TESHIO 3	34.6+	33.4+	28.8	—	4½+	IGUT 16067	1
	TESHIO 7	26.4+	15.7+	—	—	4½+	IGUT 16066	1
	TAKIKAWA 1	33.6	—	—	23.2	5+	IGUT 15985	1
	TAKIKAWA 2	44.4	33.1+	33.0	32.1	4+	IGUT 15569-2	2
	TAKIKAWA 3	30.6+	31.4	24.7	—	5+	IGUT 15986	1
	KUROMATSUNAI 1	24.3	23.5	19.7	—	5½	IGUT 15987-4	6
	KUROMATSUNAI 2	13.5	13.0	10.9	11.3	3½+	IGUT 15988	1
	TOMIKAWA	20.4+	19.7+	16.0	15.6+	5+	IGUT 15989-1	2
	OCHIAI	30.0	26.7	23.5+	21.0	5½	IGUT 15990	2
	GOJOME 1	39.3	35.0	30.8	26.3	5+	IGUT 15993-1	16
	GOJOME 3	27.2+	25.8+	25.1	18.2	6¼	IGUT 15991-1	4
	TOFUIWA	19.6+	12.4+	12.0+	—	4½+	IGUT 15992-1	2
	SAWANE 3	48.0	46.0	38.0	34.3	5+	GIYU 530	1
	FUTATSUNUMA 1	34.2+	24.2+	—	—	5½+	IGUT 15994-2	50
	FUTATSUNUMA 2	19.3+	19.7	15.3	—	4½+	IGUT 15995-1	50
	SHIGARAMI 2	23.8	23.6	17.5	—	5½	GIYU 520	2
	OMMA 4	31.8	28.7	23.8	22.6	6	IGUT 15996-1	31
	NOJIMA 2	31.5+	27.0+	24.9	—	1½+	GIYU 602	1

* Holotype of *Natica* (*Tectonatica*) *ezoana* Kanno and Matsuno, 1960.

pl. 5, figs. 13, 14 [= *Cryptonatica clausa* (Broderip and Sowerby, 1829)].

Cryptonatica janthostoma (Deshayes). Oyama, 1969, p. 86; Habe and Ito, 1976, p. 79, text-fig. 2; Honda, 1978, pl. 2, figs. 9a–b; Kanno *et al.*, 1980, pl. 4, figs. 1a–b; Amano, 1983, pp. 32–33, pl. 8, fig. 27; Majima, 1984, pp. 362–363, pl. 68, figs. 1a–2e, pl. 70, figs. 5a–b, text-figs. 2, 3; Majima and Fukuta, 1986, text-figs. 5.4, 5.5, 5.6; Majima, 1987a, figs. 2.7, 2.8, 2.9.

Natica (*Natica*) *clausa* var. *janthostoma* Deshayes. Tryon, 1886, p. 31, pl. 9, fig. 68, pl. 19, fig. 89.

Natica severa Gould, 1859, p. 43; Kuroda and Habe, 1952, p. 71; Johnson, 1964, p. 149, pl. 16, fig. 14.

Not *Natica severa* Gould. Takayasu, 1961, pl. 3, fig. 7 [= *Cryptonatica clausa* (Broderip and Sowerby, 1829)].

Not *Natica* (*Tectonatica*) *severa* Gould [= *Cryptonatica andoi* (Nomura, 1935b)]. Taki and Oyama, 1954, p. 17, pl. 6, figs. 3–4b; Kira, 1954, p. 35, pl. 17, fig. 18; Ozaki, Fukuta, and Ando, 1957, p. 165, pl. 28, fig. 5; Iwai, 1959, p. 49, pl. 1, fig. 3; Shikama and Masujima, 1969, pl. 5, figs. 21, 22.

Natica (*Tectonatica*) *ezoana* Kanno and Matsuno, 1960, p. 43, pl. 4, figs. 12, 13 [not *Natica* (*Lunatia*) *ezoana* Yabe and Nagao, 1928, Cretaceous of Hokkaido, northern Japan].

Tectonatica ezoana (Kanno and Matsuno) [not *N.* (*L.*) *ezoana* Yabe and Nagao, 1928]. Kanno, O'hara, and Kaiteya, 1968, pl. 2, figs. 11a–b; ? Kanno and Akatsu, 1972, pl. 9, fig. 3.

Tectonatica ? *satsopensis* Addicott, 1966a, p. 639, pl. 77, figs. 8, 9.

Neverita reiniana Dunker, Shimamoto, 1984, pl. 3, figs. 7a–b [not *Glossaulax reiniana* (Dunker, 1877)].

Types.—

Natica janthostoma Deshayes: type material unknown, presumably in Ecole des Mines, Paris, France, or BM(NH) (Dance, 1966, *fide* Marincovich, 1977); type locality, Kamchatka, U. S. S. R. (Oldroyd, 1927).

Natica severa Gould: MCZ 169369 (holotype: pl. 16, fig. 14 *in* Johnson, 1964; pl. 40, fig. 11 *in* Marincovich, 1977), from Hakodate Bay, Hokkaido, Japan (Gould, 1859, as "Hakodadi Bay").

Natica (*Tectonatica*) *ezoana* Kanno and Matsuno [not *Natica* (*Lunatia*) *ezoana* Yabe and Nagao, 1928]: TKD 5511 (holotype: Pl. 12, fig. 7), from Haboro and Embetsu areas, Hokkaido, lower middle Miocene Sankebetsu or Chikubetsu Formation.

Tectonatica ? *satsopensis* Addicott: USNM 649134 (holotype: pl. 77, fig. 8 in Addicott, 1966a; pl. 41, fig. 3 *in* Marincovich, 1977), from cut on south side of Still Creek logging road, 400 ft north, 2200 ft W of SE cor. sect. 5, T. 18 N., R. 7 W., Wynoochee Valley Quadrangle, Washington, U. S. A., lower (?) Pliocene Montesano Formation of Weaver (1912) (Addicott, 1966a).

Description.—Shell moderate in size, moderate in thickness, globose to globose-elongate in form; body whorl not strongly inflated, commonly evenly rounded but weakly flattened shoulder may be developed; nuclear whorls two-and-one-half, smooth (surface commonly eroded); postnuclear whorls three-and-one-half in larger specimens. Spiral sculpture of minutely developed, closely spaced striae; axial sculpture of incremental growth lines that are most distinct below sutures and on base. Parietal callus moderate in thickness, weakly filling posterior apertural angle; anterior lobe distinct. Umbilicus slightly to moderately open, largely filled by a semicircular umbilical callus that is commonly located anteriorly, so that anterior corner of the umbilicus is commonly covered by the umbilical callus; sulcus narrowly but deeply notched. Anterior inner lip and basal lip thickened.

Operculum weakly concave, thick; external surface commonly smooth, may bear weak marginal striations; central area greatly thickened, semicircular in form, which coincides morphologically with the umbilical callus; inner surface sculptured with incremental growth lines; inner and outer margins smooth.

Discussion.—Cryptonatica janthostoma is characterized by having a narrowly but deeply notched sulcus, semicircular umbilical callus situated anteriorly, and an almost smooth calcareous operculum. As pointed out by Kuroda and Habe (1949) and Marincovich (1977), some specimens of *C. janthostoma* have one or two faint spiral striations along the outer margin of their opercula.

The mode of umbilical opening of *C. janthostoma* varies with growth, as Text-figures 13.2a–c and 25.1–25.9 show. The juvenile form has a slightly open umbilicus at a deeply but narrowly notched sulcus, but the umbilical opening of some juveniles is indistinct, especially in very small specimens (Text-figs. 13.2a, 25.1). The adult umbilicus is deeply open at posterior portion of the umbilicus and the anterior and lateral portions may be shallowly channeled (Text-figs. 13.2b, 25.2–25.8). The gerontic form shows a widely open umbilicus along most of the umbilical callus margin but its opening is very shallow except for the posterior portion where the umbilicus is deeply open. In the gerontic form, the umbilical callus becomes more slender than in the earlier stages, and the sulcus is more shallowly and broadly excavated (Text-figs. 13.2c, 25.9). The gerontic form is very similar to an adult variant with open umbilicus of *Cryptonatica andoi* (Nomura, 1935b) (Text-figs. 13.3c, 25.20b, 25.21b, 25.22b).

Cryptonatica janthostoma first appears in the lower middle Miocene Sankebetsu, Chikubetsu and Takinoue formations in Hokkaido, associated with the cold-water Chikubetsu faunas. In later occurrences, the species is common in the cold waters of Japan associated with the middle middle Miocene to upper Miocene Shiobara faunas and the Pliocene and lower Pleistocene Omma-Manganji faunas.

An interesting migration history of *C. janthostoma* has been documented by Marincovich (1977), who considered the species to have expanded its range to include the northeastern Pacific in the early Pliocene, and to have withdrawn from the eastern and central North Pacific in the late Pleistocene. Marincovich (1977) also considered the present species to be almost certainly a descendant from the early Pliocene northeastern Pacific stock of *Cryptonatica clausa*, but the oldest record of the present species is from the early middle Miocene of the northwestern Pacific, as mentioned above.

Natica (*Tectonatica*) *ezoana* Kanno and Matsuno, 1960, originally described from the lower middle Miocene Chikubetsu and Sankebetsu formations of Hokkaido, is synonymous with *C. janthostoma*. The holotype of *N.* (*T.*) *ezoana* shows a greatly elevated spire (Pl. 12, fig. 7) by which Kanno and Matsuno characterized it, but its shell form safely falls within the individual variation of *C. janthostoma* that I have seen. Unfortunately, the umbilical portion of the holotype, which is a discriminative point among species of *Cryptonatica*, is not well preserved, but additional specimens from the Chikubetsu Formation exhibit deeply notched sulci that characterize *C. janthostoma* (Pl. 12, fig. 8).

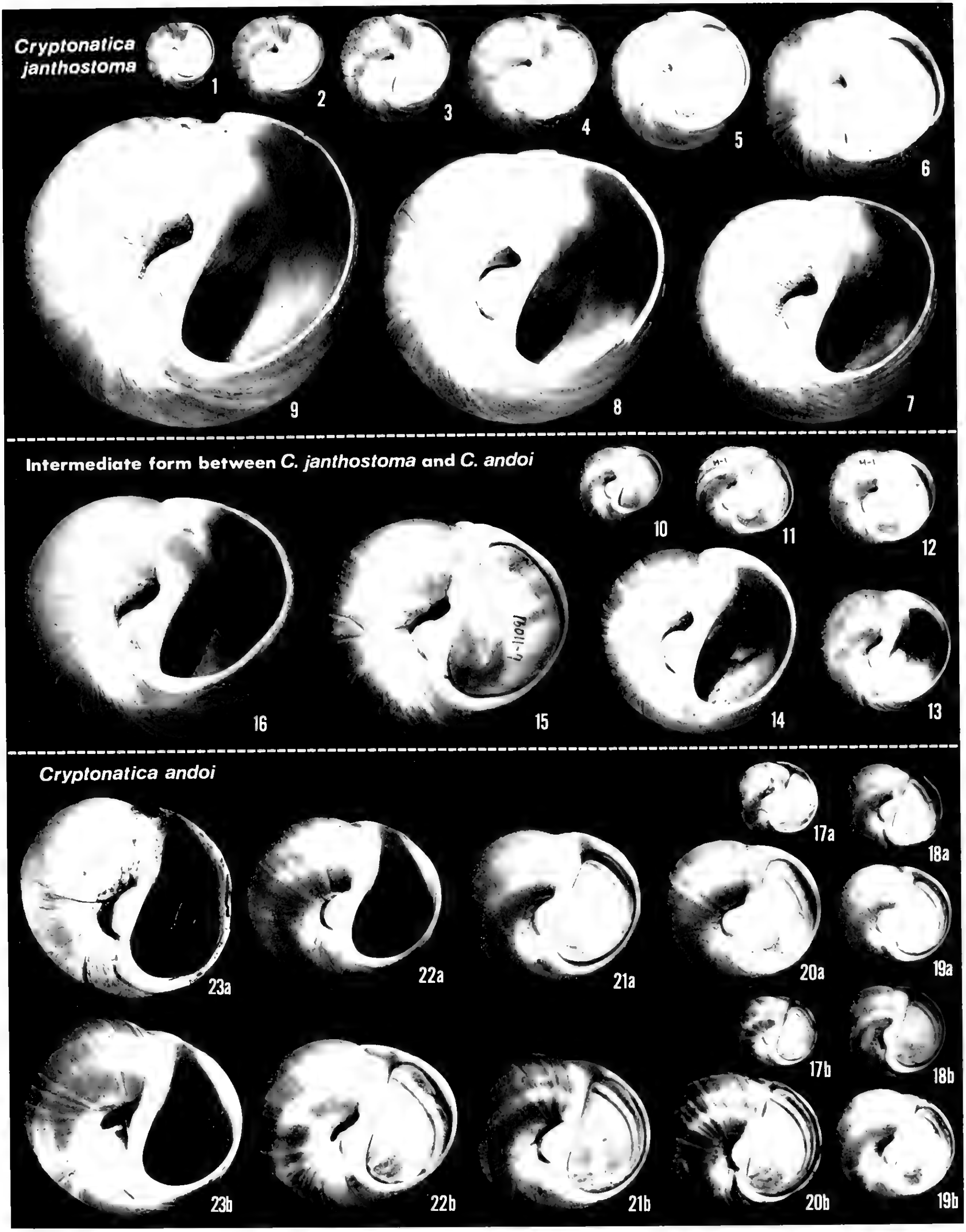
Natica (*Tectonatica*) *ezoana* Kanno and Matsuno, 1960 is a junior homonym of *Natica* (*Lunatia*) *ezoana* Yabe and Nagao, 1928, a Cretaceous naticid species of Hokkaido.

Stratigraphic occurrence.—

Lower middle Miocene: Sankebetsu or Chikubetsu Fm., Hokkaido, locality CHIKUBETSU 2 (Pl. 12, fig. 7); Chikubetsu Fm., Hokkaido, locality CHIKUBETSU 3 (Pl. 12, fig. 8); ? Hikatagawa Fm., Hokkaido (Kanno and Akatsu, 1972); Takinoue Fm., Hokkaido, locality ASAHI (Pl. 12, figs. 1).

Middle middle Miocene to upper Miocene: Togeshita Fm., Hokkaido (Amano, 1983); Maedanosawa Fm., Hokkaido, locality YONBANGAWA (Pl. 12, fig. 9); Kubota Fm., Fukushima Pref., locality TANAGURA 2 (Pl. 12, fig. 2).

Text-figure 25.—Ontogenetic variations of (1–9) *Cryptonatica janthostoma* (Deshayes, 1839), (17a–23b) *C. andoi* (Nomura, 1935b), and (10–16) the intermediate form between the two species. 1–9, IGUT 16010 (1, IGUT 16010-1; 2, IGUT 16010-2; 3, IGUT 16010-3; 4, IGUT 16010-4; 5, IGUT 16010-5; 6, IGUT 16010-6; 7, IGUT 16010-7; 8, IGUT 16010-8; and 9, IGUT 16010-9), ×1.0, Uchiura Bay, Pacific side of southern Hokkaido; 10–16, IGUT 16011 (10, IGUT 16011-1; 11, IGUT 16011-2; 12, IGUT 16011-3; 13, IGUT 16011-4; 14, IGUT 16011-5; 15, IGUT 16011-6; and 16, IGUT 16011-7), ×1.0, Hakodate Bay, southern Hokkaido; 17a–23b, IGUT 16009 (17a, IGUT 16009-1; 17b, IGUT 16009-2; 18a, IGUT 16009-3; 18b, IGUT 16009-4; 19a, IGUT 16009-5; 19b, IGUT 16009-6; 20a, IGUT 16009-7; 20b, IGUT 16009-8; 21a, IGUT 16009-9; 21b, IGUT 16009-10; 22a, IGUT 16009-11; 22b, IGUT 16009-12; 23a, IGUT 16009-13; and 23b, IGUT 16009-14), ×1.0, off Mikawa-Isshiki Fishing Port, Aichi Pref. (The lowercase letters **a** and **b** of 17–23 indicate, respectively, the specimens with the most closed umbilicus and the most open umbilicus among all of the specimens examined in each growth stage).


Cryptonatica janthostoma
1
2
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7
Intermediate form between C. janthostoma and C. andoi
10
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12
16
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14
13
Cryptonatica andoi
17a
18a
23a
22a
21a
20a
19a
17b
18b
23b
22b
21b
20b
19b

Table 42.—Measurements (in mm) and counts of the holotype and of the largest specimen of *Cryptonatica andoi* (Nomura, 1935b) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
Pliocene and lower Pleistocene	CHIKAGAWA 1	31.3	29.4	24.2	23.8	5½+	IGUT 16002-1	19
	MANGANJI 1	20.0	18.2	15.1	15.9	5+	GIYU 544-1	9
	SAWANE 4	13.9	13.8	11.0	11.2	5	GIYU 531-1	5
	HAIZUME 1	23.0+	21.5+	19.1+	—	6¾	JUE 15237	8
	HAIZUME 2	36.2+	35.0+	39.7+	—	5+	JUE 15236	8
	ISURUGI	19.8	17.1	14.7	13.2	5½	IGUT 16003-1	4
	OMMA 2	27.9+	27.0	22.5	21.1+	5+	IGUT 16005-1	10
	OMMA 5	30.4+	30.2	18.3+	22.6+	6	IGUT 16004-1	8
	NAKATSU	13.5+	8.9+	8.4+	—	4+	IGUT 15099-1	3
	NOJIMA 1	30.6	31.0	24.6	23.1	5+	GIYU 608-1	3
	NOJIMA 3	44.9+	30.9+	25.3+	—	6+	GIYU 607-1	13
	KIMITSU 2	44.9	40.8	33.9	33.4	5+	IGUT 16088	1
	KAKEGAWA 1	21.0	20.8	15.9	16.5	5+	IGUT 15069-1	10
	KAKEGAWA 2	25.3+	22.0	19.6	18.7	2+	IGUT 15071-1	14
	KAKEGAWA 3	18.0	16.1	12.9	12.7	4½+	IGUT 15085-1	6
	KAKEGAWA 5	19.8	20.3	16.4	16.5	5½	GIYU 609-1	3
	KAKAGAWA 8	17.5	17.3	15.2	13.7	5	IGUT 15082-1	2
	KAKEGAWA 12	20.2	19.8	16.7	15.3	4+	IGUT 15081-1	3
	KAKEGAWA 17	21.3+	20.0	17.0	16.9+	5+	IGUT 15079-1	5
	KAKEGAWA 22	18.9+	18.9	15.3	12.9+	5+	IGUT 15083	1
	KAKEGAWA 23	25.0	24.2	20.1	20.4	5+	IGUT 15086	1
	TONOHAMA 1	13.9+	13.4	11.4	11.3	2½+	IGUT 16006	1
	TONOHAMA 2	18.2+	18.4	14.7	—	4+	IGUT 15089-1	3
	MIYAZAKI 1	18.9+	17.8	14.1	14.5+	4½+	IGUT 15092-1	17
	MIYAZAKI 2	16.8	15.7	12.2	12.7	4+	IGUT 15095-1	2
	MIYAZAKI 6	12.8	11.8	9.1	10.1	4+	GIYU 612	1
	MIYAZAKI 8	12.9+	12.7+	13.1+	8.9+	4½+	GIYU 611-1	3
	MIYAZAKI 9	19.0+	18.1	14.6	14.0+	4½+	IGUT 16007-1	2
	MIYAZAKI 10	17.2+	16.2	12.4	13.3	5+	GIYU 613-1	4
	MIYAZAKI 11	18.4+	15.6+	16.4	—	4½+	GIYU 610	1
	YONABARU 1	16.0+	15.4	12.5	12.6+	4+	IGUT 15097	1
	Taiwan*	20.3	18.3+	15.9	16.3	4½+	IGPS 52295 (holotype)	—
upper Pleistocene	ANDEN	35.0	32.0	25.5	26.1	6	GIYU 539-1	60
	WAKIMOTO	30.2+	29.0	23.9	23.4+	5+	IGUT 16008-1	4
	NAGANUMA	34.2	32.5	27.0	25.6	3½+	UMUT CM20218**	2

* Wangwa Station 24 of Nomura (1935b).
** Lectotype, herein designated, of *Tectonatica janthostomoides* Kuroda and Habe, 1949.

Pliocene and lower Pleistocene: Yuchi Fm., Hokkaido, localities TESHIO 3 (Pl. 12, fig. 10) and TESHIO 7; Horokaoshirarika Fm., Hokkaido, localities TAKIKAWA 1 and TAKIKAWA 2; Horoka Fm., Hokkaido, locality TAKIKAWA 3; Nakanokawa Fm., Hokkaido, localities KUROMATSUNAI 1 and KUROMATSUNAI 2 (Pl. 12, fig. 3); Tomikawa Fm., Hokkaido, locality TOMIKAWA (Pl. 12, fig. 4); Kubo Fm., Iwate Pref., locality OCHIAI (Pl. 12, fig. 11); Sasaoka Fm., Akita Pref., localities GOJOME 1 (Pl. 12, fig. 12), GOJOME 3, and TOFUIWA (Pl. 12, fig. 5); Sawane Fm., Niigata Pref., locality SAWANE 3 (Pl. 12, fig. 13); Yamadahama Fm., Fukushima Pref., localities FUTATSUNUMA 1 (Pl. 12, fig. 14) and FUTATSUNUMA 2; Shigarami Fm., Nagano Pref., locality SHIGARAMI 2 (Pl. 12, fig. 6); Omma Fm., Ishikawa Pref., locality OMMA 4 (Pl. 12, fig. 15); Nojima Fm., Kanagawa Pref., locality NOJIMA 2 (Pl. 12, fig. 16).

Cryptonatica andoi (Nomura, 1935b)
Plate 13, figures 1–23;
Text-figures 5.3, 13.3a–c, 15.67, 25.17a–25.23b;
Table 42

Natica (*Natica*) *clausa* (Broderip and Sowerby). Uchiyama, 1902b, p. 395, pl. 26, figs. 23, 24 [not *Cryptonatica clausa* (Broderip and Sowerby, 1829)].

Natica janthostoma Deshayes [not *Cryptonatica janthostoma* (Deshayes, 1839)]. Yokoyama, 1920, pp. 76–77, pl. 5, figs. 3, 4; Hirase, 1934, p. 59, pl. 90, fig. 14; Yen, 1936, pp. 202–203, pl. 16, figs. 26, 26a.

Natica (*Tectonatica*) *janthostoma* Deshayes. Taki, 1937, pp. 88–89, text-figs. 5, 6 [not *Cryptonatica janthostoma* (Deshayes, 1839)].

Natica (*Tectonatica* ?) *andoi* Nomura, 1935b, p. 201, pl. 9, figs. 35a–36c.

Not *Naticarius* cf. *N. andoi* (Nomura). MacNeil, 1960, p. 56, pl. 10, figs. 17, 29, pl. 12, fig. 25 [= *Tanea undulata* (Röding, 1798)].

Tectonatica janthostomoides Kuroda and Habe, 1949, pp. 69–72, text-figs. 1c–d; Kira, 1959, p. 41, pl. 17, fig. 18; Hayasaka, 1961, p. 77, pl. 9, figs. 20a–b; Hatai, Masuda, and Suzuki, 1961, pl. 4, fig. 7; Azuma, 1961, pp. 201–202, pl. 14, fig. 10 [radula]; Shuto, 1964, pp. 289–290, pl. 42, fig. 11, pl. 43, figs. 1–3, 5; Kaseno and Matsuura, 1965, pl. 2, fig. 34; Habe and Ito, 1965a, p. 32, pl. 8, fig. 12; Iwai and Siobara, 1969, pl. 3, figs. 7a–b; Habe and Kosuge, 1970, p. 47, pl. 18, fig. 21; Yoo, 1976, pp. 65–66, pl. 10, fig. 10; Kanno *et al.*, 1978, pl. 4, fig. 6.

Natica janthostomoides (Kuroda and Habe). Ozaki, 1958, p. 144, pl. 19, figs. 1, 2.

Cryptonatica janthostomoides (Kuroda and Habe). Oyama, 1969, p. 86; Kuroda, Habe, and Oyama, 1971, pp. 173–174 [in Japanese], p. 115 [in English], pl. 19, figs. 1, 2; Oyama, 1973, pp. 32–33, pl. 7, figs. 12a–13; Okutani and Habe, 1975, pp. 82 [unnumbered fig.], 175; Habe and Ito, 1976, p. 79, text-fig. 1; Matsuura, 1977, pl. 1, fig. 29; Uyeno and Matsushima, 1979, pl. 8, fig. 2; Mori and Osada, 1979, pl. 2, fig. 6; Aoki and Baba, 1980, text-fig. 20–2; Ogasawara, 1981, pl. 2, figs. 14a–b; Majima, 1984, p. 365, pl. 70, figs. 6a–7b; Matsuura, 1985, pl. 38, fig. 8.

Not *Cryptonatica janthostomoides* (Kuroda and Habe) [= *Euspira pila* (Pilsbry, 1911)]. Ogasawara, 1977, pl. 19, figs. 5a–b; Ogasawara *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 330, pl. 165, fig. 1561.

Natica (*Tectonatica*) *janthostomoides* (Kuroda and Habe). Shikama and Horikoshi, 1963, p. 42, text-fig. 65; Iwai, 1965, p. 52, pl. 20, figs. 2, ?3, 4, 5; Shikama, 1970, p. 106, pl. 30, fig. 17; Marincovich, 1977, pp. 407–408, pl. 42, figs. 10, 11.

Natica (*Cryptonatica*) *janthostomoides* (Kuroda and Habe). Fujiyama *in* Fujiyama, Hamada, and Yamagiwa, 1982, p. 354, pl. 177, fig. 1722.

Natica (*Tectonatica*) *severa* Gould [not *N.* (*T.*) *severa* Gould, 1859)]. Taki and Oyama, 1954, p. 17, pl. 6, figs. 3–4b; Kira, 1954, p. 35, pl. 17, fig. 18; Ozaki, Fukuta, and Ando, 1957, p. 165, pl. 28, fig. 5; Shikama and Masujima, 1969, pl. 5, figs. 21, 22.

Types.—

Natica (*Tectonatica* ?) *andoi* Nomura: IGPS 52295 (holotype: Pl. 13, fig. 17), from Wangwa, Koryu-sho, Tikunan-gun, Sitiku-shu, Taiwan, Pliocene and Pleistocene Byoritsu (Miaoli) Beds (loc. Wangwa, station 24 of Nomura, 1935b).

Tectonatica janthostomoides Kuroda and Habe: UMUT CM20218 (lectotype, herein designated: Pl. 13, fig. 23), from Totsuka-ku, Yokohama City, Kanagawa Prefecture, upper Pleistocene Naganuma Formation (loc. NAGANUMA).

Description.—Shell small to moderate in size, moderate in thickness, globose to globose-elongate in form, spire moderately elevated; body whorl moderately inflated, evenly rounded except for narrowly flattened shoulder; suture distinctly impressed; nuclear whorls two-and-one-half, smooth; postnuclear whorls four in larger specimens. Spiral sculpture of minutely developed, closely spaced striae; axial sculpture of incremental growth lines that are best developed below suture and on base. Parietal callus thin, but moderately fills posterior apertural angle; anterior lobe weak. Umbilicus closed in juvenile and commonly gradually opens with growth, but may not open in some adult specimens; sulcus shallow, bearing a relatively rounded bottom; umbilical callus smooth, semicircular, with a strong funicle. In adult specimens with open umbilici, the umbilicus is shallowly open along most of the margin of the umbilical callus. Anterior inner lip and basal lip not greatly thickened. Fossil operculum known but imperfect.

Discussion.—*Cryptonatica andoi* is characterized by having a relatively shallow sulcus, commonly narrow umbilical callus, and an operculum sculptured with two marginal grooves on the external surface. A fossil shell bearing an operculum has been recorded by Majima (1984), but its external surface is greatly eroded. The operculum of modern *C. andoi* is described as follows: operculum is thick and weakly concave; external surface is sculptured with two distinct marginal grooves and a slightly raised pad at the central area that morphologically coincides with the umbilical callus; internal surface is entirely covered by a corneous layer; outer and inner margins are smooth.

Text-figure 25.17a–25.23b shows the ontogenetic variation of the umbilical part of *C. andoi* collected from off Mikawa-Ishiki Fishing Port, Aichi Prefecture, Pacific side of central Honshu. The a and b of 17–23 in Text-figure 25 exhibit, respectively, the specimens which show the most closed umbilicus and the most open umbilicus among all of the specimens examined in each growth stage. Generally, the juveniles have closed umbilici but the adults exhibit shallowly open umbilici along most of the umbilical callus margin. They change gradually with growth but the umbilici of some adults remain unopened (Text-figs. 25.20a, 25.21a).

The variant of *C. andoi* with closed umbilicus is very similar to *Cryptonatica clausa* (Broderip and Sowerby, 1829) (Pl. 11, figs. 3–22; Text-fig. 13.1a–b) in having an entirely closed umbilicus. The umbilical callus margin of this variant is generally clearly separated from the underlying whorl by a very shallow channel and the umbilical callus surface is commonly weakly rounded, especially in its margin. The umbilical callus margin of *C. clausa*, on the other hand, blends smoothly into the underlying whorl or is raised above it, and the umbilical callus surface is flatter than that of *C. andoi*. Additionally, the sulcus of *C. andoi* is weak but distinct, whereas *C. clausa* commonly lacks it. In modern specimens, these species are easily distinguishable from each other by the operculum morphology; that is, *C. clausa* possesses an entirely smooth operculum and *C. andoi* has a bisulcate operculum as described above.

Tectonatica janthostomoides Kuroda and Habe, 1949 is synonymous with *Natica* (*Tectonatica* ?) *andoi* Nomura, 1935b. The holotype (Pl. 13, fig. 17) and the paratype (Pl. 13, fig. 18) of *N.* (*T.* ?) *andoi* are small in size, with closed umbilici and weakly developed sulci. Although the type materials of *C. andoi* seem to be more similar to *C. clausa* than to the lectotype (Pl. 13, fig. 23) of *janthostomoides*, *C. andoi* is conspecific with *janthostomoides* because (1) the type materials of *C. andoi* are associated with warm-water molluscs including tropical species at locality Wangwa, station 24 of Nomura (1933, 1935b), with which *C. clausa* never occurs, and (2) the individuals in the Pliocene and lower Pleistocene warm-water faunas of Japan (Pl. 13, figs. 6–16) show a tendency to be small in size and to have umbilici closed, and some of them have umbilici open along most of the umbilical callus margin (Pl. 13, figs. 6–7, 14) in their continuous variation, in which the type materials of *C. andoi* are morphologically included.

Text-figure 25.10–25.16 shows the ontogenetic variation of modern specimens from Hakodate Bay, southern Hokkaido. Their umbilici are morphologically nearly identical with those of *C. andoi* in having a shallow sulcus and an adult umbilicus open along most of the umbilical callus margin, whereas the outer surface of their opercula are smooth except for one minutely developed marginal striation which may be observed in the operculum of *Cryptonatica janthostoma* (Deshayes, 1839). The modern specimens from Hakodate Bay are, therefore, considered to be intermediate forms between *C. andoi* and *C. janthostoma*. *Cryptonatica andoi* is now distributed in Japanese warm waters, south of southern Hokkaido (Kuroda and Habe, 1949; Habe and Ito, 1965a; Kuroda, Habe, and Oyama, 1971), but *C. janthostoma* is now distributed in Japanese cold waters, north of southwestern Hokkaido (Kuroda and Habe, 1949; Habe, 1961; Habe and Ito, 1965a). Hakodate Bay is, therefore, located on the peripheries of the geographical distributions of both *C. andoi* and *C. janthostoma*. There are two possible explanations for the presence of the intermediate forms in Hakodate Bay. (1) *Cryptonatica andoi* and *C. janthostoma* are local forms within a single species, so that the modern Hakodate population, which is located in an intermediate geographical position between the two forms, exhibits an intermediate form. (2) *Cryptonatica andoi* and *C. janthostoma* are different species and they hybridize at the geographically overlapped area (Hakodate Bay). To choose between the above two possibilities, further investigation is necessary. In fossil specimens, such a morphological overlap is also observable. In Pliocene and lower Pleistocene faunas on the northwest side of Honshu, facing the Sea of Japan, where *C. andoi* and *C. janthostoma* geographically overlap [compare the distribution of solid circles in Text-fig. 5.3 (*C. andoi*) with that of open circles in Text-fig. 3.6 (*C. janthostoma*)], the two species may not be easily distinguished from each other in shell morphologies.

Stratigraphic occurrence.—

Pliocene and lower Pleistocene: Sunagomata Fm., Aomori Pref., locality CHIKAGAWA 1 (Pl. 13, fig. 19); Higashimeya and Daishaka fms., Aomori Pref. (Iwai, 1965); Sasaoka Fm., Akita Pref., locality MANGANJI 1; Sawane Fm., Niigata Pref., locality SAWANE 4 (Pl. 13, fig. 1); Haizume Fm., Niigata Pref., localities HAIZUME 1 and HAIZUME 2 (Pl. 13, fig. 2); Natsukawa Fm., Toyama Pref., locality ISURUGI; Omma Fm., Ishikawa Pref., localities OMMA 2 (Pl. 13, figs. 3, 20), and OMMA 5; Kanzawa Fm., Kanagawa Pref., locality NAKATSU; Nojima Fm., Kanagawa Pref., localities NOJIMA 1 and NOJIMA 3 (Pl. 13, figs. 4–5, 21); Koshiba Fm., Kanagawa Pref. (Yokoyama, 1920, as "*Natica janthostoma* Deshayes"); Ichijuku Fm., Chiba Pref., locality KIMITSU 2 (Pl. 13, fig. 22); Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 1 (Pl. 13, fig. 6), KAKEGAWA 2, KAKEGAWA 5 (Pl. 13, fig. 8), KAKEGAWA 12, KAKEGAWA 17 (Pl. 13, fig. 7); Tenno Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 8, and KAKEGAWA 22; Hosoya Member of Upper Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 3 (Pl. 13, fig. 9); Nango Member of Upper Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 23; Nobori Fm., Kochi Pref., locality TONOHAMA 1 (Pl. 13, fig. 10); Ananai Fm., Kochi Pref., locality TONOHAMA 2 (Pl. 13, fig. 11); Kawabaru Member of Koyu Fm., Miyazaki Pref., locality MIYAZAKI 11 (Pl. 13, fig. 12); Tsuma Member of Koyu Fm., Miyazaki Pref., locality MIYAZAKI 8 (Pl. 13, fig. 13); Takanabe Member of Koyu Fm., Miyazaki Pref., localities MIYAZAKI 1 (Pl. 13, fig. 14), MIYAZAKI 2 (Pl. 13, fig. 15), MIYAZAKI 6, MIYAZAKI 9, and MIYAZAKI 10; Yonabaru Fm., Okinawa Pref., locality YONABARU 1 (Pl. 13, fig. 16).

Upper Pleistocene: Noheji Fm., Aomori Pref. (Iwai and Siobara, 1969); Shibikawa Fm., Akita Pref., localities ANDEN and WAKIMOTO; Naganuma Fm., Kanagawa Pref., locality NAGANUMA (Pl. 13, fig. 23); Toshima Sand, Aichi Pref. (Hayasaka, 1961).

Cryptonatica adamsiana (Dunker, 1859)
Plate 14, figures 1–17;
Text-figures 5.4, 15.68; Table 43

Natica adamsiana Dunker, 1859, pp. 231–232; Dunker, 1861, p. 14, pl. 2, fig. 20; Yokoyama, 1928a, pp. 346–347, pl. 67, fig. 9; Kuroda and Habe, 1952, p. 70.

Lunatia (*Natica*) [*sic*: *Natica* Scopoli, 1777; *Lunatia* Gray, 1847] *adamsiana* (Dunker). Dunker, 1882, p. 61, pl. 13, figs. 5, 6.

Natica (*Natica*) *adamsiana* (Dunker). Tryon, 1886, p. 27, pl. 8, fig. 46; Uchiyama, 1902a, p. 356, pl. 25, fig. 15.

Table 43.—Measurements (in mm) and counts of the largest specimen of *Cryptonatica adamsiana* (Dunker, 1859) at each locality. Within stratigraphic sets, localities are listed in order from north to south.

stratigraphic position	*locality*	*shell height*	*maximum diameter*	*minimum diameter*	*aperture height*	*number of whorls*	*specimen measured*	*number of specimens in lot*
Pliocene and lower Pleistocene	CHIKAGAWA 1	30.6+	25.5+	24.2	20.3+	5½+	GIYU 505	2
	OMMA 1	22.1	22.0	18.0	16.1	5+	IGUT 15571-2	7
	OMMA 2	10.0	9.4	8.2	7.9	4¼	IGUT 15998	1
	NAKATSU	16.6+	15.1+	13.8	—	4+	IGUT 15098	1
	KAKEGAWA 3	22.3	21.3	—	17.9	4½+	IGUT 15084-1	4
	KAKEGAWA 10	19.6+	13.7+	16.3	—	5+	IGUT 15073	1
	KAKEGAWA 11	30.8	26.6	21.9	23.0	5+	IGUT 15075-1	2
	KAKEGAWA 13	30.8	30.4	24.6	24.7	5+	IGUT 15080-1	3
	KAKEGAWA 17	23.3	22.0	19.6	17.0	5+	IGUT 15078-1	5
	KAKEGAWA 19	16.9	16.4	13.3	13.4	4+	GIYU 605-1	3
	KAKEGAWA 20	7.3+	7.7	6.6	6.0	4½	IGUT 15999	1
	TONOHAMA 1	13.8+	14.8+	14.1+	—	4½+	IGUT 16000	1
	TONOHAMA 2	20.7	18.4	14.9	15.4	4½+	IGUT 15088-1	2
	MIYAZAKI 1	24.7	22.4	18.8	18.0	4+	GIYU 604-1	10
	MIYAZAKI 2	12.3+	12.4	10.0	10.3+	4	IGUT 15094-1	2
	MIYAZAKI 5	30.3	27.7	23.0	20.3	5½+	IGUT 15096	1
	MIYAZAKI 6	21.2	20.4	16.9	16.4	4+	GIYU 606	1
upper Pleistocene	HIRADOKO	18.1	16.0	13.2	12.9	5½	IGUT 16001-1	2

Tectonatica adamsiana (Dunker). Habe, 1961, p. 39, pl. 18, fig. 6.
Not *Tectonatica adamsiana* (Dunker). Habe and Kosuge, 1970, p. 47, pl. 18, fig. 17 [= *Notocochlis gualteriana* (Récluz, 1844)].
Paratectonatica adamsiana (Dunker). Oyama, 1969, p. 85.
Natica (*Tectonatica*) *adamsiana* Dunker. Takahashi and Okamoto, 1969, p. 40, pl. 5, fig. 17.
Cryptonatica adamsiana (Dunker). Okutani and Habe, 1975, pp. 83 [unnumbered fig.], 161; Inaba, 1976, p. 88, pl. 2, figs. 6a–b [radulae]; Inaba and Oyama, 1976, pp. 141–142, text-fig. 1; Matsuura, 1977, pl. 12, fig. 18; Majima, 1984, p. 365, pl. 69, fig. 6.
Natica (*Natica*) *zebra* Lamarck. Nomura, 1935b, p. 199, pl. 9, figs. 25a–b [not *N.* (*N.*) *zebra* Lamarck, 1822].
Natica concinna Dunker. Otuka, 1935, p. 867, pl. 53, figs. 32a–c [not *Naticarius concinnus* (Dunker, 1859)].
Naticarius sp. aff. *N. concinnus* (Dunker). MacNeil, 1960, p. 56, pl. 2, fig. 21 [not *N. concinnus* (Dunker, 1859)].

Type.—Type material unknown; type locality, Dejima (as "Decima"), Nagasaki Prefecture, southern Japan (Dunker, 1859).

Description.—Shell small to moderate in size, globose to globose-elongate in form, spire weakly to greatly elevated; body whorl not greatly inflated, may bear weakly flattened sides above periphery, shoulder slightly to distinctly tabulated; suture moderately impressed; nuclear whorls two-and-one-half, smooth; postnuclear whorls about three in larger specimens; shell thickness average for genus. Spiral sculpture of minute, closely spaced, minutely wavy costellae; axial sculpture of incremental growth lines that are most distinct below suture and on base. Parietal callus moderately thickened, moderately filling posterior apertural angle; anterior lobe weak but distinct. Umbilicus deep, moderately to narrowly open along most of umbilical callus margin; sulcus shallow but broadly excavated, may bear nearly straight bottom along inner lip; umbilical callus small, nearly semicircular in form, with a low funicle. Anterior inner lip and basal lip not greatly thickened.

Operculum weakly concave; external surface sculptured with two marginal very shallow grooves and a minutely elevated pad at central area which coincides morphologically with the shape of the umbilicus.

Discussion.—*Cryptonatica adamsiana* is characterized by having a deeply open umbilicus along most of the umbilical callus margin, a small semicircular umbilical callus, and an operculum sculptured with two very shallow marginal grooves. The fossil shell of *C. adamsiana* bearing an operculum has been reported by Majima (1984).

In shell form, *C. adamsiana* is not easy to distinguish from *Tanea tosaensis* (Kuroda, 1961), living on the Pacific side of southwestern Japan (Pl. 14, fig. 19; Text-fig. 24.17a–b), and *Paratectonatica tigrina* (Röding, 1798), living in the tropical western Pacific and the Indian Ocean (Pl. 14, fig. 18). All three species have a small umbilical callus and a deeply open umbilicus along most of the umbilical callus margin. However, I assign the fossil specimens to *C. adamsiana* because a few fossil specimens are colored with irregularly developed axial light striations and vague, wide spiral bands on a brown background. The shell coloration of living *C. adamsiana* (Pl. 14, fig. 17) is of vague, wide, light-brownish spiral bands on the brown background, and may bear a white base and irregularly developed lighter axial striations, with which the fossil coloration is nearly identical. The shell of *T. tosaensis* is colored by reddish-brown spots on a light-brown background (Pl. 14, fig. 19; Text-fig. 24.17a–b), and that of *P. tigrina* by numerous dark purple spots on a white background (Pl. 14, fig. 18). Because fossil specimens bearing coloration are few, it is possible that fossil collections of the present species include some specimens of other species.

Cryptonatica adamsiana seems to be very different from other species of *Cryptonatica* in having a small umbilical callus and a relatively widely open umbilicus, by which *C. adamsiana* seems to be classifiable into *Tanea* Marwick, 1931, or *Paratectonatica* Azuma, 1961, but I assign the present species to *Cryptonatica* Dall, 1892 on the basis of radular observations. As discussed by Inaba and Oyama (1976), the radular dentition of the present species (Text-fig. 15.68) is most similar to those of the other species of *Cryptonatica* in having a basically monocuspate rachidian that is not so strongly pointed. The rachidians of species of *Tanea* (Text-figs. 15.56–15.63) are more strongly pointed and *Paratectonatica* possesses a tricuspate rachidian, with each cusp nearly equally developed (Text-fig. 15.55).

Cryptonatica adamsiana is considered to be a warm-water species because it commonly occurs in the Pliocene and lower Pleistocene warm-water Kakegawa faunas, whereas it occurs rarely in the lower Pleistocene Omma and Sunagomata formations (Pl. 14, figs. 7–8) in association with the cold-water Omma-Manganji faunas. The modern form lives in the shallow warm waters of southwestern Japan.

Stratigraphic occurrence.—

Pliocene and lower Pleistocene: Sunagomata Fm., Aomori Pref., locality CHIKAGAWA 1 (Pl. 14, fig. 7); Omma Fm., Ishikawa Pref., localities OMMA 1 (Pl. 14, fig. 8) and OMMA 2; Kanzawa Fm., Kanagawa Pref., locality NAKATSU (Pl. 14, fig. 1); Dainichi Member of Lower Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 10, KAKEGAWA 11 (Pl. 14, fig. 9), KAKEGAWA 13 (Pl. 14, fig. 10), and KAKEGAWA 17 (Pl. 14, fig. 11); Hosoya Member of Upper Kakegawa Fm., Shizuoka Pref., localities KAKEGAWA 3 (Pl. 14, fig. 12) and KAKEGAWA 19 (Pl. 14, fig. 2); Nango Member of Upper Kakegawa Fm., Shizuoka Pref., locality KAKEGAWA 20 (Pl. 14, fig. 3); Nobori Fm., Kochi Pref., locality TONOHAMA 1; Ananai Fm., Kochi Pref., locality TONOHAMA 2 (Pl. 14, fig. 13); Takanabe Member of Koyu Fm., Miyazaki Pref., localities MIYAZAKI 1 (Pl. 14, fig. 14), MIYAZAKI 2 (Pl. 14, fig. 4), MIYAZAKI 5 (Pl. 14, fig. 15), and MIYAZAKI 6 (Pl. 14, fig. 5); Yonabaru Fm., Okinawa Pref. [MacNeil, 1960, as "*Naticarius* aff. *N. concinnus* (Dunker, 1859)"].

Upper Pleistocene: Hiradoko Fm., Ishikawa Pref., locality HIRADOKO (Pl. 14, fig. 6).

INDETERMINATE TAXA

The following taxa, which have been described as naticids from Japanese Cenozoic strata, are treated herein as indeterminate taxa because their type materials are poorly preserved and no additional well-preserved topotypes have become available. They seem to be assigned to Naticidae but it is impossible to determine their precise taxonomic positions. Thus, I will discuss them separately from the systematic descriptions above. They are alphabetically arranged.

"Ampullina" asagaiensis Makiyama, 1934

Ampullina asagaiensis Makiyama, 1934, pp. 162–163, pl. 7, figs. 58, 59, 67; Oyama, Mizuno, and Sakamoto, 1960, p. 48, pl. 6, figs. 2a–e.

Holotype.—JC 100027, from shore of Cape Marie, near Matchigar on the Schmidt Peninsula, North Sakhalin, U. S. S. R., Upper Oligocene Marie Formation (Oyama, Mizuno, and Sakamoto, 1960).

Discussion.—This species cannot be recognized from its original description and figures. I have not been able to discover the type materials preserved in the collections of Kyoto University. As Makiyama (1934) wrote, none of the type materials have well-preserved apertural parts. Additional specimens previously assigned to the present species are also imperfectly preserved [Watanabe, Arai, and Hayashi, 1950, pl. 5, fig. 11 [as *Ampullina* cf. *asagaiensis*]; Hirayama, 1955, p. 118, pl. 4, figs. 10–11, 13, 15 [as *Ampullina* cf. *asagaiensis*]; Kanno, 1960, pp. 357–358, pl. 48, figs. 6–7; Kamada, 1962, pp. 160–161, pl. 19, figs. 5a–b; Kanno and Ogawa, 1964, pl. 2, fig. 16 [as *Ampullina* cf. *asagaiensis*]; and Katto and Masuda, 1979, p. 100, pl. 2, figs. 3a–b]. Although Nemoto and O'hara (1979b) reported the present species based on a well preserved specimen from the Oligocene Asagai Formation, Fukushima Prefecture, their specimen (Pl. 2, fig. 7) is assigned herein to *Euspira meisensis* (Makiyama, 1926).

"Euspira" isensis Araki, 1960
Plate 10, figure 18

Euspira isensis Araki, 1960, p. 109, pl. 9, figs. 4–7.

Holotype.—Unnumbered specimen preserved in Mie University (Pl. 10, fig. 18), from roadcut about 300 m upstream from the entrance of the valley in the west of Yanagidani, Misato-mura, Age-gun, Mie Prefecture, lower middle Miocene Kaisekizan Formation (Araki, 1960).

Discussion.—The holotype has a poorly preserved umbilicus, so that this species cannot be determined. In shell outline, the holotype seems to be similar to the gerontic form of *Euspira meisensis* (Makiyama,

1926) in having a well tabulated shoulder. They may be conspecific, but to confirm it, additional well-preserved topotypes are necessary.

Hahazimania hahazimensis
Yabe and Hatai, 1939
Plate 10, figure 19

Hahazimania hahazimensis Yabe and Hatai, 1939, pp. 210–212, pl. 12, figs. 1–4; Oyama, Mizuno, and Sakamoto, 1960, p. 47, pl. 5, figs. 10a–c; Shikama, 1970, p. 106, pl. 30, fig. 11.

Holotype.—IGPS 63362 (Pl. 10, fig. 19), from sea cliff at Nishiura, Oki-mura, Haha-jima, Ogasawara Islands, Eocene Hahajima Limestone (Oyama, Mizuno, and Sakamoto, 1960).

Discussion.—As MacNeil (1964, p. B5) pointed out, the type materials are clearly internal molds. So it is difficult to recognize the taxonomic position of the present species. MacNeil (1964) assigned his specimens to the present species [as *Ampullinopsis* cf. *A. hahazimensis*], but MacNeil's specimens are different in having a thicker shell, as pointed out in the discussion of *Ampullinopsis* sp. in this study.

"Neritaeformis (Neverita)" eodidyma
Kuroda, 1931
Plate 10, figure 17

Neritaeformis (*Neverita*) *eodidyma* Kuroda, 1931, p. 76.

Holotype.—JC 610068 (Pl. 10, fig. 17), from about 1000 m north of the entrance of Nagasawa Valley, Nishiuchi-mura, Chiisagata-gun, Nagano Prefecture, Miocene Uchimura Formation.

Discussion.—The holotype is poorly preserved, especially in the umbilical part. This species may be identified with the Naticidae in having an enlarged body whorl. The holotype seems to have a very weak transverse groove on the umbilical area (Pl. 10, fig. 17b), by which it may be assignable to *Glossaulax* Pilsbry, 1929. But its poorly preserved condition does not allow a judgement whether the groove is original or not.

"Polinices (Lunatia ?)" utoensis
Nagao, 1928a

Polinices (*Lunatia* ?) *utoensis* Nagao, 1928a, p. 119, pl. 22, figs. 21–22a.
Euspira utoensis (Nagao). Hatai and Nisiyama, 1952, p. 235.
Lunatia ? *utoensis* (Nagao). Oyama, Mizuno, and Sakamoto, 1960, p. 42, pl. 5, figs. 7a–d.

Lectotype.—IGPS 35819 (designated by Hatai and Nisiyama, 1952, p. 235), from roadcut along the seashore about 550 m west of the Akase Railway Station of the Misumi Line, Oda-mura, Uto-gun, Kumamoto Prefecture, Eocene Shiratake Formation.

Discussion.—The basal part including the umbilicus of the lectotype is not preserved. So the species cannot be assigned to a genus.

"Tectonatica janthostomoides" yamagatana
Zinbo, 1973

Tectonatica janthostomoides yamagatana Zinbo, 1973, p. 160, pl. 14, figs. 9a–b.

Holotype.—Reg. No. 18 in Yamagata Prefectural Museum, from left bank of the Shirakawa River, about 300 m northwest of Nishitakamine, Iida-machi, Nishiokitama-gun, Yamagata Prefecture, upper Miocene Utsutoge Formation (Zinbo, 1973).

Discussion.—The holotype is an internal mold of the shell. Judging from the original description and illustrations, there is no reason why *yamagatana* is assigned to the subspecies of *Tectonatica janthostomoides* Kuroda and Habe, 1949 [= *Cryptonatica andoi* (Nomura, 1935b)]. It seems to be a naticid, but further taxonomic inference is impossible.

COLLECTING LOCALITIES

Collecting localities of naticid fossils from the Cenozoic formations in Japan (Text-fig. 1) are alphabetically listed below. In the following, **A** = geographic position, **B** = stratigraphic position, **C** = lithology [— = unknown]; and **D** = list of naticid species present.

ANDEN:

A: beach cliff, about 500 m southwest of Anden, Iriai, Oga City, Akita Pref. [latitude 39°58.2′N, longitude 139°51.1′E; the same as loc. 9 of Majima, 1984].
B: upper Pleistocene Shibikawa Fm.
C: fine- to medium-grained sandstone.
D: *Euspira pila* (Pilsbry), *Glossaulax didyma didyma* (Röding), *G. reiniana* (Dunker), and *Cryptonatica andoi* (Nomura).

ARITA (Nishi-Matsuura-gun, Saga Pref.):

ARITA 1:

A: roadcut, north of Obo, Arita-machi (Shuto and Ueda, 1967).
B: middle Oligocene Kishima Fm.
C: —.
D: "*Euspira*" *aritensis* Shuto and Ueda.

ARITA 2:

A: roadcut on the boundary between Oyama-mura and Arita-machi, about 500 m northwest of the shrine at Obo, Arita-machi (Hatai and Nisiyama, 1952).
B: middle Oligocene Kishima Fm.
C: —.
D: *Mammilla insignis* (Nagao).

ASAGAI (Fukushima Pref.):

ASAGAI 1:

A: roadcut, about 1000 m northeast of Shiraiwa, Iwaki City [latitude 37°07.7′N, longitude 140°57.7′E].
B: Oligocene Asagai Fm.
C: —.
D: *Euspira meisensis* (Makiyama).

ASAGAI 2:

A: roadcut on a forest road, about 500 m north of Nanamagari, Naraha-machi, Futaba-gun [latitude 37°14.4′N, longitude 140°58.7′E].
B: Oligocene Asagai Fm.
C: fine-grained sandstone.
D: *Euspira meisensis* (Makiyama).

ASAHI:

A: river cliff on the left (south) bank of the Horonui River, about 1000 m east of the Asahi National Railway Station, Iwamizawa City, Hokkaido [latitude 43°09.2′N, longitude 141°53.4′E].
B: lower middle Miocene Takinoue Fm.
C: fine-grained sandstone.
D: *Cryptonatica janthostoma* (Deshayes).

ASHIYA (Fukuoka Pref.):

ASHIYA 1:

A: beach cliff along the sea coast about 800 m northeast of Taya, Ashiya-machi, Onga-gun (Hatai and Nisiyama, 1952).
B: lower Miocene Yamaga Fm.
C: —.
D: *Euspira meisensis* (Makiyama).

ASHIYA 2:

A: beach cliff along the sea coast of Natsugahana, about 500 m north of Taya, Ashiya-machi, Onga-gun [latitude 33°54.7′N, longitude 130°40.2′E].
B: lower Miocene Yamaga Fm.
C: sandy siltstone.
D: *Euspira meisensis* (Makiyama).

ASHIYA 3:

A: Sakamizu, Wakamatsu-ku, Kita-Kyushu City (unknown in detail).
B: lower Miocene Sakamizu Fm.
C: —.
D: *Euspira meisensis* (Makiyama).

ATETSU:

A: roadcut on the Chugoku Expressway at Kishimoto, Tetsusei-machi, Atetsu-gun, Okayama Pref. [latitude 34°54.0′N, longitude 133°18.3′E].
B: lower middle Miocene Bihoku Group.
C: siltstone.
D: *Euspira meisensis* (Makiyama).

ATSUGA:

A: river cliff on the right (west) bank of the Fupumopuzawa Valley, about 200 m upstream of its mouth, Atsuga-cho, Saru-gun, Hokkaido [latitude 42°26.2′N, longitude 142°12.8′E; the same as loc. 2 of Majima, 1984].
B: lower Pliocene Atsuga Fm.
C: fine-grained sandstone.
D: *Cryptonatica clausa* (Broderip and Sowerby).

ATSUMI:

A: beach cliff, about 500 m south of Takamatsu, Akabane-machi, Atsumi-gun, Aichi Pref. [latitude 34°37.0′N, longitude 137°14.5′E].
B: upper Pleistocene Toshima Sand of Toyohashi Group.
C: sandstone.
D: *Glossaulax didyma didyma* (Röding), *G. reiniana* (Dunker), and *Cryptonatica andoi* (Nomura).

AYUGAWA:

A: Akebihara, Tsuchiyama-machi, Kouga-gun, Shiga Pref. [latitude 34°54.8′N, longitude 136°20.9′E].
B: lower middle Miocene Kurokawa Fm.
C: fine-grained sandstone.
D: *Euspira meisensis* (Makiyama) and *Tanea minoensis* (Itoigawa).

CHICHIBU:

A: river cliff, about 300 m downstream of the Shimizu Bridge, Tochiya, Chichibu City, Saitama Pref. (the same as loc. 803 of Kanno, 1958).
B: lower middle Miocene Hiranita Fm.
C: conglomeratic sandstone (Kanno, 1958).
D: *Pachycrommium harrisi* (Pannekoek).

CHIKAGAWA (Mutsu City, Aomori Pref.):

CHIKAGAWA 1:

A: river cliff of the Chika River, about 400 m upstream of its mouth, Chikagawa [latitude 41°11.0′N, longitude 141°16.6′E; the same as loc. 5 of Majima, 1984].
B: lower Pleistocene Sunagomata Fm.
C: fine-grained sandstone.
D: *Euspira pila* (Pilsbry), *Glossaulax didyma didyma* (Röding), *G. vesicalis* (Philippi), *Cryptonatica clausa* (Broderip and Sowerby), *C. andoi* (Nomura), and *C. adamsiana* (Dunker).

CHIKAGAWA 2:

A: river cliff on the right (south) bank of the Mae River, about 100 m upstream of its mouth, Nakanosawa [latitude 41°10.4′N, longitude 141°16.8′E].
B: lower Pleistocene Sunagomata Fm.
C: medium-grained sandstone.
D: *Euspira pila* (Pilsbry), *Mammilla* sp., and *Cryptonatica clausa* (Broderip and Sowerby).

CHIKUBETSU (Tomamae-gun, Hokkaido):

CHIKUBETSU 1:

A: upper stream of the Chipotsunai River, a tributary of the Kotanbetsu River (the same as loc. 732 of Kanno and Matsuno, 1960).
B: lower middle Miocene Sankebetsu Fm. (lower member: Kanno and Matsuno, 1960).
C: —.
D: *Polinices didymoides* (Kanno and Matsuno).

CHIKUBETSU 2:

A: either locality 082301, locality 080104, locality 945, locality 21, locality 1081, or locality 651 of Kanno and Matsuno (1960).
B: lower middle Miocene Sankebetsu or Chikubetsu Fm.
C: —.
D: *Cryptonatica janthostoma* (Deshayes) [holotype of *Natica* (*Tectonatica*) *ezoana* Kanno and Matsuno].

CHIKUBETSU 3:

A: about 500 m west of locality 732 of Kanno and Matsuno (1960) (unknown in detail).
B: lower middle Miocene Chikubetsu Fm.
C: fine-grained sandstone.
D: *Cryptonatica janthostoma* (Deshayes).

CHOSHI (Choshi City, Chiba Pref.):

CHOSHI 1:

A: quarry, about 1250 m west of the Matsugishi National Railway Station, Takano-cho [latitude 35°44.0′N, longitude 140°47.0′E; the same as loc. 10 of Majima, 1984].
B: lower Pleistocene Iioka Fm.
C: siltstone.
D: *Euspira pallida* (Broderip and Sowerby) and *Cryptonatica clausa* (Broderip and Sowerby).

CHOSHI 2:

A: roadcut, east end of Miyake-machi, about 1700 m west of the Matsugishi National Railway Station [latitude 35°44.5′N, longitude 140°46.8′E].
B: lower Pleistocene Iioka Fm.
C: siltstone.
D: *Euspira pallida* (Broderip and Sowerby).

CHOSHI 3:

A: roadcut at Jyoto-ji, Tokoyodo-machi [latitude 35°42.6′N, longitude 140°45.4′E].
B: lower Pleistocene Iioka Fm.
C: siltstone.
D: *Euspira pallida* (Broderip and Sowerby).

DAISHAKA:

A: river cliff of the Shinjo River, about 300 m east of the east entrance of the Daishaka tunnel along the Ou National Railway Line, Tsurugasaka, Aomori City, Aomori Pref. [latitude 40°46.4′N, longitude 140°37.0′E; the same as loc. D-B-2 of Iwai, 1965].
B: Pliocene Daishaka Fm.
C: fine-grained sandstone.
D: *Euspira pila* (Pilsbry) and *Cryptonatica clausa* (Broderip and Sowerby).

FURANUI (Saru-gun, Hokkaido):

FURANUI 1:

A: river cliff of the Monbetsu River, about 1400 m northeast of the Hirotomi Bridge, Hatonai [latitude 42°34.9′N, longitude 142°14.5′E].
B: lower middle Miocene Furanui Fm.
C: sandy siltstone.
D: *Cryptonatica clausa* (Broderip and Sowerby).

FURANUI 2:

A: river cliff on the right (north) bank of the Monbetsu River, about 1350 m northeast of the Hirotomi Bridge, Hatonai [latitude 42°34.9′N, longitude 142°14.6′E].
B: lower middle Miocene Furanui Fm.
C: silty sandstone.
D: *Euspira meisensis* (Makiyama).

FURANUI 3:

A: river cliff on the right bank of the Monbetsu River, about 250 m upstream of locality FURANUI 2 [latitude 42°35.0′N, longitude 142°14.5′N].
B: lower middle Miocene Furanui Fm.
C: fine-grained sandstone.
D: *Sinum ineptum* (Yokoyama).

FURANUI 4:

A: river cliff on the right bank of the Monbetsu River, about 500 m upstream of locality FURANUI 2 [latitude 42°35.1′N, longitude 142°14.4′N].
B: lower middle Miocene Furanui Fm.
C: silty sandstone.
D: *Glossaulax didyma coticazae* (Makiyama).

FURANUI 5:

A: a transported concretion collected from the river bed of the Kenomai River, about 700 m northeast of the mouth of the Furanuizawa Valley [latitude 42°30.8′N, longitude 142°15.6′E].
B: ? lower middle Miocene Furanui Fm.
C: fine-grained sandstone.
D: *Euspira meisensis* (Makiyama).

FUTATSUI (Yamamoto-gun, Akita Pref.):

FUTATSUI 1:

A: roadcut at Nejirotai, about 150 m east of the Kasuge River, Fujisato-machi [latitude 40°18.7′N, longitude 140°13.5′E].
B: Pliocene Kobinaizawa Fm.
C: silty sandstone.
D: *Cryptonatica clausa* (Broderip and Sowerby).

FUTATSUI 2:

A: river cliff on the left (east) bank of the Taneume River, Tanosawa, Futatsui-cho [latitude 40°15.0′N, longitude 140°12.1′E; the same as loc. 24 of Chinzei, 1973 and loc. 6 of Majima, 1984].
B: Pliocene Kobinaizawa Fm.
C: fine-grained sandstone.
D: *Cryptonatica clausa* (Broderip and Sowerby).

FUTATSUNUMA (Futaba-gun, Fukushima Pref.):

FUTATSUNUMA 1:

A: quarry at Futatsunuma, west side of the National Highway No. 6, Hirono-machi [latitude 37°14.1N, longitude 141°00.1′E].
B: Pliocene Yamadahama Fm.
C: coarse-grained sandstone.
D: *Euspira pila* (Pilsbry), *Glossaulax didyma didyma* (Röding), and *Cryptonatica janthostoma* (Deshayes).

FUTATSUNUMA 2:

A: quarry at Futatsunuma, east side of the National Highway No. 6, Hirono-machi [latitude 37°14.1′N, longitude 141°00.2′E].
B: Pliocene Yamadahama Fm.
C: medium- to coarse-grained sandstone.
D: *Cryptonatica janthostoma* (Deshayes).

GOJOME (Gojome-cho, Minami-Akita-gun, Akita Pref.):

GOJOME 1:

A: roadcut on the ridge, about 400 m northeast of Monzen [latitude 39°55.1′N, longitude 140°10.0′E; the same as loc. 7 of Majima, 1984].
B: upper Pliocene and lower Pleistocene Sasaoka Fm.
C: fine- to medium-grained sandstone.
D: *Glossaulax didyma didyma* (Röding) and *Cryptonatica janthostoma* (Deshayes).

GOJOME 2:

A: left (south) side cliff of the dam of the Sodenosawa Lake, about 600 m north of Monzen [latitude 39°55.3′N, longitude 140°10.0′E].
B: upper Pliocene and lower Pleistocene Sasaoka Fm.
C: fine- to medium-grained sandstone.
D: *Cryptonatica clausa* (Broderip and Sowerby).

GOJOME 3:

A: left (south) side cliff of a small valley, about 50 m west of locality GOJOME 2 [latitude 39°55.3′N, longitude 140°09.9′E].
B: upper Pliocene and lower Pleistocene Sasaoka Fm.
C: fine- to medium-grained sandstone.
D: *Glossaulax didyma didyma* (Röding) and *Cryptonatica janthostoma* (Deshayes).

GOJOME 4:

A: right (north) side cliff of a small valley, about 400 m west of locality GOJOME 2 [latitude 39°55.3′N, longitude 140°09.7′E].
B: upper Pliocene and lower Pleistocene Sasaoka Fm.
C: fine- to medium-grained sandstone.
D: *Cryptonatica clausa* (Broderip and Sowerby).

GOROKU:

A: precipice at Goroku, Sendai City, Miyagi Pref. [latitude 38°15.4′N, longitude 140°49.6′E].
B: lower Pliocene Tatsunokuchi Fm.

C: —.
D: *Glossaulax didyma coticazae* (Makiyama).

HAIZUME (Niigata Pref.):

HAIZUME 1:

A: exposure at base of hill, about 100 m east of the Oginozyo National Railway Station, Izumozaki-machi, Santo-gun [latitude 37°30.7′N, longitude 138°42.5′E].
B: lower Pleistocene Haizume Fm.
C: —.
D: *Euspira pila* (Pilsbry) and *Cryptonatica andoi* (Nomura).

HAIZUME 2:

A: exposure at base of hill, about 700 m west of the Ishiji National Railway Station, Haizume, Nishiyama-machi, Kariwa-gun [latitude 37°28.8′N, longitude 138°41.1′E].
B: lower Pleistocene Haizume Fm.
C: —.
D: *Euspira pila* (Pilsbry) and *Cryptonatica andoi* (Nomura).

HAMADA:

A: Ishimi-tatamigaura, Kokubu-machi, Hamada City, Shimane Pref. [latitude 34°56.5′N, longitude 132°06.5′E].
B: lower middle Miocene Togane Fm.
C: fine- to medium-grained sandstone.
D: *Euspira meisensis* (Makiyama) and *Glossaulax didyma coticazae* (Makiyama).

HANEJI (Haneji-mura, Nago City, Okinawa Pref.):

HANEJI 1:

A: roadcut at Gabesoga [latitude 26°37.1′N, longitude 127°59.9′E].
B: lower Pleistocene Nakoshi Sandstone.
C: sandy siltstone.
D: *Tanea undulata* (Röding).

HANEJI 2:

A: river cliff of the Nakoshi River, about 400 m upstream of its mouth [latitude 26°37.2′N, longitude 128°01.5′E].
B: lower Pleistocene Nakoshi Sandstone.
C: muddy sandstone.
D: *Glossaulax didyma didyma* (Röding) and *Naticarius concinnus* (Dunker).

HANEJI 3:

A: outcrop at the Haneji Lower Secondary School [latitude 26°37.3′N, longitude 128°01.4′E].
B: lower Pleistocene Nakoshi Sandstone.
C: muddy sandstone.
D: *Mammilla* sp. and *Tanea undulata* (Röding).

HANEJI 4:

A: roadcut at Kogachi [latitude 26°37.3′N, longitude 127°59.9′E].
B: lower Pleistocene Nakoshi Sandstone.
C: —.
D: *Glossaulax didyma didyma* (Röding).

HIGASHI-INNAI (Ishikawa Pref.):

HIGASHI-INNAI 1:

A: transported concretions collected from a small valley, about 750 m southeast of Mukai-yama and about 1200 m east of Maura, Suzu City [latitude 37°28.1′N, longitude 137°06.6′E].
B: lower middle Miocene Higashi-Innai Fm..
C: —.
D: *Pachycrommium harrisi* (Pannekoek), *Euspira meisensis* (Makiyama), *Polinices mizunamiensis* Itoigawa, and *Glossaulax didyma coticazae* (Makiyama).

HIGASHI-INNAI 2:

A: exposure at base of hill, Tokunari, Wajima City [latitude 37°24.0′N, longitude 137°05.3′E; the same as loc. Tokunari of Masuda, 1956).
B: lower middle Miocene Higashi-Innai Fm.
C: sandy siltstone.
D: *Euspira meisensis* (Makiyama).

HIGASHIMEYA:

A: lower stream of the Tochinai River at Shimo-yuguchi, Hirosaki City, Aomori Pref. [latitude 40°34.1′N, longitude 140°24.8′E; the same as loc. H-2 of Iwai, 1965].
B: Pliocene Higashimeya Fm.
C: —.
D: *Cryptonatica clausa* (Broderip and Sowerby).

HIRADOKO:

A: roadcuts, about 1500 m northeast of the Shouin National Railway Station, Hiradoko, Shouin-machi, Suzu City, Ishikawa Pref. [latitude 37°27.1′N, longitude 137°18.2′E].
B: upper Pleistocene Hiradoko Fm.
C: fine- to medium-grained sandstone.
D: *Polinices sagamiensis* Pilsbry, *Glossaulax didyma didyma* (Röding), *G. vesicalis* (Philippi), *G. reiniana* (Dunker), *Sinum javanicum* (Griffith and Pidgeon), and *Cryptonatica adamsiana* (Dunker).

ICHISHI (Age-gun, Mie Pref.):

ICHISHI 1:

A: exposure at base of hill, about 300 m north of Minami-Nagano, Misato-mura [latitude 34°43.9′N, longitude 136°22.9′E].
B: lower middle Miocene Oi Fm.
C: medium- to coarse-grained sandstone.
D: *Euspira meisensis* (Makiyama).

ICHISHI 2:

A: river bed of the Nango River, about 500 m south of Ashisaka, Iono, Misato-mura [latitude 34°42.8′N, longitude 136°23.8′E; the same as loc. 12 of Majima, 1984].
B: lower middle Miocene Oi Fm.
C: siltstone.
D: *Cryptonatica ichishiana* (Shibata).

ICHISHI 3:

A: river bed of the Nango River, about 50 m downstream of locality ICHISHI 2 [latitude 34°42.8′N, longitude 136°23.8′E].
B: lower middle Miocene Oi Fm.
C: siltstone.
D: *Cryptonatica ichishiana* (Shibata).

ICHISHI 4:

A: river bed of the Nango River, about 100 m downstream of locality ICHISHI 2 [latitude 34°42.8′N, longitude 136°23.8′E].
B: lower middle Miocene Oi Fm.
C: siltstone.
D: *Cryptonatica ichishiana* (Shibata).

ICHISHI 5:

A: river bed of the Nango River, about 250 m downstream of locality ICHISHI 2 [latitude 34°42.7′N, longitude 136°23.8′E].
B: lower middle Miocene Oi Fm.
C: siltstone.
D: *Euspira mitsuganoensis* Shibata and *Cryptonatica ichishiana* (Shibata).

ICHISHI 6:

A: river cliff of the Nagano River, south of Ashisaka, Iono, Misato-mura (the same as loc. K35 of Shibata, 1970).
B: lower middle Miocene Oi Fm.
C: –.
D: *Euspira mitsuganoensis* Shibata.

ISURUGI:

A: outcrop of a Shinto-shrine at Togawa, about 1250 m east of the Hoorakuji Mineral Spring, Isurugi, Koyabe City, Toyama Pref. [latitude 36°41.7′N, longitude 136°53.2′E].
B: lower Pleistocene Natsukawa Fm.
C: fine-grained sandstone.
D: *Euspira pila* (Pilsbry) and *Cryptonatica andoi* (Nomura).

JOETSU:

A: quarry, about 1600 m northeast of the Yudono Mountain, Joetsu City, Niigata Pref. [latitude 37°09.8′N, longitude 138°12.9′E].
B: lower Pleistocene Byobudani Fm.
C: –.
D: *Glossaulax hagenoshitensis* (Shuto).

KADONOSAWA (Ninohe City, Iwate Pref.):

KADONOSAWA 1:

A: small outcrop in a tributary of the Shiratori River, about 400 m upstream of the mouth of the tributary, Shiratori, Fukuoka-machi [latitude 40°14.0′N, longitude 141°20.6′E].
B: lower middle Miocene Kadonosawa Fm.
C: fine- to medium-grained sandstone.
D: *Euspira meisensis* (Makiyama), *E. marincovichi*, n. sp., *Glossaulax didyma coticazae* (Makiyama), and *Sinum ineptum* (Yokoyama).

KADONOSAWA 2:

A: river bed of the Shiratori River at Yakata, Fukuoka-machi [latitude 40°15.2′N, longitude 141°19.7′E].
B: lower middle Miocene Kadonosawa Fm.
C: fine- to medium-grained sandstone with sparse coarse grains.
D: *Euspira meisensis* (Makiyama), *Glossaulax didyma coticazae* (Makiyama), and *Sinum ineptum* (Yokoyama).

KADONOSAWA 3:

A: river cliff on the right (east) bank of a small valley, about 500 m south of Yazawa, Fukuoka-machi [latitude 40°18.3′N, longitude 141°19.4′E].
B: lower middle Miocene Kadonosawa Fm.
C: medium-grained sandstone.
D: *Glossaulax didyma coticazae* (Makiyama).

KADONOSAWA 4:

A: a transported concretion collected from the river bed in a small valley at Nisatai, Fukuoka-machi [latitude 40°18.2′N, longitude 141°19.4′E].
B: ? lower middle Miocene Kadonosawa Fm.
C: sandstone.
D: *Sinum ineptum* (Yokoyama).

KAKEGAWA (Shizuoka Pref.):

KAKEGAWA 1:

A: river cliff in a small valley, about 700 m northwest of Dainichi, Fukuroi City [latitude 34°48.7′N, longitude 137°56.4′E; the same as loc. K-1 of Majima, 1985].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: fine- to medium-grained sandstone with pebbles.
D: *Polinices sagamiensis* Pilsbry, *Glossaulax didyma dainichiensis*, n. subsp., *G. reiniana* (Dunker), *G. hagenoshitensis* (Shuto), *Sinum javanicum* (Griffith and Pidgeon), *Natica vitellus* (Linnaeus), *Tanea tabularis* (Kuroda), and *Cryptonatica andoi* (Nomura).

KAKEGAWA 2:

A: river cliff in a small valley, about 120 m southeast of locality KAKEGAWA 1 [latitude 34°48.7′N, longitude 137°56.4′E; the same as loc. K-2 of Majima, 1985].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: fine- to medium-grained sandstone.
D: *Polinices sagamiensis* Pilsbry, *Glossaulax didyma dainichiensis*, n. subsp., *G. hagenoshitensis* (Shuto), *Sinum javanicum* (Griffith and Pidgeon), *Natica vitellus* (Linnaeus), and *Cryptonatica andoi* (Nomura).

KAKEGAWA 3:

A: roadcut near Kakegawa Baseball Field, about 650 m southeast of the Hosoya National Railway Station, Kakegawa City [latitude 34°47.1′N, longitude 137°58.2′E; the same as loc. K-3 of Majima, 1985].
B: lower Pleistocene Hosoya Member of Upper Kakegawa Fm.
C: silt-pebble bearing medium-grained sandstone intercalated in tuffaceous siltstone.
D: *Glossaulax didyma didyma* (Röding), *G. reiniana* (Dunker), *G. hagenoshitensis* (Shuto), *Mammilla* sp., *Cryptonatica andoi* (Nomura), and *C. adamsiana* (Dunker).

KAKEGAWA 5:

A: quarry, about 1500 m west of the Shikiji National Railway Station, Aijiroshima-Shimo, Toyooka-mura, Iwata-gun [latitude 34°49.3′N, longitude 137°51.1′E].
B: lower Pleistocene Dainichi Member (western end of the Member) of Lower Kakegawa Fm.
C: conglomerate with sandstone matrix.
D: *Glossaulax didyma didyma* (Röding), *Mammilla* sp., and *Cryptonatica andoi* (Nomura).

KAKEGAWA 6:

A: river cliff in a small valley, about 40 m southeast of locality KAKEGAWA 1 [latitude 34°48.7′N, longitude 137°56.4′E].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: fine- to medium-grained sandstone.
D: *Glossaulax didyma dainichiensis*, n. subsp..

KAKEGAWA 8:

A: roadcut at Asuka, Kakegawa City [latitude 34°47.3′N, longitude 137°59.9′E; the same as loc. K-8 of Majima, 1985].
B: upper Pliocene Tenno Member of Lower Kakegawa Fm.
C: fine- to medium-grained sandstone.
D: *Glossaulax didyma didyma* (Röding), *G. hagenoshitensis* (Shuto), *Eunaticina papilla* (Gmelin), and *Cryptonatica andoi* (Nomura).

KAKEGAWA 9:

A: roadcut at Shimo-Saigo, Kakegawa City [latitude 34°46.7′N, longitude 138°01.2′E; the same as loc. K-9 of Majima, 1985].
B: upper Pliocene Tenno Member of Lower Kakegawa Fm.
C: silty sandstone.
D: *Glossaulax didyma didyma* (Röding), *G. hyugensis* (Shuto), and *G. hagenoshitensis* (Shuto).

KAKEGAWA 10:

A: exposure at base of hill, about 500 m east of Kami-Iida, Mori-machi, Suchi-gun [latitude 34°48.4′N, longitude 137°55.7′E; the same as loc. K-10 of Majima, 1985].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: fine- to medium-grained sandstone with pebbles.
D: *Glossaulax didyma dainichiensis*, n. subsp., *G. hagenoshitensis*

(Shuto), *Sinum javanicum* (Griffith and Pidgeon), *Natica vitellus* (Linnaeus), *Tanea tabularis* (Kuroda), and *Cryptonatica adamsiana* (Dunker).

KAKEGAWA 11:

A: roadcut, about 500 m southeast of Hongo-Higashi, Kakegawa City [latitude 34°48.1′N, longitude 137°58.0′E; the same as loc. K-11 of Majima, 1985].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: fine- to medium-grained sandstone.
D: *Glossaulax didyma dainichiensis*, n. subsp., *G. hagenoshitensis* (Shuto), *Natica vitellus* (Linnaeus), and *Cryptonatica adamsiana* (Dunker).

KAKEGAWA 12:

A: roadcut at the east entrance of a small tunnel, about 250 m southwest of Honohashi, Kakegawa City [latitude 34°47.3′N, longitude 138°00.6′E; the same as loc. K-12 of Majima, 1985].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: conglomerate with medium-grained sandstone matrix.
D: *Glossaulax didyma dainichiensis*, n. subsp., *G. hagenoshitensis* (Shuto), and *Cryptonatica andoi* (Nomura).

KAKEGAWA 13:

A: small tunnel cut, about 300 m east of Tonoya, Kakegawa City [latitude 34°47.7′N, longitude 137°58.3′E; the same as loc. K-13 of Majima, 1985].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: fine-grained sandstone.
D: *Glossaulax didyma didyma* (Röding), *G. nodai* Majima, *G. hagenoshitensis* (Shuto), and *Cryptonatica adamsiana* (Dunker).

KAKEGAWA 14:

A: river cliff, about 500 m north of Dainichi, Fukuroi City [latitude 34°48.6′N, longitude 137°56.5′E; the same as loc. K-14 of Majima, 1985].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: fine- to medium-grained sandstone.
D: *Glossaulax hagenoshitensis* (Shuto).

KAKEGAWA 15:

A: river cliff, about 200 m south of locality KAKEGAWA 14 [latitude 34°48.4′N, longitude 137°56.5′E; the same as loc. K-15 of Majima, 1985].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: fine- to medium-grained sandstone.
D: *Glossaulax didyma dainichiensis*, n. subsp., *G. reiniana* (Dunker), and *G. hagenoshitensis* (Shuto).

KAKEGAWA 16:

A: roadcut, about 250 m east of locality KAKEGAWA 14 [latitude 34°48.5′N, longitude 137°56.6′E; the same as loc. K-16 of Majima, 1985].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: fine- to medium-grained sandstone.
D: *Glossaulax didyma dainichiensis*, n. subsp., and *G. hagenoshitensis* (Shuto).

KAKEGAWA 17:

A: roadcut, about 1000 m west of the Haranoya National Railway Station, boundary between Fukuroi and Kakegawa cities [latitude 34°48.4′N, longitude 137°56.8′E; the same as loc. K-17 of Majima, 1985].
B: upper Pliocene Dainichi Member of Lower Kakegawa Fm.
C: fine- to medium-grained sandstone.
D: *Polinices sagamiensis* Pilsbry, *Glossaulax didyma dainichiensis*, n. subsp., *G. reiniana* (Dunker), *G. nodai* Majima, *G. hagenoshitensis* (Shuto), *Natica vitellus* (Linnaeus), *Cryptonatica andoi* (Nomura), and *C. adamisana* (Dunker).

KAKEGAWA 18:

A: roadcut, about 600 m northwest of the Hosoya National Railway Station, Hosoya, Kakegawa City [latitude 34°47.5′N, longitude 137°58.3′E].
B: lower Pleistocene Hosoya Member of Upper Kakegawa Fm.
C: —.
D: *Euspira yokoyamai* (Kuroda and Habe).

KAKEGAWA 19:

A: Naka-Iida, Mori-machi, Suchi-gun (unknown in detail).
B: lower Pleistocene Hosoya Member of Upper Kakegawa Fm.
C: —.
D: *Cryptonatica adamsiana* (Dunker).

KAKEGAWA 20:

A: river cliff, about 750 m southwest of the Totomi-Sakuragi National Railway Station, Kakegawa City [latitude 34°46.3′N, longitude 137°58.1′E].
B: lower Pleistocene Nango Member of Upper Kakegawa Fm.
C: sandy siltstone.
D: *Cryptonatica adamsiana* (Dunker).

KAKEGAWA 21:

A: roadcut, about 400 m northwest of the Ukari Shinto Shrine, boundary of Fukuroi City and Suchi-gun [latitude 34°47.8′N, longitude 137°55.5′E].
B: lower Pleistocene Hosoya Member of Upper Kakegawa Fm.
C: sandy siltstone.
D: *Glossaulax didyma didyma* (Röding).

KAKEGAWA 22:

A: roadcut, about 600 m southeast of locality KAKEGAWA 9, Kakegawa City [latitude 34°46.6′N, longitude 138°01.6′E].
B: upper Pliocene Tenno Member of Lower Kakegawa Fm.
C: —.
D: *Cryptonatica andoi* (Nomura).

KAKEGAWA 23:

A: exposure at base of hill, about 1200 m southeast of the Ukari Shinto-Shrine, Ukari, Fukuroi City [latitude 34°47.4′N, longitude 137°56.4′E].
B: lower Pleistocene Nango Member of Upper Kakegawa Fm.
C: fine-grained sandstone.
D: *Cryptonatica andoi* (Nomura).

KAKEGAWA 24:

A: Hijikata, Ogasa-gun (unknown in detail).
B: lower Pleistocene Hijikata Member of Upper Kakegawa Fm.
C: —.
D: *Pliconacca atricapilla* (Martin).

KIKAI (Kikai-jima, Oshima-gun, Kagoshima Pref.):

KIKAI 1:

A: Isaneku, Kikai-machi (unknown in detail).
B: upper Pleistocene Ryukyu Limestone.
C: —.
D: *Polinices peselephanti* (Link), *Glossaulax vesicalis* (Philippi), *Tanea areolata* (Récluz), and *T. tabularis* (Kuroda).

KIKAI 2:

A: Hayamachi, Kikai-machi (unknown in detail).
B: upper Pleistocene Ryukyu Limestone.
C: —.
D: *Polinices peselephanti* (Link).

KIMITSU (Kimitsu City, Chiba Pref.):

KIMITSU 1:

A: lake-side cliff of the Koori Dam, about 500 m east of Ishiki

[latitude 35°17.5'N, longitude 139°54.5'E].
B: lower Pleistocene Mandano Fm.
C: medium-grained sandstone.
D: *Euspira yokoyamai* (Kuroda and Habe).

KIMITSU 2:

A: quarry at Sawamaki [latitude 35°16.5'N, longitude 139°59.9'E].
B: lower Pleistocene Ichijuku Fm.
C: medium- to coarse-grained sandstone.
D: *Cryptonatica andoi* (Nomura).

KITAKANEGASAWA:

A: precipice, about 250 m south of the Kitakanegasawa National Railway Station, Fukaura-machi, Nishitugaru-gun, Aomori Pref. [latitude 40°44.5'N, longitude 140°05.9'E; the same as loc. N-6 of Iwai, 1965].
B: Pliocene Narusawa Fm.
C: fine- to medium-grained sandstone.
D: *Euspira pila* (Pilsbry) and *E. yokoyamai* (Kuroda and Habe).

KIURAGI:

A: southern cliff of the isolated hill, about 250 m west of the bridge at Chogiri, Ochi-mura, Higashi-Matsuura-gun, Saga Pref. (Hatai and Nisiyama, 1952).
B: lower Oligocene Kiuragi Fm.
C: —.
D: "*Pachycrommium*" *nagaoi* (Hatai and Nisiyama).

KOKOZURA:

A: roadcut of the National Highway No. 6, Kokozura, Nakoso-machi, Iwaki City, Fukushima Pref. [latitude 36°51.1'N, longitude 140°47.5'E].
B: middle middle Miocene Kokozura Fm.
C: sandy siltsone.
D: *Euspira meisensis* (Makiyama), *Glossaulax didyma coticazae* (Makiyama), and *Sinum ineptum* (Yokoyama).

KUME (Kume-jima, Shimajiri-gun, Okinawa Pref.):

KUME 1:

A: exposure at beach, about 650 m south of Madomari, Nakazato-son [latitude 26°20.4'N, longitude 126°49.4'E].
B: Pliocene (unknown in detail) Higa Fm. (Makino, 1975 MS).
C: —.
D: *Natica vitellus* (Linnaeus).

KUME 2:

A: road-side exposure, about 500 m east of Hiyasada, Nakazato-son [latitude 26°22.6'N, longitude 126°47.2'E].
B: Pliocene (unknown in detail) Fusakina Fm. (Makino, 1975 MS).
C: —.
D: *Natica vitellus* (Linnaeus).

KUME 3:

A: exposure, about 2000 m northeast of Kategaru, Nakazato-son [latitude 26°20.6'N, longitude 126°46.9'E; the same as loc. 15 of Majima, 1984].
B: Pliocene (unknown in detail) Fusakina Fm. (Makino, 1975 MS).
C: —.
D: *Natica vitellus* (Linnaeus).

KUROMATSUNAI (Kuromatsunai-cho, Suttsu-gun, Hokkaido):

KUROMATSUNAI 1:

A: small outcrop on the left (west) bank of the Soibetsu River at Soibetsu, about 2500 m upstream of the mouth of the Soibetsu River [latitude 42°40.9'N, longitude 140°16.9'E].
B: Pliocene Nakanokawa Fm.
C: fine-grained sandstone.
D: *Euspira pila* (Pilsbry), *Cryptonatica clausa* (Broderip and Sowerby), and *C. janthostoma* (Deshayes).

KUROMATSUNAI 2:

A: small outcrop on the left (south) bank of the Shirosumi River, about 1250 m upstream of the mouth of the Shirosumi River [latitude 42°42.4'N, longitude 140°18.8'E; the same as loc. 7 of Sawada, 1962 and loc. 3 of Majima, 1984].
B: Pliocene Nakanokawa Fm.
C: massive siltstone.
D: *Euspira pila* (Pilsbry), *Cryptonatica clausa* (Broderip and Sowerby), and *C. janthostoma* (Deshayes).

MAIZURU (Ooi-gun, Fukui Pref.):

MAIZURU 1:

A: roadcut, about 600 m northeast of Ogurui, Takahama-cho [latitude 35°30.9'N, longitude 135°31.0'E].
B: lower middle Miocene Uchiura Group.
C: conglomerate.
D: *Cernina fluctuata nakamurai* (Otuka).

MAIZURU 2:

A: construction site of the Takahama Atomic Power Plant, Takahama-cho.
B: lower middle Miocene Uchiura Group.
C: —.
D: *Cernina fluctuata nakamurai* (Otuka).

MAIZURU 3:

A: roadcut, about 700 m north of Kamakura [latitude 35°31.4'N, longitude 135°27.7'E].
B: lower middle Miocene Uchiura Group.
C: coarse-grained sandstone.
D: *Euspira meisensis* (Makiyama).

MAIZURU 4:

A: roadcut, about 20 m east of locality MAIZURU 3 [latitude 35°31.4'N, longitude 135°27.7'E].
B: lower middle Miocene Uchiura Group.
C: sandy siltstone.
D: *Euspira meisensis* (Makiyama).

MANGANJI (Akita Pref.):

MANGANJI 1:

A: exposure at base of hill, Manganji, Honjo City.
B: upper Pliocene Sasaoka Fm.
C: —.
D: *Euspira pila* (Pilsbry), *Glossaulax didyma didyma* (Röding), and *Cryptonatica andoi* (Nomura).

MANGANJI 2:

A: outcrop in a small valley, about 1000 m northeast of Moriko, Yuri-machi, Yuri-gun.
B: upper Pliocene Sasaoka Fm.
C: —.
D: *Euspira pila* (Pilsbry).

MIYAZAKI (Koyu-gun, Miyazaki Pref.):

MIYAZAKI 1:

A: roadcut at Hagenoshita, Takanabe-machi [latitude 32°08.8'N, longitude 131°31.1'E; the same as loc. M-1 of Majima, 1985].
B: upper Pliocene Takanabe Member of Koyu Fm.
C: fine-grained sandstone.
D: *Euspira yokoyamai* (Kuroda and Habe), *Glossaulax didyma didyma* (Röding), *G. hyugensis* (Shuto), *G. hagenoshitensis* (Shuto), *Mammilla* sp., *Natica vitellus* (Linnaeus), *Cryptonatica andoi* (Nomura), and *C. adamsiana* (Dunker).

MIYAZAKI 2:

A: roadcut at Oku, Shintomi-machi [latitude 32°47.7'N, longitude 132°29.2'E; the same as loc. M-2 of Majima, 1985].

B: upper Pliocene Takanabe Member of Koyu Fm.
C: fine-grained sandstone.
D: *Euspira yokoyamai* (Kuroda and Habe), *Glossaulax hyugensis* (Shuto), *G. hagenoshitensis* (Shuto), *Natica vitellus* (Linnaeus), *Cryptonatica andoi* (Nomura), and *C. adamsiana* (Dunker).

MIYAZAKI 3:

A: roadcut at Koonji, Takanabe-machi [latitude 32°06.7′N, longitude 131°30.2′E; the same as loc. M-3 of Majima, 1985].
B: upper Pliocene Takanabe Member of Koyu Fm.
C: sandstone.
D: *Euspira yokoyamai* (Kuroda and Habe), *Glossaulax hyugensis* (Shuto), and *G. hagenoshitensis* (Shuto).

MIYAZAKI 4:

A: roadcut at Nihonmatsu, Takanabe-machi [latitude 32°06.7′N, longitude 131°31.7′E; the same as loc. M-4 of Majima, 1985].
B: upper Pliocene Takanabe Member of Koyu Fm.
C: fine-grained sandstone.
D: *Euspira yokoyamai* (Kuroda and Habe) and *Glossaulax hagenoshitensis* (Shuto).

MIYAZAKI 5:

A: construction excavation of the Torihama Fishing Port, Kawaminami-machi [latitude 32°10.1′N, longitude 131°33.1′E; the same as loc. M-5 of Majima, 1985].
B: lower Pleistocene Takanabe Member (uppermost part) of Koyu Fm.
C: fine-grained sandstone.
D: *Glossaulax vesicalis* (Philippi), *Glossaulax nodai* Majima, and *Cryptonatica adamsiana* (Dunker).

MIYAZAKI 6:

A: river cliff on the right (south) bank of the Hirata River, about 250 m west of Idenoue, Kawaminami-machi [latitude 32°10.9′N, longitude 131°32.1′E].
B: upper Pliocene Takanabe Member of Koyu Fm.
C: siltstone.
D: *Cryptonatica andoi* (Nomura) and *C. adamsiana* (Dunker).

MIYAZAKI 8:

A: outcrop on the right (south) bank of the Komaru River, below the Takahashi Bridge, Nakakawahara, Kijo-machi [latitude 32°09.5′N, longitude 131°28.5′E].
B: lower Pliocene Tsuma Member of Koyu Fm.
C: —.
D: *Euspira yokoyamai* (Kuroda and Habe) and *Cryptonatica andoi* (Nomura).

MIYAZAKI 9:

A: exposure at base of hill, Sakamoto, about 250 m east of the Komaru-Ohashi Bridge, Takanabe-machi [latitude 32°08.2′N, longitude 131°31.3′E].
B: upper Pliocene Takanabe Member of Koyu Fm.
C: siltstone.
D: *Euspira yokoyamai* (Kuroda and Habe) and *Cryptonatica andoi* (Nomura).

MIYAZAKI 10:

A: roadcut of the National Highway No. 10, about 750 m northeast of Hagenoshita, Takanabe-machi [latitude 32°09.0′N, longitude 131°31.4′E].
B: upper Pliocene Takanabe Member of Koyu Fm.
C: —.
D: *Euspira yokoyamai* (Kuroda and Habe) and *Cryptonatica andoi* (Nomura).

MIYAZAKI 11:

A: roadcut, about 500 m northwest of Yuriaino, Kijo-machi [latitude 32°09.2′N, longitude 131°25.8′E].
B: lower Pliocene Kawabaru Member of Koyu Fm.
C: pebble-bearing siltstone.
D: *Cryptonatica andoi* (Nomura).

MIZUNAMI (Gifu Pref.):

MIZUNAMI 1:

A: outcrop, about 200 m northwest of the Mizunami Fossil Museum, Akeyo-machi, Mizunami City [latitude 32°22.3′N, longitude 137°14.2′E].
B: lower middle Miocene Togari Fm.
C: silty sandstone.
D: *Euspira meisensis* (Makiyama).

MIZUNAMI 2:

A: construction field of the Chuo Expressway at Togari, Akeyo-machi, Mizunami City [latitude 32°22.1′N, longitude 137°14.5′E].
B: lower middle Miocene Togari Fm.
C: silty sandstone.
D: *Euspira meisensis* (Makiyama).

MIZUNAMI 3:

A: exposure on the right (north) bank of the Toki River, about 1000 m south of the Mizunami Fossil Museum, Akeyo-machi, Mizunami City [latitude 32°21.7′N, longitude 137°14.5′E].
B: lower middle Miocene Togari Fm.
C: silty sandstone.
D: *Euspira meisensis* (Makiyama).

MIZUNAMI 4:

A: Nakakoeda, Koeda-machi, Toki City (unknown in detail).
B: lower middle Miocene Nataki Fm.
C: —.
D: *Sinum ineptum* (Yokoyama).

MIZUNAMI 5:

A: river cliff at Shukunohora, Hiyoshi-machi, Mizunami City [latitude 32°24.5′N, longitude 137°16.1′E].
B: lower middle Miocene Shukunohora Sandstone.
C: ill-sorted sandstone.
D: *Pachycrommium harrisi* (Pannekoek), *Polinices mizunamiensis* Itoigawa, *Glossaulax didyma coticazae* (Makiyama), *Sigatica kurodai* Itoigawa and Shibata, and *Tanea minoensis* (Itoigawa).

MOMIJIYAMA (Yubari City, Hokkaido):

MOMIJIYAMA 1:

A: river cliff on the left (east) bank of the Yubari River, about 150 m north of the Jusan-Mile Bridge, Momijiyama [latitude 42°55.0′N, longitude 142°02.1′E; the same as loc. 46 of Kanno and Ogawa, 1964].
B: lower middle Miocene Takinoue Fm.
C: siltstone.
D: *Euspira meisensis* (Makiyama) and *Cryptonatica clausa* (Broderip and Sowerby).

MOMIJIYAMA 2:

A: river bed of a small valley, about 650 m southeast of the Jusan-Mile Bridge, Momijiyama [latitude 42°54.8′N, longitude 142°02.6′E].
B: lower middle Miocene Takinoue Fm.
C: siltstone.
D: *Cryptonatica clausa* (Broderip and Sowerby).

NAGANUMA:

A: Totsuka-ku, Yokohama City, Kanagawa Pref. (unknown in detail).
B: upper Pleistocene Naganuma Fm.
C: —.
D: *Cryptonatica andoi* (Nomura).

NAGASAKI (Nagasaki Pref.):

NAGASAKI 1:

A: sea cliff west of a 48-m-high hill, about 250 m north of Takesaki, Koyagi-machi, Nishi-Sonogi-gun (Hatai and Nisiyama, 1952).
B: lower Eocene Futagojima Fm.
C: —.
D: *Neverita eocenica* (Nagao).

NAGASAKI 2:

A: near the top of the 92-m-high hill, about 300 m west of Abo, Koyagi-machi, Nishi-Sonogi-gun (Hatai and Nisiyama, 1952).
B: upper Eocene Okinoshima Fm.
C: —.
D: *Pliconacca nomii* (Nagao).

NAGASAKI 3:

A: beach exposure on southern coast of Takashima Island, Takashima-machi, Nishi-Sonogi-gun [latitude 32°38.8′N, longitude 129°45.5′E].
B: lower Eocene Futagojima Fm.
C: silty sandstone.
D: *Neverita eocenica* (Nagao).

NAKATSU:

A: quarry at Ozawa, about 500 m south of the Takada Bridge, Aikawa-machi, Aikawa-gun, Kanagawa Pref. [latitude 35°32.0′N, longitude 139°19.9′E].
B: upper Pliocene Kanzawa Fm.
C: conglomeratic sandstone.
D: *Glossaulax didyma didyma* (Röding), *Cryptonatica andoi* (Nomura), and *C. adamsiana* (Dunker).

NAMIOKA:

A: exposure on the left (south) bank of the Shoheiji River, about 500 m southeast of Tengudaira Mountain, Namioka-machi, Minami-Tsugaru-gun, Aomori Pref. [latitude 40°43.0′N, longitude 140°38.3′E; the same as loc. D-B-9 of Iwai, 1965].
B: Pliocene Daishaka Fm.
C: fine- to medium-grained sandstone.
D: *Cryptonatica clausa* (Broderip and Sowerby).

NIIMI:

A: quarry, about 2000 m northwest of the Niimi National Railway Station, Tsujita, Nishikata, Niimi City, Okayama Pref. [latitude 34°59.4′N, longitude 133°26.3′E; the same as loc. 4 of Taguchi, Ono, and Okamoto, 1979].
B: lower middle Miocene Bihoku Group.
C: siltstone.
D: *Pachycrommium harrisi* (Pannekoek) and *Glossaulax didyma coticazae* (Makiyama).

NOJIMA (Kanagawa Pref.):

NOJIMA 1:

A: large-scaled sand quarry in the valley of Imaizumi, Kamakura City (the same as loc. 318 of Shikama and Masujima, 1969 and loc. N-1 of Majima, 1985).
B: lower Pleistocene Nojima Fm.
C: grey tuffaceous soft sandstone and conglomerate (Shikama and Masujima, 1969).
D: *Euspira yokoyamai* (Kuroda and Habe), *Polinices candidissimus* (Le Guillou), *P. sagamiensis* Pilsbry, *Glossaulax nodai* Majima, *G. hagenoshitensis* (Shuto), and *Cryptonatica andoi* (Nomura).

NOJIMA 2:

A: site of building construction, west of Yokohama City University, 850 m northwest of the Kanazawa-Hakkei Railway Station, Nishigayatsu, Kanagawa-ku, Yokohama City (the same as loc. 313 of Shikama and Masujima, 1969).
B: lower Pleistocene Nojima Fm.
C: grey tuffaceous fine sandstone with pumice patches (Shikama and Masujima, 1969).
D: *Cryptonatica clausa* (Broderip and Sowerby) and *C. janthostoma* (Deshayes).

NOJIMA 3:

A: cliff at Koizumiyato, Kamakura City (the same as loc. 321 of Shikama and Masujima, 1969).
B: lower Pleistocene Nojima Fm.
C: alternating tuffaceous siltstone with brown pumice patches (5-10 cm thick) and grey tuffaceous coarse sandstone (Shikama and Masujima, 1969).
D: *Polinices candidissimus* (Le Guillou), *Mammilla* sp., and *Cryptonatica andoi* (Nomura).

NOJIMA 4:

A: many cliffs exposed during the construction of houses in the valley head of Kuden, about 2750 m southeast by east of Otani, Kuden, Totsuka-ku, Yokohama City (the same as loc. 323 of Shikama and Masujima, 1969).
B: lower Pleistocene Nojima Fm.
C: gray tuffaceous sandstone and conglomerate (Shikama and Masujima, 1969).
D: *Polinices candidissimus* (Le Guillou).

OCHIAI:

A: river cliff on the right (south) bank of the Umiue River, Ochiai, Ninohe City, Iwate Pref. [latitude 40°18.2′N, longitude 141°13.5′E; the same as loc. 2 of Chinzei, 1959 and loc. 8 of Majima, 1984].
B: lower Pliocene Kubo Fm.
C: fine-grained sandstone.
D: *Cryptonatica clausa* (Broderip and Sowerby) and *C. janthostoma* (Deshayes).

OKURA:

A: Okura-mura, Mogami-gun, Yamagata Pref. (unknown in detail).
B: lower middle Miocene Takinosawa Fm.
C: —.
D: *Cernina fluctuata nakamurai* (Otuka).

OKUSHIRI:

A: river cliff in a small valley, about 500 m west of the streets of Tsu, Okushiri–machi, Okushiri–gun, Hokkaido.
B: lower middle Miocene Tsurikake Fm.
C: fine- to medium-grained sandstone.
D: *Tanea minoensis* (Itoigawa).

OMMA (Kanazawa City, Ishikawa Pref.):

OMMA 1:

A: river bed of the Sai River, about 1000 m southeast of the Okuwa Bridge, Okuwa-machi [latitude 36°31.6′N, longitude 136°41.2′E; the same as loc. 11 of Majima, 1984 and loc. O-1 of Majima, 1985].
B: lower Pleistocene Omma Fm.
C: fine- to medium-grained sandstone.
D: *Euspira pila* (Pilsbry), *Glossaulax didyma didyma* (Röding), *G. reiniana* (Dunker), *G. hagenoshitensis* (Shuto), and *Cryptonatica adamsiana* (Dunker).

OMMA 2:

A: river cliff of the Asano River, Tate-machi [latitude 36°31.1′N, longitude 136°42.4′E; the same as loc. O-2 of Majima, 1985].
B: lower Pleistocene Omma Fm.
C: fine- to medium-grained sandstone.
D: *Euspira pila* (Pilsbry), *Glossaulax reiniana* (Dunker), *G. hage-*

noshitensis (Shuto), *Cryptonatica andoi* (Nomura), and *C. adamsiana* (Dunker).

OMMA 3:

A: a transported subangular boulder, on the river bed of the Asano River, about 150 m west of the streets of Fukuro-Itaya-machi [latitude 36°30.8′N, longitude 136°42.5′E; the same as loc. O-3 of Majima, 1985].
B: lower Pleistocene Omma Fm.
C: fine-grained sandstone.
D: *Glossaulax hagenoshitensis* (Shuto).

OMMA 4:

A: river bed of the Sai River, about 70 m upstream of locality OMMA 1, Okuwa-machi [latitude 36°31.6′N, longitude 136°41.2′E].
B: lower Pleistocene Omma Fm.
C: fine- to medium-grained sandstone.
D: *Euspira pila* (Pilsbry) and *Cryptonatica janthostoma* (Deshayes).

OMMA 5:

A: bed of a tributary of the Asano River, below the bridge at north of Kakuma-machi [latitude 36°32.8′N, longitude 136°42.5′E; the same as loc. 16 of Kaseno and Matsuura, 1965].
B: lower Pleistocene Omma Fm.
C: fine- to medium-grained sandstone.
D: *Euspira pila* (Pilsbry), *Glossaulax reiniana* (Dunker), and *Cryptonatica andoi* (Nomura).

OMMA 6:

A: river cliff at locality OMMA 3 [latitude 36°30.8′N, longitude 136°42.5′E].
B: lower Pleistocene Omma Fm.
C: fine-grained sandstone.
D: *Euspira pila* (Pilsbry).

OMMA 7:

A: roadcut, about 150 m southeast of Konan-Gakuin and about 400 m west of Fukuro-Itaya-machi [latitude 36°30.9′N, longitude 136°42.4′E; the same as loc. 27 of Kaseno and Matsuura, 1965].
B: lower Pleistocene Omma Fm.
C: fine-grained sandstone.
D: *Glossaulax didyma didyma* (Röding).

OMMA 8:

A: Kanegawa (unknown in detail).
B: lower Pleistocene Omma Fm.
C: —.
D: *Glossaulax vesicalis* (Philippi).

OSHAMANBE:

A: bed of a tributary of the Monbetsu River, about 1500 m southeast of the Pirika Hot Spring, Oshamanbe-machi, Yamakoshi-gun, Hokkaido [latitude 42°31.8′N, longitude 140°16.3′E].
B: lower middle Miocene Kunnui Fm.
C: fine- to medium-grained sandstone.
D: *Euspira meisensis* (Makiyama).

SAKAE:

A: Sakai-zawa, Sakae-mura, Kamiminochi-gun, Nagano Pref. (unknown in detail).
B: upper Miocene Aoki Fm.
C: —.
D: *Glossaulax didyma coticazae* (Makiyama).

SAKURAI:

A: quarries at Sakurai, Kisarazu City, Chiba Pref.
B: upper Pleistocene Sakurai Fm.
C: sandstone.
D: *Polinices sagamiensis* Pilsbry, *Glossaulax reiniana* (Dunker), *Sinum javanicum* (Griffith and Pidgeon), and *Naticarius concinnus* (Dunker).

SAWANE (Sawane-machi, Sado-gun, Niigata Pref.):

SAWANE 1:

A: outcrop at Sugawa (unknown in detail).
B: lower Pleistocene Sawane Fm.
C: —.
D: *Euspira pallida* (Broderip and Sowerby) and *Cryptonatica clausa* (Broderip and Sowerby).

SAWANE 2:

A: outcrop at Ichiban-Gai (unknown in detail).
B: lower Pleistocene Sawane Fm.
C: —.
D: *Euspira pallida* (Broderip and Sowerby) and *Cryptonatica clausa* (Broderip and Sowerby).

SAWANE 3:

A: outcrop at Nishino (unknown in detail).
B: lower Pleistocene Sawane Fm.
C: —.
D: *Cryptonatica janthostoma* (Deshayes).

SAWANE 4:

A: outcrop at Sawane-mura (unknown in detail).
B: lower Pleistocene Sawane Fm.
C: —.
D: *Euspira pila* (Pilsbry) and *Cryptonatica andoi* (Nomura).

SEMATA:

A: cliff at base of hill, Sematanoseki, about 1000 m southeast of Semata-Shinden, boundary between Chiba and Ichihara cities, Chiba Pref [latitude 35°31.5′N, longitude 140°13.8′E].
B: upper Pleistocene Semata Fm.
C: medium- to coarse-grained sandstone.
D: *Euspira pila* (Pilsbry), *E. yokoyamai* (Kuroda and Habe), *Glossaulax didyma didyma* (Röding), and *G. vesicalis* (Philippi).

SENNAN:

A: river cliff 150 m west of bridge 500 m west of Adachi, Murata-machi, Shibata-gun, Miyagi Pref. (Hatai and Nisiyama, 1952).
B: middle middle Miocene to upper Miocene (unknown in detail) Kanagase Fm.
C: —.
D: *Glossaulax didyma coticazae* (Makiyama).

SETANA:

A: river cliff on the left (west) bank of the Kuroiwa River, about 500 m southeast of the Hanaishi Bridge, Imagane-cho, Setana-gun, Hokkaido [latitude 42°25.4′N, longitude 140°09.7′E; the same as loc. 20 of Sawada, 1962].
B: lower Pleistocene Chinkope Fm.
C: fine- to medium-grained sandstone.
D: *Euspira pila* (Pilsbry).

SHIGARAMI (Kamiminochi-gun, Nagano Pref.):

SHIGARAMI 1:

A: Kawashimo, Togakushi-mura (unknown in detail).
B: lower Pliocene Shigarami Fm.
C: —.
D: *Glossaulax didyma coticazae* (Makiyama).

SHIGARAMI 2:

A: Shimosoyama, Togakushi-mura (unknown in detail).
B: lower Pliocene Shigarami Fm.
C: —.
D: *Cryptonatica janthostoma* (Deshayes).

SHIGARAMI 3:

A: a short distance north of Shimosoyama, Togakushi-mura (Hatai and Nisiyama, 1952).
B: lower Pliocene Shigarami Fm.
C: –.
D: "*Sinum*" *festiva* (Yokoyama).

SHINZATO (Okinawa Pref.):

SHINZATO 1:

A: cliff about 500 m southeast of Shinzato, Sashiki-son, Shimajiri-gun [latitude 26°09.7′N, longitude 127°46.7′E; the same as localities 15, 15U, 347, 347U, O31 of Noda, 1980].
B: upper Pliocene Shinzato Fm.
C: siltstone.
D: *Euspira yokoyamai* (Kuroda and Habe), *Pliconacca atricapilla* (Martin), and *Aloconatica niasensis* (Wissema).

SHINZATO 2:

A: small road cliff at pass between Kuteken and Tedoken, Chinen-son, Shimajiri-gun [latitude 26°10.3′N, longitude 127°49.0′E; the same as loc. 317 of Noda, 1980].
B: upper Pliocene Shinzato Fm.
C: siltstone.
D: *Euspira yokoyamai* (Kuroda and Habe), *Pliconacca atricapilla* (Martin), and *Aloconatica niasensis* (Wissema).

SHINZATO 3:

A: cliff about 1000 m northeast of Ihara, Sashiki-son, Shimajiri-gun [latitude 26°10.3′N, longitude 127°48.8′E; the same as loc. 334 of Noda, 1980].
B: upper Pliocene Shinzato Fm.
C: siltstone.
D: *Euspira yokoyamai* (Kuroda and Habe) and *Pliconacca atricapilla* (Martin).

SHINZATO 4:

A: southern cliff of the Shyre Golf Links, about 1000 m northwest of Kuteken, Chinen-son, Shimajiri-gun [latitude 26°10.4′N, longitude 127°49.0′E; the same as localities 414-3, 414-5 and 415 of Noda, 1980].
B: upper Pliocene Shinzato Fm.
C: siltstone.
D: *Euspira yokoyamai* (Kuroda and Habe), *Pliconacca atricapilla* (Martin), and *Aloconatica niasensis* (Wissema).

SHINZATO 5:

A: road cliff, about 500 m southeast of Shikenbaru, Tamagusuku-son, Shimajiri-gun.
B: upper Pliocene Shinzato Fm.
C: –.
D: *Euspira yokoyamai* (Kuroda and Habe), *Pliconacca atricapilla* (Martin), and *Aloconatica niasensis* (Wissema).

SHINZATO 6:

A: beach cliff, about 1300 m southeast of Miyagi, Miyagi-jima, Yonagusuku-son, Nakagami-gun [latitude 26°21.6′N, longitude 127°59.7′E].
B: upper Pliocene Shinzato Fm.
C: siltstone.
D: *Euspira yokoyamai* (Kuroda and Habe) and *Natica vitellus* (Linnaeus).

SHINZATO 7:

A: Kuteken, Chinen-son, Shimajiri-gun.
B: upper Pliocene Shinzato Fm.
C: –.
D: *Aloconatica niasensis* (Wissema).

SHINZATO 8:

A: cliff of west side of Yakena Harbour, Yakena, Yonagusuku-son, Nakagami-gun [latitude 26°19.0′N, longitude 127°55.0′E; the same as loc. 12 of Noda, 1980].
B: upper Pliocene Shinzato Fm.
C: siltstone.
D: *Mammilla* sp.

SHINZATO 9:

A: road cliff of Route No. 331, about 500 m north of Kuteken, Chinen-son, Shimajiri-gun [latitude 26°10.0′N, longitude 127°49.7′E; the same as loc. 348 of Noda 1980].
B: upper Pliocene Shinzato Fm.
C: siltstone.
D: *Euspira yokoyamai* (Kuroda and Habe).

SHIOBARA:

A: river cliff on the right bank of the Houki River, Daikoku-Iwa, Wadayama, Shiobara-machi, Shioya-gun, Tochigi Pref. [latitude 36°56.4′N, longitude 139°53.5′E].
B: middle middle Miocene (unknown in detail) Kanomatazawa Fm.
C: fine- to medium-grained sandstone.
D: *Glossaulax didyma coticazae* (Makiyama).

SHIZUKUISHI:

A: Nishine, Shizukuishi-machi, Iwate-gun, Iwate Pref. (the same as loc. 605 on text-fig. 12 of Suto and Ishii, 1987)
B: middle middle Miocene to upper Miocene (unknown in detail) Yamatsuda Fm.
C: medium- to coarse-grained sandstone.
D: *Glossaulax didyma coticazae* (Makiyama).

SHOBARA (Shobara City, Hiroshima Pref.):

SHOBARA 1:

A: river bed of the Saizyo River, about 250 m north of the Bingo-Shobara National Railway Station [latitude 34°51.7′N, longitude 133°01.2′E].
B: lower middle Miocene Bihoku Group.
C: sandy siltstone.
D: *Cernina fluctuata nakamurai* (Otuka).

SHOBARA 2:

A: exposure at base of hill, about 1750 m east of the Bingo-Shobara National Railway Station [latitude 34°51.7′N, longitude 133°02.5′E].
B: lower middle Miocene Bihoku Group.
C: sandy siltstone.
D: *Euspira meisensis* (Makiyama).

SHOBARA 3:

A: Shinjyo-machi (the same as loc. L1-1 of Itoigawa and Nishikawa, 1976).
B: lower middle Miocene Bihoku Group.
C: –.
D: *Cernina fluctuata nakamurai* (Otuka).

TAIRA (Iwaki City, Fukushima Pref.):

TAIRA 1:

A: beach cliff at Tomigami-zaki, Numanouchi [latitude 37°00.4′N, longitude 140°58.9′E].
B: lower middle Miocene Numanouchi Fm..
C: fine- to medium-grained sandstone.
D: *Glossaulax didyma coticazae* (Makiyama) and *Sinum ineptum* (Yokoyama).

TAIRA 2:

A: outcrop at Sakashita, Kamioyada-machi.

B: lower Miocene Honya Mudstone.
C: siltstone.
D: *Bulbus fragilis* (Leach).

TAIRA 3:

A: river cliff of a small valley, about 750 m east of Oribemae, Toono-machi [latitude 37°00.6′N, longitude 140°46.4′E].
B: lower middle Miocene Nakayama Fm.
C: medium-grained sandstone.
D: *Euspira meisensis* (Makiyama).

TAKIKAWA (Hokkaido):

TAKIKAWA 1:

A: river cliff of the Horoshintachibetsu River, about 1000 m southwest of the Mabu National Railway Station, Uryu-gun [latitude 43°49.4′N, longitude 141°54.2′E].
B: Pliocene Horokaoshirarika Fm.
C: fine-grained sandstone.
D: *Cryptonatica janthostoma* (Deshayes).

TAKIKAWA 2:

A: river cliff on the right (south) bank of the Oshirarika River, about 1500 m east of Misawa, Shin-Totsugawa-cho, Kabato-gun [latitude 43°39.7′N, longitude 141°49.3′E; the same as loc. 1 of Majima, 1984].
B: Pliocene Horokaoshirarika Fm.
C: tuffaceous siltstone.
D: *Cryptonatica janthostoma* (Deshayes).

TAKIKAWA 3:

A: river cliff on the right (north) bank of the Sorachi River, about 2000 m southwest of the Higashi-Takikawa National Railway Station, Takikawa City [latitude 43°33.7′N, longitude 141°57.9′E].
B: Pliocene Horoka Fm.
C: —.
D: *Cryptonatica janthostoma* (Deshayes).

TANABE (Tanabe City, Wakayama Pref.):

TANABE 1:

A: Cape Haneyamanohana, Ikeda, Shirahama-machi [latitude 33°41.2′N, longitude 135°22.6′E].
B: lower middle Miocene Tanabe Group.
C: fine- to medium-grained sandstone.
D: *Euspira meisensis* (Makiyama).

TANABE 2:

A: wave cut beach on the southeast side of Fujishima, Shirahama-machi (Hatai and Nisiyama, 1952).
B: lower middle Miocene Tanabe Group.
C: —.
D: *Sinum ineptum* (Yokoyama).

TANAGURA (Higashi-Shirakawa-gun, Fukushima Pref.):

TANAGURA 1:

A: river cliff, about 500 m northwest of Kannonmae, Nishigouchi [latitude 36°58.5′N, longitude 140°25.3′E].
B: middle middle Miocene Kubota Fm.
C: silty sandstone.
D: *Glossaulax didyma coticazae* (Makiyama) and *Sinum ineptum* (Yokoyama).

TANAGURA 2:

A: quarry at Kubota, Nishigouchi [latitude 36°59.0′N, longitude 140°26.0′E].
B: middle middle Miocene Kubota Fm.
C: silty sandstone.
D: *Glossaulax didyma coticazae* (Makiyama), *Sinum ineptum* (Yokoyama), and *Cryptonatica janthostoma* (Deshayes).

TANAGURA 3:

A: Nishigouchi (unknown in detail).
B: middle middle Miocene Kubota Fm.
C: —.
D: *Glossaulax didyma coticazae* (Makiyama).

TESHIO (Teshio-cho, Teshio-gun, Hokkaido):

TESHIO 2:

A: roadcut, about 2200 m southwest of Yenyama [latitude 44°54.5′N, longitude 141°51.8′E].
B: lower Pliocene Yuchi Fm.
C: —.
D: *Euspira pila* (Pilsbry) and *Cryptonatica clausa* (Broderip and Sowerby).

TESHIO 3:

A: roadcut, about 1000 m southwest of Dan'noppu [latitude 44°50.9′N, longitude 141°54.0′E].
B: lower Pliocene Yuchi Fm.
C: —.
D: *Cryptonatica janthostoma* (Deshayes).

TESHIO 4:

A: roadcut, about 4500 m west of Sengen [latitude 44°49.3′N, longitude 141°52.6′E].
B: lower Pliocene Yuchi Fm.
C: —.
D: *Cryptonatica clausa* (Broderip and Sowerby).

TESHIO 5:

A: roadcuts along the Sakasazawa Forest Road, about 3000 m east of the Tamiyasu Mountain [latitude 44°50.2′N, longitude 141°52.5′E].
B: lower Pleistocene Yuchi Fm.
C: —.
D: *Euspira pila* (Pilsbry) and *Cryptonatica clausa* (Broderip and Sowerby).

TESHIO 7:

A: roadcuts along the Sakasazawa Forest Road, about 3000 m east of the Tamiyasu Mountain [latitude 44°50.6′N, longitude 141°52.5′E].
B: lower Pliocene Yuchi Fm.
C: —.
D: *Euspira pila* (Pilsbry), *Cryptonatica clausa* (Broderip and Sowerby), and *C. janthostoma* (Deshayes).

TESHIO 8:

A: outcrop, about 1000 m east of Tokotsunai [latitude 44°51.0′N, longitude 141°50.7′E].
B: lower Pliocene Yuchi Fm.
C: —.
D: *Euspira pila* (Pilsbry).

TESHIO 9:

A: roadcut, about 2500 m east of Kitakawaguchi [latitude 44°56.4′N, longitude 141°47.8′E; the same as the locality illustrated in figure 1 of Noda *et al.*, 1983].
B: lower Pliocene Yuchi Fm. (lower part).
C: sandy siltstone.
D: *Euspira pallida* (Broderip and Sowerby).

TOFUIWA:

A: small quarry at Tofuiwa, about 500 m northwest of the Hakamakoshi Mountain, Akita City, Akita Pref. [latitude 39°46.3′N, longitude 140°06.7′E].
B: upper Pliocene and lower Pleistocene Sasaoka Fm.
C: fine- to medium-grained sandstone.

D: *Euspira pila* (Pilsbry), *Cryptonatica clausa* (Broderip and Sowerby), and *C. janthostoma* (Deshayes).

TOMIKAWA:

A: river bed of the Hosokomatazawa Valley, about 1200 m upstream of its mouth, Kamiiso-machi, Kamiiso-gun, Hokkaido [latitude 41°49.5′N, longitude 140°35.7′E; the same as loc. 4 of Majima, 1984].
B: lower Pleistocene Tomikawa Fm.
C: fine- to medium-grained sandstone with pebbles.
D: *Bulbus fragilis* (Leach), *Euspira pallida* (Broderip and Sowerby), *E. pila* (Pilsbry), *Cryptonatica clausa* (Broderip and Sowerby), and *C. janthostoma* (Deshayes).

TOMIKUSA:

A: Asano-Ikekubo, Tomikusa, Anan-machi, Shimoina-gun, Nagano Pref. (the same as loc. 16 of Shikama, 1954).
B: lower middle Miocene Nukuta Fm.
C: silty sandstone (Shikama, 1954).
D: *Euspira meisensis* (Makiyama).

TONOHAMA (Kochi Pref.):

TONOHAMA 1:

A: quarry at Nobori, Hane-machi, Muroto-gun [latitude 33°22.2′N, longitude 134°03.5′E; the same as loc. T-1 of Majima, 1985].
B: upper Pliocene Nobori Fm.
C: siltstone.
D: *Euspira yokoyamai* (Kuroda and Habe), *Glossaulax hyugensis* (Shuto), *G. hagenoshitensis* (Shuto), *Mammilla* sp., *Cryptonatica andoi* (Nomura), and *C. adamsiana* (Dunker).

TONOHAMA 2:

A: roadcut, about 450 m north of Tonohama, Yasuda-machi, Aki-gun [latitude 33°26.6′N, longitude 133°58.2′E; the same as loc. T-2 of Majima, 1985].
B: upper Pliocene Ananai Fm.
C: fine-grained sandstone.
D: *Polinices sagamiensis* Pilsbry, *Glossaulax hyugensis* (Shuto), *Mammilla* sp., *Natica vitellus* (Linnaeus), *Cryptonatica andoi* (Nomura), and *C. adamsiana* (Dunker).

TONOHAMA 3:

A: river cliff in a small valley, about 350 m northeast of Higashidani, Aki-gun [latitude 33°26.7′N, longitude 133°58.4′E; the same as loc. T-3 of Majima, 1985].
B: upper Pliocene Ananai Fm.
C: fine- to medium-grained sandstone.
D: *Glossaulax hagenoshitensis* (Shuto).

TSUYAMA:

A: exposure at base of hill, about 400 m southwest of Doi, Sho-Ou-cho, Katsuta-gun, Okayama Pref. [latitude 35°05.1′N, longitude 134°08.7′E].
B: lower middle Miocene Bihoku Group.
C: conglomeratic sandstone.
D: *Pachycrommium harrisi* (Pannekoek) and *Glossaulax didyma coticazae* (Makiyama).

WAKIMOTO:

A: quarry, about 500 m southwest of the Wakimoto National Railway Station, Wakimoto, Oga City, Akita Pref. [latitude 39°54.6′N, longitude 139°54.0′E].
B: upper Pleistocene Shibikawa Fm.
C: medium-grained sandstone with pebbles.
D: *Euspira pila* (Pilsbry) and *Cryptonatica andoi* (Nomura).

YANAGAWA:

A: river cliff of the Horose River, at the southeast of Yanagawa Park, a tributary of the Abukuma River, Soma-gun, Fukushima Pref. (Hatai and Nisiyama, 1952).
B: lower middle Miocene (unknown in detail) Yanagawa Fm
C: —.
D: *Glossaulax didyma coticazae* (Makiyama).

YATSUO (Nei-gun, Toyama Pref.):

YATSUO 1:

A: cliff on the left (west) bank of the Muromaki River, about 750 m downstream of the Yatsuo Dam, Unoki, Yatsuo-cho [latitude 30°33.8′N, longitude 137°06.4′E].
B: lower middle Miocene Yumuro Member of Yatsuo Fm.
C: sandy siltstone.
D: *Euspira meisensis* (Makiyama).

YATSUO 2:

A: river bed of the tributary of the Zinzu River, about 250 m east of Sakogi, Yatsuo-cho [latitude 30°33.8′N, longitude 137°10.7′E].
B: lower middle Miocene Kashio Member of Yatsuo Fm.
C: silty sandstone.
D: *Polinices mizunamiensis* Itoigawa.

YATSUO 3:

A: exposure on the left (west) bank of the Kubusu River at Kashio, Yatsuo-cho [latitude 30°33.9′N, longitude 137°09.5′E; the same as loc. 13 of Majima, 1984].
B: lower middle Miocene Joyama Member (lowest part) of Yatsuo Fm.
C: pebble-bearing siltstone.
D: *Euspira meisensis* (Makiyama), *E. marincovichi*, n. sp., *Polinices mizunamiensis* Itoigawa, *Glossaulax didyma coticazae* (Makiyama), *Tanea minoensis* (Itoigawa), and *Cryptonatica ichishiana* (Shibata).

YATSUO 4:

A: cliff on the tributary of the Zinzu River, about 400 m northwest of Tsuzara, Yatsuo-cho [latitude 30°34.2′N, longitude 137°10.8′E].
B: lower middle Miocene Joyama Member (lowest part) of Yatsuo Fm.
C: pebble-bearing silty sandstone.
D: *Glossaulax didyma coticazae* (Makiyama).

YONABARU (Okinawa Pref.):

YONABARU 1:

A: exposure at Haebaru, Katsuren-machi, Gushikawa City [latitude 26°20.5′N, longitude 127°52.4′E].
B: lower Pliocene Yonabaru Fm.
C: siltstone.
D: *Cryptonatica andoi* (Nomura).

YONABARU 2:

A: outcrop, about 400 m east of the Ozato Senior High School, Ozato-son, Shimajiri-gun (the same as loc. 14 of Majima, 1984).
B: lower Pliocene Yonabaru Fm.
C: siltstone.
D: *Aloconatica niasensis* (Wissema).

YONABARU 3:

A: Tomoyose, Kotinda-machi, Shimajiri-gun [latitude 26°09.7′N, longitude 127°43.4′E].
B: lower Pliocene Yonabaru Fm.
C: siltstone.
D: *Polinices candidissimus* (Le Guillou).

YONBANGAWA:

A: a transported concretion collected from the river bed of the Yonban River, about 3000 m south of Sakkuru Mountain, Tobetsu-machi, Ishikari-gun, Hokkaido [latitude 43°33.0′N, longitude 141°37.2′E].

B: middle middle Miocene to upper Miocene (unknown in detail) Maedanosawa Fm.

C: fine- to medium-grained sandstone.

D: *Cryptonatica janthostoma* (Deshayes).

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PLATES

EXPLANATION OF PLATE 1

Figure Page

1–4. ***Cernina fluctuata nakamurai*** (Otuka) 28

1. Front view (a), basal view (b), IGPS 90493, ×0.4; lower middle Miocene Takinosawa Formation, Yamagata Prefecture, locality OKURA. Holotype of *Globularia* (?) *monstrosa* Hatai. Note outer lip partly missing.
2. Front view (a), basal view (b), PKA unnumbered, ×0.4; lower middle Miocene Uchiura Group, Fukui Prefecture, locality MAIZURU 2. Note specimen slightly deformed.
3. Front view (a), basal view (b), UMUT CM12747, ×0.4; lower middle Miocene Bihoku Group, Hiroshima Prefecture, locality SHOBARA 1. Holotype.
4. Front view (a), basal view (b), IGUT 15723-1, ×0.4; lower middle Miocene Bihoku Group, Hiroshima Prefecture, locality SHOBARA 1. Topotype.

5. **"*Pachycrommium*" *nagaoi*** (Hatai and Nisiyama) 31

Front view, IGPS 36148, ×2.5; lower Oligocene Kiuragi Formation, Nagasaki Prefecture, locality KIURAGI. Holotype.

6–9. ***Pachycrommium harrisi*** (Pannekoek) 30

6. Front view, MFM unnumbered, ×1.0; lower middle Miocene Shukunohora Sandstone, Gifu Prefecture, locality MIZUNAMI 5.
7. Front view (a), basal view (b), IGUT 16033-11, ×1.3; lower middle Miocene Higashi-Innai Formation, Ishikawa Prefecture, locality HIGASHI-INNAI 1.
8. Front view (a), basal view (b), TKD 6165, ×1.0; lower middle Miocene Hiranita Formation, Saitama Prefecture, locality CHICHIBU. Holotype of *Pachycrommium japonicum* Kanno.
9. Front view (a), basal view (b), IGUT 16034-1, ×1.5; lower middle Miocene Bihoku Group, Okayama Prefecture, locality TSUYAMA.

10–12. ***Bulbus fragilis*** (Leach) 32

10. Front view (a), basal view (b), GIYU 600-2, ×1.1; lower Miocene Honya Mudstone, Fukushima Prefecture, locality TAIRA 2.
11. Front view (a), basal view (b), GIYU 600-1, ×0.9; lower Miocene Honya Mudstone, Fukushima Prefecture, locality TAIRA 2.
12. Front view (a), basal view (b), IGUT 15954, ×0.8; lower Pleistocene Tomikawa Formation, Hokkaido, locality TOMIKAWA.

13–16. ***Pliconacca atricapilla*** (Martin) 64

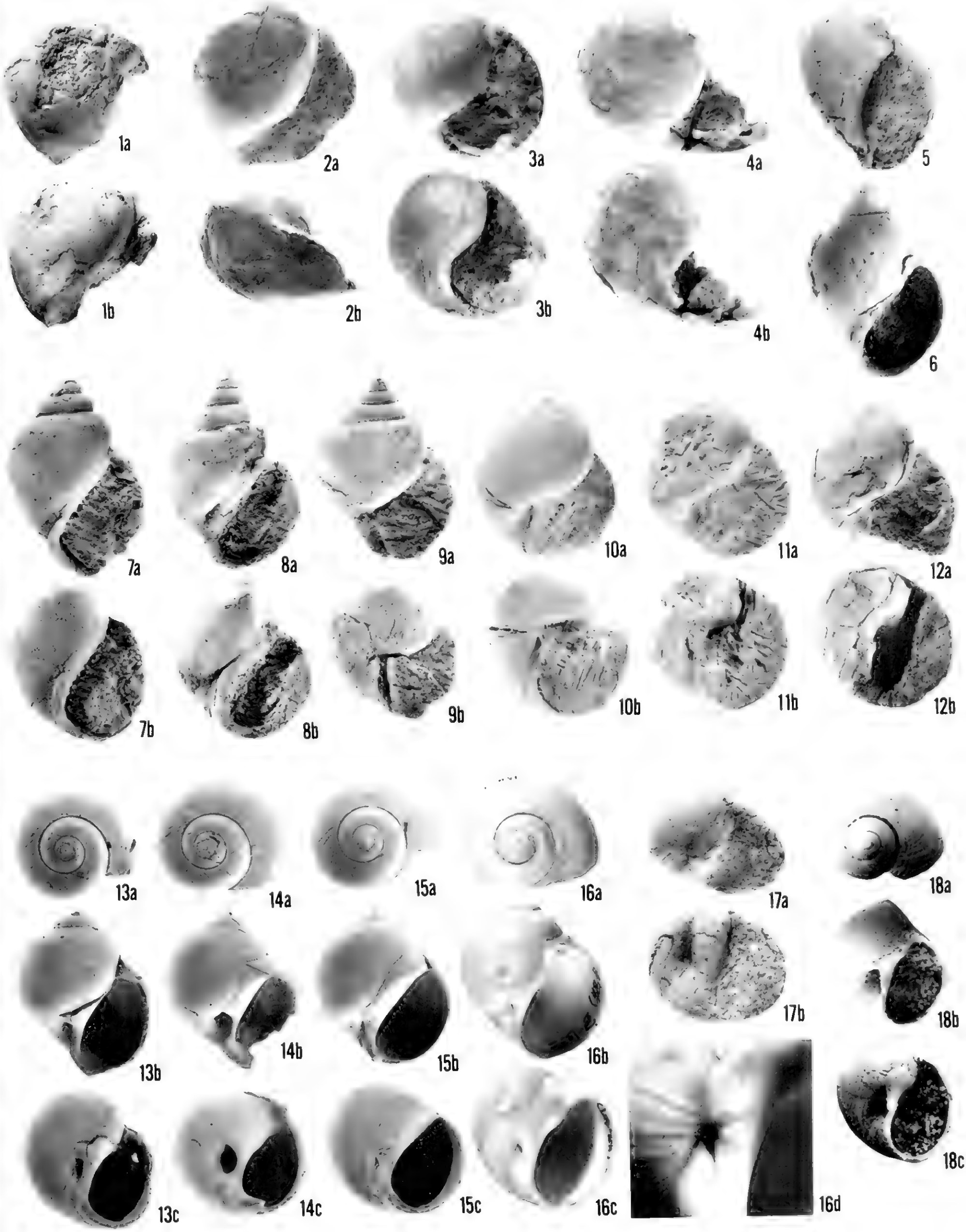
13. Apical view (a), front view (b), basal view (c), GIYU 584, ×1.4; lower Pleistocene Hijikata Member of Upper Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 24.
14. Apical view (a), front view (b), basal view (c), IGUT 15800, ×1.6; upper Pliocene Shinzato Formation, Okinawa Prefecture, locality SHINZATO 1.
15. Apical view (a), front view (b), basal view (c), IGUT 10499, ×1.5; upper Pliocene Shinzato Formation, Okinawa Prefecture, locality SHINZATO 3. Holotype of *Naticarinus* [*sic*] *okinawaensis* Noda.
16. Apical view (a), front view (b), basal view (c), enlarged umbilical callus (d), IGUT 15803, ×1.2 (a–c), ×3.0 (d); Holocene, off Mikawa-Isshiki Fishing Port, Aichi Prefecture. Enlarged umbilical callus (d), showing minutely developed transverse callus grooves.

17. ***Pliconacca nomii*** (Nagao) 63

Front view (a), basal view (b), IGPS 36151, ×2.5; upper Eocene Okinoshima Formation, Nagasaki Prefecture, locality NAGASAKI 2. Holotype.

18. ***Sigatica kurodai*** Itoigawa and Shibata 67

Apical view (a), front view (b), basal view (c), MFM 10073, ×3.9; lower middle Miocene Shukunohora Sandstone, Gifu Prefecture, locality MIZUNAMI 5. Holotype. Note subsutural and basal spiral sculpture.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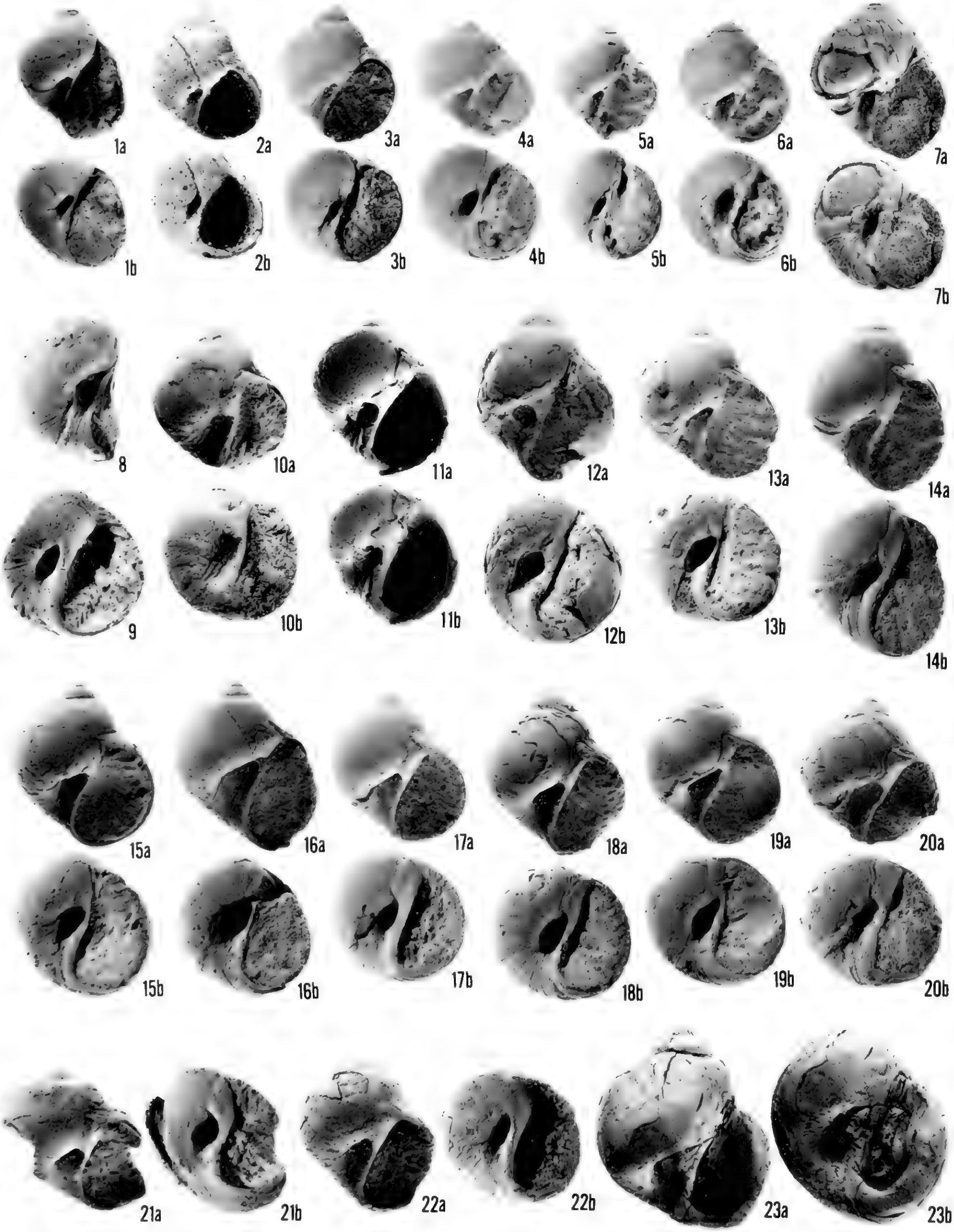
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EXPLANATION OF PLATE 2

Figure | Page

1–23. ***Euspira meisensis*** (Makiyama) 33

1. Front view (a), basal view (b), IGPS 90421, ×2.0; lower middle Miocene Higashi-Innai Formation, Ishikawa Prefecture, locality HIGASHI-INNAI 2. Holotype of *Polinices* (*Euspira*) *otukai* Masuda.
2. Front view (a), basal view (b), IGUT 15748, ×1.4; lower middle Miocene Nakayama Formation, Fukushima Prefecture, locality TAIRA 3. Rubber cast.
3. Front view (a), basal view (b), IGUT 15732-1, ×1.5; lower middle Miocene Yumura Member of Yatsuo Formation, Toyama Prefecture, locality YATSUO 1.
4. Front view (a), basal view (b), IGUT 15743-1, ×2.6; lower middle Miocene Uchiura Group, Fukui Prefecture, locality MAIZURU 4.
5. Front view (a), basal view (b), IGUT 15745-1, ×2.2; lower middle Miocene Bihoku Group, Okayama Prefecture, locality ATETSU.
6. Front view (a), basal view (b), IGUT 15744-1, ×2.3; lower middle Miocene Bihoku Group, Okayama Prefecture, locality SHOBARA 2.
7. Front view (a), basal view (b), CU 7900118, ×1.2; Oligocene Asagai Formation, Fukushima Prefecture, locality ASAGAI 1.
8. Basal view, IGUT 15749-2, ×1.2; Oligocene Asagai Formation, Fukushima Prefecture, locality ASAGAI 2.
9. Basal view, IGUT 15751, ×0.9; lower Miocene Yamaga Formation, Fukuoka Prefecture, locality ASHIYA 2. Rubber cast.
10. Front view (a), basal view (b), IGPS 36135, ×1.5; lower Miocene Yamaga Formation, Fukuoka Prefecture, locality ASHIYA 1. Holotype of *Polinices* (*Euspira*) *ashiyaensis* Nagao.
11. Front view (a), basal view (b), CC 100017, ×1.0; lower middle Miocene Heirokudo Formation, North Korea. Topotype.
12. Front view (a), basal view (b), IGUT 15740, ×0.8; lower middle Miocene Takinoue Formation, Hokkaido, locality MOMIJIYAMA 1.
13. Front view (a), basal view (b), IGUT 15738-1, ×1.0; lower middle Miocene Furanui Formation, Hokkaido, locality FURANUI 2.
14. Front view (a), basal view (b), IGUT 15727-3, ×1.0; lower middle Miocene Kadonosawa Formation, Iwate Prefecture, locality KADONOSAWA 2.
15. Front view (a), basal view (b), IGUT 15730-1, ×1.2; lower middle Miocene Higashi-Innai Formation, Ishikawa Prefecture, locality HIGASHI-INNAI 1.
16. Front view (a), basal view (b), GIYU 572-2, ×1.3; lower middle Miocene Nukuta Formation, Nagano Prefecture, locality TOMIKUSA.
17. Front view (a), basal view (b), IGUT 15733-1, ×0.9; lower middle Miocene Togari Formation, Gifu Prefecture, locality MIZUNAMI 2.
18. Front view (a), basal view (b), GIYU 573-1, ×0.9; lower middle Miocene Kurokawa Formation, Shiga Prefecture, locality AYUGAWA.
19. Front view (a), basal view (b), GIYU 573-2, ×0.9; lower middle Miocene Kurokawa Formation, Shiga Prefecture, locality AYUGAWA.
20. Front view (a), basal view (b), IGUT 15737-1, ×1.2; lower middle Miocene Oi Formation, Mie Prefecture, locality ICHISHI 1.
21. Front view (a), basal view (b), IGUT 15746-1, ×0.8; lower middle Miocene Togane Formation, Shimane Prefecture, locality HAMADA. Note specimen slightly deformed.
22. Front view (a), basal view (b), IGUT 15741-3, ×1.1; middle middle Miocene Kokozura Formation, Fukushima Prefecture, locality KOKOZURA.
23. Front view (a), basal view (b), IGPS 36137, ×0.8; lower Miocene Sakamizu Formation, Fukuoka Prefecture, locality ASHIYA 3. Basal part clay cast.

EXPLANATION OF PLATE 3

Figure | Page

1–4. ***Euspira marincovichi***, new species 35

1. Front view (a), basal view (b), IGUT 15724, ×1.4; lower middle Miocene Kadonosawa Formation, Iwate Prefecture, locality KADONOSAWA 1. Holotype.
2. Front view (a), basal view (b), IGUT 15725-13, ×1.3; lower middle Miocene Kadonosawa Formation, Iwate Prefecture, locality KADONOSAWA 1. Paratype.
3. Front view (a), basal view (b), IGUT 15728-2, ×1.0; lower middle Miocene Joyama Member of Yatsuo Formation, Toyama Prefecture, locality YATSUO 3. Paratype.
4. Front view (a), basal view (b), IGUT 15728-3, ×1.2; lower middle Miocene Joyama Member of Yatsuo Formation, Toyama Prefecture, locality YATSUO 3. Paratype.

5, 6. ***Euspira mitsuganoensis*** Shibata 36

5. Front view (a), basal view (b), IGUT 15736-1, ×1.1; lower middle Miocene Oi Formation, Mie Prefecture, locality ICHISHI 5.
6. Front view (a), basal view (b), ESN 30019, ×1.3; lower middle Miocene Oi Formation, Mie Prefecture, locality ICHISHI 6. Holotype.

7–13. ***Euspira pallida*** (Broderip and Sowerby) 37

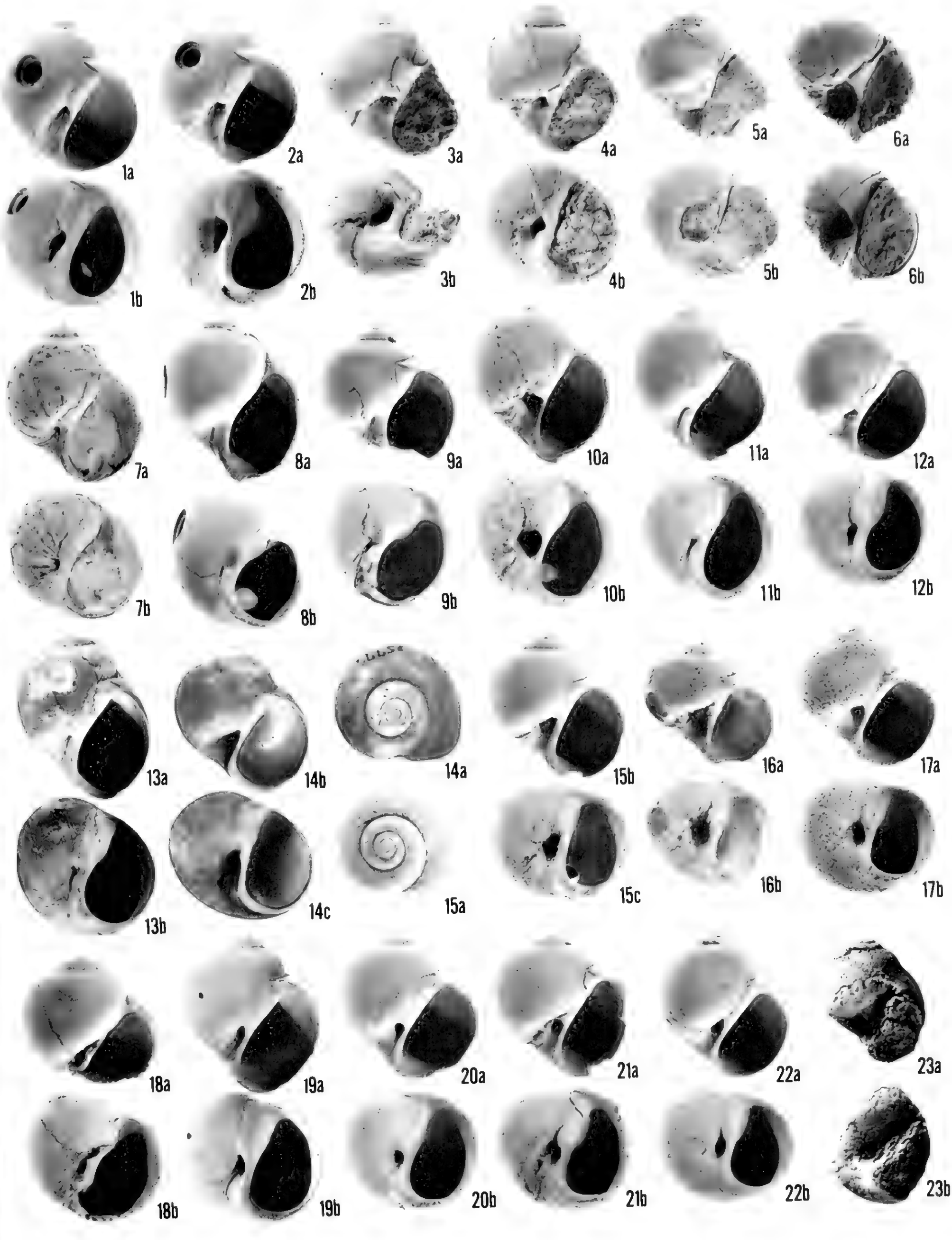
7. Front view (a), basal view (b), IGUT 15593, ×1.1; lower Pliocene Yuchi Formation, Hokkaido, locality TESHIO 9. Rubber cast.
8. Front view (a), basal view (b), IGUT 15774-1, ×1.0; lower Pleistocene Tomikawa Formation, Hokkaido, locality TOMIKAWA.
9. Front view (a), basal view (b), GIYU 532-1, ×1.7; lower Pleistocene Sawane Formation, Niigata Prefecture, locality SAWANE 2.
10. Front view (a), basal view (b), IGUT 15773-26, ×2.0; lower Pleistocene Iioka Formation, Chiba Prefecture, locality CHOSHI 1.
11. Front view (a), basal view (b), IGUT 15773-6, ×1.5; lower Pleistocene Iioka Formation, Chiba Prefecture, locality CHOSHI 1.
12. Front view (a), basal view (b), IGUT 15773-2, ×1.1; lower Pleistocene Iioka Formation, Chiba Prefecture, locality CHOSHI 1.
13. Front view (a), basal view (b), IGUT 15775-1, ×1.1; Holocene, 18 mi off Muroran, Hokkaido.

14–22. ***Euspira yokoyamai*** (Kuroda and Habe) 40

14. Apical view (a), front view (b), basal view (c), IGUT 15779, ×1.8; Holocene, off Mikawa-Isshiki Fishing Port, Aichi Prefecture.
15. Apical view (a), front view (b), basal view (c), IGUT 15786-1, ×1.8; lower Pleistocene Mandano Formation, Chiba Prefecture, locality KIMITSU 1.
16. Front view (a), basal view (b), IGUT 15788, ×2.4; Pliocene Narusawa Formation, Aomori Prefecture, locality KITAKANE-GASAWA.
17. Front view (a), basal view (b), GIYU 582-1, ×1.8; lower Pleistocene Nojima Formation, Kanagawa Prefecture, locality NOJIMA 1.
18. Front view (a), basal view (b), GIYU 581, ×1.6; upper Pliocene Tenno Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 18.
19. Front view (a), basal view (b), IGUT 15781-1, ×1.7; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 2.
20. Front view (a), basal view (b), GIYU 579, ×1.7; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 3.
21. Front view (a), basal view (b), IGUT 15789-1, ×1.8; upper Pliocene Shinzato Formation, Okinawa Prefecture, locality SHINZATO 1.
22. Front view (a), basal view (b), IGUT 15790-1, ×1.7; upper Pliocene Shinzato Formation, Okinawa Prefecture, locality SHINZATO 2.

23. "***Euspira***" ***aritensis*** Shuto and Ueda 41

Front view (a), basal view (b), GK L7974, ×4.1; middle Oligocene Kishima Formation, Saga Prefecture, locality ARITA 1. Holotype.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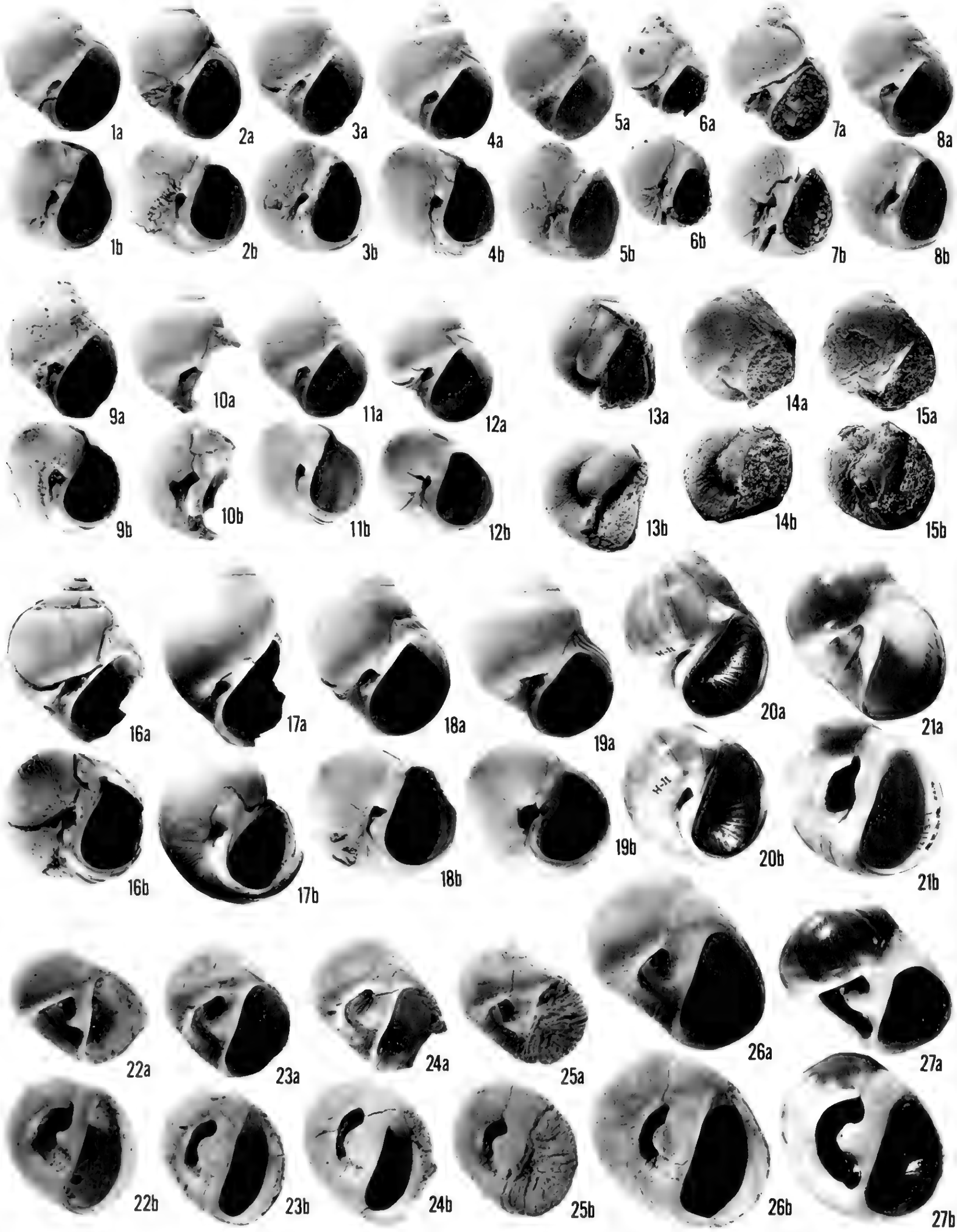
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EXPLANATION OF PLATE 4

Figure Page

1–12. ***Euspira pila*** (Pilsbry) 38

1. Front view (a), basal view (b), IGUT 15762-2, ×1.5; Pliocene Nakanokawa Formation, Hokkaido, locality KUROMATSUNAI 2.
2. Front view (a), basal view (b), IGUT 15764-2, ×1.3; lower Pleistocene Tomikawa Formation, Hokkaido, locality TOMIKAWA.
3. Front view (a), basal view (b), IGUT 15759-1, ×1.7; lower Pleistocene Sunagomata Formation, Aomori Prefecture, locality CHIKAGAWA 2.
4. Front view (a), basal view (b), IGUT 15765, ×1.1; Pliocene Daishaka Formation, Aomori Prefecture, locality DAISHAKA.
5. Front view (a), basal view (b), IGUT 15769, ×2.3; Pliocene Narusawa Formation, Aomori Prefecture, locality KITAKANE-GASAWA.
6. Front view (a), basal view (b), IGUT 15766-1, ×2.2; upper Pliocene and lower Pleistocene Sasaoka Formation, Akita Prefecture, locality TOFUIWA.
7. Front view (a), basal view (b), GIYU 545-1, ×1.6; upper Pliocene Sasaoka Formation, Akita Prefecture, locality MANGANJI 1.
8. Front view (a), basal view (b), GIYU 574, ×1.5; lower Pleistocene Sawane Formation, Niigata Prefecture, locality SAWANE 4.
9. Front view (a), basal view (b), IGUT 15804, ×1.3; Pliocene Yamadahama Formation, Fukushima Prefecture, locality FUTATSUNUMA 1.
10. Front view (a), basal view (b), IGUT 15771-1, ×1.4; lower Pleistocene Natsukawa Formation, Toyama Prefecture, locality ISURUGI.
11. Front view (a), basal view (b), GIYU 538-1, ×1.8; upper Pleistocene Shibikawa Formation, Akita Prefecture, locality ANDEN.
12. Front view (a), basal view (b), IGUT 15805-1, ×1.1; upper Pleistocene Semata Formation, Chiba Prefecture, locality SEMATA.

13–15. ***Neverita eocenica*** (Nagao) 49

13. Front view (a), basal view (b), IGPS 35699, ×2.1; lower Eocene Futagojima Formation, Nagasaki Prefecture, locality NAGASAKI 1. Lectotype. Note smooth umbilical callus.
14. Front view (a), basal view (b), IGUT 15951-2, ×2.2; lower Eocene Futagojima Formation, Nagasaki Prefecture, locality NAGASAKI 3. Note transverse callus groove slightly developed.
15. Front view (a), basal view (b), IGUT 15951-1, ×1.7; lower Eocene Futagojima Formation, Nagasaki Prefecture, locality NAGASAKI 3.

16–20. ***Euspira pila*** (Pilsbry) 38

16. Front view (a), basal view (b), IGUT 16070-1, ×0.9; lower Pliocene Yuchi Formation, Hokkaido, locality TESHIO 5.
17. Front view (a), basal view (b), IGPS 90442, ×0.6; lower Pleistocene Sunagomata Formation, Aomori Prefecture, locality CHIKAGAWA 1. Holotype of *Euspira pila shimokitaensis* Hatai, Masuda, and Suzuki.
18. Front view (a), basal view (b), IGUT 15758-2, ×0.9; lower Pleistocene Sunagomata Formation, Aomori Prefecture, locality CHIKAGAWA 1.
19. Front view (a), basal view (b), IGUT 15754-1, ×0.9; lower Pleistocene Omma Formation, Ishikawa Prefecture, locality OMMA 4.
20. Front view (a), basal view (b), IGUT 11107-1, ×0.7; Holocene, Funka Bay, Hokkaido.

21,22. ***Polinices peselephanti*** (Link) 46

21. Front view (a), basal view (b), IGUT 11108-1, ×0.7; Holocene, Kagoshima Bay, Kagoshima Prefecture.
22. Front view (a), basal view (b), GIYU 523-2, ×0.8; upper Pleistocene Ryukyu Limestone, Kagoshima Prefecture, locality KIKAI 2.

23–27. ***Polinices sagamiensis*** Pilsbry 45

23. Front view (a), basal view (b), IGUT 15721-4, ×0.6; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1.
24. Front view (a), basal view (b), IGUT 15807, ×0.6; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 17.
25. Front view (a), basal view (b), IGUT 15808, ×0.8; upper Pliocene Ananai Formation, Kochi Prefecture, locality TONOHAMA 2.
26. Front view (a), basal view (b), IGUT 15721-5, ×0.6; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1.
27. Front view (a), basal view (b), IGUT 11109-6, ×0.8; Holocene, off Mikawa-Isshiki Fishing Port, Aichi Prefecture.

EXPLANATION OF PLATE 5

Figure Page

1–25. ***Glossaulax didyma coticazae*** (Makiyama) 51

1. Front view (a), basal view (b), CC 100231, ×1.0; lower middle Miocene Mankodo Formation, North Korea. Holotype*.
2. Front view (a), basal view (b), CC 100231, ×1.1; lower middle Miocene Mankodo Formation, North Korea. Paratype*.
3. Front view (a), basal view (b), IGUT 15835, ×1.2; lower middle Miocene Furanui Formation, Hokkaido, locality FURANUI 4.
4. Front view (a), basal view (b), IGUT 15844-2, ×1.5; lower middle Miocene Kadonosawa Formation, Iwate Prefecture, locality KADONOSAWA 1.
5. Front view (a), basal view (b), IGUT 15846-1, ×1.2; lower middle Miocene Kadonosawa Formation, Iwate Prefecture, locality KADONOSAWA 3.
6. Front view (a), basal view (b), SHM 6110, ×0.7; lower middle Miocene Yanagawa Formation, Fukushima Prefecture, locality YANAGAWA.
7. Front view (a), basal view (b), IGUT 15838-1, ×1.3; lower middle Miocene Higashi-Innai Formation, Ishikawa Prefecture, locality HIGASHI-INNAI 1.
8. Front view (a), basal view (b), IGUT 15852-2, ×1.6; lower middle Miocene Joyama Member of Yatsuo Formation, Toyama Prefecture, locality YATSUO 3.
9. Front view (a), basal view (b), IGUT 15950-1, ×2.2; lower middle Miocene Shukunohora Sandstone, Gifu Prefecture, locality MIZUNAMI 5.
10. Front view (a), basal view (b), IGUT 15858-1, ×1.6; lower middle Miocene Bihoku Group, Okayama Prefecture, locality TSUYAMA.
11. Front view (a), basal view (b), IGUT 15854-1, ×2.3; lower middle Miocene Bihoku Group, Okayama Prefecture, locality NIIMI.
12. Front view (a), basal view (b), GSJ F12556, ×1.8; middle middle Miocene to upper Miocene Yamatsuda Formation, Iwate Prefecture, locality SHIZUKUISHI.
13. Front view (a), basal view (b), SHM 21708, ×0.6; middle middle Miocene to upper Miocene Kanagase Formation, Miyagi Prefecture, locality SENNAN.
14. Front view (a), basal view (b), IGUT 15839-2, ×1.0; middle middle Miocene Kubota Formation, Fukushima Prefecture, locality TANAGURA 2.
15. Front view (a), basal view (b), IGUT 15842-1, ×0.8; middle middle Miocene Kubota Formation, Fukushima Prefecture, locality TANAGURA 1.
16. Front view (a), basal view (b), UMUT CM25918, ×1.0; middle middle Miocene Kubota Formation, Fukushima Prefecture, locality TANAGURA 3. Lectotype, herein designated, of *Natica kiritaniana* Yokoyama.
17. Front view (a), basal view (b), IGUT 15851, ×1.1; middle middle Miocene to upper Miocene Kanomatazawa Formation, Tochigi Prefecture, locality SHIOBARA.
18. Front view (a), basal view (b), IGUT 15837, ×1.5; middle middle Miocene Kokozura Formation, Fukushima Prefecture, locality KOKOZURA.
19. Front view (a), basal view (b), JC 610093, ×0.9; upper Miocene Aoki Formation, Nagano Prefecture, locality SAKAE. Lectotype, herein designated, of *Neritaeformis* (*Neverita*) *fissuratus* Kuroda.
20. Front view (a), basal view (b), IGUT 15849-5, ×0.9; lower Pliocene Tatsunokuchi Formation, Miyagi Prefecture, locality GOROKU.
21. Front view (a), basal view (b), IGUT 15849-4, ×0.8; lower Pliocene Tatsunokuchi Formation, Miyagi Prefecture, locality GOROKU.
22. Front view (a), basal view (b), IGUT 15849-3, ×0.9; lower Pliocene Tatsunokuchi Formation, Miyagi Prefecture, locality GOROKU.
23. Front view (a), basal view (b), SHM 2261, ×0.9; lower Pliocene Tatsunokuchi Formation, locality GOROKU.
24. Front view, IGUT 15849-2, ×0.8; lower Pliocene Tatsunokuchi Formation, locality GOROKU.
25. Front view, IGUT 15849-1, ×0.7; lower Pliocene Tatsunokuchi Formation, locality GOROKU.

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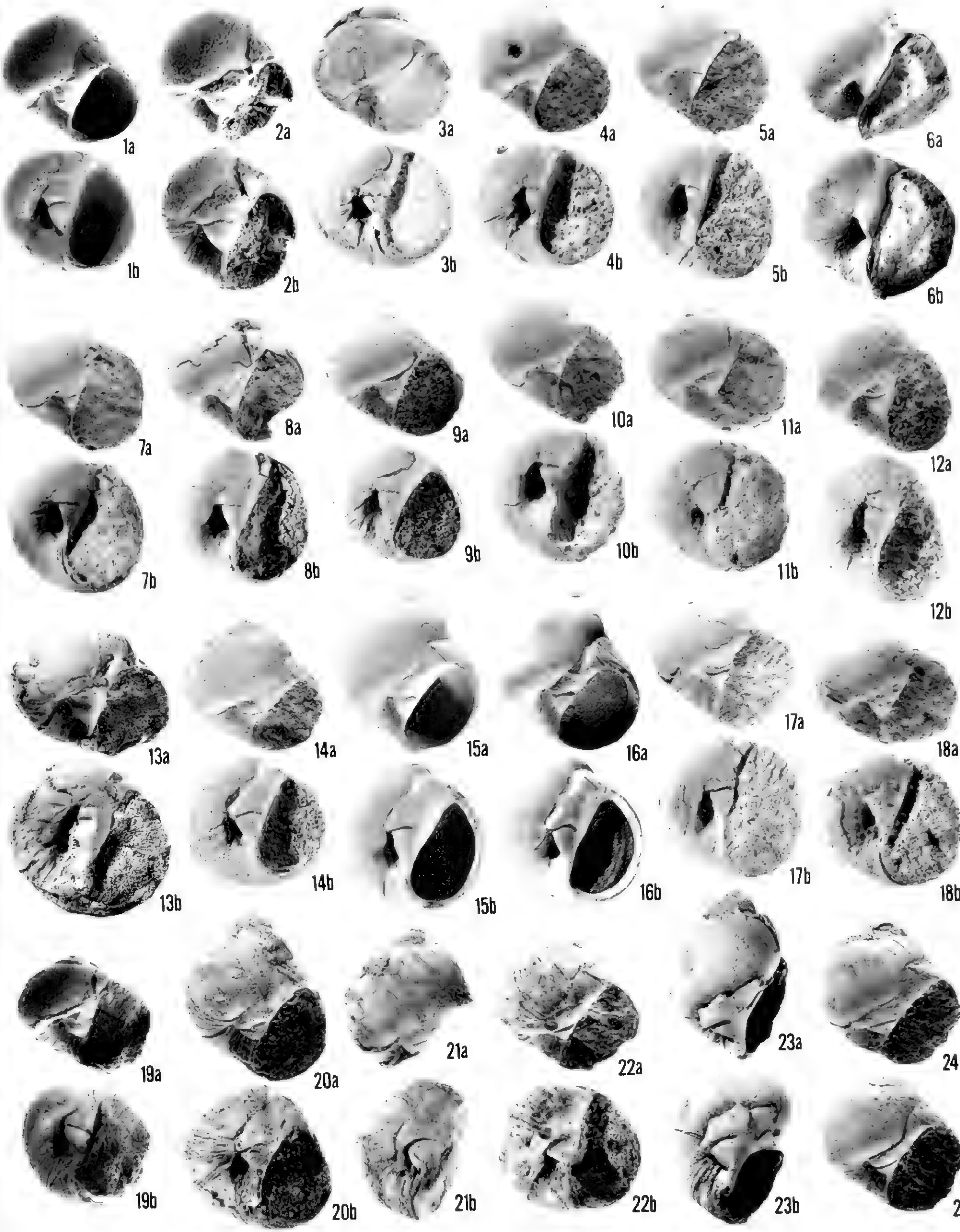
* One of two specimens bearing the same catalogue number.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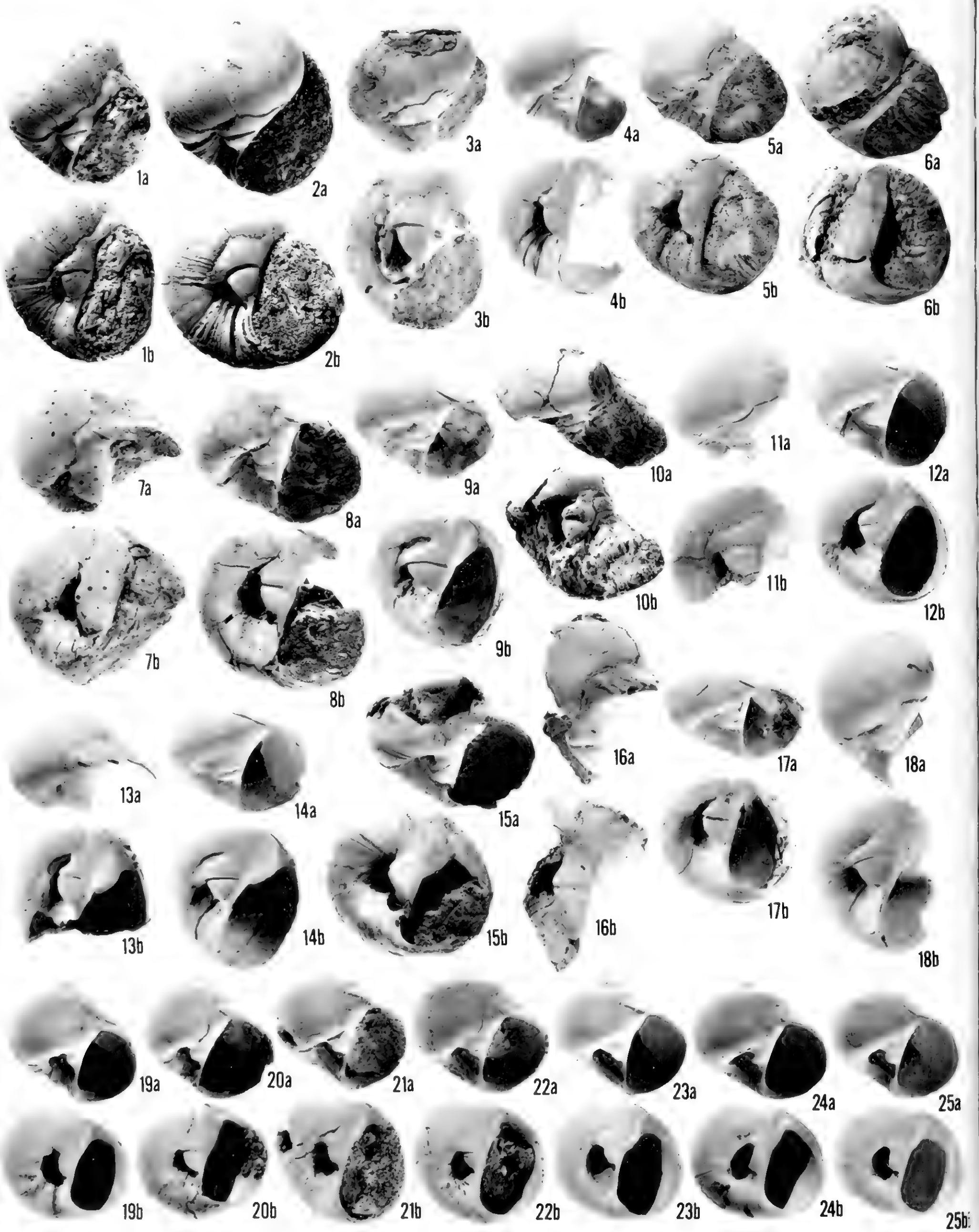
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EXPLANATION OF PLATE 6

Figure | Page

1–3. *Glossaulax didyma coticazae* (Makiyama) 51

1. Front view (a), basal view (b), IGPS 15967*, ×0.9; lower Pliocene Tatsunokuchi Formation, Miyagi Prefecture, locality GOROKU.
2. Front view (a), basal view (b), IGPS 15967*, ×0.8; lower Pliocene Tatsunokuchi Formation, Miyagi Prefecture, locality GOROKU.
3. Front view (a), basal view (b), GIYU 521, ×0.8; lower Pliocene Shigarami Formation, Nagano Prefecture, locality SHIGARAMI 1.

4–18. *Glossaulax didyma didyma* (Röding) 53

4. Front view (a), basal view (b), IGUT 15886-3, ×1.1; Pliocene Yamadahama Formation, Fukushima Prefecture, locality FUTATSUNUMA 1.
5. Front view (a), basal view (b), IGUT 11101-2, ×0.7; Pliocene Kanzawa Formation, Kanagawa Prefecture, locality NAKATSU.
6. Front view (a), basal view (b), IGUT 11101-1, ×0.7; Pliocene Kanzawa Formation, Kanagawa Prefecture, locality NAKATSU.
7. Front view (a), basal view (b), IGUT 15877, ×0.6; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 13.
8. Front view (a), basal view (b), IGUT 15876-2, ×0.7; upper Pliocene Tenno Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 8.
9. Front view (a), basal view (b), IGUT 15876-1, ×0.8; upper Pliocene Tenno Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 8.
10. Front view (a), basal view (b), IGUT 15878-1, ×0.7; upper Pliocene Tenno Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 9.
11. Front view (a), basal view (b), IGUT 15878-2, ×1.0; upper Pliocene Tenno Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 9.
12. Front view (a), basal view (b), IGUT 16076, ×0.9; upper Pleistocene Nakoshi Sandstone, Okinawa Prefecture, locality HANEJI 4.
13. Front view (a), basal view (b), IGUT 15879-1, ×0.7; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1.
14. Front view (a), basal view (b), IGUT 15879-2, ×0.8; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1.
15. Front view (a), basal view (b), IGUT 15890, ×0.6; upper Pliocene and lower Pleistocene Sasaoka Formation, Akita Prefecture, locality GOJOME 3.
16. Front view (a), basal view (b), IGUT 15884-1, ×0.8; lower Pleistocene Sunagomata Formation, Aomori Prefecture, locality CHIKAGAWA 1.
17. Front view (a), basal view (b), IGUT 15875-3, ×0.9; lower Pleistocene Hosoya Member of Upper Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 3.
18. Front view (a), basal view (b), IGUT 15875-6, ×0.9; lower Pleistocene Hosoya Member of Upper Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 3.

19–25. *Glossaulax reiniana* (Dunker) 60

19. Front view (a), basal view (b), IGUT 15722-13, ×1.1; lower Pleistocene Omma Formation, Ishikawa Prefecture, locality OMMA 1.
20. Front view (a), basal view (b), IGUT 15861, ×0.8; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 15.
21. Front view (a), basal view (b), IGUT 15860-3, ×1.6; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 17.
22. Front view (a), basal view (b), IGUT 15859-1, ×1.2; lower Pleistocene Hosoya Member of Upper Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 3.
23. Front view (a), basal view (b), IGUT 15867, ×1.9; upper Pleistocene Hiradoko Formation, Ishikawa Prefecture, locality HIRADOKO.
24. Front view (a), basal view (b), IGUT 15863-2, ×0.7; upper Pleistocene Sakurai Formation, Chiba Prefecture, locality SAKURAI.
25. Front view (a), basal view (b), IGUT 15869, ×1.2; upper Pleistocene Toshima Sandstone of Toyohashi Group, Aichi Prefecture, locality ATSUMI.

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* One of two specimens bearing the same catalogue number.

EXPLANATION OF PLATE 7

Figure | Page

1–5. ***Glossaulax didyma didyma*** (Röding) 53

1. Front view (a), basal view (b), IGUT 15893-53, ×1.0; lower Pleistocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 5.
2. Front view (a), basal view (b), IGUT 15893-8, ×0.8; lower Pleistocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 5.
3. Front view (a), basal view (b), GIYU 599-5, ×0.7; lower Pleistocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 5.
4. Front view (a), basal view (b), GIYU 599-23, ×0.8; lower Pleistocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 5.
5. Front view (a), basal view (b), GIYU 599-7, ×0.7; lower Pleistocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 5.

6–16. ***Glossaulax didyma dainichiensis***, new subspecies 58

6. Front view (a), basal view (b), IGUT 15826-36, ×0.9; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1. Paratype.
7. Front view (a), basal view (b), IGUT 15826-84, ×1.2; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1. Paratype.
8. Front view (a), basal view (b), IGUT 15826-52, ×1.1; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1. Paratype.
9. Front view (a), basal view (b), IGUT 15826-42, ×1.0; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1. Paratype.
10. Front view (a), basal view (b), IGUT 15826-38, ×0.8; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1. Paratype.
11. Front view (a), basal view (b), IGUT 15826-39, ×0.8; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1. Paratype.
12. Front view (a), basal view (b), IGUT 15833, ×0.9; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 6.
13. Front view (a), basal view (b), IGUT 15827-17, ×0.8; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 2. Paratype.
14. Front view (a), basal view (b), IGUT 15826-40, ×0.9; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1. Paratype.
15. Front view (a), basal view (b), IGUT 15825, ×0.7; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1. Holotype.
16. Front view (a), basal view (b), IGUT 15826-1, ×0.6; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1. Paratype.

17–24. ***Glossaulax vesicalis*** (Philippi) 59

17. Front view (a), basal view (b), GIYU 624, ×0.7; Holocene, off Kii Peninsula, Wakayama Prefecture.
18. Front view (a), basal view (b), IGUT 15872-3, ×1.0; lower Pleistocene Sunagomata Formation, Aomori Prefecture, locality CHIKAGAWA 1.
19. Front view (a), basal view (b), GIYU 535, ×0.8; lower Pleistocene Omma Formation, Ishikawa Prefecture, locality OMMA 8.
20. Front view (a), basal view (b), IGUT 15870, ×0.9; lower Pleistocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 5.
21. Front view (a), basal view (b), IGUT 15874-1, ×0.7; Holocene, off Mikawa-Isshiki Fishing Port, Aichi Prefecture.
22. Front view, IGUT 15871-1, ×1.0; upper Pleistocene Hiradoko Formation, Ishikawa Prefecture, locality HIRADOKO.
23. Front view, IGUT 15873-2, ×0.9; upper Pleistocene Semata Formation, Chiba Prefecture, locality SEMATA.
24. Front view (a), basal view (b), GIYU 525, ×0.9; upper Pleistocene Ryukyu Limestone, Kagoshima Prefecture, locality KIKAI 1.


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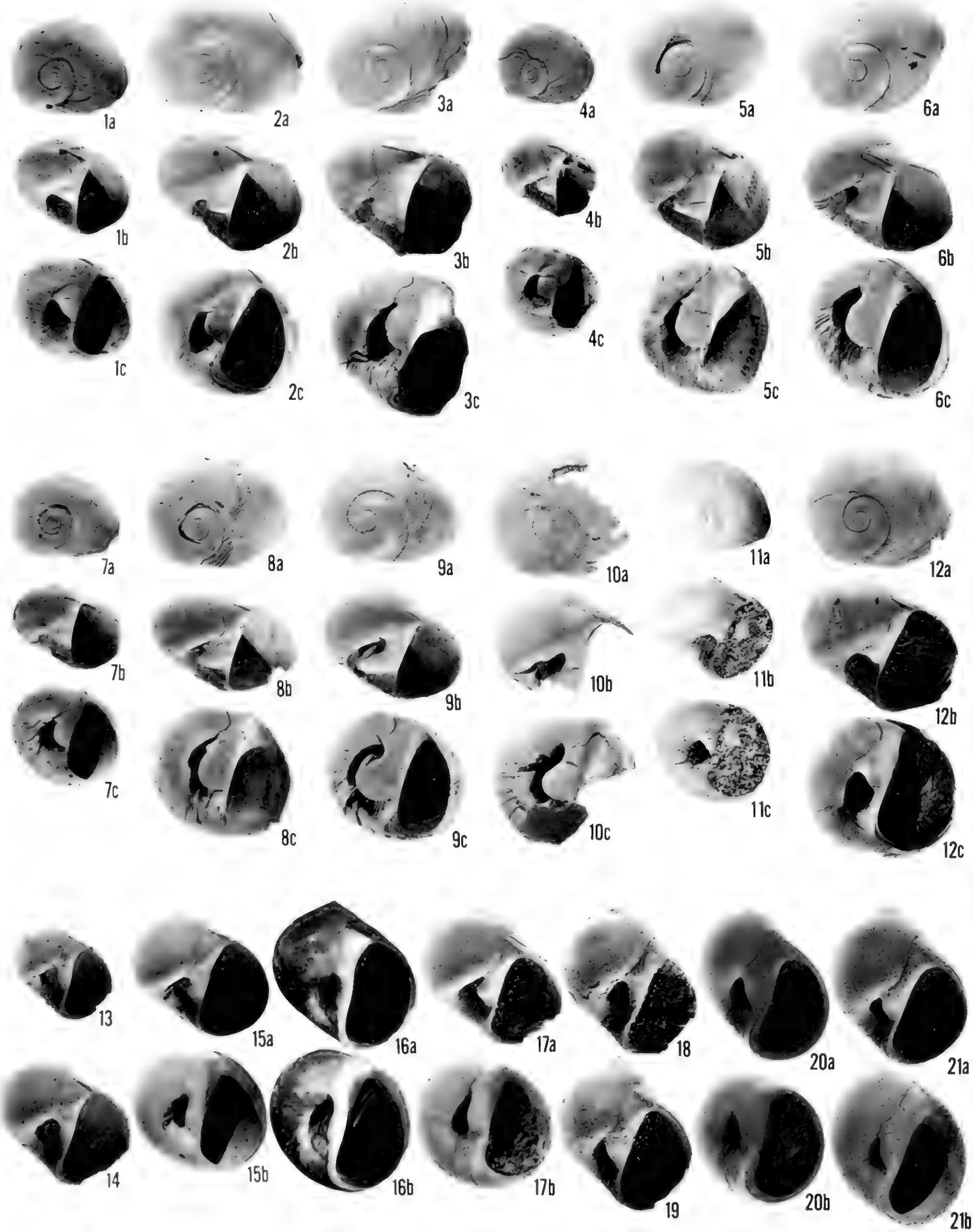
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EXPLANATION OF PLATE 8

Figure — Page

1–3. ***Glossaulax hyugensis*** (Shuto) 61
1. Apical view (a), front view (b), basal view (c), IGUT 15699-3, ×2.2; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1. Form 1J.
2. Apical view (a), front view (b), basal view (c), GIYU 570, ×0.9; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1. Form 1T.
3. Apical view (a), front view (b), basal view (c), IGUT 15699-49, ×0.9; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1. Form 1U.

4–10. ***Glossaulax hagenoshitensis*** (Shuto) 62
4. Apical view (a), front view (b), basal view (c), IGUT 15700-47, ×2.2; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1. Form 3Ja.
5. Apical view (a), front view (b), basal view (c), IGUT 15700-29, ×1.6; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1. Form 3Ua.
6. Apical view (a), front view (b), basal view (c), IGUT 15700-44, ×0.9; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1. Form 3Ta.
7. Apical view (a), front view (b), basal view (c), IGUT 15705-122, ×2.2; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 10. Form 3Jb.
8. Apical view (a), front view (b), basal view (c), IGUT 15705-46, ×1.8; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 10. Form 3Ub.
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10. Apical view (a), front view (b), basal view (c), IGUT 11102, ×1.2; lower Pleistocene Byobudani Formation, Niigata Prefecture, locality JOETSU. Form 3Tb.

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13–16. ***Polinices candidissimus*** (Le Guillou) 44
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14. Front view, GIYU 585-1, ×1.4; lower Pleistocene Nojima Formation, Kanagawa Prefecture, locality NOJIMA 1.
15. Front view (a), basal view (b), IGUT 16078, ×0.9; lower Pliocene Yonabaru Formation, Okinawa Prefecture, locality YONABARU 3.
16. Front view (a), basal view (b), IGUT 15810, ×0.6; Holocene, off Mikawa-Isshiki Fishing Port, Aichi Prefecture.

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19. Front view, IGUT 15984-1, ×2.1; lower middle Miocene Shukunohora Sandstone, Gifu Prefecture, locality MIZUNAMI 5. Topotype.
20. Front view (a), basal view (b), ESN 20059, ×2.2; lower middle Miocene Shukunohora Sandstone, Gifu Prefecture, locality MIZUNAMI 5. Holotype.
21. Front view (a), basal view (b), IGUT 15984-2, ×2.4; lower middle Miocene Shukunohora Sandstone, Gifu Prefecture, locality MIZUNAMI 5. Topotype.

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1. Front view, IGUT 16039, ×2.1; lower Pleistocene Sunagomata Formation, Aomori Prefecture, locality CHIKAGAWA 2.
2. Front view, GIYU 618, ×1.9, lower Pleistocene Nojima Formation, Kanagawa Prefecture, locality NOJIMA 3.
3. Front view, IGUT 16040, ×1.8; lower Pleistocene Hosoya Member of Upper Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 3.
4. Front view, IGUT 16042-1, ×2.1; upper Pliocene Nobori Formation, Kochi Prefecture, locality TONOHAMA 1.
5. Front view, IGUT 16043-1, ×2.0; upper Pliocene Ananai Formation, Kochi Prefecture, locality TONOHAMA 2.
6. Front view, IGUT 16082, ×1.6; upper Pliocene Shinzato Formation, Okinawa Prefecture, locality SHINZATO 8.
7. Front view (a), basal view (b), IGUT 16044-1, ×1.8; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1.
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11. Apical view (a), dorsal view (b), IGUT 15811-1, ×1.1; lower middle Miocene Furanui Formation, Hokkaido, locality FURANUI 3.
12. Dorsal view (a), front view (b), basal view (c), UMUT CM12079, ×1.4; lower middle Miocene Kadonosawa Formation, Iwate Prefecture, locality KADONOSAWA 1. Holotype of *Sinum yabei* Otuka.
13. Apical view (a), front view (b), basal view (c), IGUT 15812-1, ×1.2; lower middle Miocene Kadonosawa Formation, Iwate Prefecture, locality KADONOSAWA 1.
14. Apical view (a), front view (b), basal view (c), IGUT 15814-1, ×1.2; lower middle Miocene Numanouchi Formation, Fukushima Prefecture, locality TAIRA 1. Note basal part partly missing.
15. Dorsal view (a), front view (b), MFM unnumbered, ×1.1; lower middle Miocene Nataki Formation, Gifu Prefecture, locality MIZUNAMI 4.
16. Front view, IGUT 16036, ×0.9; lower middle Miocene Kadonosawa Formation, Iwate Prefecture, locality KADONOSAWA 4.
17. Apical view (a), front view (b), dorsal view (c), basal view (d), UMUT CM 24624, ×1.5; lower middle Miocene Tanabe Group, Wakayama Prefecture, locality TANABE 2. Holotype. Note specimen slightly deformed.
18. Apical view (a), front view (b), basal view (c), IGUT 15815, ×1.6; middle middle Miocene Kubota Formation, Fukushima Prefecture, locality TANAGURA 1.
19. Apical view (a), front view (b), basal view (c), IGUT 15816, ×1.5; middle middle Miocene Kubota Formation, Fukushima Prefecture, locality TANAGURA 2.
20. Apical view (a), front view (b), basal view (c), IGUT 15813-2, ×1.4; middle middle Miocene Kokozura Formation, Fukushima Prefecture, locality KOKOZURA.

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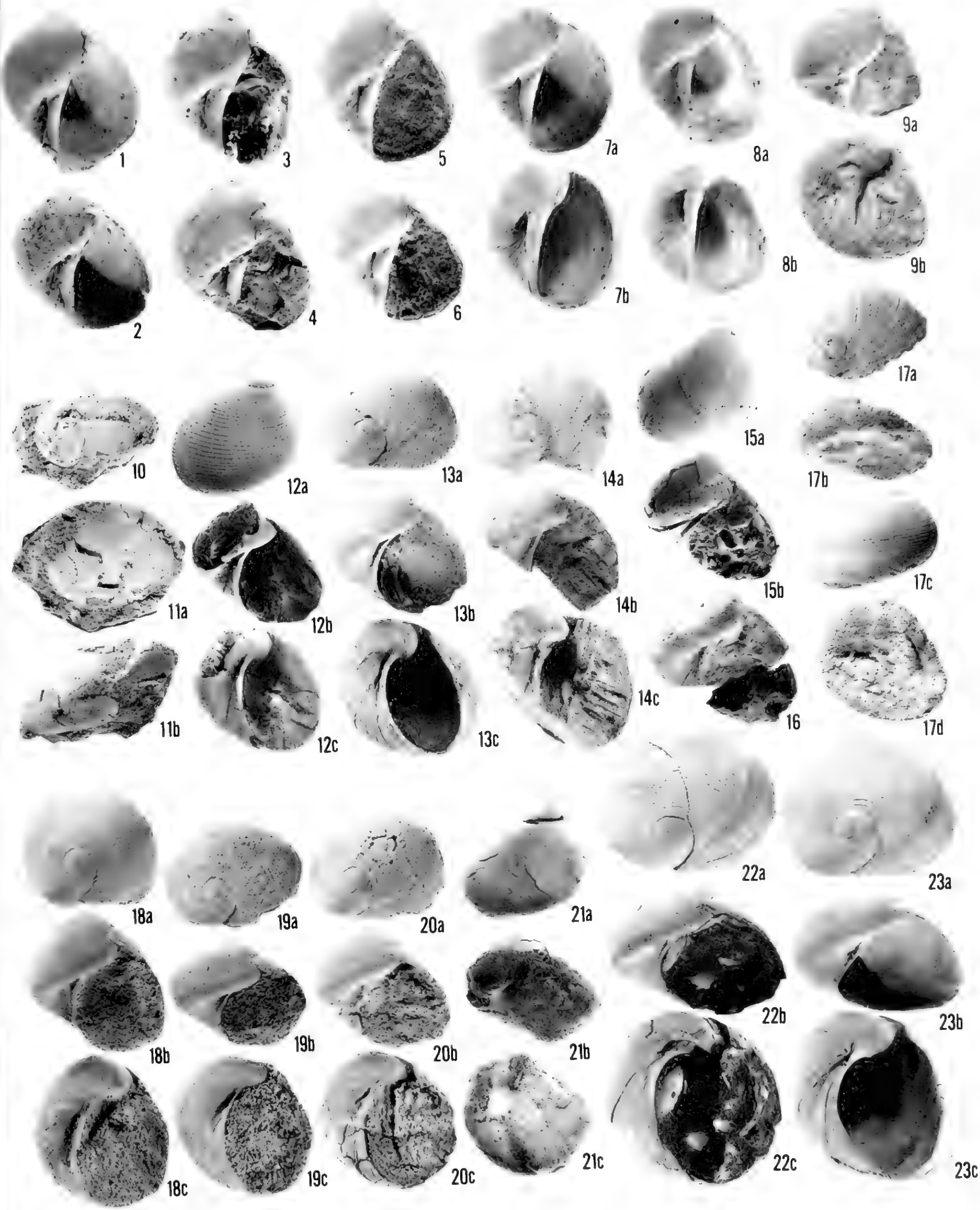
23. Apical view (a), front view (b), basal view (c), IGUT 15822-1, ×0.9; upper Pleistocene Sakurai Formation, Chiba Prefecture, locality SAKURAI.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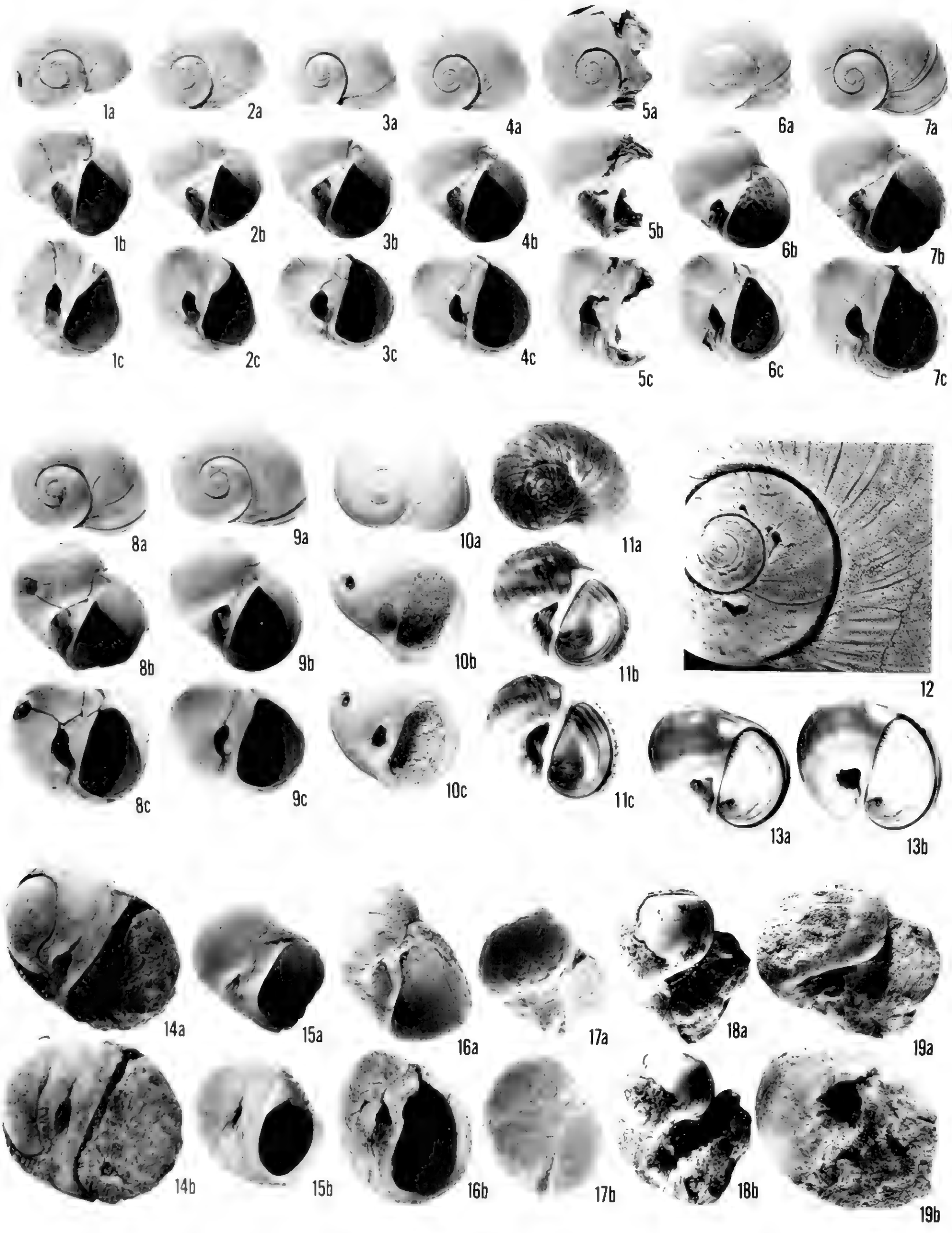
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2. Apical view (a), front view (b), basal view (c), IGUT 15077-3, ×1.3; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 17.
3. Apical view (a), front view (b), basal view (c), IGUT 15246-1, ×1.0; upper Pliocene Ananai Formation, Kochi Prefecture, locality TONOHAMA 2.
4. Apical view (a), front view (b), basal view (c), IGUT 15090-2, ×1.1; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1.
5. Apical view (a), front view (b), basal view (c), IGUT 15093, ×1.1; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 2. Note outer lip partly missing.
6. Apical view (a), front view (b), basal view (c), GIYU 620-2, ×1.1; upper Pliocene Fusakina Formation, Okinawa Prefecture, locality KUME 2.
7. Apical view (a), front view (b), basal view (c), IGUT 15068-4, ×0.8; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1.
8. Apical view (a), front view (b), basal view (c), IGUT 15072-1, ×1.2; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 10.
9. Apical view (a), front view (b), basal view (c), IGUT 16080, ×1.2; upper Pliocene Shinzato Formation, Okinawa Prefecture, locality SHINZATO 6.
10. Apical view (a), front view (b), basal view (c), IGPS 52261, ×1.2; upper Pliocene Byoritsu Formation, Taiwan, locality Wangwa Station 14 of Nomura (1935b).
11. Apical view (a), front view (b), basal view (c), IGUT 16087, ×0.6; Holocene, Shibushi Bay, Kagoshima Prefecture.
12. Apical view, IGUT 15072-2, ×3.6; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 10. Enlarged lower whorls, showing distinctly incised suture.

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14. ***Polinices didymoides*** Kanno and Matsuno ... 43
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19. ***Hahazimania hahazimensis*** Yabe and Hatai ... 95
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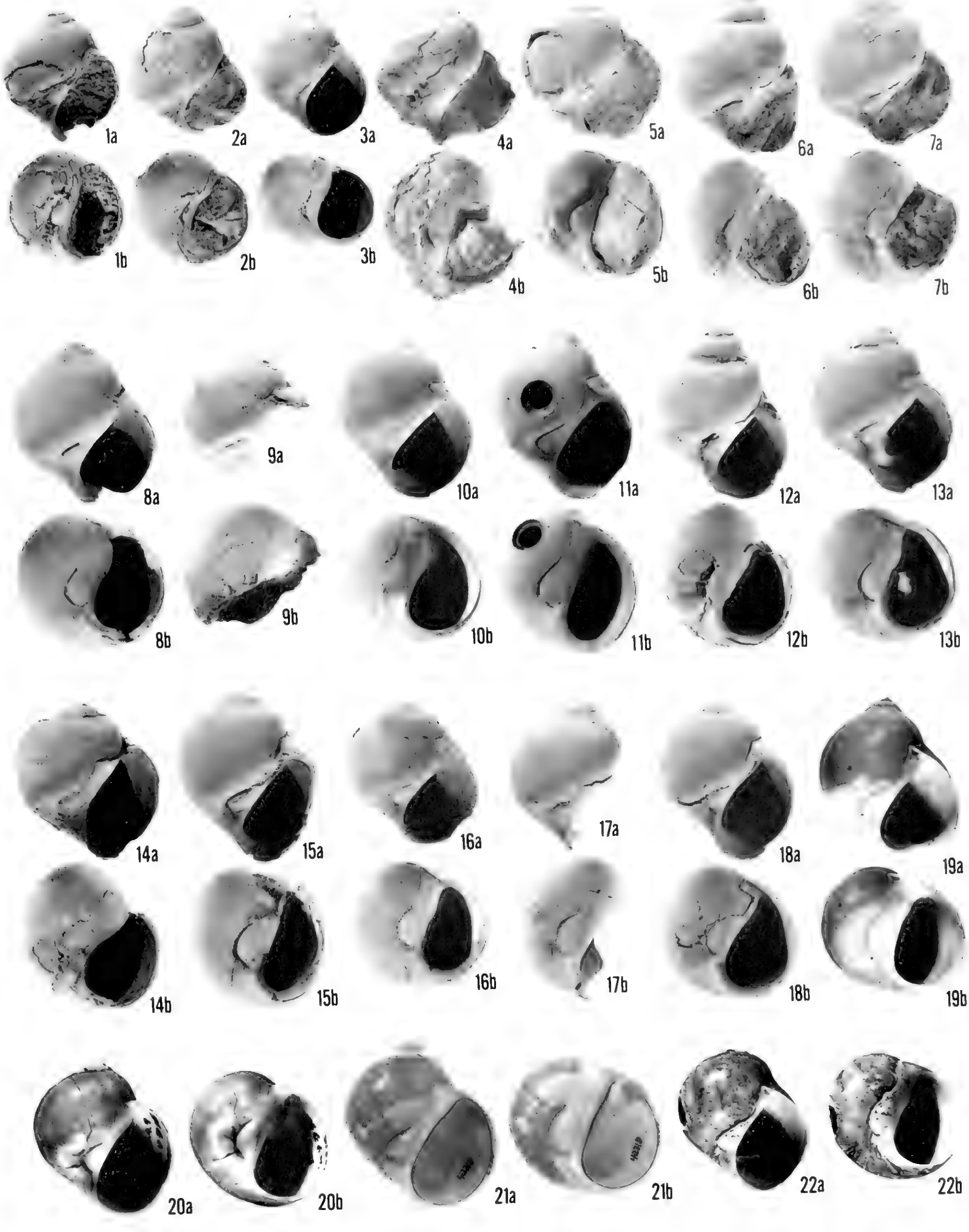
1. Front view (a), basal view (b), IGUT 15557, ×1.6; lower middle Miocene Joyama Member of Yatsuo Formation, Toyama Prefecture, locality YATSUO 3.
2. Front view (a), basal view (b), IGUT 15976-1, ×1.5; lower middle Miocene Oi Formation, Mie Prefecture, locality ICHISHI 4.

3–22. ***Cryptonatica clausa*** (Broderip and Sowerby) 83

3. Front view (a), basal view (b), IGUT 15570-3, ×1.8; lower Pleistocene Iioka Formation, Chiba Prefecture, locality CHOSHI 1.
4. Front view (a), basal view (b), IGUT 15957-3, ×0.7; lower middle Miocene Takinoue Formation, Hokkaido, locality MOMIJIYAMA 1.
5. Front view (a), basal view (b), IGUT 15958, ×1.2; lower middle Miocene Takinoue Formation, Hokkaido, locality MOMIJIYAMA 2.
6. Front view (a), basal view (b), IGUT 15956-2, ×0.9; lower middle Miocene Furanui Formation, Hokkaido, locality FURANUI 1.
7. Front view (a), basal view (b), IGUT 15956-1, ×0.9; lower middle Miocene Furanui Formation, Hokkaido, locality FURANUI 1.
8. Front view (a), basal view (b), IGUT 16058-1, ×0.9; lower Pliocene Yuchi Formation, Hokkaido, locality TESHIO 5.
9. Front view (a), basal view (b), IGUT 15961-3; ×1.3; lower Pleistocene Tomikawa Formation, Hokkaido, locality TOMIKAWA.
10. Front view (a), basal view (b), GIYU 616-1, ×1.0; lower Pleistocene Sunagomata Formation, Aomori Prefecture, locality CHIKAGAWA 1.
11. Front view (a), basal view (b), SHM 6151, ×1.3; Pliocene Daishaka Formation, Aomori Prefecture, locality DAISHAKA. Holotype of *Natica* (*Tectonatica*) *tugaruana* Nomura and Hatai.
12. Front view (a), basal view (b), HU unnumbered, ×0.9; Pliocene Higashimeya Formation, Aomori Prefecture, locality HIGASHIMEYA.
13. Front view (a), basal view (b), IGUT 15575-5, ×0.9; lower Pliocene Kubo Formation, Iwate Prefecture, locality OCHIAI.
14. Front view (a), basal view (b), IGUT 15966-1, ×0.7; Pliocene Kobinaizawa Formation, Akita Prefecture, locality FUTATSUI 2.
15. Front view (a), basal view (b), IGUT 15968-1, ×1.3; upper Pliocene and lower Pleistocene Sasaoka Formation, Akita Prefecture, locality GOJOME 4.
16. Front view (a), basal view (b), IGUT 15969-2, ×2.0; upper Pliocene and lower Pleistocene Sasaoka Formation, Akita Prefecture, locality TOFUIWA.
17. Front view (a), basal view (b), GIYU 533, ×0.8; lower Pleistocene Sawane Formation, Niigata Prefecture, locality SAWANE 1.
18. Front view (a), basal view (b), GIYU 603, ×1.3; lower Pleistocene Nojima Formation, Kanagawa Prefecture, locality NOJIMA 2.
19. Front view (a), basal view (b), NSMT Mo51530, ×0.6; Holocene, off Cape Soya, Hokkaido. Holotype of *Cryptonatica zenryumaruae* Habe and Ito.
20. Front view (a), basal view (b), IGUT 15972, ×1.0; Holocene, Musashi Bank, off Teshio, Hokkaido.
21. Front view (a), basal view (b), NSMT Mo42318, ×1.0; Holocene, Sakhalin, U. S. S. R.
22. Front view (a), basal view (b), IGUT 11105-2, ×1.4; Holocene, off Tomikawa Fisshing Port, Hokkaido.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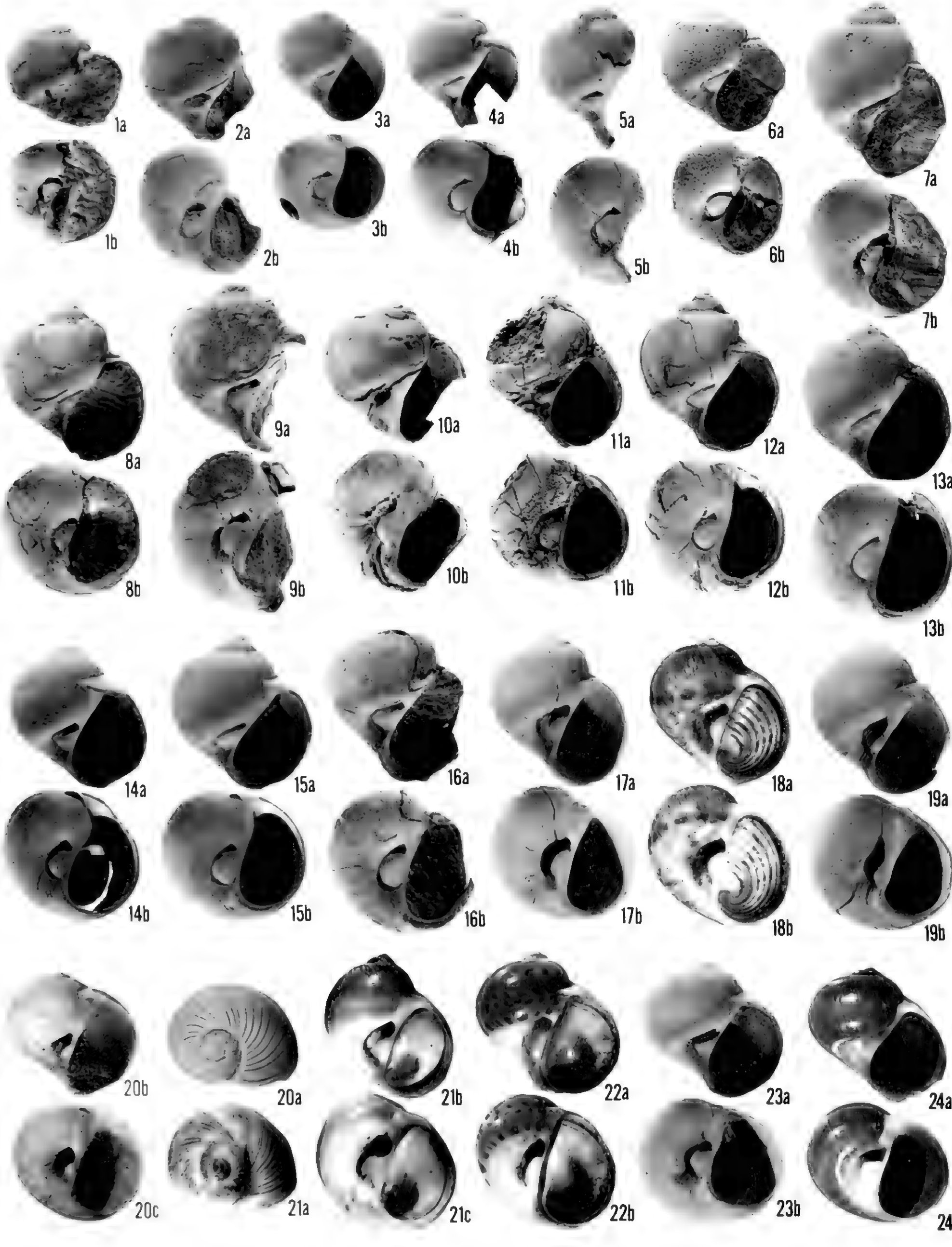
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1–16. ***Cryptonatica janthostoma*** (Deshayes) 86

1. Front view (a), basal view (b), IGUT 15978-2, ×1.1; lower middle Miocene Takinoue Formation, Hokkaido, locality ASAHI.
2. Front view (a), basal view (b), IGUT 15980, ×1.8; middle middle Miocene Kubota Formation, Fukushima Prefecture, locality TANAGURA 2. Note outer lip partly missing.
3. Front view (a), basal view (b), IGUT 15988, ×1.0; Pliocene Nakanokawa Formation, Hokkaido, locality KUROMATSUNAI 2.
4. Front view (a), basal view (b), IGUT 15989-1, ×1.1; lower Pleistocene Tomikawa Formation, Hokkaido, locality TOMIKAWA.
5. Front view (a), basal view (b), IGUT 15992-1, ×1.4; upper Pliocene and lower Pleistocene Sasaoka Formation, Akita Prefecture, locality TOFUIWA. Note outer lip entirely missing.
6. Front view (a), basal view (b), GIYU 520, ×1.0; lower Pliocene Shigarami Formation, Nagano Prefecture, locality SHIGARAMI 2.
7. Front view (a), basal view (b), TKD 5511, ×0.9; lower middle Miocene Sankebetsu or Chikubetsu Formation (unknown in detail), Hokkaido, locality CHIKUBETSU 2. Holotype of *Natica* (*Tectonatica*) *ezoana* Kanno and Matsuno.
8. Front view (a), basal view (b), IGUT 16068, ×0.7; lower middle Miocene Chikubetsu Formation, Hokkaido, locality CHIKUBETSU 3.
9. Front view (a), basal view (b), IGUT 15979, ×0.9; middle middle Miocene to upper Miocene Maedanosawa Formation, Hokkaido, locality YONBANGAWA. Note outer lip partly missing.
10. Front view (a), basal view (b), IGUT 16067, ×0.8; lower Pliocene Yuchi Formation, Hokkaido, locality TESHIO 3. Note outer lip partly missing.
11. Front view (a), basal view (b), IGUT 15990, ×1.0; lower Pliocene Kubo Formation, Iwate Prefecture, locality OCHIAI.
12. Front view (a), basal view (b), IGUT 15993-1, ×0.9; upper Pliocene and lower Pleistocene Sasaoka Formation, Akita Prefecture, locality GOJOME 1.
13. Front view (a), basal view (b), GIYU 530, ×0.6; lower Pleistocene Sawane Formation, Niigata Prefecture, locality SAWANE 3.
14. Front view (a), basal view (b), IGUT 15994-1, ×1.0; Pliocene Yamadahama Formation, Fukushima Prefecture, locality FUTATSUNUMA 1.
15. Front view (a), basal view (b), IGUT 15996-2, ×0.9; lower Pleistocene Omma Formation, Ishikawa Prefecture, locality OMMA 4.
16. Front view (a), basal view (b), GIYU 602, ×0.9; lower Pleistocene Nojima Formation, Kanagawa Prefecture, locality NOJIMA 2. Note outer lip partly missing.

17, 18. ***Naticarius concinnus*** (Dunker) 76

17. Front view (a), basal view (b), IGUT 16049, ×1.9; upper Pleistocene Sakurai Formation, Chiba Prefecture, locality SAKURAI.
18. Front view (a), basal view (b), GIYU 623, ×1.7; Holocene, off Hayama, Sagami Bay, Kanagawa Prefecture.

19, 20. ***Aloconatica niasensis*** (Wissema) 81

19. Front view (a), basal view (b), IGUT 16075, ×1.6; upper Pliocene Shinzato Formation, Okinawa Prefecture, locality SHINZATO 1.
20. Apical view (a), front view (b), basal view (c), IGUT 16053, ×2.3; upper Pliocene Shinzato Formation, Okinawa Prefecture, locality SHINZATO 7.

21. ***Notocochlis gualteriana*** (Récluz) 77

Apical view (a), front view (b), basal view (c), YCM 865, × 1.5; Holocene, Sagami Bay, Pacific side of central Japan.

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Front view (a), basal view (b), IGUT 11106, ×1.0; Holocene, Cape de Nazu, Senegal.

23, 24. ***Tanea areolata*** (Récluz) 80

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24. Front view (a), basal view (b), PKS unnumbered, ×1.5; Holocene, Amami-Ooshima, Kagoshima Prefecture.

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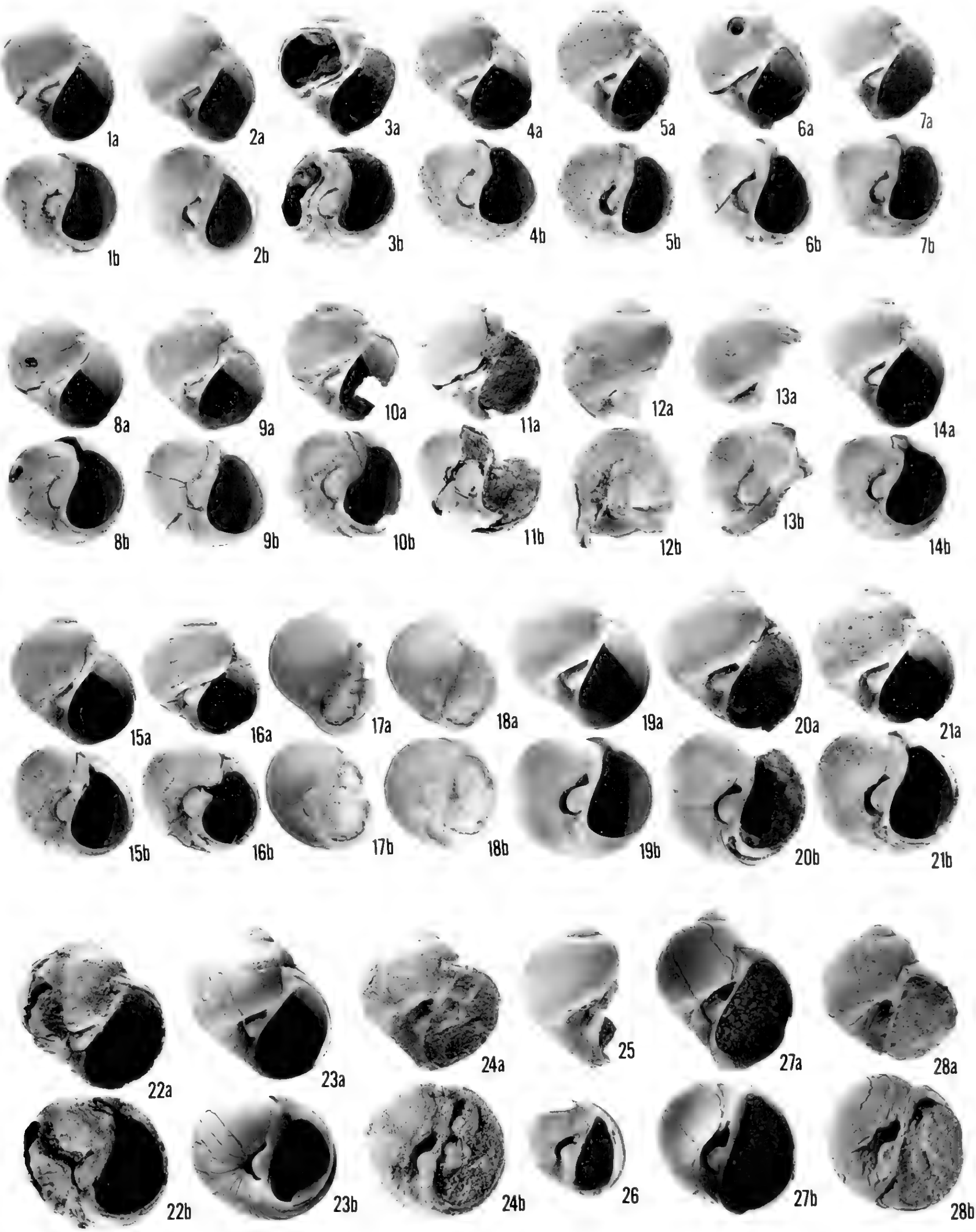
1. Front view (a), basal view (b), GIYU 531-2, ×1.7; lower Pleistocene Sawane Formation, Niigata Prefecture, locality SAWANE 4.
2. Front view (a), basal view (b), JUE 15236, ×1.1; lower Pleistocene Haizume Formation, Niigata Prefecture, locality HAIZUME 2.
3. Front view (a), basal view (b), IGUT 16005-4, ×1.1; lower Pleistocene Omma Formation, Ishikawa Prefecture, locality OMMA 2.
4. Front view (a), basal view (b), GIYU 607-5, ×1.4; lower Pleistocene Nojima Formation, Kanagawa Prefecture, locality NOJIMA 3.
5. Front view (a), basal view (b), GIYU 607-7, ×1.9; lower Pleistocene Nojima Formation, Kanagawa Prefecture, locality NOJIMA 3.
6. Front view (a), basal view (b), IGUT 16069-2, ×1.2; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 1.
7. Front view (a), basal view (b), IGUT 15079-4, ×1.6; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 17.
8. Front view (a), basal view (b), GIYU 609-1, ×1.1; lower Pleistocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 5.
9. Front view (a), basal view (b), IGUT 15085-1, ×1.4; lower Pleistocene Hosoya Member of Upper Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 3.
10. Front view (a), basal view (b), IGUT 16006, ×1.6; upper Pliocene Nobori Formation, Kochi Prefecture, locality TONOHAMA 1.
11. Front view (a), basal view (b), IGUT 16089-1, ×1.3; upper Pliocene Ananai Formation, Kochi Prefecture, locality TONOHAMA 2. Note outer lip partly missing.
12. Front view (a), basal view (b), GIYU 610, ×1.3; lower Pliocene Kawabaru Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 11. Note outer lip entirely missing.
13. Front view (a), basal view (b), GIYU 611-1, ×1.6; lower Pliocene Tsuma Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 8. Note outer lip partly missing.
14. Front view (a), basal view (b), IGUT 15092-3, ×1.5; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1.
15. Front view (a), basal view (b), IGUT 15095-1, ×1.5; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 2.
16. Front view (a), basal view (b), IGUT 15097, ×1.4; lower Pliocene Yonabaru Formation, Okinawa Prefecture, locality YONABARU 1. Note outer lip partly missing.
17. Front view (a), basal view (b), IGPS 52295*, ×1.2; upper Pliocene Byoritsu Formation, Taiwan, locality Wangwa station 24 of Nomura (1935b). Holotype.
18. Front view (a), basal view (b), IGPS 52295*, ×1.4; upper Pliocene Byoritsu Formation, Taiwan, locality Wangwa station 24 of Nomura (1935b). Paratype.
19. Front view (a), basal view (b), IGUT 16002-2, ×0.9; lower Pleistocene Sunagomata Formation, Aomori Prefecture, locality CHIKAGAWA 1.
20. Front view (a), basal view (b), IGUT 16005-1, ×1.0; lower Pleistocene Omma Formation, Ishikawa Prefecture, locality OMMA 2.
21. Front view (a), basal view (b), GIYU 607-2, ×0.8; lower Pleistocene Nojima Formation, Kanagawa Prefecture, locality NOJIMA 3.
22. Front view (a), basal view (b), IGUT 16088, ×0.6; lower Pleistocene Ichijuku Formation, Chiba Prefecture, locality KIMITSU 2.
23. Front view (a), basal view (b), UMUT CM20218, ×0.8; upper Pleistocene Naganuma Formation, Kanagawa Prefecture, locality NAGANUMA. Lectotype, herein designated, of *Tectonatica janthostomoides* Kuroda and Habe.

24–28.	*Tanea minoensis* (Itoigawa)	78

24. Front view (a), basal view (b), IGUT 16065, ×1.6; lower middle Miocene Tsurikake Formation, Hokkaido, locality OKUSHIRI.
25. Front view, IGUT 16037-1, ×1.9; lower middle Miocene Joyama Member of Yatsuo Formation, Toyama Prefecture, locality YATSUO 3. Note outer lip entirely missing.
26. Basal view, IGUT 16037-2, ×2.3; lower middle Miocene Joyama Member of Yatsuo Formation, Toyama Prefecture, locality YATSUO 3. Note lower conch whorls partly missing.
27. Front view (a), basal view (b), ESN 20061, ×1.2; lower middle Miocene Shukunohora Sandstone, Gifu Prefecture, locality MIZUNAMI 5. Holotype.
28. Front view (a), basal view (b), GIYU 617, ×1.7; lower middle Miocene Kurokawa Formation, Shiga Prefecture, locality AYUGAWA.

* One of two specimens bearing the same catalogue number.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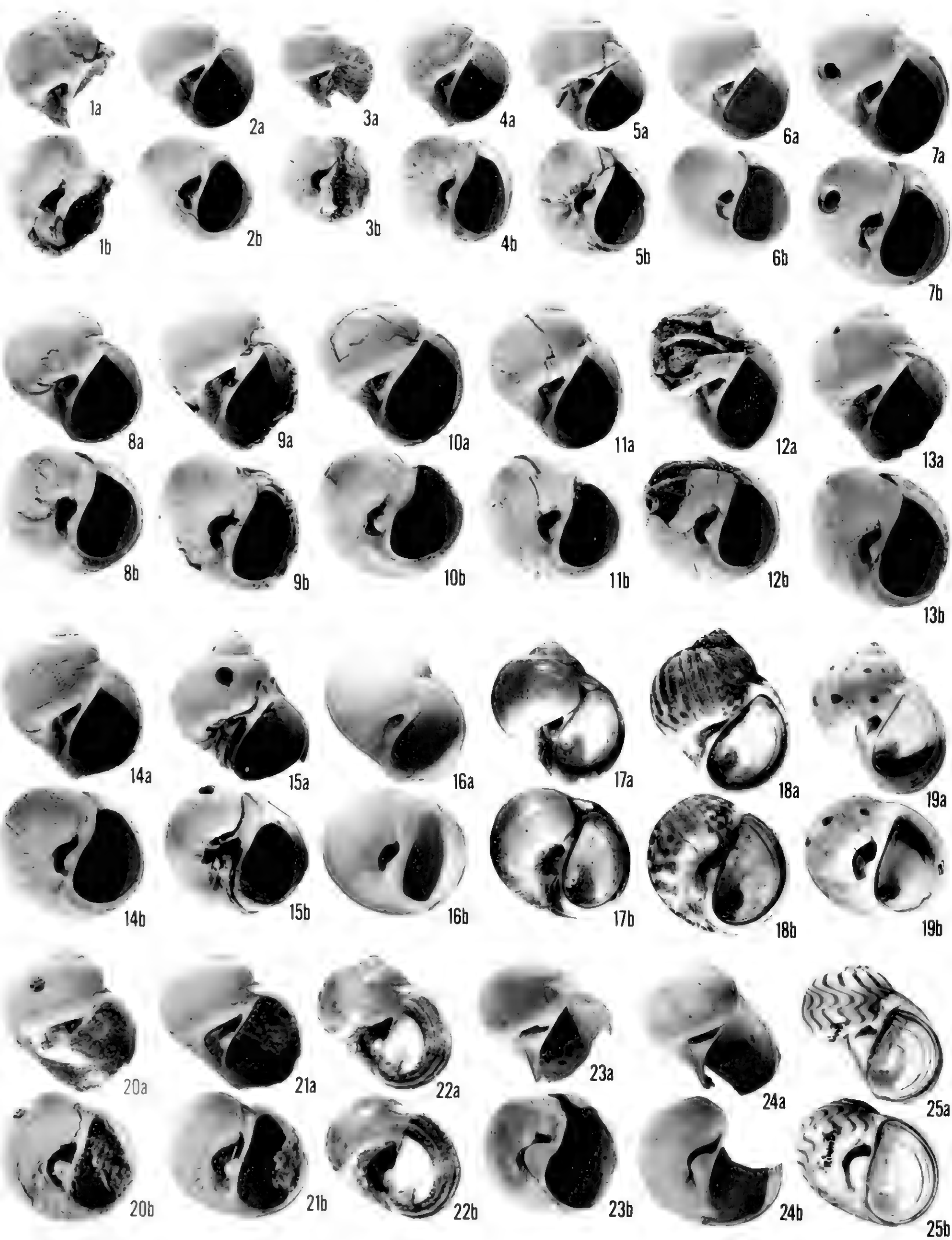
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14b 15b 16b 17b 18b 19b
20a 21a 22a 23a 24a 25a
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1. Front view (a), basal view (b), IGUT 15098, ×1.4; upper Pliocene Kanzawa Formation, Kanagawa Prefecture, locality NAKATSU. Note outer lip entirely missing.
2. Front view (a), basal view (b), GIYU 605-1, ×1.3; lower Pleistocene Hosoya Member of Upper Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 19.
3. Front view (a), basal view (b), IGUT 15999, ×2.3; lower Pleistocene Nango Member of Upper Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 20.
4. Front view (a), basal view (b), IGUT 15094-1, ×1.9; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 2.
5. Front view (a), basal view (b), GIYU 606, ×1.1; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 6.
6. Front view (a), basal view (b), IGUT 16001-1, ×1.4; upper Pleistocene Hiradoko Formation, Ishikawa Prefecture, locality HIRADOKO.
7. Front view (a), basal view (b), IGUT 15997, ×1.3; lower Pleistocene Sunagomata Formation, Aomori Prefecture, locality CHIKAGAWA 1.
8. Front view (a), basal view (b), IGUT 15571-2, ×1.2; lower Pleistocene Omma Formation, Ishikawa Prefecture, locality OMMA 1.
9. Front view (a), basal view (b), IGUT 15075-1, ×1.0; upper Pliocene Dainichi Member of Lower Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 11.
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12. Front view (a), basal view (b), IGUT 15084-1, ×1.2; lower Pleistocene Hosoya Member of Upper Kakegawa Formation, Shizuoka Prefecture, locality KAKEGAWA 3.
13. Front view (a), basal view (b), IGUT 15088-1, ×1.4; upper Pliocene Ananai Formation, Kochi Prefecture, locality TONOHAMA 2.
14. Front view (a), basal view (b), GIYU 604-1, ×1.2; upper Pliocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 1.
15. Front view (a), basal view (b), IGUT 15096, ×0.9; lower Pleistocene Takanabe Member of Koyu Formation, Miyazaki Prefecture, locality MIYAZAKI 5.
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Front view (a), basal view (b), IGUT 16090-2, ×1.2; Holocene, off Mikawa-Isshiki Fishing Port, Aichi Prefecture. Note *T. tosaensis* is very similar to *C. adamsiana* in shell morphology.

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21. Front view (a), basal view (b), GIYU 527, ×1.2; upper Pleistocene Ryukyu Limestone, Kagoshima Prefecture, locality KIKAI 1.
22. Front view (a), basal view (b), NSMT Mo42092, ×1.4; Holocene, off Mikawa-Isshiki Fishing Port, Aichi Prefecture.

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23. Front view (a), basal view (b), IGUT 16084, ×2.1; lower Pleistocene Nakoshi Sandstone, Okinawa Prefecture, locality HANEJI 1.
24. Front view (a), basal view (b), IGUT 16085, ×1.6; lower Pleistocene Nakoshi Sandstone, Okinawa Prefecture, locality HANEJI 3.
25. Front view (a), basal view (b), NSMT Mo64469, ×1.0; Holocene, Okinawa Prefecture (unknown in detail).

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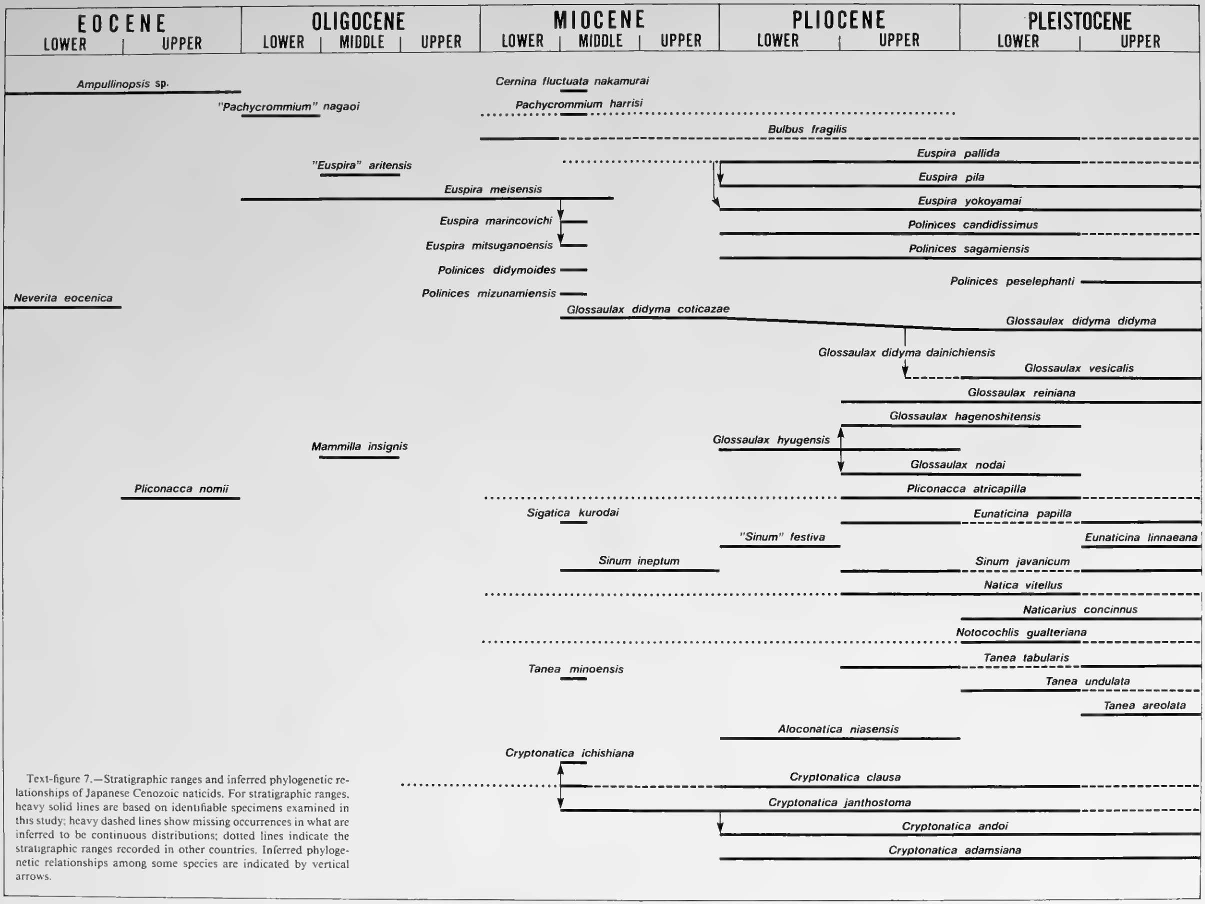
Note: Page numbers are in light face; plate numbers are in **bold face** type; principal discussions are in *italics*. **B** indicates the foldout inside the back cover.



Text-figure 7.—Stratigraphic ranges and inferred phylogenetic relationships of Japanese Cenozoic naticids. For stratigraphic ranges, heavy solid lines are based on identifiable specimens examined in this study; heavy dashed lines show missing occurrences in what are inferred to be continuous distributions; dotted lines indicate the stratigraphic ranges recorded in other countries. Inferred phylogenetic relationships among some species are indicated by vertical arrows.

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Collinson, J.
1962. *Size of lettering for text-figures.* Journal of Paleontology, vol. 36, p. 1402.

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