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A Late Oligocene or Earliest Miocene Molluscan Fauna From Sitkinak Island, Alaska

By RICHARD C. ALLISON *and* LOUIE MARINCOVICH, JR.

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Describes the late Oligocene or earliest Miocene molluscan fauna from the Narrow Cape Formation on Sitkinak Island, noting the mixture of Asiatic, North American, and endemic high-latitude North Pacific taxa.

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CONTENTS

ILLUSTRATIONS

[Plates follow index]

TABLES

A LATE OLIGOCENE OR EARLIEST MIOCENE MOLLUSCAN FAUNA FROM SITKINAK ISLAND, ALASKA

By RICHARD C. ALLISON and LOUIE MARINCOVICH, JR.

ABSTRACT

The Narrow Cape Formation of Sitkinak Island, in the western Gulf of Alaska, contains a marine molluscan fauna of late Oligocene or earliest Miocene age that represents the Juanian Stage [= *Echinophoria apta* Zone] of the Pacific Northwest (Washington and Oregon) provincial molluscan chronology. The Narrow Cape Formation on Sitkinak Island is older than the type Narrow Cape Formation on Kodiak Island, which contains mollusks referable to the Newportian Stage. The fauna of the Narrow Cape Formation of Sitkinak Island lived in the outer neritic zone in a cool-temperate marine climate. The co-occurrence of taxa with Asiatic, North American, and high-latitude North Pacific zoogeographic affinities makes this fauna especially important for the development of circum-North Pacific chronostratigraphic correlations.

INTRODUCTION

Upper Oligocene or lowest Miocene strata, predominantly of marine siltstone and approximately 210 m thick, crop out on Sitkinak Island, south of Kodiak Island, in the western Gulf of Alaska (fig. 1). Terrestrial sedimentary rocks containing coal and fossil plants have long been known from Sitkinak Island (Dall, 1896; Smith, 1939), but the marine beds were not discovered until 1962, during the course of field work by George W. Moore of the U.S. Geological Survey. MacNeil (1965, p. G9) made the first literature reference to these marine strata and referred them to the "*Echinophoria apta* zone of the Oligocene and Miocene." Moore (1967) published a geologic map of the Kodiak Island area showing these marine beds as Miocene in age. In 1969 Moore named and described the Narrow Cape Formation with its type section at Narrow Cape on Kodiak Island, and assigned the marine siltstone of Sitkinak Island to the Narrow Cape Formation (fig. 2). The first published account of mollusks from the Narrow Cape Formation on Sitkinak Island was by Allison (1976, 1978), who assigned these strata to the Juanian Stage [=*Echinophoria apta Zone*], which he considered to be of late Oligocene and early Miocene age. This fauna has great significance for circum-North Pacific chronostratigraphic correlation because of its mixture of North American, Asiatic, and endemic high-latitude molluscan taxa. Our purpose here is to document this fauna and discuss its paleoecology, faunal affinities, and correlations.

Fossils examined for this study were collected by George W. Moore in 1962, 1975, and 1978, by geologists of Marathon Oil Co. in 1971, and by geologists of Mobil Oil Co. in 1971 and 1975. These collections are housed at the U.S. Geological Survey in Menlo Park, Calif., and the University Museum, University of Alaska, Fairbanks, Alaska. The illustrated specimens are housed at the U.S. National Museum of Natural History, Washington, D.C., and the University of Alaska Museum, Fairbanks.

We are indebted to Mobil Oil Co. for providing data for the columnar section (fig. 2). George W. Moore of the U.S. Geological Survey and John Armentrout of Mobil Oil Company have provided valuable information concerning the stratigraphy of the Narrow Cape Formation on Sitkinak Island. Kristin McDougall examined the benthic foraminifers from four of our samples; Warren O. Addicott made helpful suggestions on the report. Photographs of the fossils were made by Kenji Sakamoto. All are of the U.S. Geological Survey.

FAUNAL COMPOSITION

The molluscan fauna of the Narrow Cape Formation on Sitkinak Island (pls. 1-3) consists of at least the 44 recognizable taxa listed in table 6. Specimens

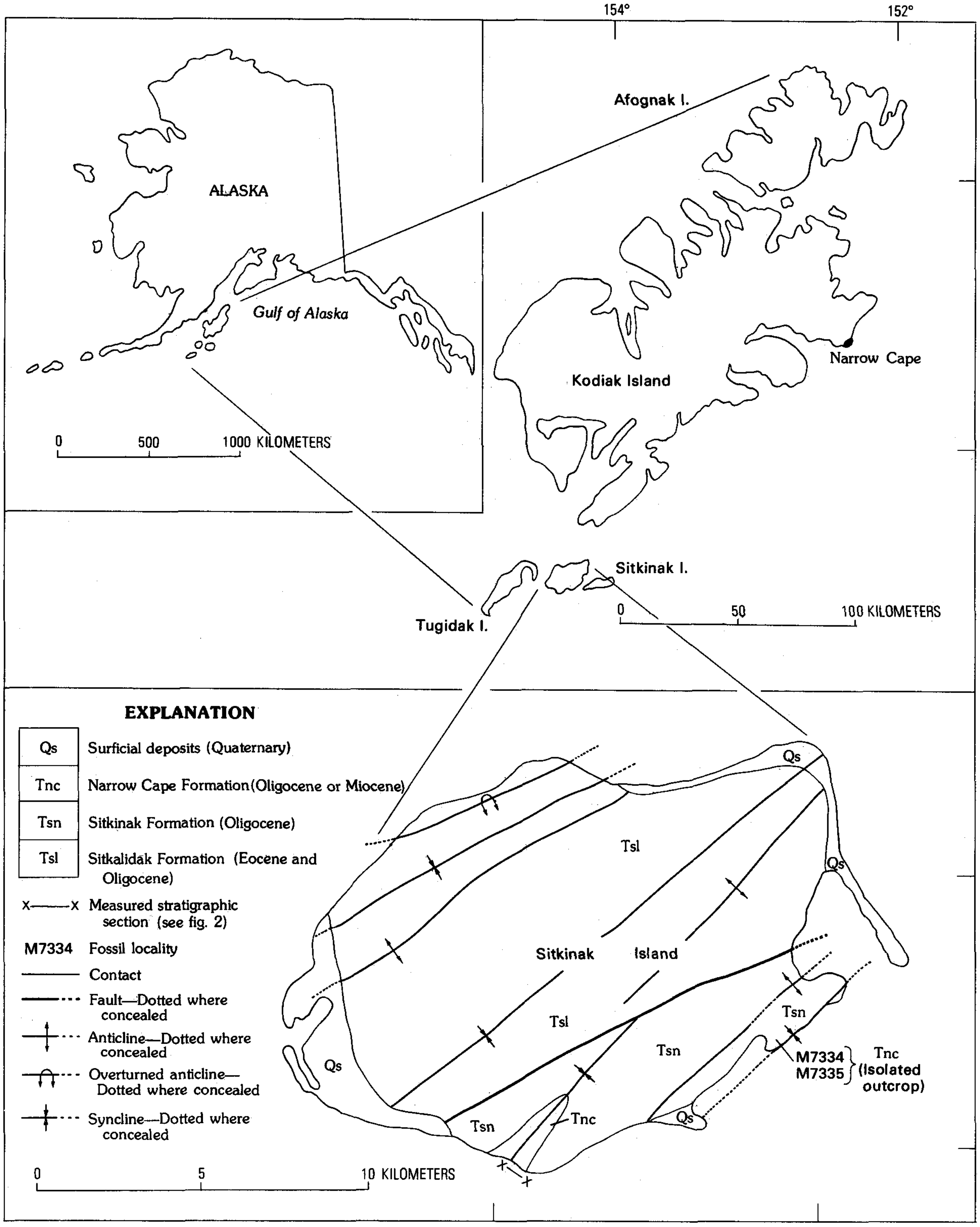

FIGURE 1.—Index map of the Kodiak Island area, Alaska, showing outcrops of the Narrow Cape Formation on Sitkinak Island.

were examined from 17 collections within a measured stratigraphic section (fig. 2), augmented by 10 collections from unknown stratigraphic positions and two collections (M7334 and M7335) from a separate outcrop (fig. 1). Among the 44 recognizable taxa are 22 bivalves, 20 gastropods, one cephalopod, and one

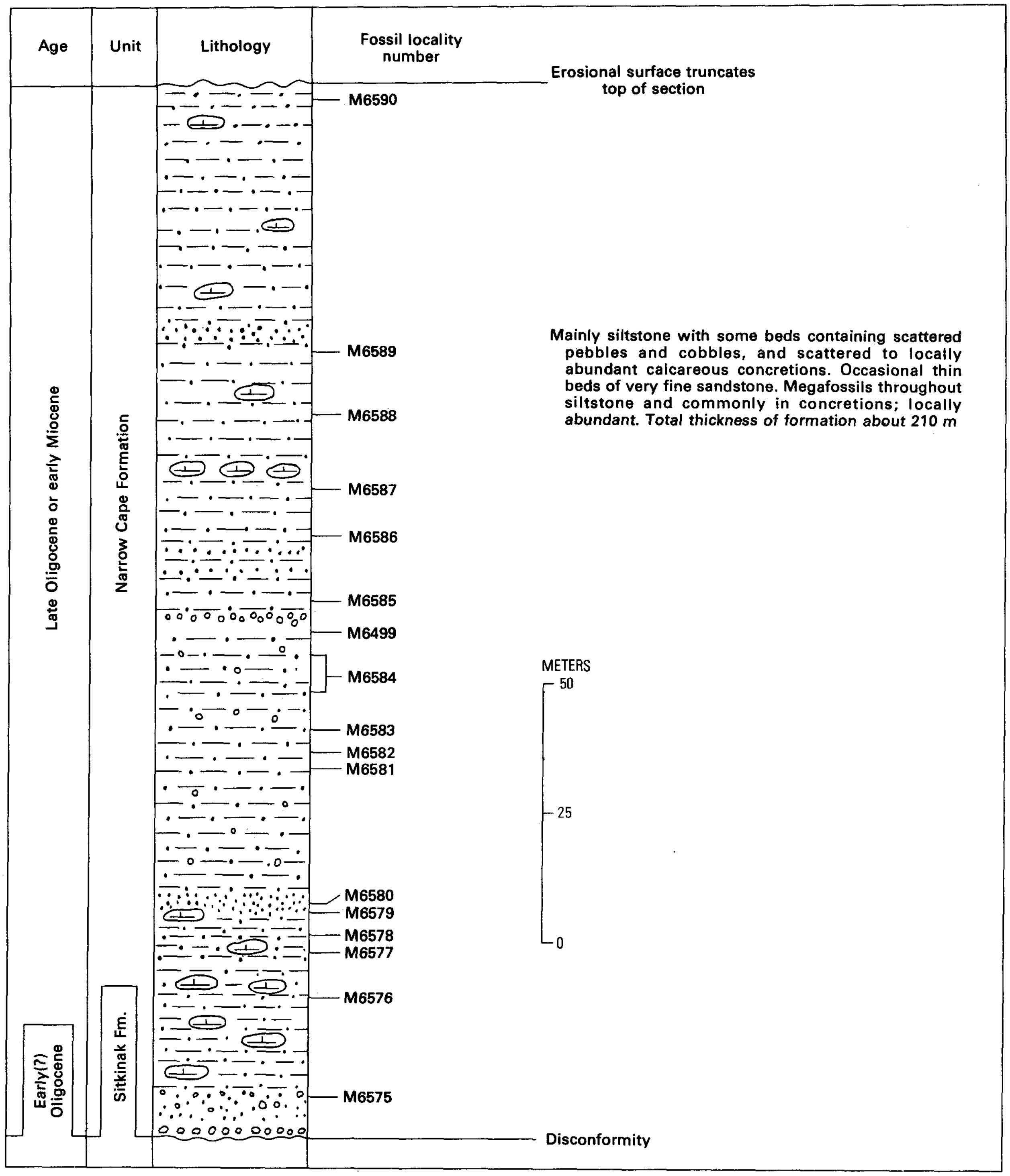

FIGURE 2.—Stratigraphic section of the Narrow Cape Formation on Sitkinak Island, Alaska, showing megafossil localities. Adapted from data supplied by Mobil Oil Co., George W. Moore (oral commun., 1979), and Nilsen and Moore (1979). See figure 1 for geographic location of section.

scaphopod.

The fauna contains a mixture of western North American, endemic high-latitude North Pacific, and Asiatic taxa (Allison, 1978). This aspect of the fauna holds the promise of correlating upper Oligocene or lowermost Miocene strata along the margin of the North Pacific from Japan to California.

AGE AND CORRELATION

The mollusks of the Narrow Cape Formation on Sitkinak Island are referable to the Juanian Stage of the provincial molluscan chronology of the Pacific Northwest (Oregon and Washington) (Addicott, 1976b; Allison, 1978). The Juanian Stage is coeval with the *Echinophoria apta* Zone of the Pacific Northwest (Armentrout, 1975; Addicott, 1976b; Allison, 1978) and is mostly of late Oligocene age and partly of early Miocene age (Allison, 1976, 1978).

The zonal fossil *Echinophoria apta*(Tegland) is present in one collection from Sitkinak Island (table 6; pl. 3, fig. 1). Taxa suggesting that the Sitkinak Island marine strata are no older than the Juanian Stage or the *E. apta* Zone are: *Macoma calcarea* (Gmelin), *M. incongrua* (von Martens) of Kanno (1971), *M.* cf. *M. moesta moesta* (Deshayes), *Pitar angustifrons* (Conrad), *Spisula* cf. *S. hannibali* (Clark and Arnold), *Natica clausa* Broderip and Sowerby, *Polinices ramonensis* (Clark), and *Priscofusus clarki* Kanno (table 1). Species that suggest an age no younger than the Juanian Stage are *Bruclarkia* cf. *B. andersoni* (Wiedey), *Neverita washingtonensis* (Weaver), and *Priscofusus clarki* Kanno (table 1).

The *Echinophoria apta* Zone corresponds to the upper part of the Zemorrian benthic foraminiferal Stage of California (Durham, 1944; Armentrout, 1975; Addicott, 1976b). This correlation is generally confirmed in the Narrow Cape Formation on Sitkinak Island by the presence of Zemorrian benthic foraminifers from four samples (table 2). No identifiable planktic microfossils were found.

On the basis of its molluscan fauna, the Narrow Cape Formation on Sitkinak Island correlates with the Juanian part of the Poul Creek Formation in the northeastern Gulf of Alaska, with the Sooke Formation of Vancouver Island, British Columbia, Canada, and with the Pysht Formation of the Twin River Group (Snavely and others, 1978) of northwestern Washington.

Asiatic taxa in the Narrow Cape Formation on Sitkinak Island permit general but unrefined correlations with late Oligocene to early Miocene formations of Japan, Sakhalin, and Kamchatka (table 3). Some of the Asiatic taxa useful in correlation are *Clinocardium* cf. *C. makiyamae* Kamada, *Cyclocardia* cf. C. *subnipponica* (Nagao), *C.* cf. *C. tokunagai* (Yokoyama), *Mya grewingki* Makiyama, and *Turritella* cf. *T. chichibuensis* Ida. These taxa suggest

TABLE 1.—*Occurrence in Pacific Northwest Tertiary molluscan stages of selected species from the Narrow Cape Formation on Sitkinak Island*

Series	Eocene	Oligocene		Miocene		
Molluscan stages	Galvinian	Matlockian	Juanian	Pillarian	Newportian	Wishkahan
Pelecypods:						
Acila (Acila) gettysburgensis (Reagan)		—	—	—		
Crenella porterensis Weaver	—	—	—	—	—	
Macoma (Macoma) calcarea (Gmelin)			-?-	—	—	→
Macoma (Macoma) incongrua (von Martens) of Kanno			-?-	—	—	→
Macoma (Macoma) cf. *M. (M.) moesta moesta* (Deshayes)			-?-	—	—	→
Macoma twinensis Clark	—	—	—	- - -	-?-	
Pitar (Katherinella) angustifrons (Conrad)			—	—	—	
?*Serripes hamiltonensis* (Clark)		-?-	—	—	—	-?
Spisula cf. *S. hannibali* (Clark and Arnold)			—	—		
Spisula albaria (Conrad), s.l		—	—	—	—	→
Gastropods:						
Bruclarkia cf. *B. andersoni* (Wiedey)		—	—			
Calyptraea cf. *C. diegoana* (Conrad)	←	—	—	—	—	→
Echinophoria apta (Tegland)			—			
Natica (Cryptonatica) clausa Broderip and Sowerby			—	—	—	→
Neverita (Neverita) washingtonensis (Weaver)	←	—	-?-			
Polinices (Euspira) cf. *P. (E.) lincolnensis* (Weaver)	—	—	—	—	—	
Polinices (Euspira) ramonensis (Clark)			—	—	—	
Priscofusus clarki Kanno		?-	—	-?		
Priscofusus aff. *P. stewarti* (Tegland)		—	—	—		

TABLE 2. —*Benthic foraminifers from the Narrow Cape Formation on Sitkinak Island*

[Identifications by Kristin McDougall. M = megafossil locality, Mf = microfossil locality]

Fossil localities	M1489/Mf3093	M6578/Mf3094	M6586/Mf3095	M6592/Mf3096
Foraminifers:				
Bathysiphon sanctaecrucis Cushman and Kleinpell	×	....	....	....
Bathysiphon sp	....	....	×	....
Bolivina marginata adelaidana Cushman and Kleinpell	....	×	×	....
Buccella mansfieldi oregonensis (Cushman, Stewart, and Stewart)	....	×	....	....
Cassidulina crassipunctata Cushman and Hobson	....	×	×	×
Cibicides elmaensis Rau	....	×	×	....
Cibicides sp	....	....	....	×
Cyclammina pacifica Beck	....	....	×	....
Cyclammina spp	×	....	×	....
Dentalina consobrina d'Orbigny	....	....	×	....
Dentalina sp	....	....	×	....
Elphidium sp	×	×	×	....
Entosolenia sp. of Rau (1964)	....	....	×	....
?*Entosolenia* sp	....	....	....	×
Eponides mexicanus (Cushman)	×	....	....	....
Eponides sp	....	×	....	....
Haplophragmoides sp. A	×	....	....	×
Haplophragmoides spp. indet	....	....	×	....
Melonis cf. *M. pompilioides* (Fichtel and Moll)	×	×	×	×
Nonion planatum Cushman and Thomas	....	×	....	....
Pseudonodosaria conica (Neugeboren)	×	×	×	×
?*Trochammina* sp	×	....	....	....
?Planktic foraminifers	....	×	....	....
Miscellanea:				
?Radiolaria	....	×	....	....
Ostracods	....	....	×	....

correlations with the Iwaki and Asagai Formations of the Joban Coal Field of Japan, the Ushikubitoge Formation and Nenokami Sandstone of the Chichibu Basin of Japan, the Poronai Formation of Hokkaido, Japan, and the Nissakutan and Marie Formations of Sakhalin (table 3). Menner and others (1977, p. 83, table 1) and Gladenkov (1980, fig. 3) appear to refer these strata to the Gakhinian Stage of western Kamchatka and the Machigarian Stage of northern Sakhalin, which they placed in the upper Oligocene.

TABLE 3.—*Reported occurrences in North Pacific strata of some mollusks from the Narrow Cape Formation on Sitkinak Island*

Taxon	Reference	Occurrence
Clinocardium cf. *C. makiyamae* Kamada, 1962.	Kamada (1962)	Asagai Formation of the Uchigo Group, Joban Coal Field, Japan.
Cyclocardia cf. *C. belogolovensis* (Ilyina, 1963).	Ilyina (1963)	Vayampol'sk Series, Kamchatka.
Cyclocardia cf. *C. subnipponica* (Nagao, 1928).	Kamada (1962)	Yamaga Formation of the Ashiya Group, northern Kyushu, Japan. Iwaki Formation of the Uchigo Group, Joban Coal Field, Japan.
Cyclocardia cf. *C. tokunagai* (*Yokoyama, 1924*).	Kamada (1962); Ilyina (1963).	Asagai Formation of the Uchigo Group, Joban Coal Field, Japan. Vayampol'sk Series, Kamchatka.
Cyclocardia cf. *C. wajampolkensis* (*Ilyina, 1963*).	Ilyina (1963); Menner and others (1977).	Viventekian Stage, "zone of *Delectopecten pedroanus*"; late Oligocene or early Miocene.
Macoma cf. *M. optiva* (Yokoyama, 1923)	Kamada (1962); Kanno, (1960); Ilyina (1963); Zhidkova and others, (1968; 1972); Ikebe and others 1972);	Narrow Cape Formation, Kodiak Island, Alaska. Unga Conglomerate Member of the Bear Lake Formation, Alaska. Upper part of Bear Lake Formation, Alaska (questionable occurrence). Joban Coal Field, Japan: Numanouchi/Kokozura Formations, Taga Group. Nakayama Formation, Shirado Group. Honya Formation, Yunagaya Group. Chichibu Basin, Japan: Hikokubo Group: Nemokami Sandstone. Ushikubitoge Formation: Tomita Siltstone Member. Shirasu Sandstone Member. Fujina Formation, SW. Honshu, N15/N16 zones of Blow (1969). Kadonosawa Series, N. Honshu, Japan. "Sankebetsu Miocene," Hokkaido, Japan. Kurile Islands, U.S.S.R.: Alekhin, Kamui, Shumnov Suites. Sakhalin, U.S.S.R.: Kurasii, Sertunai, Maruyam, Aleksandrov, Okobykai, Borskaya Suites. Kamchatka: Vayampol'sk Series. Il'insk, Kakert, Kuluven Suites.
Mya (?*Arenomya*) *grewingki* Makiyama, 1934.	Kamada (1962); MacNeil (1965).	Akahira Formation, Chichibu Basin, Japan. Nenokami Sandstone, Chichibu Basin, Japan. Asagai Formation, Joban Coal Field, Japan. Poronai Formation, Hokkaido, Japan. Marie Formation, Matchgar, Sakhalin, U.S.S.R. Maoka Group, S. Sakhalin, U.S.S.R. Nissakutan Formation, Sakhalin, U.S.S.R.
Periploma (*Aelga*) *besshoense* (Yokoyama, 1924).	Kamada (1962); Kanno (1971); Ilyina (1963).	Yakataga and Poul Creek Formations, Alaska, Juanian(?) to Wishkahan(?). Asagai Formation of the Uchigo Group, Joban Coal Field, Japan. Shirasaka Formation of the Uchigo Group, Joban Coal Field, Japan. Poronai Formation, Hokkaido, Japan. Kuluven Suite, Kamchatka, U.S.S.R.
Buccinum aff. *B. kurodai* Kanehara, 1937.	Kamada (1962)	Mizunoya and Honya Formations, Yunagaya Group, Joban Coal Field, Japan. Nutoya beds, Sakhalin, U.S.S.R.
Turritella (*Hataiella*) cf. *T.* (*H.*) chichibuensis Ida, 1952.	Kanno (1960); Kotaka (1959); Ikebe and others (1972).	Chichibu Basin, Japan: Tachigase Formation [= Tatsugase]: same as Akahira Formation (Blow, 1969, zones N5/N6). Nenokami Sandstone, Hikokubo Group.
Dentalium (*Coccodentalium*) cf. *D.* (*C.*) *nunomae* Takeda, 1953, of Kanno (1971).	Kanno (1971)	Poronai to Takinoue Formations, Hokkaido, Japan.

In western North America, as in Asia, the stratigraphic interval represented by the Narrow Cape Formation on Sitkinak Island has been variously assigned to the late Oligocene or early Miocene. In recent years, Addicott's (1976a) study of mollusks from the upper part of the Twin River Group of western Washington has shown that the Oligocene-Miocene boundary occurs high in the *Echinophoria apta* Zone. He later proposed the Juanian Stage to coincide with the *E. apta* Zone (Addicott, 1976b). Using inferences drawn from planktic microfossil correlations, Allison (1976, 1978) independently concluded that the Juanian Stage was mostly of late Oligocene age, and that its uppermost part was of early Miocene age. The faunal composition of the Sitkinak Island beds (table 1) suggests that the Narrow Cape Formation there is coeval with the Pysht Formation of the Twin River Group of Snavely and others (1978) and is of late Oligocene or earliest Miocene age.

RELATION TO THE TYPE NARROW CAPE FORMATION OF KODIAK ISLAND

When Moore (1969) referred the Tertiary marine strata of Sitkinak Island to the Narrow Cape Formation, he realized that these beds were older than the type Narrow Cape Formation of Kodiak Island (fig. 1). MacNeil (*in* Moore, 1969) regarded mollusks from the middle part of the type Narrow Cape Formation to be of middle Miocene age and mollusks near the base of the formation on Sitkinak Island to be of early Miocene age. Our opinion that the Narrow Cape Formation on Sitkinak Island is older than the type Narrow Cape Formation of Kodiak Island is the same as MacNeil's (*in* Moore, 1969), but we refer the latter to the Newportian molluscan Stage of late early and early middle Miocene age and to the late Saucesian through Luisian benthic foraminiferal Stages. Thus, the molluscan faunas of these two units suggest that the type Narrow Cape Formation is entirely younger than the Narrow Cape Formation on Sitkinak Island. The Pillarian molluscan Stage and the early Saucesian benthic foraminiferal Stage constitute a missing interval between the Kodiak Island and the Sitkinak Island marine strata.

PALEOECOLOGY

WATER DEPTH

The Narrow Cape Formation on Sitkinak Island evidently was deposited in the outer neritic zone of the continental shelf (Allison, 1978). Most of the mollusk species are extinct or belong to genera with broad depth distributions, but a few taxa suggest probable lower depth limits and still fewer indicate probable upper depth limits. No shallowing or deepening trends are evident within the section. Table 4 shows the maximum depth range known to us for some living taxa that also occur in the Sitkinak Island marine strata. Taxa not listed in table 4 either have very broad depth ranges, are extinct, or have no data available for them.

TABLE 4.—*Maximum known depth ranges of some living taxa found in the Narrow Cape Formation on Sitkinak Island*

Taxa	Minimum depth (m)	Maximum depth (m)
Clinocardium	0	220
Macoma (Macoma) calcarea	0	226
Macoma (Macoma) incongrua	0	200 (usually below 51)
Macoma (Macoma) moesta moesta	0	261
Mya	0	168
Pitar	0	543
Serripes	0	201
Spisula	0	111
Ancistrolepis	37	2514
Calyptraea	0	141
Musashia, s.l	100	800 (poorly known)
Priscofusus (living analog: *Fusinus*)	0	186
Turritella	0 (seldom less than 18)	186

Figure 3 shows the range in depth suggested by the fossil mollusks for each locality. Many of these assemblages contain only eurybathyal taxa that are not useful for paleobathymetric interpretations. The overlap of bathymetric data in table 4 indicates that the Narrow Cape Formation on Sitkinak Island accumulated in the outer neritic zone between depths of about 100 and 186 m. Benthic foraminifers from four localities (table 2) suggest outer neritic depths of 100 to 200 m (Kristin McDougall, oral commun., 1979).

WATER TEMPERATURE

Analysis of the geographic ranges of modern analogs of mollusks from the Narrow Cape Formation on Sitkinak Island suggests that a cool-temperate marine climate existed at Sitkinak Island during the late Oligocene. The latitudinal ranges and marine climatic zones of some modern molluscan analogs shown in table 5 set limits on paleotemperature interpretation.

The marine climate classification used here follows Hall (1964), who defined the cool-temperate marine climate as having water temperatures warming to 10°C for only 3 or 4 months of the year and the mild-temperate marine climate as having water temperatures that reach near to, or slightly below, 15°C each year.

TABLE 5.—*Latitudinal ranges and marine climatic tolerances of living analogs of some mollusks from the Narrow Cape Formation on Sitkinak Island*

[Eurythermal taxa are omitted. The marine climate classification follows Hall (1964). Latitudinal ranges collated from Dall (1921), Keen (1937), Kotaka (1959), MacGinitie (1959), MacNeil (1965), Shikama (1967), Bernard (1970), Coan (1971), and Mann (1977)]

	Latitudinal range, western north America (degrees north latitude)	Latitudinal range, eastern Asia (degrees north latitude)	Marine climate zones					
			Inner Tropical	Outer Tropical	Warm Temperate	Mild Temperate	Cool Temperate	Boreal
Liocyma fluctuosa (Gould)	48-72						—	—
Macoma (Macoma) calcarea (Gmelin)	37-48?; 48-72					-?-	—	—
Macoma (Macoma) moesta moesta (Deshayes)	52-72						—	—
Macoma (Macoma) moesta alaskana Dall	48-60						—	—
Mya (Arenomya)	37-55; to 64?					—	—	-?-
Pitar	19-57		—	—	—	—	—	
Serripes	48-72						—	—
Ancistrolepis beringianus Dall	54 range unknown					?	—	?
Ancistrolepis eucosmius Dall	44-57					—	—	
Beringius	48-72						—	—
Buccinum pemphigus major Dall		?43-58?					—	—
Calyptraea	23-56			—	—	—	—	
Musashia (Musashia)		33-35.5		—	—			
Turritella (large) (*T. cooperi* stock)	8-37		—	—	—	—		
Turritella (large) (*Neohaustator*)		? to 46+	—	—	—	—	—	

Taxa suggesting water temperatures no warmer than the cool-temperate zone include (table 5): *Liocyma* cf. *L. fluctuosa* (Gould), *Macoma* cf. *M. moesta moesta* (Deshayes), *M.* cf. *M. moesta alaskana* Dall, ?*Serripes hamiltonensis* (Clark), *Ancistrolepis* aff. *A. beringianus* Dall, ?*Beringius* sp., and *Buccinum* cf. *B. pemphigus major* Dall. Strauch (1968, 1971) reports that large specimens of *Hiatella arctica* (Linnaeus), which occur in the Sitkinak Island beds (pl. 1, fig. 21), reach such large size only in cold water (see Rowland and Hopkins, 1971, and Allison, 1973, for critiques of

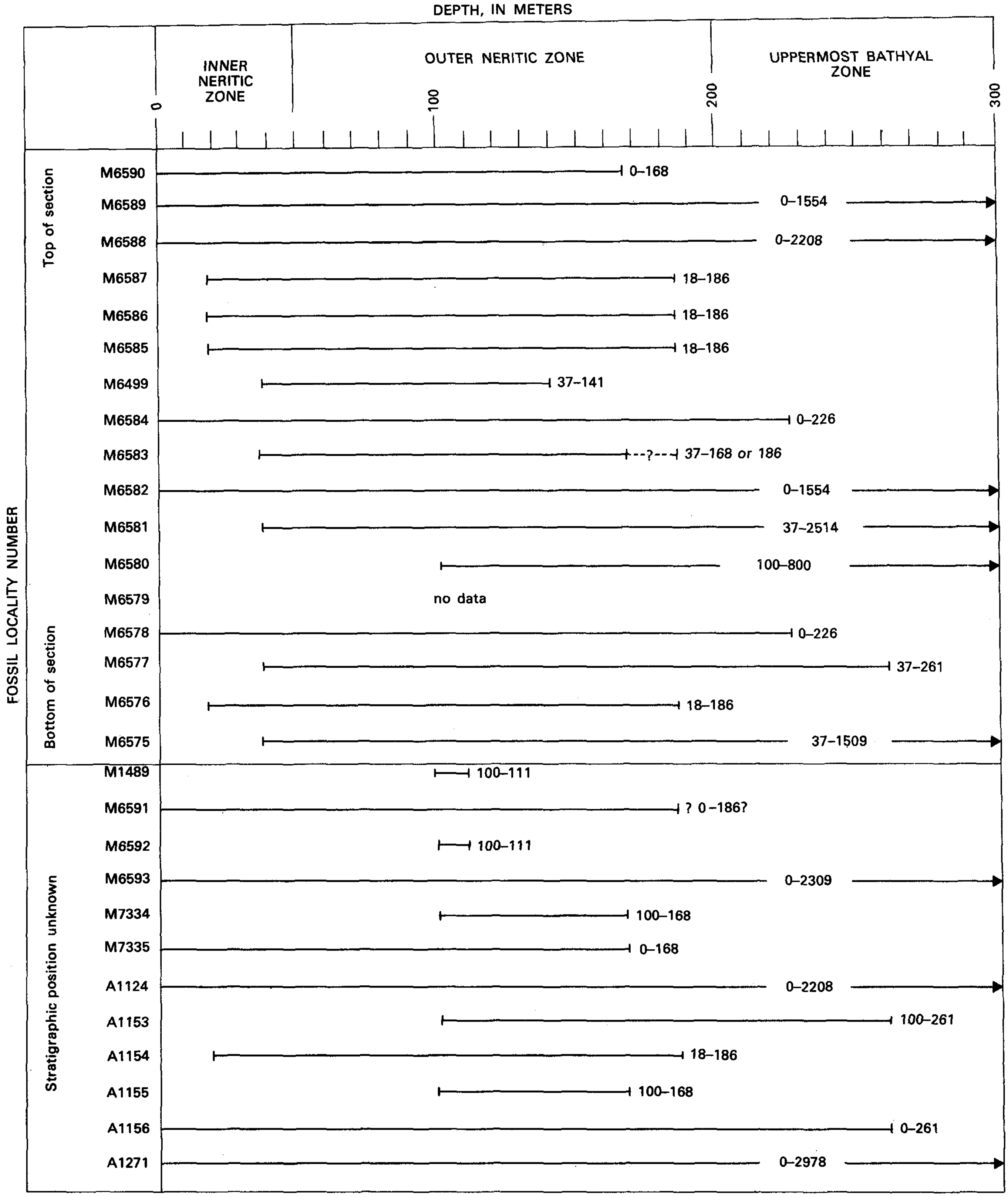

FIGURE 3.—Chart showing inferred paleobathymetry for each fossil locality, based on the fossil mollusks.

Strauch's quantitative techniques). In addition, the presence of *Macoma calcarea* (Gmelin), *Mya grewingki* Makiyama, and *Ancistrolepis* aff. *A. eucosmius* Dall suggest that water temperature was no warmer than that of the mild-temperate climatic zone.

Only one of the Sitkinak Island taxa, *Musashia* (*Musashia*) sp., has living analogs that live in water no cooler than the warm-temperate climatic zone along the present Asiatic coast. Several other Sitkinak Island mollusks that belong to extinct genera or subgenera suggest temperatures no cooler than the mild-temperate climatic zone: *Echinophoria, Priscofusus,* and *Bruclarkia*. Although their exact temperature tolerances are not known, these three taxa are usually found in warmer-water Tertiary faunas at

TABLE 6.—*Occurrences of fossil mollusks in the Narrow Cape Formation, Sitkinak Island*

[In "Zoogeographic Affinity" column, NA = North American, A = Asiatic, E = endemic North Pacific, EPC = endemic, pre-circumboreal, C = cosmopolitan, U = unknown]

Taxa	Zoogeographic affinity	Localities in stratigraphic order (from bottom of section, at left, to top of section, at right)																	Localities with stratigraphic position unknown											
		M6575	M6576	M6577	M6578	M6579	M6580	M6581	M6582	M6583	M6584	M6499	M6585	M6586	M6587	M6588	M6589	M6590	M1489	M6591	M6592	M6593	M7334	M7335	A-1124	A-1153	A-1154	A-1155	A-1156	A-1271
Bivalves:																														
Acila (*Acila*) *gettysburgensis* (Reagan, 1909)	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--
Acila sp. indet	U	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Clinocardium cf. *C. makiyamae* Kamada, 1962	A	--	--	--	×	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
Clinocardium cf. *C. hannibali* Keen, 1954	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	×	--	--	×	--	--	--	--
Clinocardium sp. indet	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Crenella porterensis Weaver, 1912	NA	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyclocardia cf. *C. belogolovensis* (Ilyina, 1963)	A	--	×	--	--	--	×	--	--	--	--	×	--	--	--	--	--	--	×	--	--	--	--	--	--	--	×	×	--	--
Cyclocardia cf. *C. subnipponica* (Nagao, 1928)	A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	×	--	×	--	--	--
Cyclocardia cf. *C. tokunagai* (Yokoyama, 1924)	A	--	--	--	--	--	×	--	×	×	×	×	--	--	--	×	--	--	×	--	×	--	--	--	--	--	--	×	--	--
Cyclocardia cf. *C. wajampolkensis* (Ilyina, 1963)	A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	×	×	--	--
Cyclocardia sp. indet	U	--	--	--	--	--	--	--	×	×	--	×	--	×	--	--	--	×	--	--	--	--	--	--	--	×	×	--	--	--
Hiatella arctica (Linnaeus, 1767)	C	×	×	--	×	--	×	--	×	×	×	×	×	×	--	--	×	--	×	×	×	--	--	×	--	×	×	×	--	×
Liocyma cf. *L. fluctuosa* (Gould, 1841)	EPC	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	×	--	--	--	--
Macoma (*Macoma*) *calcarea* (Gmelin, 1791)	EPC	--	×	--	×	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Macoma (*Macoma*) *incongrua* (von Martens, 1865) of Kanno (1971)	EPC	--	×	--	--	--	--	--	--	×	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Macoma (*Macoma*) cf. *M.* (*M.*) *moesta moesta* (Deshayes, 1845)	EPC	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Macoma (*Macoma*) cf. *M.* (*M.*) *moesta alaskana* Dall, 1900	E	--	×	×	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	×	--
Macoma cf. *M. optiva* (Yokoyama, 1923)	A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--
Macoma twinensis Clark, 1925	NA	--	×	--	--	--	--	--	--	cf.	--	×	×	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--
Macoma sp. indet	U	--	--	--	--	--	--	--	×	×	--	--	×	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	×	--
?*Macoma* sp	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
Mya (?*Arenomya*) *grewingki* Makiyama, 1934	A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	×	×	--	--	--	×	--	--
?*Mya* sp	U	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
Periploma (*Aelga*) *besshoense* (Yokoyama, 1924)	A	×	--	--	×	--	?	--	×	--	--	--	?	--	--	?	--	--	--	--	--	×	--	--	--	--	--	--	--	--
?*Periploma* sp	U	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Pitar (*Katherinella*) *angustifrons* (Conrad, 1849)	NA	--	--	--	--	--	--	--	--	--	--	--	×	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
?*Serripes hamiltonensis* (Clark, 1932)	E	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
Spisula cf. *S. hannibali* (Clark and Arnold, 1923)	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	×	--	--	--	--	--	--	--	--	--
Spisula sp. indet	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
Gastropods:																														
Ancistrolepis aff. *A. beringianus* Dall, 1919	E	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	×	--	--	--	--	--	--	--	--	--
Ancistrolepis aff. *A. eucosmius* (Dall, 1891)	E	--	--	×	--	--	--	--	--	×	--	×	--	--	--	--	--	--	×	--	--	--	--	--	--	×	--	--	--	--
Ancistrolepis sp. "C"	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
Ancistrolepis sp. indet	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
?*Ancistrolepis* sp	U	×	--	--	--	--	--	×	--	--	×	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
?*Beringius* sp	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
Bruclarkia cf. *B. andersoni* (Wiedey, 1928)	NA	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Bruclarkia sp indet	U	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Buccinum aff. *B. kurodai* Kanehara, 1937	A	--	--	--	--	--	--	--	--	--	--	?	--	--	--	--	--	×	--	--	×	--	--	--	×	×	--	--	--	--
Buccinum cf. *B. pemphigus major* Dall, 1919	A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
Buccinum sp	U	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
Calyptraea cf. *C. diegoana* (Conrad, 1855)	NA	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Echinophoria apta (Tegland, 1931)	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
Epitonium (*Nitidiscala*) sp	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Musashia (*Musashia*) sp	A	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	×	--	×	--	×	--	--	×	--	×	--	--
Natica (*Cryptonatica*) *clausa* Broderip and Sowerby, 1829	EPC	--	--	--	--	×	--	--	×	×	--	×	--	--	×	--	×	×	--	×	×	--	--	--	--	--	--	--	--	--
Naticid indet	U	--	×	--	--	--	×	--	×	×	--	--	×	×	--	--	--	--	--	--	--	--	×	--	--	×	--	--	--	--
Neptuneidae indet	U	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Neverita (*Neverita*) *washingtonensis* (Weaver, 1916)	NA	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Oenopota sp. indet	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Parasyrinx sp	U	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
Polinices (*Euspira*) *ramonensis* (Clark, 1918)	NA	--	×	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Polinices (*Euspira*) cf. *P.* (*E.*) *lincolnensis* (Weaver, 1916)	NA	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Priscofusus clarki Kanno, 1971	E	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	×	?	--	--	--	--	--	--	--	--	--	--
Priscofusus aff. *P. stewarti* (Tegland, 1933)	NA	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Turritella (*Hataiella*) cf. *T.* (*H.*) *chichibuensis* Ida, 1952	A	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Turritella (*Hataiella*) sp	U	--	×	--	--	--	--	--	--	×	--	--	×	×	×	--	--	--	×	--	×	--	--	--	--	--	×	×	--	--
Cephalopod:																														
Aturia angustata (Conrad, 1849)	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
Scaphopod:																														
Dentalium (*Coccodentalium*) cf. *D.* (*C.*) *nunomae* Takeda, 1953, of Kanno (1971)	A	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

more southerly latitudes than that of Sitkinak Island. Large turritellids were restricted to warmer waters in most of the Americas during the Cenozoic but extend into the cool-temperate zone in Asia today. The extinct subgenus *Turritella* (*Hataiella*) also occurs in the Yakataga Formation of the northeastern Gulf of Alaska in molluscan assemblages that appear to represent temperatures near the mild-temperate to cool-temperate boundary (Allison, 1978).

Cool-temperate faunal elements in the Sitkinak Island beds appear to us to be much more significant indicators of the marine climate than the occurrence of the warmer-water taxon *Musashia*. Although *Musashia* (*Musashia*) is known today only from regions with outer tropical and warm-temperate surface waters in Asia, it appears to dwell only in deeper, and therefore colder, water. Thus its occurrence in the Sitkinak Island Oligocene fauna may be compatible with inferred cool-temperate surface waters.

The relatively uniform distribution of mollusks throughout the stratigraphic section suggests that water temperatures remained uniform during the deposition of the formation.

The inferred marine climate of the fauna from the Narrow Cape Formation on Sitkinak Island differs significantly from that of the fauna of the type Narrow Cape Formation on Kodiak Island. The presence of *Dosinia, Securella, Anadaara* (*Anadara*), and *Ficus* in the type Narrow Cape Formation implies a warm-temperate or outer-tropical marine climate (Addicott, 1969; Allison, 1978).

PALEOZOOGEOGRAPHIC AFFINITIES

Thirty-nine of the 58 entries on the faunal checklist (table 6) are suitable for evaluation of zoogeographic affinities. Among these 39 taxa, 38 percent have North American affinities, 33 percent have Asiatic affinities, and 26 percent are endemic to the high-latitude North Pacific. Thirteen percent of the Sitkinak Island fauna (included above in the endemics) is composed of "pre-circumboreal" taxa (Allison, 1978); these species apparently gave rise to taxa that later passed through Bering Strait to the Arctic Ocean, where some achieved circumboreal distribution. *Hiatella arctica* (Linnaeus, 1767), a cosmopolitan bivalve that constitutes 3 percent of the fauna, is the most abundant species in the collections. The zoogeographic affinities of each taxon are given in table 6.

The co-occurrence in the Sitkinak Island strata of molluscan taxa from these three zoogeographically distinct areas greatly enhances the potential of this fauna for making chronostratigraphic correlations along the North Pacific margin.

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INDEX

[Italic page numbers indicate major references]

PLATES 1–3

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PLATE 1

All figured specimens are from the Narrow Cape Formation, Sitkinak Island

(All figures X1, unless noted otherwise)

FIGURES

1. *Acila* (*Acila*) *gettysburgensis* (Reagan, 1909). Univ. Alaska UA2513, UA loc. A–1156. Length 17.3 mm, height 12.5 mm (X2).
2. *Clinocardium* cf. *C. makiyamae* Kamada, 1962. USNM 265810, USGS loc. M6578. Length 37.5 mm, height 33.3 mm.

3, 4. *Clinocardium* cf. *C. hannibali* Keen, 1954. USNM 265811, USGS loc. M6592. Length 30.8 mm, height 28.6 mm.

5, 6. *Crenella porterenis* Weaver, 1912. USNM 265826, USGS loc. M6585. Length 11.9 mm, height 14.9 mm.

7, 8. *Cyclocardia* cf. *C. belogolovensis* (Ilyina, 1963). USNM 265812, USGS loc. M6499. Length 29.5 mm, height 30.3 mm.

9. *Cyclocardia* cf. *C. belogolovenis* (Ilyina, 1963). Univ. Alaska UA2514, UA loc. A-1155. Length 28.1mm, height 30.8 mm.

10. *Cyclocardia* cf. *C. subnipponica* (Nagao, 1928). USNM 265813, USGS loc. M1489. Length 34.7 mm, height 28.2 mm.

11, 13. *Cyclocardia* cf. *C. tokunagai* (Yokoyama, 1924). USNM 265815, USGS loc. M6499. Length 21.7 mm, height 18.8 mm.

12. *Cyclocardia* cf. *C. tokunagai* (Yokoyama, 1924). USNM 265814, USGS loc. M6499. Length 22.9 mm, height 22.5 mm.

14, 15. *Cyclocardia* cf. *C. tokunagai* (Yokoyama, 1924). Univ. Alaska UA2516, UA loc. A–1155. Length 24.7 mm, height 21.4 mm.

16, 17. *Cyclocardia* cf. *C wajampolkensis* (Ilyina, 1963). USNM 265816, USGS loc. M1489. Length 25.7 mm, height 20.0 mm.

18. *Cyclocardia* cf. *C. wajampolkensis* (Ilyina, 1963). Univ. Alaska UA2517, UA loc. A-1155. Length 22.5 mm, height 23.0 mm.

19, 20. *Cyclocardia* cf. *C. wajampolkensis* (Ilyina, 1963). Univ. Alaska UA2515, UA loc. A–1155. Length 29.6 mm, height 25.9 mm.

21. *Hiatella arctica* (Linnaeus, 1767). USNM 265817, USGS loc. M1489. Length 42.4 mm, height 20.3 mm.

22, 23. *Hiatella arctica* (Linneaus, 1767). USNM 265818, USGS loc. M6499. Length 26.0 mm, height 13.2 mm.

24, 25. *Liocyma* cf. *L. fluctuosa* (Gould, 1841). USNM 265819, USGS loc. M6575. Length 11.0 mm, height 9.mm (X1½).

26. *Macoma (Macoma) incongrua* (von Martens, 1865) of Kanno (1971). USNM 265820, USGS loc. M6499. Length 20.0 mm, height 17.1 mm.

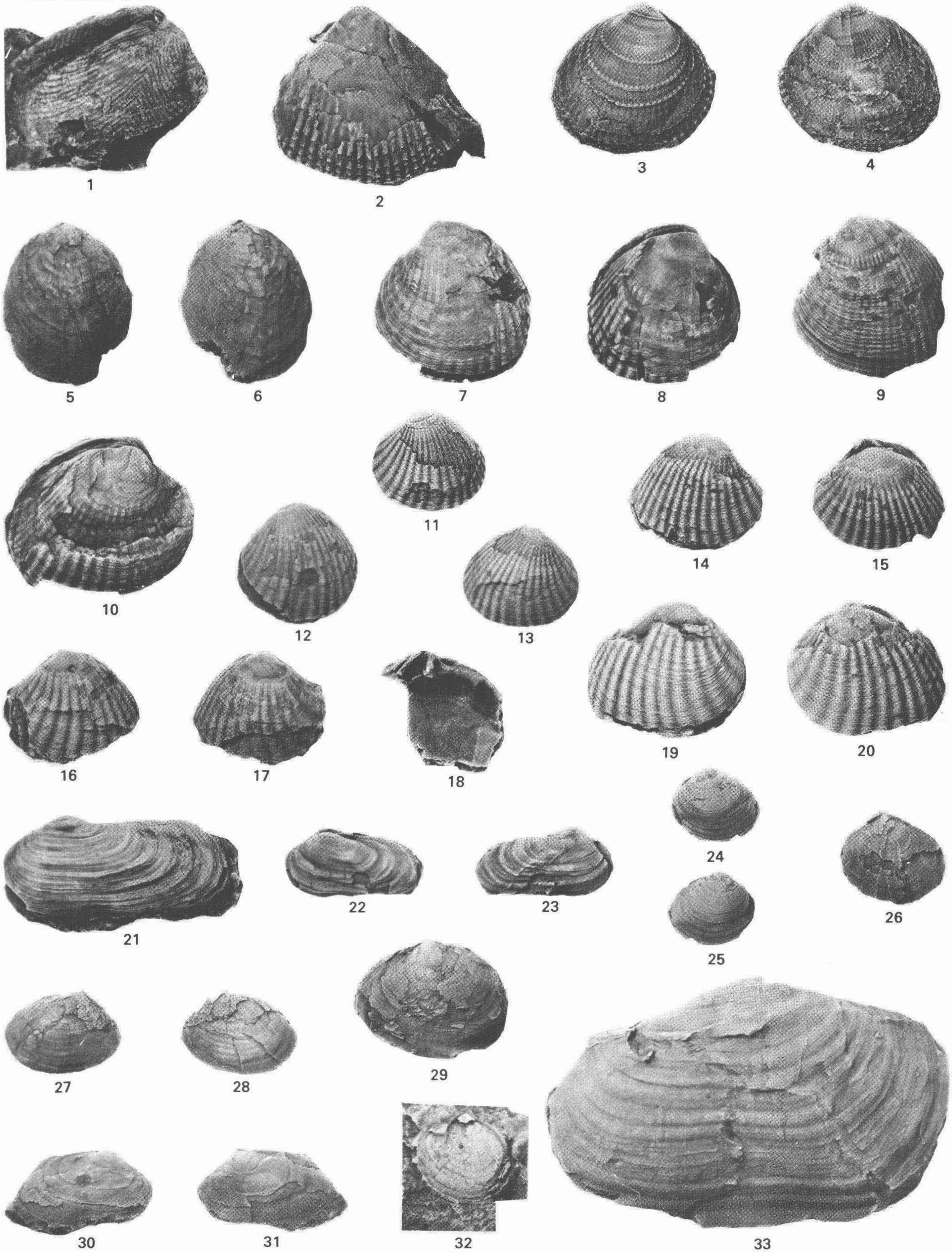
27, 28. *Macoma (Macoma)* cf. *M.* (*M.*) *moesta moesta* (Deshayes, 1854). USNM 265821, USGS loc. M6578. Length 20.7 mm, height 15.2 mm.

29. *Macoma twinensis* Clark, 1925. USNM 265824, USGS loc. M6585. Length 28.7 mm, height 22.3 mm.

30, 31. *Macoma* (*Macoma*) cf. *M.* (*M.*) *moesta alaskana* Dall, 1900. USNM 265823, USGS loc. M6576. Length 18.5 mm, height 10.3 mm (X1½).

32. *Macoma* cf. *M. optiva* (Yokoyama, 1923). Univ. Alaska UA2518, UA loc. A–1156. Length 17.0 mm, height 15.9 mm.

33. *Mya* (?*Arenomya*) *grewingki* Makiyama, 1934. USNM 265850, USGS loc. M7334. Length 75.5 mm, height 48.7 mm.



ACILA, CLINOCARDIUM, CRENELLA, CYCLOCARDIA, HIATELLA, LIOCYMA, MACOMA, MYA

PLATE 2

All figured specimens are from the Narrow Cape Formation, Sitkinak Island

(All figures X1, unless noted otherwise)

FIGURES

1. *Periploma (Aelga) besshoense* (Yokoyama, 1924). USNM 265828, USGS loc. M6575. Length 51.6 mm, height 42.3 mm.
2. *Periploma (Aelga) besshoense* (Yokoyama, 1924). USNM 265825, USGS loc. M6582. Length 31.3 mm, height 21.8 mm.

3, 4. *Pitar (Katherinella) angustifrons* (Conrad, 1849). USNM 265829, USGS loc. M6585. Length 40.3 mm, height 34.4 mm.

5. ?*Serripes hamiltonensis* (Clark, 1932). USNM 265831, USGS loc. M1489. Length 34.0 mm, height 31.8 mm.

6, 7. *Ancistrolepis* aff. *A. beringianus* Dall, 1919. USNM 265833, USGS loc. M1489. Height 41.2 mm, diameter 26.0 mm.

8. *Spisula* cf. *S. hannibali* (Clark and Arnold, 1923). USNM 265827, USGS loc. M1489. Length 69.3 mm, height 58.4 mm.
9. *Ancistrolepis* sp. "C". USNM 265835, USGS loc. M6592. Height 38. 5mm, diameter 24.3 mm.
10. *Ancistrolepis* aff. *A. eucosmius* (Dall, 1891). USNM 265834, USGS loc. M1489. Height 28.3 mm, diameter 18.6 mm.

11, 12. *Bruclarkia* cf. *B. andersoni* (Wiedey, 1928). USNM 265836, USGS loc. M6499. Height 40.7 mm, diameter 23.2 mm.

13. ? *Beringius* sp. USNM 265830, USGS loc. M1489. Height 38.1 mm, diameter 19.6 mm.

14, 15. *Buccinum* cf. *B. pemphigus major* Dall, 1919. USNM 265839, USGS loc. M6592. Height 25.5 mm, diameter 20.3 mm.

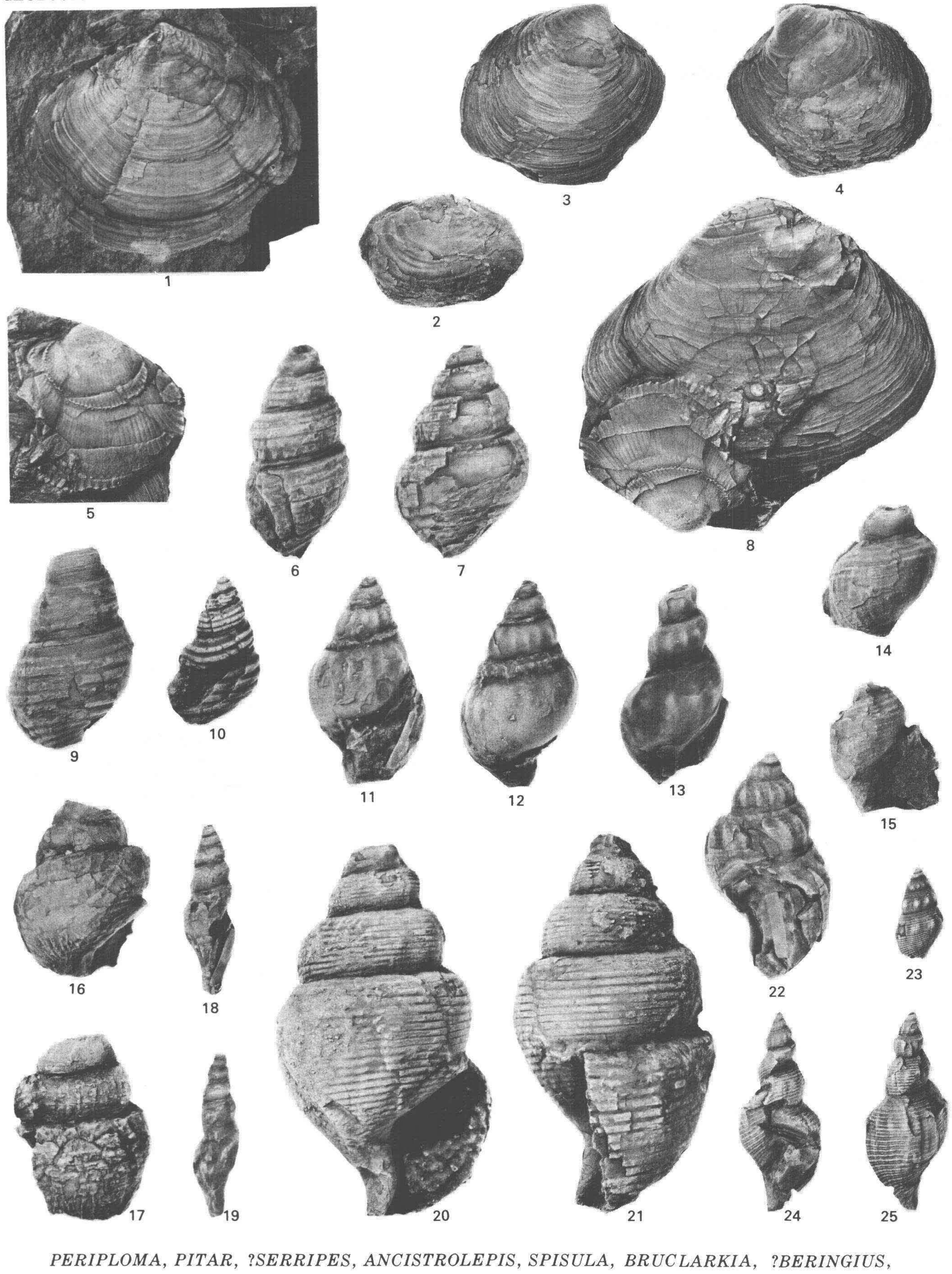
16, 17. *Buccinum* aff. *B. kurodai* Kanehara, 1937. USNM 265837, USGS loc. M6592. Height 35.0 mm, diameter 26.0 mm.

18, 19. *Parasyrinx* sp. USNM 265843, USGS loc. M6499. Height 33.0 mm, diameter 9.5 mm.

20, 21. *Buccinum* aff. *B. kurodai* Kanehara, 1937. Univ. Alaska UA2510, UA loc. A-1153. Height 74.3 mm, diameter 42.3 mm.

22. *Buccinum* sp. USNM 265838, USGS loc. M1489. Height 43.2 mm, diameter 24.3 mm.
23. *Priscofusus* aff. *P. stewarti* (Tegland, 1933). USNM 265840, USGS loc. M6585. Height 17.4 mm, diameter 9.5 mm.

24, 25. *Priscofusus clarki* Kanno, 1971. USNM 265844, USGS loc. M1489. Height 39.0 mm, diameter 16.0 mm.



PERIPLOMA, PITAR, ?SERRIPES, ANCISTROLEPIS, SPISULA, BRUCLARKIA, ?BERINGIUS, BUCCINUM, PARASYRINX, PRISCOFUSUS

PLATE 3

All figured specimens are from the Narrow Cape Formation, Sitkinak Island

(All figures X1, unless noted otherwise)

FIGURES

1. *Echinophoria apta* (Tegland, 1931). USNM 265842, USGS loc. M1489. Height 49.0 mm, diameter 43.0 mm.

2, 3. *Calyptraea* cf. *C. diegoana* (Conrad, 1855). USNM 265848, USGS loc. M6499. Length 14.7 mm, height 4.4 mm, width 11. 1 mm (X2).

4. *Turritella* (*Hataiella*) cf. *T.* (*H.*) *chichibuensis* Ida, 1951. USNM 265832, USGS loc. M6499. Height 32.8 mm, diameter 10.7 mm.

5, 6, 7. *Epitonium* (*Nitidiscala*) sp. USNM 265849, USGS loc. M7334. Height 22.0 mm, diameter 11.8 mm (X1½).

8, 14. *Musashia,* (*Musashia*) sp. Univ. Alaska UA2511, UA loc. A-1155. Height 85.0 mm, diameter 50.1 mm.

9. *Natica* (*Cryptonatica*) *clausa* Broderip and Sowerby, 1829. USNM 265853, USGS loc. M6592. Height 31.9 mm, diameter 28.0 mm.

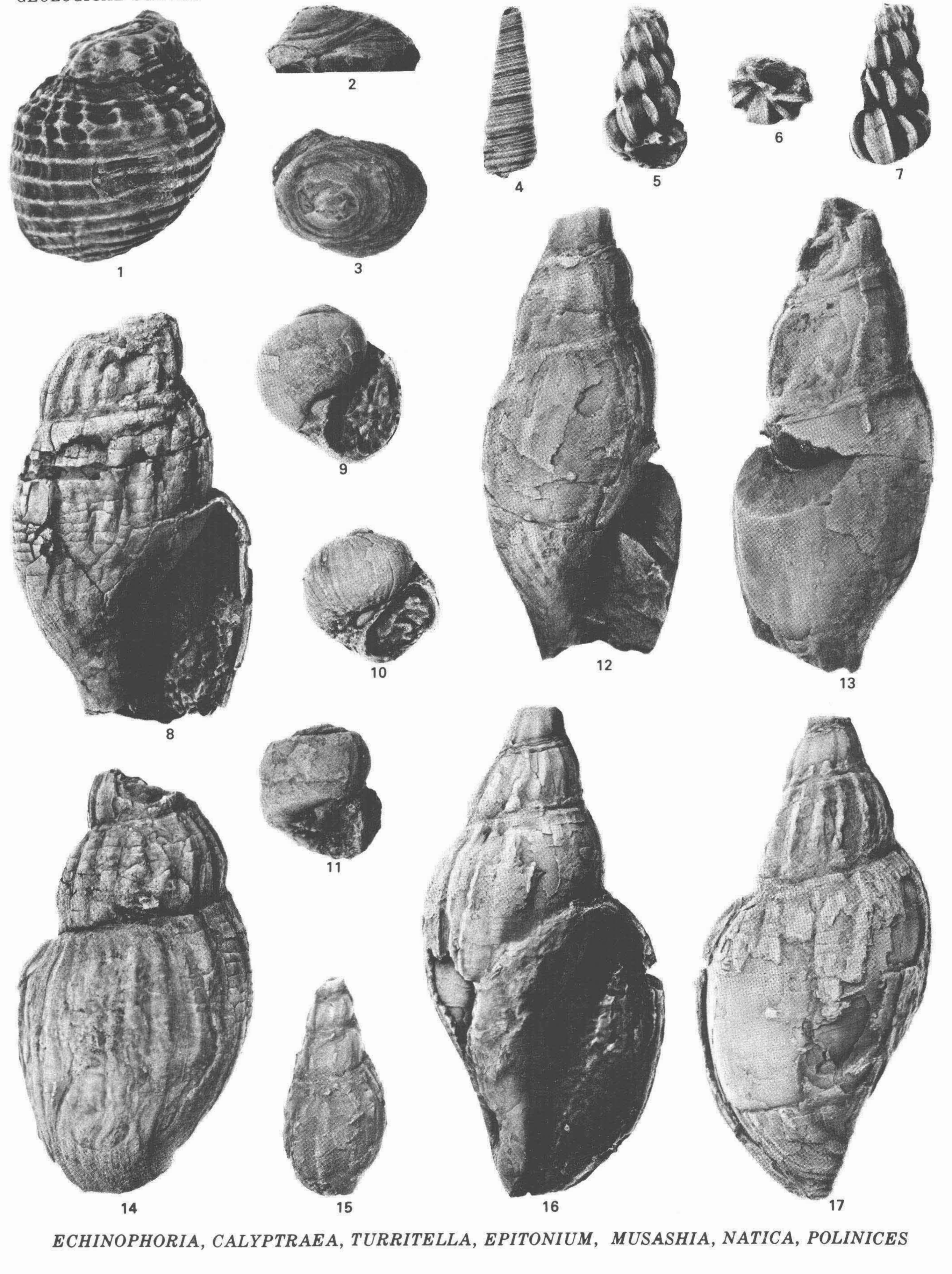
10. *Natica* (*Cryptonatica*) *clausa* Broderip and Sowerby, 1829. USNM 265846, USGS loc. M6587. Height 26.3 mm, diameter 26.6 mm.

11. *Polinices* (*Euspira*) *ramonensis* (Clark, 1918). USNM 265847, USGS loc. M6585. Height 13.6 mm, diameter 12.8 mm (X2).

12, 13. *Musashia* (*Musashia*) sp. USNM 265845, USGS loc. M6592. Height 93.3 mm, diameter 38.4 mm.

15. *Musashia* (*Musashia*) sp. USNM 265841, USGS loc. M6580. Height 43.5 mm, diameter 20.5 mm.

16, 17. *Musashia* (*Musashia*) sp. Univ. Alaska UA2512, UA loc. A-1153. Height 97.3 mm, diameter 51.0 mm.



ECHINOPHORIA, CALYPTRAEA, TURRITELLA, EPITONIUM, MUSASHIA, NATICA, POLINICES