# Shorter Contributions to Paleontology, 1979

Western Hemisphere Cretaceous Itieriidae Gastropods

*By* HEINZ A. KOLLMANN *and* NORMAN F. SOHL

Ostracode Biostratigraphy of Pliocene and Pleistocene Deposits of the Cape Fear Arch Region, North and South Carolina

*By* THOMAS M. CRONIN *and* JOSEPH E. HAZEL

Miocene Mollusks of the Topsy Formation, Lituya District, Gulf of Alaska Tertiary Province, Alaska

*By* LOUIE MARINCOVICH, JR.

Variability in *Trithyrodinium* Drugg 1967

*By* FRED E. MAY *and* DON G. BENSON, JR.

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[Letters designate the chapters]


(A) Western Hemisphere Cretaceous Itieriidae Gastropods, by Heinz A. Kollmann and Norman F. Sohl

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(D) Variability in *Trithyrodinium* Drugg 1967, by Fred E. May and Don G. Benson, Jr.

# CONVERSION FACTORS

| Metric unit | | Inch-Pound equivalent |
|---|---|---|
| **Length** | | |
| millimeter (mm) | = 0.03937 | inch (in) |
| meter (m) | = 3.28 | feet (ft) |
| kilometer (km) | = .62 | mile (mi) |
| **Area** | | |
| square meter ($m^2$) | = 10.76 | square feet ($ft^2$) |
| square kilometer ($km^2$) | = .386 | square mile ($mi^2$) |
| hectare (ha) | = 2.47 | acres |
| **Volume** | | |
| cubic centimeter ($cm^3$) | = 0.061 | cubic inch ($in^3$) |
| liter (L) | = 61.03 | cubic inches |
| cubic meter ($m^3$) | = 35.31 | cubic feet ($ft^3$) |
| cubic meter | = .00081 | acre-foot (acre-ft) |
| cubic hectometer ($hm^3$) | =810.7 | acre-feet |
| liter | = 2.113 | pints (pt) |
| liter | = 1.06 | quarts (qt) |
| liter | = .26 | gallon (gal) |
| cubic meter | = .00026 | million gallons (Mgal or $10^6$ gal) |
| cubic meter | = 6.290 | barrels (bbl) (1 bbl=42 gal) |
| **Weight** | | |
| gram (g) | = 0.035 | ounce, avoirdupois (oz avdp) |
| gram | = .0022 | pound, avoirdupois (lb avdp) |
| metric tons (t) | = 1.102 | tons, short (2,000 lb) |
| metric tons | = 0.9842 | ton, long (2,240 lb) |
| **Specific combinations** | | |
| kilogram per square centimeter ($kg/cm^2$) | = 0.96 | atmosphere (atm) |
| kilogram per square centimeter | = .98 | bar (0.9869 atm) |
| cubic meter per second ($m^3/s$) | = 35.3 | cubic feet per second ($ft^3/s$) |

| Metric unit | | Inch-Pound equivalent |
|---|---|---|
| **Specific combinations—Continued** | | |
| liter per second (L/s) | = .0353 | cubic foot per second |
| cubic meter per second per square kilometer [($m^3/s$)/$km^2$] | = 91.47 | cubic feet per second per square mile [($ft^3/s$)/$mi^2$] |
| meter per day (m/d) | = 3.28 | feet per day (hydraulic conductivity) (ft/d) |
| meter per kilometer (m/km) | = 5.28 | feet per mile (ft/mi) |
| kilometer per hour (km/h) | = .9113 | foot per second (ft/s) |
| meter per second (m/s) | = 3.28 | feet per second |
| meter squared per day ($m^2/d$) | = 10.764 | feet squared per day ($ft^2/d$) (transmissivity) |
| cubic meter per second ($m^3/s$) | = 22.826 | million gallons per day (Mgal/d) |
| cubic meter per minute ($m^3/min$) | =264.2 | gallons per minute (gal/min) |
| liter per second (L/s) | = 15.85 | gallons per minute |
| liter per second per meter [(L/s)/m] | = 4.83 | gallons per minute per foot [(gal/min)/ft] |
| kilometer per hour (km/h) | = .62 | mile per hour (mi/h) |
| meter per second (m/s) | = 2.237 | miles per hour |
| gram per cubic centimeter ($g/cm^3$) | = 62.43 | pounds per cubic foot ($lb/ft^3$) |
| gram per square centimeter ($g/cm^2$) | = 2.048 | pounds per square foot ($lb/ft^2$) |
| gram per square centimeter | = .0142 | pound per square inch ($lb/in^2$) |
| **Temperature** | | |
| degree Celsius (°C) | = 1.8 | degrees Fahrenheit (°F) |
| degrees Celsius (temperature) | =[(1.8×°C)+32] | degrees Fahrenheit |

# Miocene Mollusks of the Topsy Formation, Lituya District, Gulf of Alaska Tertiary Province, Alaska

*By* LOUIE MARINCOVICH, JR.

SHORTER CONTRIBUTIONS TO PALEONTOLOGY, 1979

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# MIOCENE MOLLUSKS OF THE TOPSY FORMATION, LITUYA DISTRICT, GULF OF ALASKA TERTIARY PROVINCE, ALASKA

By LOUIE MARINCOVICH, JR.

ABSTRACT

The Topsy Formation in the Lituya district of the Gulf of Alaska Tertiary Province contains a molluscan fauna of Newportian age (late early Miocene to early middle Miocene) that correlates with similar faunas in the Pacific Northwest and in the lower part of the Yakataga Formation at Cape Yakataga, in the nearby Yakataga district. Topsy mollusks with living representatives or homologues suggest deposition in cool-temperature water at inner sublittoral depths of about 20 to 50 m.

## INTRODUCTION

Sedimentary rocks of the Topsy Formation occur in the southeastern part of the Gulf of Alaska Tertiary Province (fig. 1), an area which extends about 600 km along the arcuate coast of the eastern Gulf of Alaska from the Katalla district in the west to the Lituya district in the east (Plafker, 1967). In this province, the Poul Creek and Yakataga Formations are the principal marine sedimentary units and together consist of upper Eocene to Holocene deposits with an aggregate thickness of about 6,100 to 7,600 m (Plafker, 1971). The Yakataga Formation alone consists of about 5,000 m of lower Miocene to Holocene marine deposits that preserve a continuous record of localized glacial conditions in this area of the North Pacific (Plafker and Addicott, 1976). The Lituya district (fig. 1), centered on Lituya Bay, contains the southeasternmost outcrops of Tertiary marine sedimentary rocks in the Gulf of Alaska region and is the only area in which the Topsy Formation occurs.

The Topsy Formation consists of marine siltstone and sandstone that crop out between Lituya Bay and Icy Point (fig. 1) and that extensively underlie foothills of the Fairweather Range for about 40 km adjacent to the Gulf of Alaska shoreline. Outcrops are generally small and isolated owing to cover by dense vegetation and glaciers. Persistent rain and fog in summer also limit access to Topsy exposures. Because discontinuous outcrops and structurally complex geology in this area preclude reliable lithologic correlations with other formations in this region and because no well-preserved, age-diagnostic fossils have been reported before from these strata, the age and depositional environment of the Topsy have been subjects for speculation. Molluscan fossils collected in 1975 now shed light on the age and depositional environment of the Topsy and suggest correlations with sedimentary rocks elsewhere in the Gulf of Alaska Tertiary Province and in the Pacific Northwest (Oregon and Washington). Benthic foraminifers (Rau and others, 1977) or other microfossils have not been found in Topsy strata.

The outcrop extent of the Topsy Formation shown in figure 1 is modified from that previously published (Plafker, 1967). Strata adjacent to the coastline immediately north of Icy Point, which were formerly assigned to the Yakataga Formation, are now included in the Topsy Formation, on the basis of 1975 fieldwork done by George Plafker and Travis Hudson. The Topsy does not occur on Cenotaph Island in Lituya Bay (fig. 1), so sand dollar echinoids reported from the Topsy by Wagner (1974) should be attributed to the Yakataga Formation.

Sedimentary rocks now included in the Topsy Formation were first discriminated from those of the Yakataga Formation by Miller (1953, 1961), who considered them to be, in part, stratigraphically equivalent to volcanic rocks on Cenotaph Island and on the southern margin of Lituya Bay (fig. 1). Sparse and poorly preserved invertebrates in these rocks indicated a Tertiary age, and Miller (1961) thought that they were likely of Miocene age because of their conformable relation with overlying

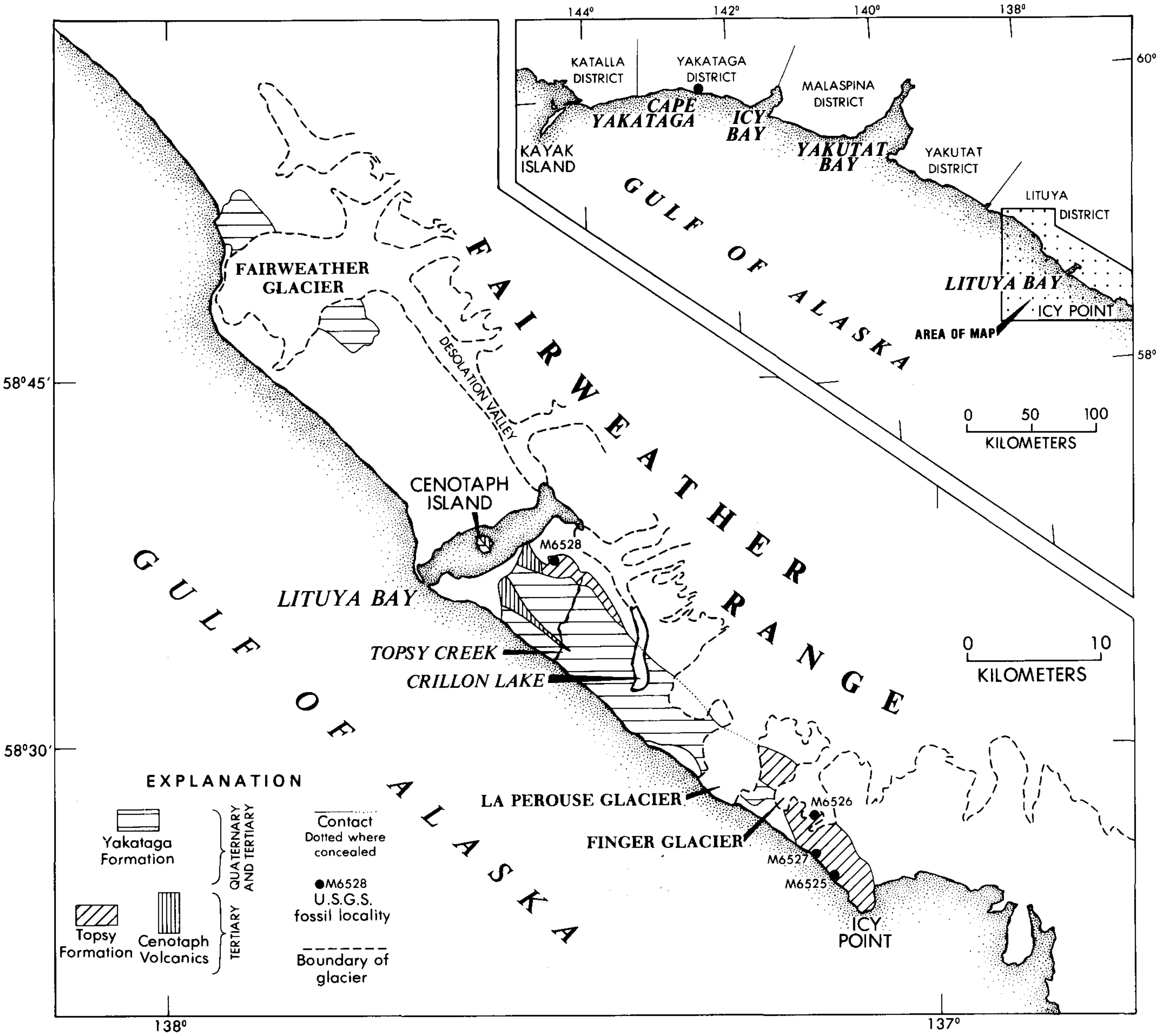



FIGURE 1.—Distribution of the Topsy Formation and other Cenozoic marine sedimentary and volcanic rocks in the Lituya district, Gulf of Alaska Tertiary Province (inset). Geology modified from Miller (1961) and Plafker (1967).

beds thought to contain late Miocene fossils. A tentative Miocene age was also assigned to these rocks by MacNeil and others (1961). Plafker (1967) named the Topsy Formation and Cenotaph Volcanics, noting that the Topsy consists of about 365 m of hard calcareous siltstone and sandstone that intertongue with and, in part, conformably overlie the Cenotaph Volcanics. Plafker (1967) did not specify an age for the Topsy strata but assigned the Cenotaph Volcanics an age of "post-early Oligocene(?) to pre-middle Miocene," thereby implying an age of about late Oligocene to early Miocene or younger for the Topsy. Later, Plafker (1971) considered most of the Topsy Formation to be Miocene, possibly containing beds as old as middle Oligocene and as young as middle Miocene. Notes on the molluscan fauna by Marincovich (1976a, b), from which the present report is expanded, suggested an early or middle Miocene age for the Topsy Formation.

## ACKNOWLEDGMENTS

Helpful discussions of molluscan taxonomy and geologic field relations were held with Warren O.

Addicott and George Plafker, U.S. Geological Survey. Richard C. Allison, University of Alaska, critically read this work and provided valuable unpublished information on Alaskan Tertiary mollusks. Catherine Ariey, Atlantic Richfield Co., also provided useful data on molluscan biostratigraphy at Cape Yakataga, based on her unpublished thesis work. Kenji Sakamoto, U.S. Geological Survey, photographed the specimens.

## FAUNAL COMPOSITION

No well-preserved molluscan taxa have been reported previously from the Topsy Formation. The present collections, made in 1975, consist of 20 taxa, consisting of 8 gastropods and 12 bivalves. Four additional bivalves tentatively assigned generic or specific names are too poorly preserved for confident identification. The preponderance of bivalve taxa and individuals over gastropods (table 1) is usual for Gulf of Alaska Cenozoic faunas, including modern ones. The Topsy genera are each represented by a single species except for *Macoma, Neptunea,* and *Natica.*

Seven of the bivalve taxa are represented by articulated and closed specimens, suggesting little or no post mortem transport of these faunal elements. However, the known Topsy molluscan taxa probably represent a small fraction of the original fauna. The absence of fossils from most outcrops of the Topsy contrasts sharply with the known abundance of faunas from coeval strata of the Yakataga Formation. This absence suggests either an original low-diversity fauna or post mortem destruction of fossils by wave and current action. The paucity of observed fossils also could be an artifact of collecting, considering the difficulties imposed by topography, and weather in the Lituya district.

TABLE 1.—*Fossils of the Topsy Formation*

[Number of specimens given for each entry; A, articulated bivalve; F, fragment]

| Species | Localities | | | |
|---|---|---|---|---|
| | M6528 | M6527 | M6526 | M6525 |
| Gastropods | | | | |
| *Calliostoma* sp. | 1 | --- | --- | --- |
| Turbinidae | 1F | --- | --- | --- |
| *Natica (Cryptonatica) clausa* Broderip and Sowerby | 1 | --- | --- | --- |
| *Natica (Cryptonatica) oregonensis* (Conrad) | --- | --- | --- | 1 |
| *Fusitriton oregonensis* (Redfield) | 1 | --- | --- | --- |
| *?Neptunea (Neptunea) plafkeri* Kanno | --- | --- | --- | 1F |
| *Neptunea (Sulcosipho)* cf. *N. (S.) tabulata* (Baird) | --- | --- | --- | 1F |
| *?Colus* sp. | 1F | --- | --- | 1F |
| Bivalves | | | | |
| *Acila (Truncacila) taliaferroi* Clark | 1 | --- | --- | 1,4A |
| *Acila (Truncacila)* sp. | --- | --- | 2,1A | 7,3A |
| *Nuculana (?Saccella)* sp. | 1 | --- | --- | --- |
| *?Chlamys* sp. | 1F | --- | --- | --- |
| *Lucinoma acutilineata* (Conrad) | 1 | 14A,3F | --- | --- |
| *Thyasira* cf. *T. disjuncta* (Gabb) | --- | --- | --- | 1F |
| *Macoma albaria* (Conrad) | --- | --- | --- | 1A |
| *Macoma* aff. *M. albaria* (Conrad) | 1 | --- | --- | --- |
| *Macoma incongrua* (von Martens) | 2 | --- | --- | --- |
| *Macoma* cf. *M. incongrua* (von Martens) | 1A | --- | --- | --- |
| *Macoma* aff. *M. twinensis* Clark | 1,4A | --- | --- | --- |
| *Spisula addicotti* Kanno | 1 | --- | --- | --- |
| *?Spisula* sp. | 1F | --- | --- | --- |
| *Periploma (Aelga) besshoense* (Yokoyama) | 1 | --- | --- | --- |
| *?Periploma* sp. | 1A,2F | --- | --- | --- |
| *Mya* sp. | --- | --- | 1F | --- |
| Sand dóllar echinoid | 1F | --- | --- | --- |
| Fish vertebra | 1F | --- | --- | --- |

## AGE AND CORRELATION

Some of the Topsy mollusks are known in Tertiary strata of the Pacific Northwest. The overlapping stratigraphic ranges of these species (fig. 2), as they are known in the Pacific Northwest, place the Topsy fauna within the Newportian Stage of Addicott

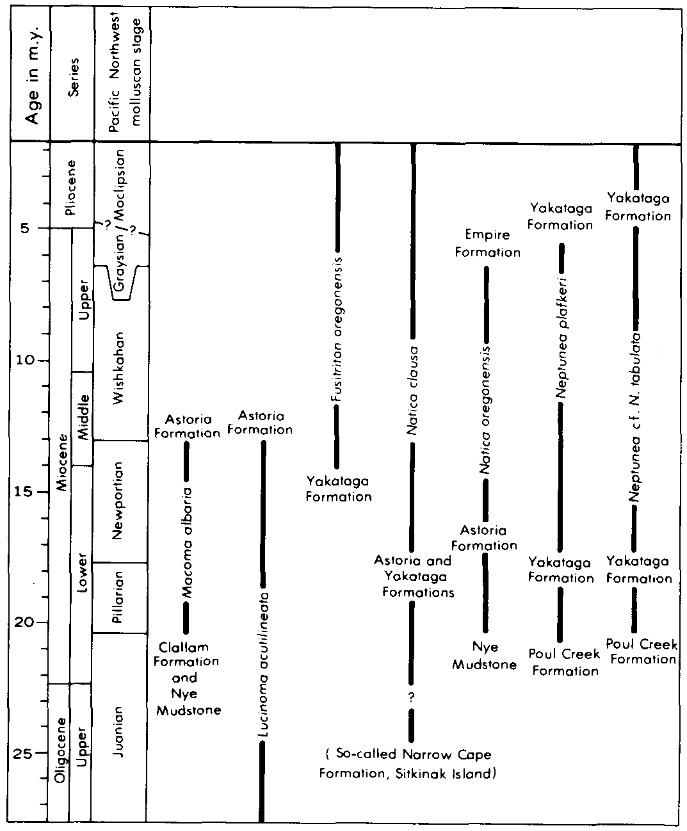



FIGURE 2.—Known stratigraphic ranges in Pacific Northwest and Gulf of Alaska Tertiary Provinces of selected Topsy Formation mollusks. Occurrences in Alaskan formations (Pouls Creek, Yakataga, and so-called Narrow Cape Formation) are based on literature reports and unpublished studies of C. A. Ariey and R. C. Allison. Formations of first and last occurrences as well as other relevant stratigraphic occurrences are shown. Pacific Northwest molluscan stages from Addicott (1976b), as modified by Allison (1976). The Topsy Formation is inferred to be of Newportian age.

(1976b). When first proposed, the Newportian Stage was assigned exclusively to the middle Miocene, encompassing the whole of that subseries (Addicott, 1976b). Subsequently, Allison (1976) reinterpreted the stage boundaries by relying more heavily on Berggren and Van Couvering's (1974) planktonic microfossil correlations with European Cenozoic strata. He concluded that the Newportian Stage is of late early Miocene and early middle Miocene age (fig. 2). In terms of California benthic foraminiferal stages, this interval includes the upper half of the Saucesian Stage and the overlying Relizian and Luisian Stages (Allison, 1976). Allison's interpretation of the Newportian Stage is used here in assessing the age of the Topsy molluscan fauna. However, the work of relating Alaskan Cenozoic faunas to biostratigraphic schemes proposed for other regions is still in its early stages, and major changes in the inferred age relations of Alaskan faunas may yet occur.

Ironically, because Cenozoic molluscan faunal composition and biostratigraphy in the Gulf of Alaska region are not yet well known, correlations from the Topsy fauna to other Gulf of Alaska faunas are more speculative than are those to Tertiary faunas in the Pacific Northwest. However, the basal part the Yakataga Formation at Cape Yakataga (fig. 1) bears a molluscan fauna of Newportian age (Kanno, 1971; Plafker and Addicott, 1976; Allison, 1976; and Ariey 1978a, b) and thus is approximately coeval with the Topsy Formation. Both *Neptunea* species in the Topsy, *N. plafkeri* (questionably identified) and *N.* cf. *N. tabulata* of Kanno (1971), have previously been reported only in the Yakataga Formation, at several localities (Nelson, 1974). Their earliest reported occurrences are in the lower part of the Yakataga Formation at Cape Yakataga (Clark, 1932; Kanno, 1971; Nelson, 1974), although they evidently occur in the underlying Poul Creek Formation at that location (Ariey, 1978a). The earliest occurrence of *Fusitriton oregonensis* in the northeast Pacific, or what may be a closely allied or new species (Smith, 1970), is also at Cape Yakataga. Smith (1970, p. 492) reported specimens of "*Fusitriton* sp. ? aff. *F. oregonensis*" from either the Poul Creek or Yakataga Formations. More recent collecting of the Cape Yakataga section (Ariey, 1978a) showed *F. oregonensis* missing in the upper part of the Poul Creek Formation but present in the stratigraphically highest Newportian fauna (early middle Miocene) and in the immediately overlying Wishkahan fauna (late middle Miocene to late Miocene) of the basal Yakataga Formation (fig. 2).

*Lucinoma acutilineata* and *Macoma albaria* have their highest stratigraphic occurrences in the Astoria Formation of southwestern Washington and of the Newport embayment of coastal Oregon, in faunas of Newportian age (Addicott, 1976b). *Macoma albaria* is reported in faunas no older than Pillarian in the Clallam Formation in northwestern Washington and the Nye Mudstone of the Newport area in Oregon (Moore, 1963; Addicott, 1976a). In the Pacific Northwest, *Natica clausa* first occurs in Newportian faunas of the Astoria Formation. Its reported first occurrence in Alaska is in lower Miocene strata in the upper Poul Creek Formation (Marincovich, 1977), and it has since been recognized in the Juanian fauna of the so-called Narrow Cape Formation on Sitkinak Island in the western Gulf of Alaska (R. C. Allison, oral commun., 1977). *Natica oregonensis* was formerly known only in the Pacific Northwest, where it ranges from the Pillarian (Nye Mudstone) to Wishkahan (Empire Formation); it has been questionably identified in the Newportian fauna of the Narrow Cape Formation on Kodiak Island in the western Gulf of Alaska (R. C. Allison, oral commun., 1977).

The single Topsy species with Asian affinities is *Periploma besshoense*, which is known in Eocene or Oligocene to upper Miocene strata in Japan (Kanno, 1971; Hatai and Nisiyama, 1952). This species has a variable shell outline in Japanese faunas, and Kanno (1971) noted the presence of two distinct morphologic forms of *P. besshoense* in strata at Cape Yakataga. Kanno (1971) collected the typical Japanese form, nearly circular in outline, in the upper part of the Poul Creek Formation and a more elongate and somewhat rostate form in the overlying Yakataga Formation. The elongate form in the lower part of the Yakataga Formation is also present in the Topsy (fig. 3), so if Kanno's (1971) tentative conclusions are correct, this form of *P. besshoense* would strengthen correlation of the Topsy Formation with the lower Yakataga Formation at Cape Yakataga.

In summary, the Topsy molluscan fauna correlates with Newportian faunas at Cape Yakataga and in Washington and Oregon. Further, the occurrence together of *Fusitriton oregonensis*, *Macoma albaria*, and *Lucinoma acutilineata* suggests probable assignment of the Topsy to the upper Newportian Stage of latest early Miocene and early middle Miocene age. This interval is approximately equivalent to the Relizian and Saucesian Stages of California benthic foraminiferal terminology, based on interpretations of Pacific Northwest molluscan stages by Allison (1976).

## PALEOECOLOGY

### WATER DEPTH

The Topsy molluscan fauna represents a shallow, cool-temperature marine environment. The deep-burrowing bivalve *Mya* lives between the intertidal zone and 50 m depth in the northeastern Pacific (Keen and Coan, 1974), and large individuals such as the Topsy specimen (52 mm in height, incomplete) dwell under optimal growth conditions in the shallower portion of this range. The bivalve genera *Spisula* and *Periploma* also have narrow bathymetric ranges in the modern northeastern Pacific; *Spisula* is known from the intertidal zone to 100 m on sand, and *Periploma* is known between 20 and 90 m (Burch, 1945; Keen and Coan, 1974). The modern homologue of *Lucinoma acutilineata, L. annulata* (Reeve, 1850), lives in depths of 20 to 800 m and occurs abundantly, as in the Topsy, in the shallowest part of its range. *Thyasira disjuncta*, tentatively identified in the Topsy, is reported in water as shallow as 10 m or less in the Gulf of Alaska (Kanno, 1971) but only between 150 and 750 m off of western Canada (Bernard, 1972). Noting the occurrence of *T. disjuncta* at 10 m or less in the Gulf of Alaska but no shallower than 60 m off of Japan, Kanno (1971) speculated that depth distribution is a function of water temperature for this species, which is further suggested by Bernard's relatively deep-water records for western Canada.

All of the Topsy gastropod taxa are known in shallow marine habitats. *Fustriton oregonensis* lives between the southern Bering Sea and San Diego, Calif., from the intertidal zone to 2,370 m. It occurs in increasingly deep water southward, reflecting its preference for cool water. From Washington northward, it is found intertidally except where winter sea ice occurs and to depths of 430 m; it has been observed spawning in the intertidal zone (Smith, 1970). *Natica clausa* has its depth distribution strongly controlled by water temperature, so it may occur as shallowly as 9 m in Arctic seas but only below 150 m off southern California (Marincovich, 1977). The closely related species *Natica oregonensis* is extinct and known from Oregon and Washington in Neogene faunas of shallow to moderate depth (Moore, 1963; Marincovich, 1977). *Calliostoma* ranges from the intertidal zone to 915 m in the modern northeastern Pacific (Keen and Coan, 1974) and is most common in depths of about 70 m or less, commonly associated with kelp beds (Burch, 1946; McLean, 1969).

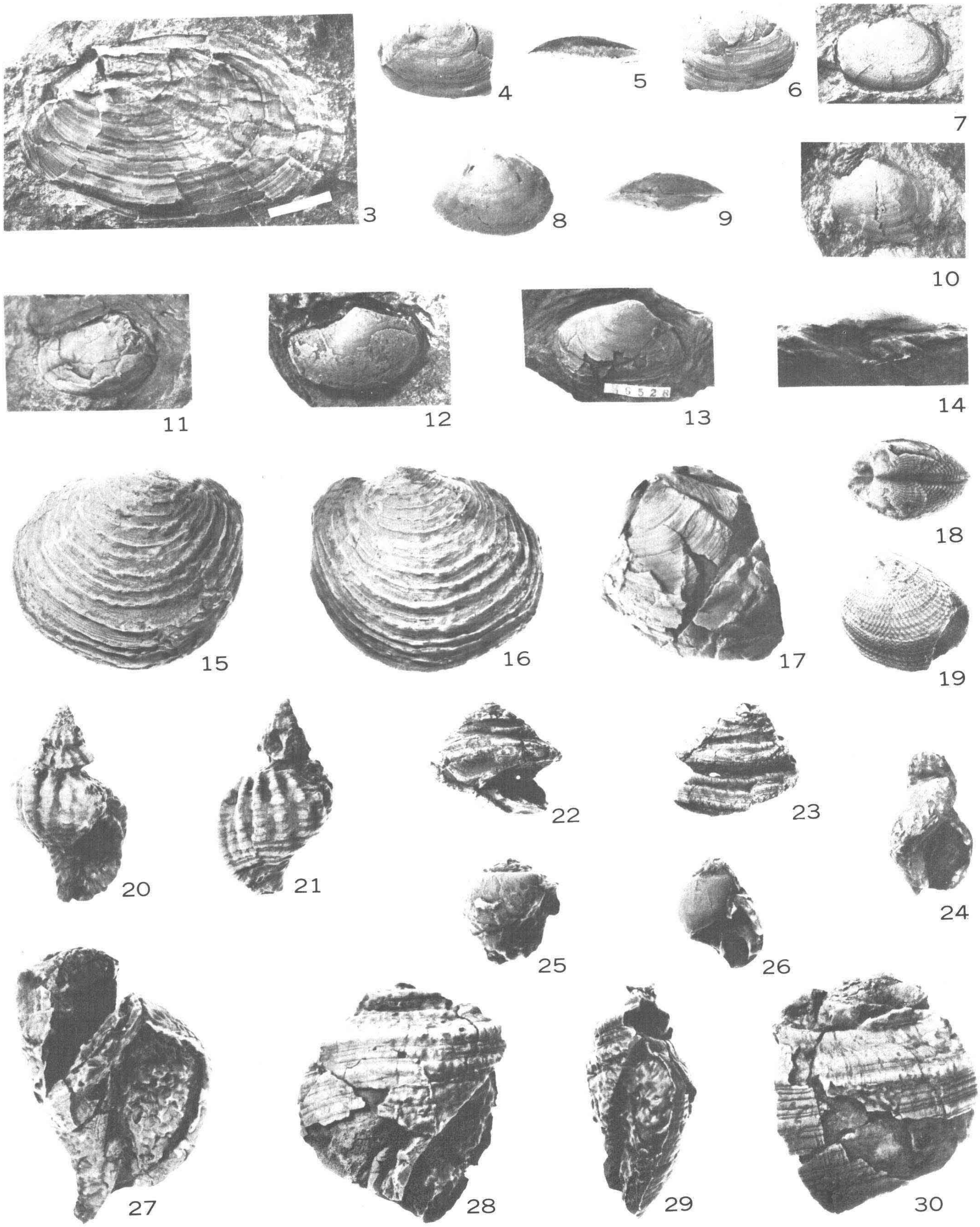
In summary, mollusks of the Topsy Formation collectively suggest water depths of about 20 to 50 m. Even though some taxa are known to range into shallower or greater depths, a range of 20 to 50 m is the broadest interval necessary to account for the presence of all of the Topsy mollusks. None of the Topsy taxa or their modern counterparts are known to live exclusively in greater or lesser depths. The fact that most of the bivalves are articulated indicates that post mortem transport had little or no effect on species composition of the Topsy fauna.

### WATER TEMPERATURE

Cool-temperate water temperatures similar to those of the modern open coastline of the Lituya district are indicated by the Topsy mollusks, although few reliable data are known on natural temperature tolerances for their living representatives. Some of the species, such as *Fusitriton oregonensis, Natica clausa,* and *Thyasira disjuncta,* have geographic ranges extending as far south as California or Baja California. However, such species inhabit low latitudes by living in cold bottom-water below the influence of warmer surface-water masses. They inhabit inner sublittoral areas only when surface waters are of cool-temperate to arctic temperatures. All of the Topsy species still living or with modern homologues include the Lituya district within their geographic ranges.

The bivalve genus *Acila,* represented in the Topsy fauna by *Acila (Truncacila) taliaferroi,* can survive in temperate water ranging from about 4.4°C to 21.1°C and *Truncacila* favors cool-temperate habitats (Schenck, 1936), presumably ranging from about 4.4°C to 12.7°C. The lowest temperature in which living *Truncacila* have been recorded is 3.6°C (Schenck, 1936). Living *Acila* are not known below a depth of 1,465 m, nor are they known in the intertidal zone (Schenck, 1936).

*Fusitriton oregonensis* lives in temperate to cold water along the North Pacific rim from Japan to southern California in depths to 2,370 m. It has been observed in the intertidal zone from Puget Sound, Wash., to southeastern Alaska and has been collected from depths as shallow as 18 m in the southern Bering Sea and 9 m in the Gulf of Alaska (Smith, 1970). Southwestward from the Bering Sea and south of Puget Sound, it lives in progressively greater depths. This species has also been reported in temperatures of 7°C to 11°C in Puget Sound and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FIGURES 3. *Periploma (Aelga) besshoense* (Yokoyama). USNM 250860. Height 33.4 mm, length 54.2 mm.

4–6. *Macoma albaria* (Conrad). USNM 250862. Height 16.5 mm, length 22.1 mm.
4. Right valve.
5. Dorsal aspect.
6. Left valve.

7–9. *Macoma* aff. *M. twinensis* Clark.
7. USNM 250866, right valve, height 12.7 mm, length 20.0 mm.
8. USNM 250865, left valve, height 17.5 mm, length 23.4 mm.
9. USNM 250865, dorsal aspect.

10. *Macoma incongrua* (von Martens). USNM 250864. Right valve, height 14.7 mm, length 19.1 mm.

11. *Spisula addicotti* Kanno. USNM 250871, right valve, height 14.6 mm, length 22.7 mm.

12. *Nuculana (Saccella)* sp. USNM 250867, right valve, height 11.3 mm, length 17.0 mm.

13–14. *Macoma* aff. *M. albaria* (Conrad). USNM 250863.
13. Left valve, height 15.3 mm, length 24.8 mm.
14. Dorsal aspect.

15–16. *Lucinoma acutilineata* (Conrad). USNM 250861. Specimen distorted.
15. Left valve, height 40.0 mm, length 44.4 mm.
16. Right valve.

17. *Thyasira* cf. *T. disjuncta* (Gabb). USNM 250870, left valve, height 36.5 mm, length 36.2 mm.

18–19. *Acila (Truncacila) taliaferroi* Clark. USNM 250868, height 15.8 mm, length 17.3 mm.
18. Dorsal aspect.
19. Right valve.

20–21. *Fusitriton oregonensis* (Redfield). USNM 250874, height 39.7 mm, diameter 22.5 mm. Specimen distorted.
20. Apertural view.
21. Backside view, showing spiral sculpture.

22–23. *Calliostoma* sp. USNM 250872, height 22.8 mm, diameter 26.2 mm. Specimen distorted.
22. Apertural view.
23. Backside view, showing fine spiral sculpture.

24. ?*Colus* sp. USNM 250876, height 27.6 mm, diameter 16.2 mm. Specimen distorted and worn.

25. *Natica (Cryptonatica) clausa* Broderip and Sowerby. USNM 250869, height 10.4 mm, diameter 10.0 mm.

26. *Natica (Cryptonatica) oregonensis* (Conrad). USNM 250873, height 11.1 mm, diameter 8.0 mm.

27. ?*Neptunea (Neptunea) plafkeri* Kanno. USNM 250875, height 54.0 mm. diameter 36.3 mm. Apertural view, specimen distorted.

28–30. *Neptunea (Sulcosipho)* cf. *N. (S.) tabulata* (Baird). USNM 250877, height 42.3 mm, greatest diameter 39.0 mm, least diameter 22.9 mm. Specimen distorted.
28. Oblique apertural view, showing spiral sculpture.
29. Apertural view, showing shoulder tabulation.
30. Backside view, showing spiral sculpture.

in waters less than 8°C off of southern California (Valentine and Emerson, 1961).

Modern surface-water temperatures in the eastern Gulf of Alaska range from monthly averages of 6.7°C in February to 14.4°C in August (LaViolette and Seim, 1969). Nearshore marine temperatures significantly different from those of the modern Lituya district are not required to account for the Topsy fauna.

## SYSTEMATIC PALEONTOLOGY

### Acila (Truncacila) taliaferroi Clark, 1932

Figures 18–19

This species is characterized by its moderate size and relatively high shell, somewhat inflated valves, nearly vertical axis of bifurcation of its fine, subdued radial sculpture and by the shape of its escutcheon. Interior features of the valves are unknown.

*Acila (Truncacila) taliaferroi* is most similar to *A. (T.) conradi* (Meek, 1864), which occurs in the lowermost Pillarian and Newportian Stages of the Pacific and in coeval beds in California, and to *A. (T.) empirensis* Howe, 1922, known from the Wishkahan and Graysian (?) Stages of the Pacific Northwest. *Acila taliaferroi* and *A. conradi* are identical in shell outline and inflation of their valves. However, *A. taliaferroi* may be distinguished by its smaller size (*A. conradi* attains a height of 21.7 mm; Schenck, 1936), relatively greater height, less elongate escutcheonal area, and distinctly more vertical axis of bifurcation of the radial ribs. The last two features are most useful for quickly separating specimens of the two species. Both species show a band of obsolete radial ribbing along the adult ventral shell margin, but the occurrence of secondary bifurcation of the radial ribs is more pronounced on *A. conradi* than on *A. taliaferroi*.

Compared to *A. empirensis*, *A. taliaferroi* is smaller (the former species is as much as 19.3 mm high and 25.9 mm long; Schenck, 1936), has a more acutely rounded anterior extremity and finer radial sculpture standing in much lower relief. In addition, the angle of bifurcation of the radial sculpture is more vertical in *A. taliaferroi* and the secondary bifurcation is less pronounced than in *A. empirensis*. Undistorted individuals of *A. taliaferroi* usually have more inflated valves than specimens of *A. conradi* or *A. empirensis.*

The largest individual of *A. taliaferroi* from the Topsy Formation is 15.8 mm high and 17.3 mm long, and the smallest is 12.0 mm high and 12.1 mm long. Specimens from the lower part of the Yakataga Formation throughout the Gulf of Alaska region are of similar size. Wherever they occur, however, most individuals are somewhat distorted from burial compaction and tectonic forces.

The precise stratigraphic range of *A. taliaferroi* has not been established. It has been reported previously only from about the upper 213 m of the Poul Creek Formation (Clark, 1932; Addicott and others, 1971) and from the lower part of the Yakataga Formation (Kanno, 1971) in the Yakataga district. These occurrences span a stratigraphic interval approximately equal to the Pillarian and Newportian Stages (early Miocene through early middle Miocene) of the Pacific Northwest.

### Lucinoma acutilineata (Conrad, 1849)

Figures 15–16

The combination of nearly circular outline, regularly spaced and sharply raised concentric lamellae, and concentric interspaces with numerous fine threads distinguishes this species. As noted by Addicott (1976a), *L. acutilineata* is usually preserved with articulated valves, as it is in the Topsy Formation. All Topsy specimens are distorted.

The specimens at hand are the first ones reported from Alaska, although this species is found commonly in middle Tertiary strata in Washington, Oregon, and California. The earliest occurrence of *L. acutilineata* is in the Eugene Formation of west-central Oregon (Hickman, 1969), strata which have been assigned to the late Eocene to early Oligocene part of the Galvinian Stage by Armentrout (1975). Its highest startigraphic appearance is in the Astoria Formation in northwestern Oregon (Moore, 1963), which is included in the Newportian Stage (Addicott, 1976b). The presence of *L. acutilineata* in the Topsy fauna provides a significant tie with the better known Tertiary faunas of Washington and Oregon and is evidence that the Topsy is no younger than early middle Miocene.

The modern homologue of this species is *Lucinoma annulata* (Reeve, 1850), which lives in depths of 20 to 800 m between Alaska and Baja California, Mexico, but is found most abundantly in the inner sublittoral zone (0–100 m) (Burch, 1944). Compared to *L. acutilineata, L. annulata* has a shorter posterior dorsal margin (Stewart *in* Tegland, 1933) and a heavier hinge (Moore, 1963). As also pointed out by Moore (1963), the anterior tooth on the right valve of *L. acutilineata* is short and blunt, rather than thin and bladelike on *L. annulata,* and the cardinal tooth seems to be shorter on *L. annulata.* In addition, the left anterior tooth of *L. acutilineata* is heavier and not so deeply incised as on *L. annulata* (Moore, 1963).

### Macoma albaria (Conrad, 1849)

Figures 4–6

This species is characterized by its relatively small size, by the proximity of its beaks to the posterior end, and by its posteriorly flexed valves.

*Macoma albaria* has not been recognized previously from Alaska. Its presence in the Topsy provides a new tie between Tertiary strata of the Gulf of Alaska and the Pacific Northwest. This bivalve is well known in Miocene deposits in Oregon and Washington, where it has been reported in the Pillarian Nye Mudstone and Newportion Astoria Formation in western Oregon (Moore, 1963) and in the Pillarian Clallam Formation in northwestern Washington (Addicott, 1976a). As noted by Addicott (1976a), *M. albaria* is similar to *M. twinensis* Clark, 1925. The latter species is known from upper Oligocene rocks in northwestern Washington and is doubtfully reported from the lower Miocene Clallam Formation (Addicott, 1976a) in the same area. The importance of *M. albaria* in the Topsy rests on its last known occurrence in middle Miocene strata of Oregon. Even if its stratigraphic range were extended to encompass the upper Oligocene records now assigned to *M. twinensis,* its value in dating the Topsy Formation would not be diminished.

### Macoma aff. M. albaria (Conrad, 1849)

Figures 13–14

This species is represented by a single left valve that is well preserved and nearly complete but shows only exterior features. Its shape is most similar to that of *M. albaria* (Conrad, 1849), which occurs in lower and middle Miocene strata of Oregon and Washington (Moore, 1963; Addicott, 1976a). However, the Topsy specimen is distinctly more inflated than *M. albaria,* has a straighter ventral margin, a more prominent umbo, and blunter posterior termination. This valve is also similar to *M. twinensis* Clark, 1925, which is found in faunas of late Oligocene and possibly early Miocene age in Oregon and Washington (Addicott, 1976a), but differs from the latter species by its more prominent umbo, smaller relative height, and more inflated left valve. An-other similar species is *M. brota* Dall, 1916, which lives from Arctic Canada to Puget Sound, Wash., and is reported in Pleistocene faunas in Arctic Canada and British Columbia (Coan, 1971). The Topsy *Macoma,* however, is distinguished from *M. brota* by having a less elevated anterior dorsal margin, a more narrowly rounded anterior end and straighter ventral margin, and a distinctly more inflated left valve. Future studies may reveal an ancestral relation between *M. brota* and the Miocene Macomas mentioned here.

#### Macoma incongrua (von Martens, 1865)

Figure 10

This relatively small *Macoma* is characterized by its inflated valves, broadly and evenly rounded anterior end, and acutely angled posterior end. The posterior dorsal and ventral margins are straight and steeply sloping, and there is a distinct flexure to the right and a slight gape at the posterior end.

This species is the most frequently encountered *Macoma* in Gulf of Alaska Tertiary strata. It is well represented in beds of the lower part of the Yakataga Formation in the Yakataga and Lituya districts (of presumed early to late Miocene age) and has been reported in the upper part of the Poul Creek Formation at Cape Yakataga (Kanno, 1971) in beds of presumed early Miocene age. Its occurrence in the Pliocene and Pleistocene portions of the Yakataga Formation has been reported but not well documented, and it has been questionably reported in strata as old as late Oligocene (Kanno, 1971).

As noted by Coan (1971) and Kanno (1971), Holocene specimens from the northeastern Pacific referred to *M. incongrua* differ in interior shell features from Holocene specimens of Japan (from which the holotype comes). Northeastern Pacific Pleistocene and Holocene specimens referred to *M. incongrua* by earlier workers have been placed in *Macoma* (*Macoma*) *obliqua* (Sowerby, 1917) by Coan (1971), a species also recognized in the Red Crag (lower Pleistocene) of England. Because interior shell features are not observable in most Alaskan Tertiary specimens referred to *M. incongrua,* and differences between *M. incongrua* and *M. oblique* are not always expressed in exterior morphology, the identity of specimens from the upper part of the Poul Creek and lower part of the Yakataga Formations is uncertain. It is most probable that these Miocene specimens belong to *M. incongrua* rather than *M. obliqua,* but proof of this will depend on collecting more Alaskan specimens in which interior features can be observed.

Individuals from the Topsy Formation figured here are of average size for Gulf of Alaska Tertiary specimens.

#### Macoma aff. M. twinensis Clark, 1925

Figures 7–9

Specimens from the Topsy Formation are juveniles and young adults, resembling the holotype of *M. twinensis* Clark, 1925, which is also a juvenile specimen. Juveniles of *M. twinensis* differ from adults by having a more acutely rounded posterior end and less distinct umbones.

*Macoma twinensis* is reported in faunas of late Eocene through early Miocene age in the Pacific Northwest, its highest stratigraphic occurrence being doubtfully identified specimens from the lower Miocene Clallam Formation (Addicott, 1976a). The largest Topsy specimens are much more inflated than young adults of *M. twinensis* from the Pacific Northwest, so their species assignment will be uncertain until adult Topsy specimens are collected.

#### Mya sp.

This genus is represented in the Topsy Formation by a single right valve with its posterior end missing. The specimen is 52 mm high, with its umbo and ventral margin nearly intact.

The Topsy specimen most probably is *Mya* (*Mya*) *cuneiformis* (Boehm, 1915), which commonly occurs in Yakataga Formation faunas of presumed middle Miocene age in the Lituya district and is especially abundant in the Cenotaph Island section. MacNeil (1965) cited records of *M. cuneiformis* from presumed middle Miocene strata in the Cape Yakataga area and on Kodiak Island, Alaska, and from presumed middle Miocene to lower Pliocene beds in Japan and Sakhalin. *Mya* (*Mya*) *truncata* Linnaeus, 1758, is also common in middle Miocene to Holocene faunas of southern Alaska (MacNeil, 1965), though it is not so common as *M. cuneiformis* in the Yakataga Formation of the Lituya district.

In the modern northeastern Pacific, *Mya* species occupy a bathymetric range from the intertidal zone to 50 m (Keen and Coan, 1974), burrowing into sandy mud.

#### Nuculana (Saccella) sp.

Figure 12

*Saccella* is characterized by having a pointed posterior rostrum, sculpture of strong concentric rugae, posterior and anterior series of teeth equal, and a

U-shaped pallial sinus. The Topsy specimens are molds and casts that preserve only small portions of exterior sculpture and hinge lines and that lack impressions of pallial lines. The visible features of these specimens, however, suggest placement in *Saccella*. This subgenus is represented by many North Pacific Tertiary species, although it has not yet been recognized in the Yakataga Formation.

**Periploma (Aelga) besshoense (Yokoyama, 1924)**
Figure 3

When typically developed, the shell of this species is nearly equidimensional, with its posterior extremity distinctly compressed and slightly produced; the anterior margin is broadly rounded. The most common variation is for the posterior end to be greatly produced and broadly rounded, whereas the anterior end is reduced and often slightly truncated (Kanno, 1971).

This species was described from Japan, where it occurs in Oligocene and Miocene strata. Kanno (1971) recognized it in the upper part of the Poul Creek Formation and the lower part of the Yakataga Formation of the Yakataga district. He further noted that the posteriorly elongate variety seemed to occur only in the lower part of the Yakataga Formation, whereas the typical variety was found only in the upper part of the Poul Creek Formation. The Topsy Formation specimen is of the elongate variety known in the lower part of the Yakataga Formation, which provides a possible link between these two stratigraphic intervals. As emphasized by Kanno (1971), the seeming division of shell forms between the Yakataga and Poul Creek Formations requires confirmation.

*Periploma* lives in the modern northeastern Pacific in depths of 20 to 90 m (Burch, 1944; Keen and Coan 1974) ranging from Alaska to Peru.

**Spisula addicotti Kanno, 1971**
Figure 11

The shell of this species is elongate anteriorly, with prominent umbones situated posteriorly, and broadly rounded anterior and posterior extremities (especially in younger individuals).

This species has been reported only from the Poul Creek Formation (upper Eocene to lower Miocene; Allison, 1976) in the Yakataga district (Clark, 1932; Kanno, 1971; Addicott and others, 1971). Thus, its presence in the Topsy Formation is its highest known stratigraphic occurrence. The Topsy specimen is a juvenile showing the broadly rounded extremities that seem to characterize this species, especially in younger individuals.

*Spisula addicotti* may be a junior synonym of *S. trapezoides* (Clark, 1932), which is known from the upper part of the Poul Creek Formation (lower Miocene; Allison, 1976) in the Yakataga district (Clark, 1932; Addicott and others, 1971) and from Wishkahan faunas of the upper part of the Bear Lake Formation (upper middle Miocene to upper Miocene) on the Alaska Peninsula (R. C. Allison, oral commun., 1977). Compared to illustrations of the holotype of *S. trapezoides*, (Clark 1932; Addicott and others, 1971), *S. addicotti* appears to have a distinctly more elongate posterior end and a more evenly rounded posterior termination. However, the Topsy specimen of *S. addicotti* and the holotype of *S. trapezoides* are juveniles, making comparisons difficult.

Modern northeastern Pacific *Spisula* species inhabit depths from the intertidal zone to 100 m in sand substrates of exposed beaches and bays (Keen and Coan, 1974).

**Thyasira cf. T. disjuncta (Gabb, 1866)**
Figure 17

This lucinacean bivalve is characterized by its trigonal shape, broadly arched posterior dorsal margin, nearly straight anterior dorsal margin, strong sulcus that extends along the posterior dorsal slope from the umbo to the anterior ventral margin, and edentulous hinge.

Although some molluscan specialists have considered *T. disjuncta* to be synonymous with *T. bisecta* (Conrad, 1849), Bernard (1972) has exhaustively documented the anatomical differences and pointed out the distinctive shell morphology of each. I follow Bernard (1972) in considering *Conchocele* Gabb, 1866, into which *T. disjuncta* has often been placed, a junior synonym of *Thyasira*. The straight rather than concave anterior dorsal margin and less prominent umbo of *T. disjuncta* that distinguish it from *T. bisecta* are missing from the Topsy specimen. *T. bisecta* has never been reliably reported in Alaska Tertiary faunas, and illustrated *Thyasira* specimens from the Poul Creek Formation (Clark, 1932; Kanno, 1971; Addicott and others, 1971) are undoubtely *T. disjuncta*. It is highly probable that the Topsy specimen is also *T. disjuncta*, although confirmation of this will depend on finding additional specimens.

*Thyasira disjuncta* is known in the North Pacific from late Eocene or early Oligocene to Holocene and in the modern Caribbean fauna (Boss, 1967). Because of confusion by past workers between *T. disjuncta* and *T. bisecta*, it is difficult to determine from literature records the exact geographic range of the former species in the North Pacific. In Gulf of Alaska Tertiary strata, *T. disjuncta* is recorded from the lower part of the Poul Creek Formation (Kanno, 1971) as well as from the upper part (Clark, 1932; Addicott and others, 1971) in the Yakataga district. Specimens from a large erratic boulder at Cape Yakataga were judged by Kanno (1971, p. 62) to have come from the Poul Creek Formation, though he considered it possible they could have come from the overlying Yakataga Formation. The only known record of this species from the Yakataga Formation in the Yakataga district is that of Kanno (1971, p. 22) from the Chaix Hills in strata of probable late Miocene or Pliocene age. Because its stratigraphic occurrence represents such an extensive time interval, even though the species occurs widely, it is not useful for correlation or age determination.

Besides *T. disjuncta*, the only other Tertiary *Thyasira* known in Alaska is *T. alaskana* Kauffman, 1969. This species occurs on the Arctic coastal plain of northeastern Alaska, in the upper Miocene(?) and Pliocene Nuwok Member of the Sagavanirktok Formation, and is of Atlantic affinities.

### Calliostoma sp.

Figure 22–23

This genus has not been reported previously as a fossil in Alaska, although species of *Calliostoma* do live today as far north as southeastern Alaska. The species from the Topsy Formation is most similar to *Calliostoma cammani* Dall, 1909, from the middle to lower Pliocene Empire Formation in Oregon. However, sculptural features of the Topsy specimen exclude it from *C. cammani*. It might belong to one of the Tertiary species described from Japan, the oldest of which is said to be Oligocene in age (Hatai and Nisiyama, 1952), or from the eastern Soviet Union. At present, no comparative specimens of Japanese or Soviet *Calliostoma* species are available, and literature citations are not sufficient to evaluate them, so comparisons with the Topsy specimen must be deferred.

### ?Colus sp.

Figure 24

The elongate fusiform shell and relatively small aperture of the Topsy specimen suggest placement in *Colus* or an allied genus. This specimen is too worn and incomplete for certain generic placement, but parts of the exterior surface appear to be intact and smooth, further suggesting *Colus* as the most likely genus. *Colus* specimens are in the Poul Creek and Yakataga Formations, but are often too worn for specific identification, considering that differences among many *Colus* species are subtle.

### Natica (Cryptonatica) clausa Broderip and Sowerby, 1829

Figure 25

A smooth, nearly globular shell with a semicircular callus concealing the umbilicus characterizes this species. It is distinguished from *N.* (*C*) *oregonensis* (Conrad, 1865) by its less elongate body whorl and lower spire. In general, fossil specimens of *N. clausa* also have distinctly thicker shells than *N. oregonensis;* modern individuals of *N. clausa* tend to have somewhat thinner shells than fossil specimens.

*Natica clausa* occurs commonly in cool- and cold-water Miocene to Holocene faunas of the North Pacific and is the only naticid found routinely in Alaskan Neogene and Pleistocene strata. Its reported first occurrence in the Gulf of Alaska Tertiary Province is in the upper part of the Poul Creek Formation (lower Miocene) of the Yakataga district (Marincovich, 1977), from strata of presumed late Juanian or Pillarian age. A coeval or possibly older occurrence is now known in the Juanian fauna of the so-called Narrow Cape Formation on Sitkinak Island in the western Gulf of Alaska (R. C. Allison, oral commun., 1977).

The single specimen of *N. clausa* from the Topsy Formation is 10.4 mm in height and 10.0 mm in diameter, which is average for Miocene specimens and much smaller than Pliocene to Holocene individuals. All fossil and modern occurrences of *N. clausa* are in faunas of decidedly cool- or cold-water aspect or in faunas with a well-developed cold-water element (Marincovich, 1977), so the presence of this species in the Topsy is strong evidence for a cool-temperate or slightly colder marine hydroclimate.

### Natica (Cryptonatica) oregonensis (Conrad, 1865)

Figure 26

This species is characterized by its smooth whorls and its semicircular callus concealing the umbilicus and by its elevated spire and elongate body whorl. These last two characters distinguish *N. oregonensis* from the related *N. clausa* Broderip and Sowerby, which also occurs in the Topsy Formation.

This is the first certain report of *N. oregonensis* north of Washington and Oregon, although it has been questionably identified in the Newportian fauna of the Narrow Cape Formation on Kodiak Island in the western Gulf of Alaska (R. C. Allison, oral commun., 1977). It was previously known from the Astoria Formation of western Washington and western Oregon (Newportian Stage) and from the Empire Formation at Coos Bay, Oregon (Wishkahan and Graysian(?) Stages as used by Allison, 1976) (Marincovich, 1977). It is now also known in the Nye Mudstone (Pillarian Stage) of northwestern Oregon, on the basis of reassignment to the Nye Mudstone of localities formerly attributed to the Astoria Formation in northwestern Oregon (W. O. Addicott, oral commun., 1977). These verified occurrences range in age from early Miocene to early late Miocene.

### ?Neptunea (Neptunea) plafkeri Kanno, 1971

Figure 27

This species is discriminated from other Tertiary Neptuneas and similar large gastropods in the Gulf of Alaska region by its high spire, acute apical angle, long anterior canal, and nearly smooth shell sculptured only with fine incremental growth lines and a few radial varices of low relief near the aperture (Kanno, 1971; Nelson, 1974).

The poor condition of the Topsy specimen, missing all but an incomplete and worn body whorl, makes identity uncertain. This specimen is not deeply sculptured as are many Neptuneas, and the best preserved parts of the exterior surface show only fine incremental growth lines.

*Neptunea plafkeri* was described from specimens collected in the lower part of the Yakataga Formation at Cape Yakataga (Kanno, 1971), and it has also been collected in the upper part of the Poul Creek Formation there (C. A. Ariey, 1978a). This species is also reported from several Miocene localities of the Yakataga Formation in the Yakataga district and in beds now assigned to the Topsy Formation at Icy Point in the Lituya district (Nelson, 1974). The sum of its known stratigraphic occurrences suggests a range of about early Miocene to middle or possibly late Miocene for *N. plafkeri.*

### Neptunea (Sulcosipho) cf. N. (S.) tabulata (W. Baird, 1863)

Figures 28–30

When seen as well-preserved fossil or modern specimens, *N. tabulata* is easily recognized by its elongate shape, strongly tabulate shoulder bounded by a thickened and minutely scaly spiral cord, and by its fine spiral ribs covering the whole outer surface. The Topsy specimen is a distorted and incomplete body whorl lacking earlier whorls or an anterior canal. The tabulate shoulder and fine spiral sculpture show up well and suggest placement of the specimen in *N. tabulata.* Even though there appear to be three sizes of spiral ribs on both *N. tabulata* and the Topsy specimen, however, the ribs of true *N. tabulata* are more boldly sculptured, seem to occur in a more regular sequence, and appear to be separated by wider interspaces than the ribs of the Topsy individual.

The specimens figured by Kanno (1971) as *Neptunea* (*Sulcosipho*) cf. *N.* (*S.*) *tabulata* appear to be the same as the Topsy shell. A specimen cited by Clark (1932) and refigured by Addicott and others (1971) as *Neptunea* aff. *N. tabulata* also probably is the same species. Kanno's (1971) specimens were collected from the lower part of the Yakataga Formation at Cape Yakataga, and Clark's (1932) specimens from the same area also probably came from the lower part of the Yakataga Formation (Addicott and others, 1971). Nelson (1974) reported this species in middle Miocene to lower Pliocene beds of the Yakataga Formation throughout the Gulf of Alaska Tertiary Province. Recent collecting at Cape Yakataga has produced this species from the upper part of the Poul Creek Formation (C. A. Ariey, 1978a). Thus, the known occurrences of this species indicate an approximate age range of early Miocene to early Pliocene.

### Fusitriton oregonensis (Redfield, 1846)

Figures 20–21

The characteristic features of this high-spired snail are its coarse axial ribs and fine, flattened spiral costae that are usually bifurcated. Most spiral interspaces on the Topsy specimen contain one slender thread, although such threads may be absent or as numerous as three per interspace (Smith, 1970).

This species is well known in North Pacific Miocene and younger faunas, being most abundant in Pliocene and younger strata from Japan and Alaska south to California (Smith, 1970). Until recently, no precise data were known on the earliest occurrence of *F. oregonensis.* Smith (1970) reported specimens of "*Fusitriton* sp. ? aff. *F. oregonensis*" from Cape Yakataga Miocene strata of either the Poul Creek or Yakataga Formations. Recent collecting by C. A. Ariey (oral commun., 1977), however, showed *F. oregonensis* missing from the upper part of the Poul Creek Formation at Cape Yakataga but present in the stratigraphically highest Newportian fauna and in the Wishkahan fauna of the lower part of the Yakataga Formation there. Thus, the oldest verified occurrence of this species is in the early middle Miocene portion of the Newportian Stage, thereby making *F. oregonensis* the species most important for inferring a maximum age for the Topsy fauna.

Modern occurrences are in temperate to cold waters of the North Pacific rim from Japan to southern California. Although *F. oregonensis* is known from depths as great as 2,370 m, it has been observed in the intertidal zone from Puget Sound, Washington, to southeastern Alaska, and in depths as shallow as 18 m in the southern Bering Sea and 9 m in the Gulf of Alaska (Smith, 1970). Southwest from the Bering Sea and south of Puget Sound, it lives in progressively greater depths. It has been collected in temperatures of 7–11°C in Puget Sound and in waters less than 8°C off of southern California (Valentine and Emerson, 1961).

## FOSSIL LOCALITY DESCRIPTIONS

The following locality numbers for the Topsy Formation are assigned by the Menlo Park, Calif., center of the U.S. Geological Survey. Fossil collections are housed in the Branch of Paleontology and Stratigraphy, Menlo Park, Calif., except for illustrated specimens, which are kept in the National Museum of Natural History, Washington, D.C.:

M6525 (Plafker field locality 75APr45A).—Isolated outcrop in intertidal zone of rock and sand beach about 3.3 km northeast of Icy Point; 669 m south and 274 m west of NW. cor. sec. 15, T. 40 S., R. 50 E., Mt. Fairweather (B–4) quadrangle, Lituya district, southeastern Alaska. Collected by George Plafker and Travis Hudson, June 1975.

M6526 (Plafker field locality 75APr40A).—Isolated outcrop along southern margin of Finger Glacier, 182 m south and 486 m west of NE. cor. sec. 33, T. 39 S., R. 50 E., Mt. Fairweather (B–4) quadrangle, Lituya district, southeastern Alaska. Collected by George Plafker and Travis Hudson, June 1975.

M6527 (Plafker field locality 75APr43D).—Isolated outcrop in intertidal zone of rock and sand beach, about 5.8 km north of Icy Point; 730 m south and 30 m east of NW. cor. sec. 10, T. 40 S., R. 40 E., Mt. Fairweather (B–4) quadrangle, Lituya district, southeastern Alaska. Collected by George Plafker and Travis Hudson, June 1975.

M6528 (Marincovich field locality 75AM65).—Isolated outcrop near head of Fall Creek, along strike from lower part of type-section of Topsy Formation, 289 m south and 274 m west of NE. cor. sec. 33, T. 37 S., R. 48 E., Mt. Fairweather (C–5) quadrangle, Lituya district, southeastern Alaska. Collected by Louie Marincovich, George Plafker, and Travis Hudson, June 1975.

## REFERENCES CITED


Addicott, W. O., 1976a, Molluscan paleontology of the lower Miocene Clallam Formation, northwestern Washington: U.S. Geological Survey Professional Paper 976, 44 p., 9 pls., 10 figs.

———1976b, Neogene molluscan stages of Oregon and Washington, *in* Wornardt, W. W., ed., Symposium on the Neogene of the Pacific Coast: Society of Economic Paleontologists and Mineralogists, Pacific Section, San Francisco, Calif., April 1976, p. 95–115, 5 pls., 6 figs.

Addicott, W. O., Kanno, Saburo, Sakamoto, Kenji, and Miller, D. J., 1971, Clark's Tertiary molluscan types from the Yakataga district, Gulf of Alaska, *in* U.S. Geological Survey Research 1971: U.S. Geological Survey Professional Paper 750–C, p. C18–C33, 6 figs.

Allison, R. C., 1976, Late Oligocene through Pleistocene molluscan faunas in the Gulf of Alaska region: International Congress on Pacific Neogene Stratigraphy, First, Tokyo, 1976, Abstracts of Papers, p. 10–13. Reprinted *in* Saito, Tsunemasa, and Ujiie, Hiroshi, eds., 1977, International Congress on Pacific Neogene Stratigraphy, First, Tokyo, 1976, Proceedings, p. 313–316.

Ariey, Catherine A, 1978a, Molluscan biostratigraphy of the upper Poul Creek and lower Yakataga Formations, Yakataga district, Gulf of Alaska: University of Alaska, M.S. thesis, Fairbanks, 249 p., 6 pls., 13 figs.

———1978b, Molluscan biostratigraphy of the upper Poul Creek and lower Yakataga Formations, Yakataga district, Gulf of Alaska: Stanford University Publications Geological Sciences, vol. 14, p. 1–2.

Armentrout, J. M., 1975, Molluscan biostratigraphy of the Lincoln Creek Formation, southwest Washington, *in* Weaver, D. W., and others, eds., Paleogene symposium and selected technical papers: American Association of Petroleum Geologists, Society of Economic Paleontologists and Mineralogists, Society of Economic Geophysicists, Pacific Sessions, 1975 annual meeting, Long Beach, Calif., p. 14–48, 7 figs.

Berggren, W. A., and Van Couvering, John, 1974, The late Neogene: Palaeogeography, Palaeoecology, Palaeoclimatology, v. 16, nos. 1–2, p. 1–216.

Bernard, F. R., 1972, The genus *Thyasira* in western Canada (Bivalvia: Lucinacea): Malacologia, v. 11, no. 2, p. 365–389, 17 figs.

Boss, K. J., 1967, *Thyasira disjuncta* (Gabb, 1866) in the Caribbean Sea: Bulletin of Marine Science, v. 17, no. 2, p. 386–388.

Burch, J. Q., ed., 1944–46, Distributional list of the West American marine mollusks from San Diego, California, to the Polar Sea: Conchological Club South California, 3 v. pagination various.

Clark, B. L., 1932, Fauna of the Poul and Yakataga Formations (upper Oligocene) of southern Alaska: Geological

Society of America Bulletin, v. 43, p. 797–846, pls. 14–21, 1 fig.

Coan, E. V., 1971, The northwest American Tellinidae: Velinger, v. 14, suppl., 63 p., 12 pls., 30 figs.

Hatai, Kotora, and Nisiyama, Syozo, 1952, Check list of Japanese Tertiary marine Mollusca: Tohoku University Science Reports, ser. 2 (Geology), Special v. 3, 464 p.

Hickman, C. J. S., 1969, The Oligocene marine molluscan fauna of the Eugene Formation in Oregon: Oregon University Museum of Natural History Bulletin 16, 112 p. 14 pls. 4 figs.

Kanno, Saburo, 1971, Tertiary molluscan fauna from the Yakataga district and adjacent areas of southern Alaska: Palaeontological Society of Japan, Special Paper 16, 154 p., 18 pls., 20 figs.

Kauffman, E. G., 1969, Systematics and evolutionary position of a new Tertiary *Thyasira* (Bivalvia) from Alaska: Journal of Paleontology v. 43, no. 5, pt. 1, p. 1099–1110, pl. 127, 5 figs.

Keen, A. M., and Coan, Eugene, 1974, Marine molluscan genera of western North America—an illustrated key: Stanford, Calif., Stanford University Press, 208 p.

LaViolette, P. E., and Seim, S. A., 1969, Monthly charts of mean minimum and maximum sea-surface temperatures of the North Pacific Ocean: U.S. Naval Oceanographic Office Special Publication 123, 54 p.

McLean, J. H., 1969, Marine shells of southern California: Los Angeles County Museum of Natural History, science series, 24, zoology no. 11, 104 p., 54 figs.

MacNeil, F. S., 1965, Evolution and distribution of the genus *Mya*, and Tertiary migrations of Mollusca: U.S. Geological Survey Professional Paper 483–G, p. G1–G51, 11 pls., 3 figs.

MacNeil, F. S., Wolfe, J. A., Miller, D. J., and Hopkins, D. M., 1961, Correlation of Tertiary formations of Alaska: American Association of Petroleum Geologists Bulletin, v. 45, no. 11, p. 1801–1809.

[Marincovich, Louie, Jr.], 1976a, Fauna of Miocene age from the Topsy Formation, Alaska, *in* Geological Survey research 1976: U.S. Geological Survey Professional Paper 1000, p. 195.

Marincovich Louie, Jr., 1976b, Miocene mollusks from the Topsy Formation, Lituya district, *in* Cobb, E. H., ed., The United States Geological Survey in Alaska—Accomplishments during 1975: U.S. Geological Survey Circular 733, p. 58.

———1977, Cenozoic Naticidae (Mollusca: Gastropoda) of the northeastern Pacific: Bulletins of American Paleontology, v. 70, no. 294, p. 169–494, pls. 17–42, 13 figs.

Miller, D. J., 1953, Preliminary geologic map and correlated columnar sections of Tertiary rocks in the southwestern part of the Lituya district, Alaska: U.S. Geological Survey Open-File Report, 53–193, 2 map sheets.

———1961, Geology of the Lituya district, Gulf of Alaska Tertiary Province, Alaska: U.S. Geological Survey open-file map.

Moore, E. J., 1963, Miocene marine mollusks from the Astoria Formation in Oregon: U.S. Geological Survey Professional Paper 419, 109 p., 32 pls., 9 figs.

Nelson, C. M., Jr., 1974, Evolution of the Late Cenozoic gastropod *Neptunea* (Gastropoda: Buccinacea): Berkeley, California University, Ph. D. thesis., 802 p., 66 pls. 17 figs.

Plafker, George, 1967, Geologic map of the Gulf of Alaska Tertiary Province, Alaska: U.S. Geological Survey Miscellaneous Investigations, Map I–484, scale 1:500,000.

———1971, Pacific margin Tertiary basin, *in* Future petroleum provinces of North America: American Association of Petroleum Geologists Memoir 15, p. 120–135.

Plafker, George, and Addicott, W. O., 1976, Glaciomarine deposits of Miocene through Holocene age in the Yakataga Formation along the Gulf of Alaska margin, Alaska: U.S. Geological Survey Open-File Report 76–84, 36 p., 6 figs.

Rau, W. W., Plafker, George, and Winkler, G. R., 1977, Preliminary foraminiferal biostratigraphy and correlation of selected stratigraphic sections and wells in the Gulf of Alaska Tertiary Province: U.S. Geological Survey Open-File Report 77–747, 54 p.

Schenck, H. G., 1936, Nuclid bivalves of the genus *Acila*: Geological Society of America Special Paper 4, 149 p. 18 pls. 15 figs.

Smith, J. T., 1970, Taxonomy, distribution, and phylogeny of the cymatiid gastropods *Argobuccinum, Fusitriton, Mediargo, and Priene*: Bulletins of American Paleontology, v. 56, no. 254, p. 445–573, pls. 39–49, 17 figs.

Tegland, N. M., 1933, The fauna of the type Blakeley upper Oligocene of Washington: California University, Department of Geological Sciences Bulletin, v. 23, no. 3, p. 81–174, pls. 2–15.

Valentine, J. W., and Emerson, W. K., 1961, Environmental interpretation of Pleistocene marine species—a discussion: Journal of Geology, v. 69, no. 5, p. 616–618.

Wagner, C. D., 1974, Fossil and Recent sand dollar echinoids of Alaska: Journal of Paleontology, v. 48, no. 1, p. 105–123, 3 pls., 2 figs.