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Biostratigraphy of the Marine Neogene Sequence at Cape Blanco, Southwestern Oregon

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Biostratigraphy of the Marine Neogene Sequence at Cape Blanco, Southwestern Oregon

By WARREN O. ADDICOTT

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

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A study of fossiliferous marine sandstone constituting two unconformity-bounded sequences of early and middle Miocene and of late Miocene age

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CONTENTS

	Page
Abstract	G1
Introduction	1
Previous studies	2
Stratigraphic setting	3
Paleontology of the sandstone of Floras Lake	8
Invertebrate macrofauna	8
Provincial age	8
Correlation	9
Paleoecology	10
Paleontology of the restricted Empire Formation	11
Age and provenance of *Scutella blancoensis* Kew	14
References cited	16
Index	19

ILLUSTRATIONS

[Plates follow index]

PLATE 1. *Nucella, Bruclarkia, Cancellaria, Polinices, Natica, Priscofusus, Molopophorus, Liracassis, Crepidula, Megasurcula, Yoldia, Solen, Ophiodermella, Spisula, Tellina.*

2. *Mytilus, Nucella, Katherinella, Macoma, Crepidula, Cancellaria, Kewia, Olivella, Priscofusus, Tellina, Nassarius, Cryptonatica, Securella, Spisula.*

3. *Clinocardium, Siliqua, Crepidula, Acila, Calliostoma, Chlamys, Trophonopsis, Glycymeris, Nassarius, Nucella, Felaniella, Molopophorus, Kewia, Opalia, Securella.*

	Page
FIGURE 1. Index map of Pacific coast of the United States, showing location of Cape Blanco	G1
2. Sketch map of Cape Blanco-Blacklock Point area, showing megainvertebrate-fossil localities	3
3. Sketch of seacliff section of sandstone of Floras Lake	4
4-8. Photographs showing:	
4. Buff sandstone of the restricted Empire Formation	4
5. Concretionary sandstone and pebble conglomerate of basal part of sandstone of Floras Lake at Fin Rock	6
6. Seacliff exposure of sandstone of Floras Lake southeast of Cape Blanco	7
7. Unconformable contact between *Mytilus middendorffi*-bearing sandstone of Floras Lake and the restricted Empire Formation southeast of lighthouse at Cape Blanco	8
8. Angular unconformity between the restricted Empire Formation and the Port Orford Formation of Baldwin (1945)	10
9. Chart showing correlation of Neogene formations exposed at Cape Blanco with Pacific Northwest Tertiary molluscan chronology	10
10. Photograph showing unconformable contact between sandstone of Floras Lake and the restricted Empire Formation	12
11. Photograph showing unconformable contact between the restricted Empire Formation and the Port Orford Formation	15
12. Photograph showing *Psephidia* beds in upper part of the Port Orford Formation of Baldwin (1945) exposed near Elk River	16

TABLES

	Page
TABLE 1. Marine macroinvertebrates from the sandstone of Floras Lake (lower part of the Empire Formation of Diller, 1903) exposed near Cape Blanco, Oregon	G9
2. Provincial stratigraphic range of species in the Cape Blanco Newportian fauna, with notes on their occurrence in the California Neogene molluscan province	11
3. Late Miocene (Wishkahan) macroinvertebrates from the lower part of the restricted Empire Formation near Cape Blanco, Oregon	13

BIOSTRATIGRAPHY OF THE MARINE NEOGENE SEQUENCE AT CAPE BLANCO, SOUTHWESTERN OREGON

By WARREN O. ADDICOTT

ABSTRACT

A shallow-water marine sandstone sequence—the Empire Formation of Diller (1903)—exposed at and near Cape Blanco, southwestern Oregon, contains molluscan assemblages referable to the provincial Newportian, Wishkahan, and, probably, Graysian Stages. Sandy siltstone from the stratigraphically highest part of the sequence contains siliceous microfossils coeval with assemblages that occur in the type section of the provincial Graysian Stage in southwestern Washington. All but the earliest Miocene seems to be represented in this 260-m-thick shallow-water sequence. Although Pliocene strata are not preserved, this nevertheless constitutes the most complete marine Neogene sequence in Oregon.

An unconformity within the sandstone sequence separates the lower strata containing the Newportian assemblages from stratigraphically higher strata containing the Wishkahan assemblages. The lower strata—160 m of sandstone, conglomerate, and tuff—are here called the sandstone of Floras Lake. Use of the name "Empire Formation" has been restricted to the upper 100 m, sandstone and silty sandstone. The sandstone of Floras Lake contains a macroinvertebrate fauna that demonstrates the temporal equivalence of the Newportian Stage with the "Temblor" Stage of California. The molluscan fauna from the lower concretionary sandstone of the overlying Empire Formation is coeval with the fauna in the type section of the Empire Formation at Coos Bay, about 60 km to the north.

INTRODUCTION

A sequence of shallow-water fossiliferous sandstone of Miocene age is exposed in a late Cenozoic section near Cape Blanco, southwestern Oregon (fig. 1). This sequence, commonly known as the Empire Formation of Diller (1903), contains rich but relatively low diversity assemblages of marine macrofossils, principally mollusks. Although the Pliocene is not represented in the section, the sequence nevertheless constitutes the most complete late Cenozoic section exposed on the Oregon coast. Possibly for this reason, it has received considerable study over the 120 years since its discovery (Newberry, 1856). However, composite stratigraphic collections of fossils and the absence of detailed biostratigraphic study have led to widely divergent age determinations on and correlations of these strata.

The basal Miocene strata, here referred to as the sandstone of Floras Lake, are the focus of this report. These strata were included in the Empire Formation by Diller (1903), who correlated them with his type Empire Formation (Diller, 1899) at Coos Bay, about 60 km to the north. Unbeknownst to Diller and later investigators, however, two distinct Miocene faunas separated by an unconformity are represented in his

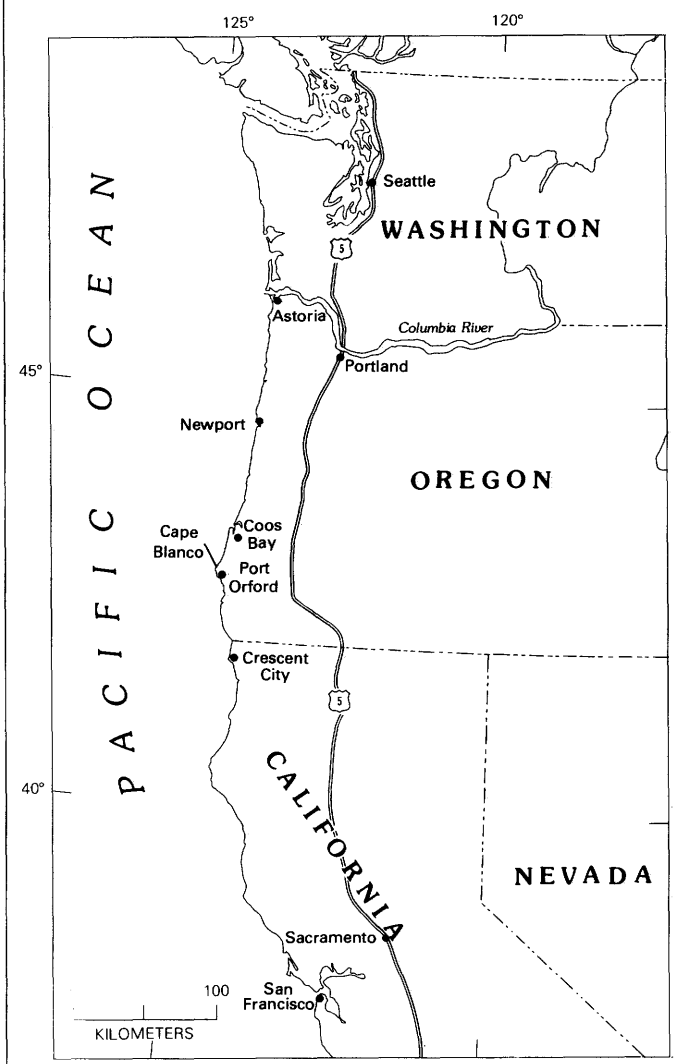


FIGURE 1.—Pacific coast of the United States, showing location of Cape Blanco.

Empire Formation at Cape Blanco. The sandstone and the conglomerate lenses below the unconformity contain mollusks of early and middle Miocene age that are comparable to the fauna of the Astoria Formation of Oregon, as first noted by Durham (1953), whereas the lithologically similar sandstone above the unconformity contains an invertebrate macrofauna of late Miocene age and is in part coeval with the type Empire Formation at Coos Bay.

This report documents the age of the 260-m sequence constituting the Empire Formation of Diller (1903) at Cape Blanco and discusses the age and correlation of the molluscan assemblages in this sequence. Emphasis is on the early and middle Miocene fauna of the 160-m section below the unconformity. These lower assemblages are referable to the provincial Newportian Stage of Addicott (1976). Some of the confusion over the age of this shallow-water marine sequence can be traced to the fact that the only published faunal list from the Empire (Arnold and Hannibal, 1913, loc. NP26) was based on material from both above and below the unconformity. The fauna from the sandstone and siltstone overlying the unconformity, based on U.S. Geological Survey collections, is listed herein for the first time. The taxonomy of this late Miocene fauna is well known, owing to monographic treatment of the fauna of the Empire Formation at Coos Bay (Dall, 1909), some 60 km to the north, and to subsequent biostratigraphic studies of the type section between the Sitka dock and the bridge to Charleston (Weaver, 1945; Armentrout, 1967).

Acknowledgments.—Invertebrate macrofaunal collections from the Miocene sequence were obtained in 1964, 1968, 1969, 1971, 1977, and 1978. R. J. Janda assisted in securing fossil collections in 1969 and 1971; he also made available a sequence of black-and-white photographs of the seacliffs southeast of Cape Blanco from which the sketch section was constructed. Hiroshi Noda helped in stratigraphic sampling in 1978. E. M. Baldwin of the University of Oregon, Eugene, lent fossil material collected from the Cape Blanco section and discussed with me the sequence of his Neogene and Quaternary stratigraphic units (Baldwin, 1945). J. A. Barron provided a late Miocene age determination based on a diatomaceous assemblage from near the top of the Miocene sequence southeast of Cape Blanco. Fossil photography is by Kenji Sakamoto.

PREVIOUS STUDIES

The many references to the age of the marine strata near Cape Blanco over the past 120 years point to a continuing interest in this unique coastal section of Neogene and Quaternary age. The provincial age and correlation of the sandstone and the congolomerate lenses in the lower part of the section have been subject to contradictory viewpoints because they were based, in large part, on a stratigraphically mixed collection (Arnold and Hannibal, 1913, loc. NP26) that spanned 200 m or more of section and included assemblages from what are now known to be two provincial stages, the Newportian and the Wishkahan. A recapitulation of earlier work may help place the present study in proper perspective.

Newberry (1856, p. 59) considered the marine Neogene strata that he recognized near Cape Blanco to be probably correlative with sandstone and shale at Astoria, Oreg., later described as the Astoria Formation. His report was cited by Dall and Harris (1892), who included these strata in the Neogene, and by Diller (1896), who assigned them to the Miocene.

Diller (1902, 1903) was the first to describe and map the Neogene sequence near Cape Blanco. W. H. Dall (in Diller, 1902, p. 30–31) identified fossils from near the base of sandstone cropping out between Blacklock Point and Floras Lake, northeast of Cape Blanco, as Miocene and correlated the assemblage with the Empire Formation at Coos Bay. A thicker and lithological similar section southeast of Cape Blanco was assigned by Diller to the Empire Formation (as the "Empire beds") on the basis of paleontologic determinations by Dall. The lower 120 to 150 m of this section and the Neogene section north of Blacklock Point were subsequently determined to be middle Miocene (Durham, 1953).

The first molluscan assemblages recorded from these strata (Arnold and Hannibal, 1913, p. 590–591) included specimens from a locality between Blacklock Point and Floras Lake (3 species) and the stratigraphically mixed collection of Miocene species from southeast of Cape Blanco (24 species), referred to above. Arnold and Hannibal (1913, p. 590) considered the Empire Formation to be middle Miocene but younger than both the Astoria and the Clallam Formations, which they considered to be of "Oligocene-Miocene age." The Empire was correlated with formations that are now considered to be late Miocene.

The age of the Empire Formation at Cape Blanco continued to be controversial for many years after Arnold and Hannibal's (1913) report. The exposures were considered to be as old as Oligocene by Kew (1920) on the basis of an echinoid (*Scutella blancoensis*), and as young as Pliocene (Schenck, 1928; Bandy, 1950). Other workers (Hertlein and Crickmay, 1925; Weaver, 1942) considered the Empire Formation at Cape Blanco to be late Miocene and (or) early Pliocene. Schenck (1936, p. 95), who reviewed the problem of the age of

the Empire Formation at Cape Blanco, pointed out the provincial Miocene affinities of *Scutella blancoensis* Kew and the Pliocene affinities of the associated mollusks, as noted by other workers (see Howe, 1922). The age of the Empire Formation of Diller (1903) southeast of Cape Blanco was clarified by Durham (1953), who identified the unconformity within the formation at a point about 1½ km southeast of Cape Blanco. This unconformity separates early or middle Miocene molluscan assemblages below from late Miocene assemblages coeval with the type Empire Formation at Coos Bay, Oreg., above. Durham's (1953) discovery explained the anomalous mixing of such middle Miocene species as *Acila conradi*, *Mytilus middendorffi*, *Nassarius arnoldi*, *Cancellaria oregonensis*, and "*Fusus*" [*Bruclarkia*] *stanfordensis* with such characteristic late Miocene (then considered Pliocene) species as *Cardium* [*Clinocardium*] *meekianum*, *Calliostoma cammani*, and *Thais precursor*, all listed by Arnold and Hannibal (1913).

STRATIGRAPHIC SETTING

Miocene sandstone unconformably overlies sandstone and pebbly mudstone of the Upper Jurassic Otter Point Formation at Cape Blanco (Dott, 1971), and middle Eocene shale and sandstone (Bandy, 1944) in the seacliff southeast of the cape. At Blacklock Point (fig. 2), about 6 km northeast of Cape Blanco, Miocene sandstone and pebble conglomerate unconformably overly sandstone and mudstone included by Dott (1971) in his Upper Cretaceous Hunters Cove Formation.

All of the Neogene sequence exposed near Cape Blanco was included in the Empire Formation of Diller (1903); as I show, however, it seems advisable to restrict the use of this term to the upper part of the sequence, which is late Miocene. The Empire at Cape Blanco is unconformably overlain by the Pleistocene Port Orford Formation of Baldwin (1945), a unit rich in molluscan fossils. Unconformably capping the late Cenozoic strata at Cape Blanco are marine-terrace deposits of late Pleistocene age. Mollusks and a few foraminifers have been identified from these strata (Addicott, 1964; Bandy, 1950).

The Neogene sequence exposed between Blacklock Point and Floras Lake, a distance of about 3 to 4 km, consists of massive brown-weathering fine- to medium-grained sandstone that forms prominent steep cliffs. Pebble- and cobble-conglomerate lenses, as much as ⅓ m thick, are common in the lowest part of this seacliff section. Associated with the conglomerate lenses in the lowest 30 to 50 m of section is a low-diversity faunal assemblage of disarticulated *Balanus* plates, *Mytilus middendorffi* Grewingk, *Nucella packi* (Clark), and scattered poorly preserved aragonitic mollusks, including *Molopophorus* sp. and a naticid. A 1½- to 2-m-thick gray thin-bedded pumiceous tuff bed occurs near the top of the exposed section. Concretionary beds in a 15-m interval below the tuff bed contain common well-preserved valves of *M. middendorffi* (USGS loc. M4130). The stratigraphically highest molluscan assemblage (USGS loc. M4132) occurs in concretionary strata exposed in a small gully opposite the middle part of Floras Lake; this assemblage includes *M. middendorffi* and other species characteristic of the Newportian Stage.

The continuously exposed Neogene section of massive conglomeratic and concretionary sandstone that contains a tuff bed near the top constitutes the reference section for the sandstone of Floras Lake, an informal term developed by R. J. Janda (written commun.,

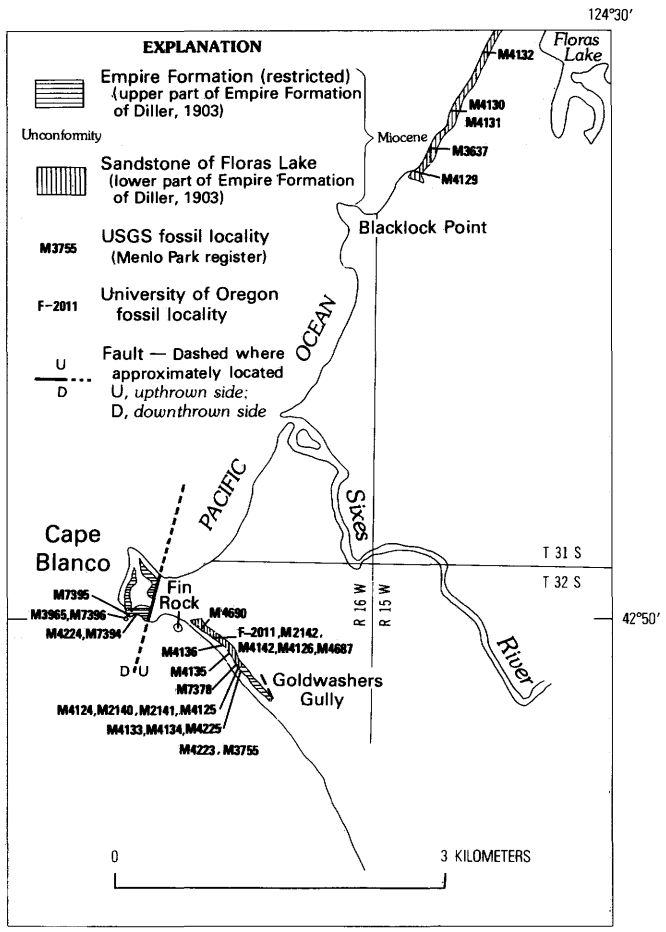


FIGURE 2.—Cape Blanco-Blacklock Point area (Cape Blanco quadrangle), showing megainvertebrate-fossil localities. Modified from Dott (1962).

1975) to avoid use of the potentially confusing name "Empire Formation," in the sense of Diller (1903), for these earlier Miocene strata (Addicott, 1980). Accordingly, the use of the name "Empire Formation" in the Cape Blanco area has been restricted to those strata of late Miocene age (upper part of the Empire Formation of Diller, 1903) that unconformably overlie the sandstone of Floras Lake (lower part of Empire Formation of Diller, 1903) and unconformably underlie the Quaternary Port Orford Formation of Baldwin (1945) (Addicott, 1980). The restricted Empire (fig. 3) is lithologically similar to strata constituting the type section of the Empire Formation at Coos Bay, about 6 km to the north, and to exposures of the formation at intermediate points along the coast (Diller, 1903). This usage is also in close biostratigraphic agreement with the sections exposed at those places.

The Empire Formation has been considered middle Miocene to Pliocene. The middle Miocene age (Durham, 1953; Moore, 1963) was based on strata in the Cape Blanco area (sandstone of Floras Lake) that are now excluded from the Empire. The Pliocene age (Diller, 1896; Howe, 1922; Weaver, 1945) was based on a much lower placement of the Miocene-Pliocene boundary in the provincial sequence—at 9–10 m.y.; this boundary is currently placed at 5 m.y. Thus, the Empire Formation is late Miocene.

On the west side of the north-northeast-trending fault bounding the outer part of Cape Blanco, the sandstone of Floras Lake is not exposed. Instead, the Neogene strata that unconformably overlie Mesozoic sandstone and mudstone in the steep seacliffs at the cape are referable to the restricted Empire Formation. This massive concretionary marine sandstone (fig. 4) contains molluscan assemblages of late Miocene age that are referable to the Wishkahan Stage. Epifaunal marine macroinvertebrates, including *Balanus* and *Chlamys*, are abundant near the base (USGS loc. M3965). Stratigraphically higher beds contain infaunal bivalve assemblages; the venerid bivalve *Securella* is common (USGS loc. M4224).

In the seacliff section southeast of Cape Blanco, the sandstone of Floras Lake grades from pebble and cobble conglomerate near the base to tuff and fine-grained micaceous sandstone near the top. Although the contact with the underlying Eocene shale and sandstone is concealed, the trend of this contact is unconformable, as in the Blacklock Point-Floras Lake section a few kilometers to the north. The basal part of the unit is well exposed at Fin Rock (figs. 3, 5), where the lowest few meters consists of pebble- and cobble-conglomerate lenses and grayish-brown concretionary sandstone that has a knobby texture on weathered surfaces. The conglomerate lenses, as much as ½ m thick, contain

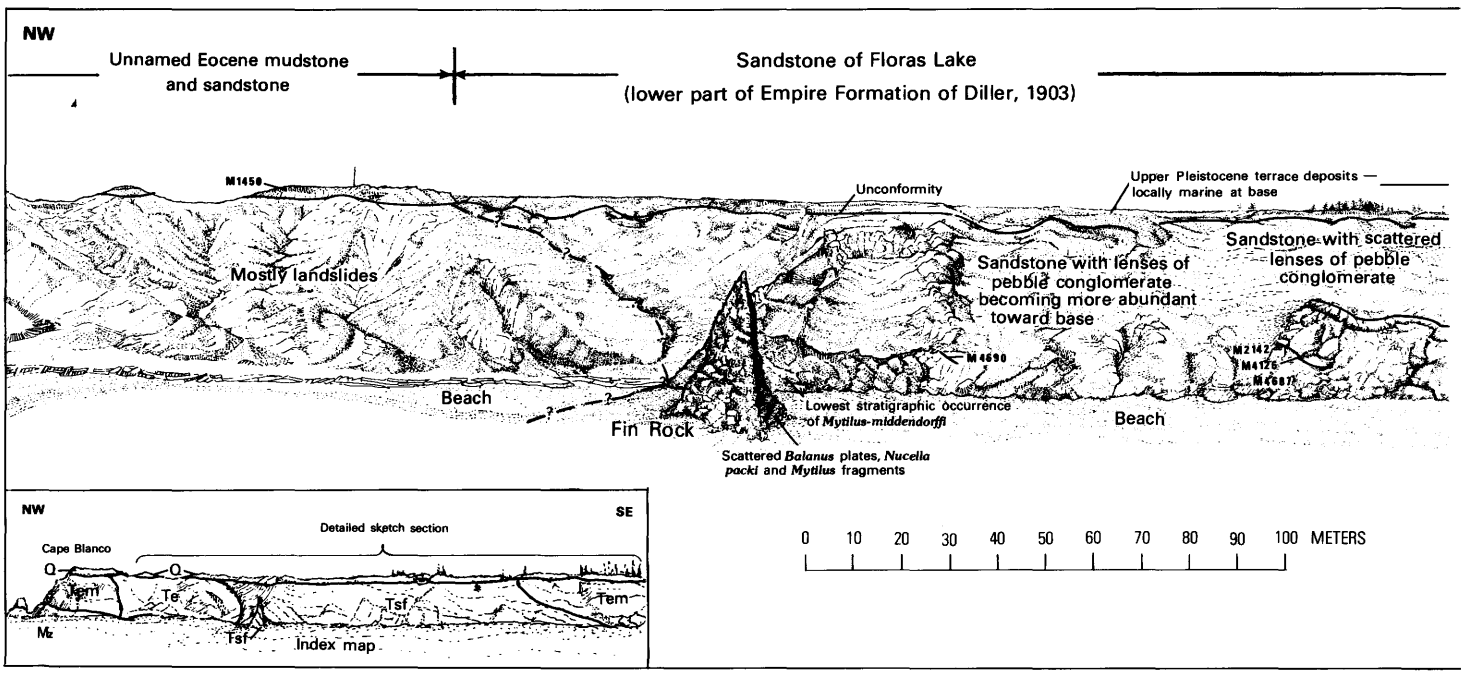


FIGURE 3.—Seacliff section of sandstone of Floras Lake in an area about 1 to 1½ km southeast of lighthouse at Cape Blanco (see fig. 2 for Formation (upper Miocene);

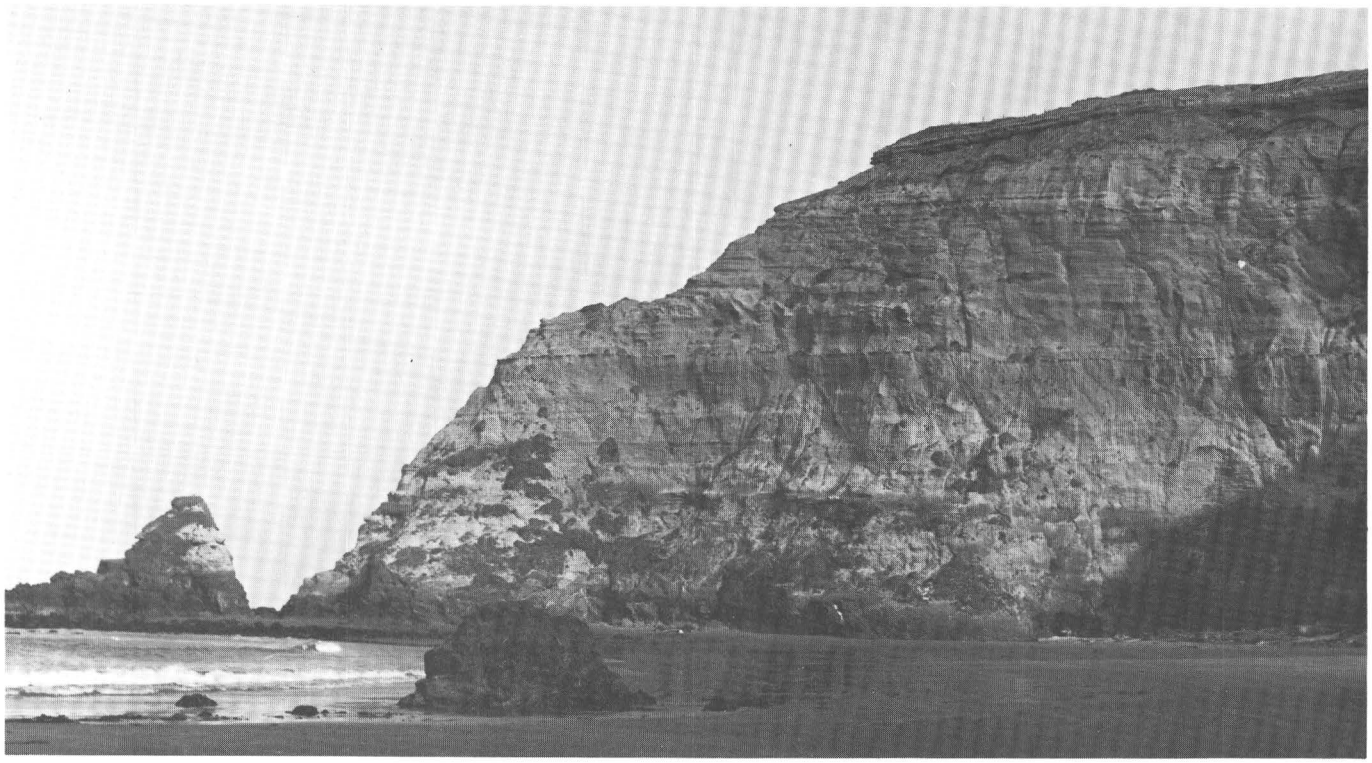
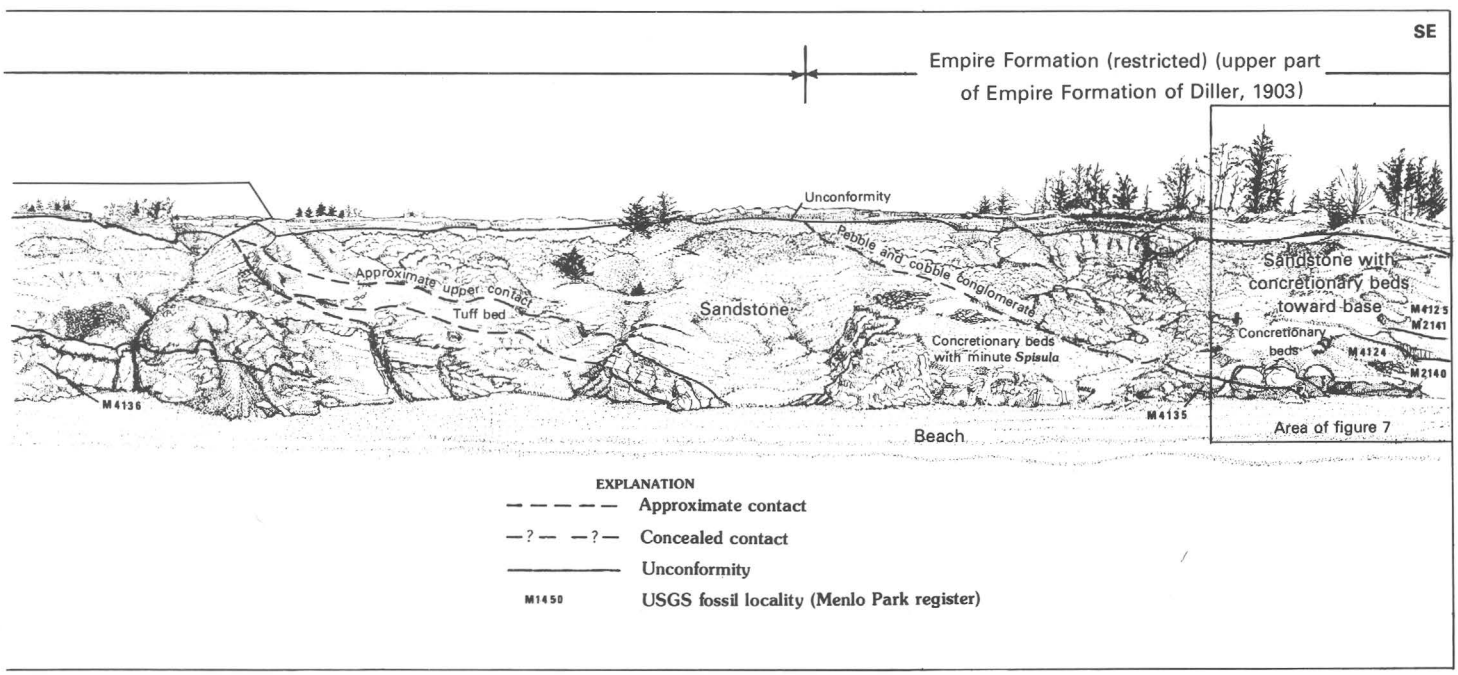


FIGURE 4.—Buff sandstone of the restricted Empire Formation unconformably overlying dark Mesozoic sandstone and mudstone (Dott, 1962) at southwest tip of Cape Blanco. Height of small point is about 12 m. View northwestward.



location). Mz, Mesozoic rocks; Te, Eocene rocks; Tsf, sandstone of Floras Lake (lower and middle Miocene); Tem, restricted Empire Q, Pleistocene terrace deposits.

barnacle plates and scattered individuals of the shallow-water gastropod *Nucella*. These strata grade upward into crossbedded sandstone containing scattered conglomerate lenses and carbonized-wood fragments that occur as lenses in beds which are locally crossbedded. The main fossiliferous localities are in concretionary beds in a 50- to 60-m interval below a tuff bed near the top of the formation (fig. 6). This 7- to 8-m-thick tuff generally is poorly exposed; it is light gray, thin bedded, and pumiceous and contains scattered fossil leaves (Wolfe and Hopkins, 1967). Above the tuff is 30 m of massive carbonaceous and micaceous sandstone, containing scattered large flattened concretions. Minute specimens of articulated *Spisula albaria* (Conrad) are extremeley abundant in many of these concretions.

The contact between the micaceous fine-grained sandstone of the uppermost part of the sandstone of Floras Lake and the unconformably overlying restricted Empire Formation is well exposed at the base of the seacliff about 1½ km southeast of Cape Blanco (fig. 7). The unconformable surface has about 2 m of relief at beach level. The basal conglomerate of the restricted Empire Formation is almost 1 m thick; it consists principally of pebbles and boulders, as much as about 0.2 m in diameter. Larger flattened boulders, as much as 1 m in diameter, occur with regularity along the contact. The boulders are fossiliferous and contain poorly preserved bivalves that suggest a post-Newportian age and are apparently penecontemporaneous. Some of the larger boulders are pitted with pholad burrows, as much as 5 cm in diameter. A University of California collection purportedly from this conglomerate (UCMP loc. A8710) is, in my opinion, a

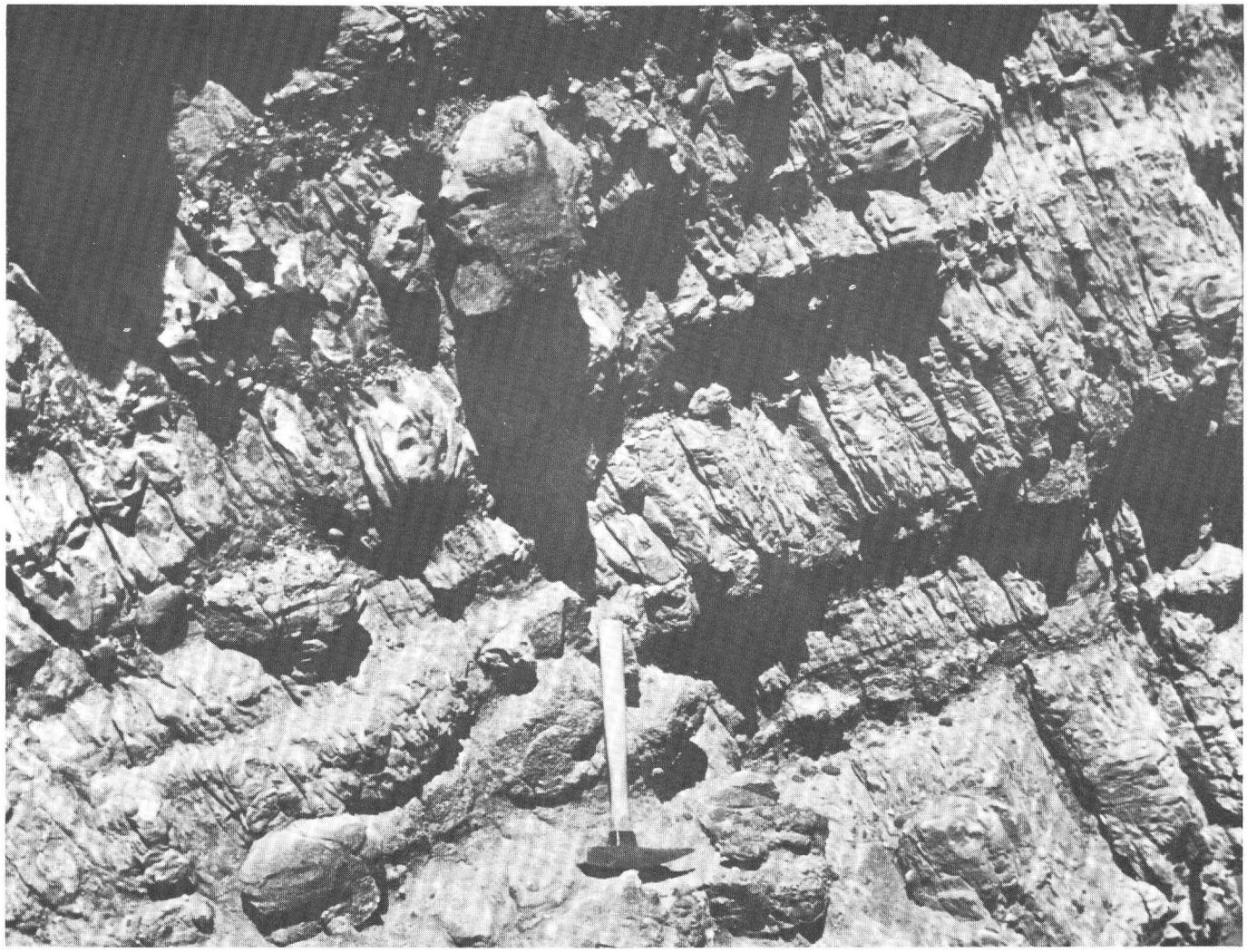


FIGURE 5.—Concretionary sandstone and pebble conglomerate of basal part of sandstone of Floras Lake exposed at low tide on Fin Rock, about 0.5 km east of Cape Blanco (see fig. 2 for location).

stratigraphically mixed sample; most of the specimens are from the Coos Conglomerate Member and the *Pactinopecten*-bearing unit of the type Empire Formation at Coos Bay. There may also be some material from the restricted Empire Formation at Cape Blanco.

The seacliff section of the restricted Empire Formation southeast of Cape Blanco consists of a 0.5-m-thick basal conglomerate, an overlying 35- to 40-m interval of concretionary medium-grained buff sandstone with scattered pebble-conglomerate lenses, and a 50- to 60-m interval of white- to tan-weathering massive very fine grained sandstone and sandy siltstone. The sequence of units is conformable. The lowest 14 to 15 m of the sandstone unit includes the basal pebble to cobble conglomerate containing large sandstone boulders. The conglomerate of lenses in the massive concretionary sandstone unit is fine grained and better sorted than the conglomerate in the lower part of the sandstone of Floras Lake. Vein quartz and chert clasts are very common in this conglomerate. Conspicuous concretionary beds in this interval contain abundant mollusks, notably the shallow-water bivalve *Securella securis* (Shumard) (USGS locs. M2140, M2141, M4124, M4125, M4133, M4134, M4225). The stratigraphically higher part of the basal sandstone unit is less fossiliferous and contains only scattered lenses of pebble conglomerate. The overlying massive sandy siltstone and very fine grained sandstone unit contains a 2-m-thick bed of fine- to medium-grained sandstone and a ½-m-thick pebble bed some 20 m above the base. The massive siltstone contains widely scattered molds of bivalve mollusks. Commonly occurring taxa are: *Lucinoma annulata* (Reeve), *Macoma* cf. *M. calcarea* (Gmelin), *Nuculana* sp., *Portlandia* sp., *Compsomyax* cf. *C. subdiaphana* (Carpenter), and *Cnesterium scissurata* (Dall) (USGS locs. M3755, M4223).

Southeast of Cape Blanco, the restricted Empire Formation is unconformably overlain by poorly consolidated conglomerate and sandstone of the Port Orford Formation of Baldwin (1945). The angular unconformity between these formations (fig. 8) is well exposed in the seacliff southeast of the cape, in the vicinity of

FIGURE 6.—Seacliff exposure of sandstone of Floras Lake about 1 km southeast of Cape Blanco. Massive gray and brown sandstone with scattered pebble-conglomerate lenses and concretionary beds in lower part of section, to left, include best fossiliferous localities in the unit (USGS locs. M2142, M4126, M4687). Conspicuous float from tuff bed is visible in grassy area midway up cliff face at right edge of photograph. Miocene sandstone is unconformably capped by flat-lying fossiliferous stratum and fluvial gravel of late Pleistocene age at top of seacliff. View north-northwestward.

the beach-access road at the mouth of Goldwasher's Gully.

PALEONTOLOGY OF THE SANDSTONE OF FLORAS LAKE

INVERTEBRATE MACROFAUNA

The molluscan fauna of the sandstone of Floras Lake consists of 30 identified molluscan taxa, including 6 taxa identified only as to genus, an echinoid, and a barnacle (table 1). Plates 1 and 2 illustrate most of these macrofossils. Descriptions of the U.S. Geological Survey localities are listed in the Menlo Park, Calif., register of Cenozoic larger-invertebrate localities.

PROVINCIAL AGE

The molluscan fauna of the sandstone of Floras Lake is referable to the Newportian Stage (Addicott, 1976) of the Pacific Northwest Neogene molluscan province (fig. 9). Species that are restricted in stratigraphic occurrence to this stage and are also of fairly widespread distribution in rocks of this age in western Oregon and Washington include: *Molopophorus mat-*

FIGURE 7.—Unconformable contact between *Mytilus middendorffi*-bearing sandstone of Floras Lake and the restricted Empire Formation in seacliff about 1½ km southeast of lighthouse at Cape Blanco (see fig. 2 for location). The Empire is unconformably overlain by late Pleistocene terrace deposits near top of 60-m-high seacliff. View northeastward.

TABLE 1.—*Marine macroinvertebrates from the sandstone of Floras Lake (lower part of the Empire Formation of Diller, 1903) exposed near Cape Blanco, Oregon*

[M number, U.S. Geological Survey, Menlo Park, Calif., Cenozoic locality register, F number, University of Oregon, Eugene, locality. ×, present as identified; cf., similar form; sp., species not determinable; ?, doubtful identification]

Species	Localities										
	Southeast of Cape Blanco							North of Blacklock Point			
	M4687	M2142	M4126	M4135	M4136	M4690	F-2011	M4129	M4130	M4132	M3637
Gastropods:											
Bruclarkia oregonensis (Conrad) (pl. 1, figs. 2, 7, 12, 16)	×	×	×	×	×	×	×	---	---	×	---
Cancellaria n. sp.? aff. *C. alaskensis* Clark (pl. 1, fig. 6; pl. 2, fig. 8)	---	---	---	---	×	×	---	---	---	---	---
cf. *C. ocoyana* Addicott	---	---	---	---	×	---	---	---	---	---	---
Crepidula praerupta Conrad (pl. 2, fig. 6)	---	---	---	---	×	---	---	---	---	---	---
rostralis (Conrad) (pl. 1, figs. 17, 18)	---	×	---	---	---	---	---	---	---	---	---
Cryptonatica oregonensis (Conrad) (pl. 2, fig. 17)	×	---	---	sp.	---	---	sp.	---	sp.	---	---
Liracassis sp. (pl. 1, fig. 14)	---	---	---	---	---	---	---	---	---	×	---
Megasurcula sp. (pl. 1, fig. 19)	---	---	×	---	---	---	?	---	---	×	---
Molopophorus cf. *M. anglonanus* (Anderson) (pl. 1, fig. 15)	sp.	×	---	---	×	---	---	---	---	---	---
matthewi Etherington (pl. 1, figs. 11, 21)	---	×	×	---	×	×	cf.	cf.	---	×	?
Nassarius arnoldi Anderson (pl. 2, fig. 13)	---	---	---	---	---	×	---	---	---	---	---
Natica cf. *N. clarki* Etherington (pl. 1, fig. 9)	---	---	×	---	---	---	---	---	---	---	---
Nucella sp. A (pl. 1, fig. 22; pl. 2, fig. 2)	---	---	---	---	---	---	×	---	---	---	---
sp. B (pl. 2, figs. 14, 15)	---	---	---	---	---	---	×	---	---	---	---
packi (Clark) (pl. 1, figs. 1, 3-5, 13)	---	×	×	---	cf.	---	---	×	×	×	×
Olivella cf. *O. ischnon* Keen (pl. 2, figs. 10, 16)	×	xp.	c	---	?	sp.	×	?	---	---	---
Ophiodermella cf. *O. olympicensis* Addicott (pl. 1, figs. 25, 29)	---	---	×	---	---	×	---	---	---	---	---
Polinices lincolnensis (Weaver) (pl. 1, fig. 8)	×	---	×	---	×	---	---	---	---	---	---
Priscofusus cf. *P. medialis* (Conrad) (pl. 1, fig. 10; pl. 2, fig. 11)	---	---	×	---	---	---	---	---	---	---	---
Bivalves:											
Katherinella cf. *K. angustifrons* (Conrad) (pl. 2, figs. 3, 7)	---	×	---	---	×	---	---	?	?	×	---
Macoma cf. *M. flagleri* Etherington (pl. 2, fig. 18)	---	×	×	×	---	×	---	---	---	?	---
cf. *M. secta* (Conrad) (pl. 2, fig. 5)	---	×	---	---	---	×	---	---	---	---	---
Mytilus middendorffi Grewingk (pl. 2, figs. 1, 4, 19)	×	×	×	×	×	×	---	cf.	×	×	×
Securella sp. (pl. 2, fig. 20)	×	---	---	---	×	---	---	---	---	---	---
Solen conradi Dall (pl. 1, fig. 24)	---	cf.	×	?	---	---	---	---	---	---	---
Spisula albaria (Conrad) (pl. 1, figs. 26, 28)	×	×	×	cf.	cf.	×	×	---	---	---	?
cf. *S. selbyensis* Packard (pl. 2, fig. 21)	---	---	×	---	×	sp.	---	---	---	---	---
Tellina emacerata Conrad (pl. 1, fig. 27; pl. 2, fig. 12)	×	?	×	---	×	---	×	---	---	?	---
Yoldia (Kalayoldia) cf. *Y. (K.) carnerosensis* Clark (pl. 1, fig. 23)	×	×	×	---	×	×	?	---	---	?	---
aff. *Y. cooperi* Gabb	×	---	---	---	---	---	---	---	---	---	---
Scaphopod:											
Dentalium sp.	---	---	---	×	×	---	---	---	---	---	---
Echinoid:											
Kewia cf. *K. blancoensis etheringtoni* Weaver (pl. 2, fig. 9)	---	---	×	---	---	?	---	---	---	---	---
Barnacle:											
Balanus sp.	---	×	×	---	---	---	---	×	×	---	---

thewi Etherington, *Nassarius arnoldi* (Anderson), *Macoma flagleri* Etherington, and *Mytilus middendorffi* Grewingk. Other species have provincial stratigraphic ranges that extend from the older Juanian and (or) Pillarian Stages into the Newportian, or from the Newportian into the younger Wishkahan and (or) Graysian Stages (table 2). The cooccurrence of these species in the fossil record, then, is a further indication of a Newportian age.

Correlative strata at Coos Bay, some 60 km to the north, yielded small assemblages from dredgings (Moore, 1963) and from a recently discovered 9-m-thick section of sandstone on the east shore of Coos Bay (Baldwin, 1966; Armentrout, 1967, 1978) that contains typical Newportian mollusks. These *Dosinia*-rich collections contain a few specimens of the characteristic Newportian species *Mytilus middendorffi* Grewingk (USGS loc. 18284).

CORRELATION

The Newportian fauna at Cape Blanco is of interprovincial chronostratigraphic significance in that it demonstrates the temporal equivalence of this Pacific Northwest time-stratigraphic unit with the "Temblor" Stage of central and southern California. Almost 80 percent of the 23 specifically identified molluscan species in the Cape Blanco fauna occur in the fauna of the "Temblor" Stage, and many of these species are stratigraphically restricted to that stage (table 2). The much larger molluscan fauna from the type section of the Newportian Stage, about 200 km to the north, has only a small percentage of species in common with the "Temblor" Stage (Moore, 1963; Snavely and others, 1964, p. 150), partly because of the presence of many endemic species in the Neogene molluscan province of the Pacific Northwest during the Miocene.

The occurrence of the distinctive plicate mussel *Mytilus middendorffi* Grewingk (pl. 2, figs. 1, 4, 19) in the sandstone of Floras Lake permits correlation of this unit with late Miocene and early middle Miocene deposits extending from southern California to the Gulf of Alaska (Allison and Addicott, 1976) and, possibly, Kamchatka (Pronina, 1969).

PALEOECOLOGY

Low-diversity assemblages of epifaunal invertebrates—*Mytilus*, *Balanus*, and *Nucella*—in the lower parts of the Blacklock Point and Cape Blanco sections indicate deposition in extremely shallow water close to a rocky shoreline. Moreover, lenses of pebble conglomerate characteristic of these basal strata appear to be homologous with the pebble gravel that occurs in the present-day surf-zone sediment of this area. In the Puget Sound area of northwestern Washington, *Mytilus* and *Balanus* form extensive beds in the lower reaches of the modern intertidal zone; dense accumulations of these macroinvertebrates can, therefore, be taken as indicative of low-intertidal to high-subtidal environments. Living species of *Nucella* similar to those in the sandstone of Floras Lake prey on young mussels and, to a lesser extent, on barnacles (Paris, 1960; Houston, 1971). The intimate association of *Nucella* with mussel beds in the intertidal zone along the east North Pacific coast has been noted by other workers (Smith and Gordon, 1948; McLean, 1969; Rice, 1971). This assemblage, then, suggests a rocky intertidal environment. The presence of these three invertebrates in pebble congomerate and pebbly sandstone indicates transportation in the surf zone, but their generally very good preservation indicates that the tests were not subjected to prolonged abrasion and that deposition may have been fairly rapid.

Upsection, faunal diversity increases markedly, and infaunal bivalves and vagrant epifaunal forms become especially common. *Nucella* and *Mytilus* are present, but *Spisula*, *Macoma*, *Bruclarkia*, and naticoid gastropods characterize the middle to upper parts of the section southeast of Cape Blanco; faunal diversity increases northeast of Blacklock Point, though to a much lesser extent. This increase in diversity, together with the appearance of *Katherinella*, *Liracassis*, and *Dentalium*, indicates waters deepening to about 10 to

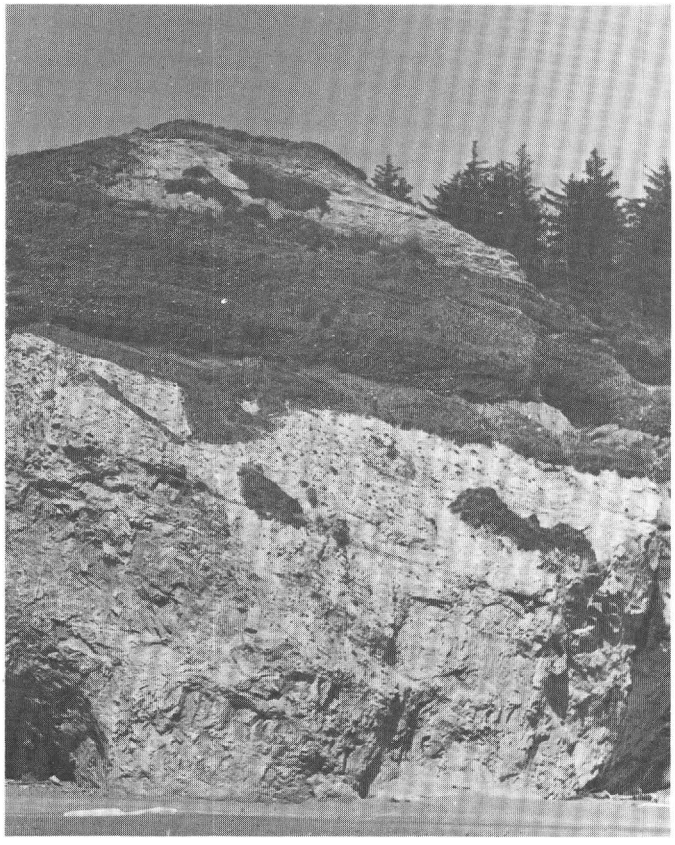


FIGURE 8.—Angular unconformity between massive silty sandstone and siltstone of the restricted Empire Formation and overlying conglomerate and sandstone of the Port Orford Formation of Baldwin (1945) in seacliff about 2 km southeast of lighthouse at Cape Blanco (see fig. 2 for location). Seacliff is about 60 m high. View northeastward.

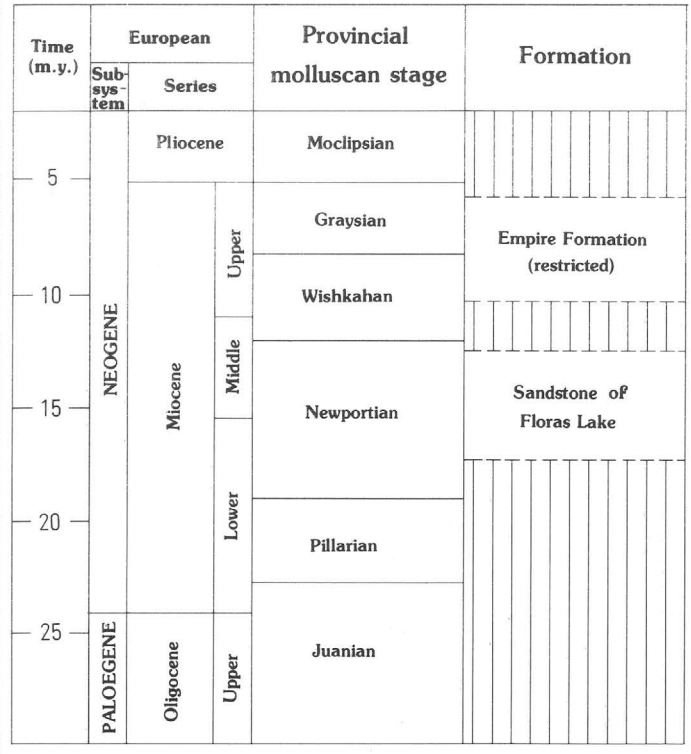


FIGURE 9.—Correlation of Neogene formations exposed at Cape Blanco, Oreg., with Pacific Northwest Territory molluscan chronology (Addicott, 1976).

TABLE 2.—*Provincial stratigraphic range of species in the Cape Blanco Newportian fauna, with notes on their occurrence in the California Neogene molluscan province*

[Data principally from Loel and Corey, 1932; Moore, 1963; Addicott, 1970, 1972, 1973, 1976; Marincovich, 1977]

Species	Pacific Northwest molluscan stage					Occurrence in California Neogene molluscan stages
	Juanian	Pillarian	Newportian	Wishkahan	Graysian	
Bruclarkia oregonensis (Conrad)		—	—			"Vaqueros" and "Temblor"
Cancellaria ocoyana Addicott			—			"Temblor"
Crepidula praerupta (Conrad)	—	—	—	—	—	"Vaqueros" and "Temblor"
rostralis (Conrad)		—	—			"Temblor"
Cryptonatica oregonensis (Conrad)		—	—			(not recorded in California Neogene)
Molopophorus cf. *M. anglonana* (Anderson)			—			"Vaqueros" and "Temblor"
matthewi Etherington			—			(not recorded in California Neogene)
Nassarius arnoldi (Anderson)			—			"Temblor"
Natica cf. *N. clarki* Etherington		—	—			(not recorded in California Neogene)
Nucella packi (Clark)			—			"Vaqueros" and "Temblor"
Olivella cf. *O. ischnon* Keen			—			"Temblor"
Ophiodermella cf. *O. olympicensis* Addicott		—	—			(not recorded in California Neogene)
Polinces victorianus Clark and Arnold		—	—			"Vaqueros" and "Temblor"
Priscofusus cf. *P. medialis* (Conrad)		—	—			"Vaqueros" and "Temblor"
Katharinella angustifrons (Conrad)		—	—			"Temblor"
Macoma cf. *M. flagleri* Etherington			—			(not recorded in California Neogene)
cf. *M. secta* (Conrad)			—	—	—	"Vaqueros" to Holocene
Mytilus middendorffi Grewingk			—			"Temblor"
Solen conradi Dall		—	—	—		"Vaqueros" and "Temblor"
Spisula albaria (Conrad)		—	—	—	—	Unnamed to "Etchegoin"
cf. *S. selbyensis* Packard			—			"Temblor"
Tellina emacerata (Conrad)		—	—	—		Unnamed to "Margaritan"
Yoldia cf. *Y. carnerosensis* Clark			—			"Temblor" and "Margaritan"

20 m. A field identification of *Patinopecten* in the upper part of the Blacklock Point section supports this depth.

The stratigraphically highest beds of the sandstone of Floras Lake exposed southeast of Cape Blanco (USGS loc. M4135) contain an assemblage of minute articulated specimens of *Spisula* and scattered *Dentalium*. The rocks are highly micaceous, an indicator of relatively quiet and possibly deeper water conditions than those present when stratigraphically lower units in the sandstone of Floras Lake were laid down. Mica does not occur in appreciable amounts in modern sediment of the California coast in waters shallower than about 10 to 20 m; however, it is highly concentrated at depths greater than 35 to 40 m (Galliher, 1932).

The succession of marine macroinvertebrate communities preserved in the 150- to 180-m-thick early and middle Miocene section southeast of Cape Blanco indicates deposition in the inner sublittoral zone but suggests some progressive deepening as deposition progressed. The occurrence of fossil leaves (Wolfe and Hopkins, 1967, p. 70–71) in a 5- to 10-m-thick thin-bedded locally cross-stratified tuff bed near the top of the formation may indicate a brief reversal of this deepening trend. According to J. A. Wolfe (written commun., 1977), the taxonomic composition of the florule and fragmentation of the leaf specimens indicate transportation in a high-energy environment. No marine mollusks were found with the fossil leaves.

The taxonomic predominance of gastropods over bivalves suggests an open-coast depositional environment rather than the protected-bay environment typified by many of the bivalve-dominated assemblages from the middle and late Miocene of northern California (Clark, 1915; Hall, 1958). This relation was first observed by Packard (1918) in the modern level-bottom faunal assemblages of San Francisco Bay and the adjacent open-coastal area of northern California.

Probably the most significant paleoecologic aspect of the macrofauna in the sandstone of Floras Lake is its deposition in unusually shallow water. Assemblages from the lowest part of the unit are of markedly shallower water aspect than any of the well-known assemblages (Moore, 1963) of the Newportian Stage farther north along the Oregon and Washington coast (from Coos Bay to the mouth of the Columbia River). The characteristic faunal elements of the sandstone of Floras Lake—*Mytilus*, *Balanus*, and *Nucella*—occur exceedingly rarely in assemblages from the coeval Astoria Formation. These genera occur in only three of the more than 200 collections listed by Moore (1963, table 2). Moreover, the presumably shallow water echinoid *Kewia* (USGS locs. M4125, M4690) is not reported from any locality in the Astoria Formation of Oregon.

PALEONTOLOGY OF THE RESTRICTED EMPIRE FORMATION

The restricted Empire Formation (upper part of the Empire Formation of Diller, 1903) contains mollusks of late Miocene age referable to the Wishkahan Stage (pl. 3;.table 3). Southeast of Cape Blanco, where the formation unconformably overlies the sandstone of Floras Lake, these mollusks occur in the lower 30 m of the restricted Empire (fig. 10). Mollusks observed in and collected from the basal conglomerate (loc. M7378) include: *Chlamys* sp., *Securella securis* (Shumard), *Yoldia* (*Kalayoldia*) sp., *Spisula* sp., *Saxidomus giganteus* (Deshayes), *Cryptonatica* sp., and *Olivella* sp. The previously noted mixed collection of mollusks (UCMP loc. A8710) that is allegedly from this conglomerate contains specimens of *Crepidula princeps* (Conrad),

Securella securis (Shumard), *Macoma* spp., *Pseudocardium* sp., and other mollusks that are identical in preservation to material from the Coos Conglomerate Member of the Empire Formation at Coos Bay, 60 km north. They have the characteristic yellow coarse-grained sandstone matrix and show signs of transportation before ultimate deposition. The *Patinopecten coosensis* (Shumard) specimens in this collection presumably are from the rocks exposed at Pecten Point in the lower part of the type section of the Empire Formation at Coos Bay. The mixing can be explained by the fact that this material was collected by a student group that visited all the localities in question during a brief field trip in 1952; the presumption is that inadequate notes may have been kept with the samples and that mixing occurred as a result. Very poorly preserved sand-dollar echinoids in this collection that seem to be *Scutellaster oregonensis* (Clark) may be from the Empire section at Coos Bay rather than from Cape Blanco.

At Cape Blanco, where the Empire unconformably overlies pebbly mudstone of Mesozoic age (Dott, 1962), the Empire is bounded on the east side of the Cape by a

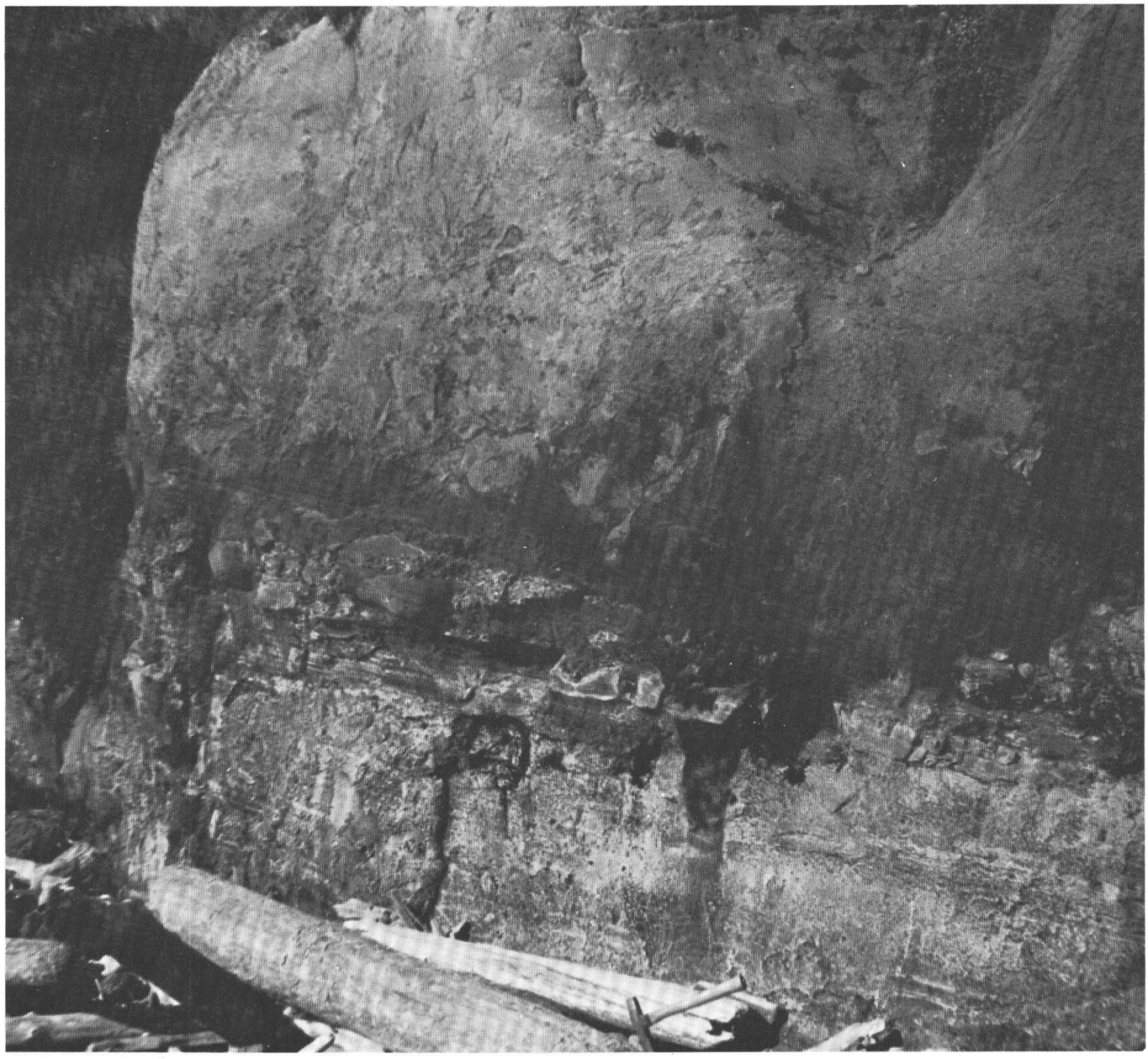


FIGURE 10.—Unconformable contact between bedded micaceous sandstone of Floras Lake and massive concretionary sandstone of the restricted Empire Formation exposed in seacliff southeast of Cape Blanco.

TABLE 3.—*Late Miocene (Wishkahan) macroinvertebrates from the lower part of the restricted Empire Formation near Cape Blanco, Oregon*

[M number, U.S. Geological Survey, Menlo Park, Calif., Cenozoic locality register; ×, present as identified; cf., similar form; ?, doubtful identification; g, genera only]

Species	Localities												
	Fin Rock-Goldwasher's Gully								Cape Blanco				
	M2140	M2141	M4124	M4125	M4133	M4134	M4225	M7978	M3965	M4224	M7369	M7394	M7395
Gastropods:													
Acmaea sp	---	×	---	---	---	---	---	---	---	---	---	---	---
Calliostoma cammani Dall	---	---	---	---	---	---	---	---	---	---	×	---	---
Crepidula aduncа Sowerby	---	cf.	---	×	---	---	---	---	×	---	---	---	---
cf. *C. princeps* Conrad	---	---	---	---	---	---	---	---	×	---	g	×	---
cf. *C. onyx* Sowerby	---	---	---	×	---	---	---	---	---	---	---	---	---
Cryptonatica cf. *C. clausa* (Broderip and Sowerby)	---	×	---	---	---	?	---	---	---	?	---	g	---
Diodora sp	---	---	---	---	---	---	---	---	---	---	×	---	---
Liomesus sulcatus Dall	---	---	---	---	---	---	---	---	---	---	---	×	---
Littorina petricola Dall	---	---	---	---	×	---	---	---	---	---	---	---	---
Mediargo sp	---	×	---	---	---	---	---	---	---	---	---	---	---
Molopophorus bogachieli (Reagan)	cf.	×	---	×	---	×	---	---	---	×	---	---	---
Nassarius andersoni (Weaver)	---	---	---	---	---	cf.	---	---	---	---	×	g	---
hoquiamensis Addicott	---	---	---	---	---	---	---	---	×	---	---	---	---
Neptunea lyrata (Gmelin)	---	---	---	---	---	---	---	---	---	---	---	×	---
Nucella canaliculata (Duclos)	×	---	---	×	×	---	×	---	cf.	cf.	×	---	---
etchegoinensis (Arnold)	---	×	---	cf.	---	---	---	---	---	---	---	---	---
lima (Gmelin)	cf.	cf.	---	×	×	×	---	---	---	---	×	---	---
Ocenebra sp	---	×	---	---	---	---	---	---	---	---	---	---	---
Olivella sp	---	---	---	---	---	---	---	×	---	---	---	---	---
Opalia wishkahensis Durham	---	---	cf.	---	---	×	---	---	---	---	---	---	---
Polinices sp	---	---	---	---	---	---	---	---	---	---	---	×	---
Trochita n. sp. Moore	---	---	---	---	---	---	---	---	---	×	---	---	---
Trophonopsis cf. *T. stuarti* (Smith)	---	---	---	---	---	---	---	---	---	---	×	---	---
sp	---	---	---	---	---	---	---	---	---	---	×	---	---
Bivalves:													
Acila blancoensis Howe	×	×	×	×	×	---	×	---	---	×	---	---	---
Anadara trilineata (Conrad)	×	---	×	×	---	cf.	?	---	---	×	cf.	×	---
Arca sp	---	---	---	---	---	---	---	---	×	---	---	---	---
Chlamys hodgei (Hertlein)	---	---	---	---	---	---	---	g	×	---	×	g	×
sp	---	---	---	---	---	---	---	---	---	---	×	---	×
Clinocardium meekianum (Gabb)	×	×	×	cf.	×	cf.	cf.	---	---	×	×	?	---
Cnesterium aff. *C. scissurata* (Dall)	---	×	---	---	---	---	---	---	---	---	---	---	---
Felaniella parilis (Conrad)	×	---	---	×	---	---	×	---	---	×	×	---	---
Glycymeris grewingki Dall	×	---	×	---	×	---	×	---	cf.	×	×	g	---
Lucinoma cf. *L. acutilineata* (Conrad)	---	---	×	---	---	---	---	---	---	---	---	---	---
Macoma indentata Carpenter	---	---	---	×	---	---	---	---	---	---	---	---	---
secta (Conrad)	×	---	cf.	---	---	---	---	---	---	---	---	×	---
Mizuhopecten n. sp	---	---	---	---	---	---	---	---	---	---	×	---	---
Modiolus sp	---	×	---	---	---	---	---	---	---	---	---	---	---
Pandora sp	---	---	---	---	---	---	×	---	---	---	---	---	---
Securella securis (Shumard)	×	---	×	×	---	×	×	---	×	×	cf.	×	---
Saxidomus giganteus (Deshayes)	---	---	---	---	---	---	---	×	---	---	---	---	---
Siliqua cf. *S. lucida* (Conrad)	---	×	---	×	---	---	?	---	---	---	---	---	---
Spisula cf. *S. albaria coosensis* Howe	×	---	×	×	×	---	---	g	---	×	---	---	---
praecursor Dall	---	×	---	---	---	---	---	---	---	---	---	---	---
Tellina aragonia Dall	---	---	---	---	---	---	---	---	---	×	---	---	---
cf. *T. bodegensis* Hinds	---	---	---	---	---	---	---	---	---	×	---	---	---
Tellinella merriami (Weaver)	---	×	---	---	---	---	cf.	---	---	---	---	---	---
Tresus pajaroanus (Conrad)	---	---	×	---	---	---	---	---	---	---	---	---	---
Yoldia cooperi Gabb	×	---	---	---	---	---	---	---	---	---	---	---	---
Echinoid:													
Kewia blancoensis (Kew)	---	×	---	---	---	---	---	---	---	---	g	---	---
Barnacle:													
Balanus tintinnabulum coosensis Dall	---	×	---	---	---	---	---	---	---	---	---	g	---
Terebratalia transversa caurina Gould	---	---	---	---	---	---	---	---	---	---	---	---	×

north-northeast-trending fault that juxtaposes the restricted Empire Formation containing Wishkahan assemblages on the west side against middle Eocene marine strata on the east side (Dott, 1971, fig. 34). The basal Miocene strata on the east side of the fault that unconformably overlie the Eocene strata consist of poorly fossiliferous sandstone and conglomerate of early and middle Miocene age; these strata are referable to the Newportian Stage.

Table 3 lists mollusks collected from the basal part of the restricted Empire Formation. Species from the restricted Empire that occur only in the Wishkahan Stage include: *Acila blancoensis* Howe, *Glycymeris grewingki* Dall [= *G. gabbi* Dall], *Tellinella merriami* (Weaver), and *Opalia wishkahensis* Durham. Many other species appear in the Wishkahan Stage but range into younger strata: *Nassarius* cf. *N. andersoni* (Weaver), *Nucella canaliculata* (Duclos), *Molopophorus bogachieli* (Rea-

gan), *Clinocardium meekianum* (Gabb), and *Securella securis* (Shumard). The close identity with the much larger fauna of the type section of the Empire Formation at Coos Bay suggests that these two units are coeval. The greater diversity of the type Empire fauna may result from the much broader area of exposure in addition to the concentration of reworked fossils in the intraformational Coos Conglomerate Member. Another factor is the apparently greater depth of deposition of the type Empire Formation, as judged by the common occurrence of the bivalve *Patinopecten* and the gastropod *Neptunea* in sandstone that underlies the Coos Conglomerate Member; neither genus is known from the Cape Blanco exposures. The Empire Formation at Coos Bay was long considered to be Pliocene (Diller, 1986; Howe, 1922; Weaver, 1945), but recalibration of the provincial molluscan chronology with European standards (Addicott, 1976) has raised the Miocene-Pliocene boundary such that the formation here is now assigned a late Miocene age.

Scattered bivalves in the massive sandy siltstone and very fine grained sandstone of the upper part of the restricted Empire Formation (see list on p. 7) constitute a low-diversity assemblage of poorly preserved mollusks that is not diagnostic of provincial age and correlation. Siliceous microfossils that occur with these mollusks, however, indicate a late late Miocene age. Correlation of the diatom florule with florules in the upper part of the Montesano Formation of Weaver (1912) of southwestern Washington (J. A. Barron, oral commun., 1977) suggests that the molluscan assemblage may be referable to the Graysian Stage. The assemblage from U.S. Geological Survey microfossil locality Mf3943 (=M3755) includes the diatoms *Actinoptychus minutus* Greville, *A. vulgaris* var. *monicae* Grunow, *Coscinodiscus lineatus* var. *leptopus* Grunow, *C. temperi* Brun, *Denticula hustedtii* Simonsen and Kanaya, *Lithodesmium californicum* Grunow, *Nitzschia praereinholdii* Schrader, *Rouxia californica* Peragallo, *Stephanopyxis schenckii* Kanaya, and *Thalassiosira lineata* Jouse. Also recorded from locality Mf3943 are the silicoflagellates *Distephanus speculum* var. *pseudocrux* Schulz and *D. pseudofibula* (Schulz) Bukry. J. A. Barron (oral commun., 1979) correlated this assemblage with North Pacific Diatom Zone 11 and assigned it to the late Miocene, noting that benthic foraminifers of the upper part of the Mohnian Stage occur in this zone in southern California.

The restricted Empire Formation is unconformably overlain by the conglomerate and sandstone of the Port Orford Formation of Baldwin (1945), the lower part of which contains early Pleistocene molluscan assemblages composed entirely of living species. The inner, sublittoral fauna of this formation has long been of interest to malacologists (Arnold and Hannibal, 1913, p. 595–597; Martin, 1916, p. 245–247; Smith, 1919, p. 138; Hertlein and Crickmay, 1925, p. 275–276; Zullo, 1961; Allison and others, 1962). The molluscan and echinoid fauna of the Port Orford was the subject of doctoral research by Barry Roth at the University of California, Berkeley (Roth, 1979).

The basal part of the Port Orford, the "Goldwasher's Gully member" (R. J. Janda, written commun., 1978), consists of buff sandstone and thin pebble-conglomerate beds, exposed at Goldwasher's Gully (fig. 11). This unit contains scattered burrows and molds of invertebrates that suggest a marine origin. The unit is truncated by a 7- to 8-m-thick conglomerate that is regarded by sedimentologists as fluvial in origin (R. J. Janda, oral commun., 1979). The conglomerate oversteps the so-called Goldwasher's Gully member of the Port Orford Formation to lie unconformably on the Empire Formation west of Goldwasher's Gully (fig. 11). The conglomerate forms the basal part of the Elk River Formation, a unit containing exceptionally rich deposits of bivalves in its upper part. Excellent exposures of these fossiliferous beds occur a few meters stratigraphically above a conspicuous bluish-gray massive silty sandstone containing scattered concretions with *Katherinella* and *Pactinopecten caurinus* (Gould). These deposits are informally known as the *Psephidia* beds, owing to the dense accumulation of this small bivalve (see Clifton and Boggs, 1970). The beds are best exposed in seacliffs about 2½ km southeast of Goldwasher's Gully (fig. 12).

AGE AND PROVENANCE OF *SCUTELLA BLANCOENSIS* KEW

Contradictory statements as to the geologic age and stratigraphic occurrence of the type specimens of *Scutella [Kewia] blancoensis* Kew have left the chronostratigraphic status of this species in doubt. The species has been considered to be as old as Oligocene (Kew, 1920) and as young as Pliocene (Weaver, 1942). Recent mapping (Dott, 1962; R. J. Janda, unpub. data, 1978) and biostratigraphic studies on the stratigraphic occurrence of this taxon strongly suggest that it is of provincial early late Miocene age and referable to the Wishkahan Stage.

The type specimens of *Scutella blancoensis* Kew (1920, p. 64–65, pl. 11, figs. 1a–1c) are from two localities near Cape Blanco (Stanford Univ. loc. NP26, California Acad. Sci. loc. 17). Both these localities are in strata southeast of Cape Blanco of possible late Miocene age that may be coeval with the type Empire Formation of the Coos Bay area. Kew's (1920, p. 65) statement that the types are from "Basal sandstone, sea cliffs north of lighthouse, Cape Blanco" seems to be

in error because Stanford University locality NP26 is described as "basal sandstone, seacliffs southeast of lighthouse for a mile along shore" (Arnold and Hannibal, 1913, p. 591), and California Academy of Sciences locality 17 is from seacliffs about 2 to 2½ km southeast of Cape Blanco. If either or both of these specimens were actually collected from the north side of Cape Blanco, a late Miocene age is clearly indicated; the associated molluscan fauna (USGS locs. M3965, M4224) in the basal part of the restricted Empire Formation that encircles the cape and unconformably overlies Mesozoic strata (Dott, 1962, pl. 2) includes species referable to the Wishkahan Stage, the early part of the provincial late Miocene.

A fossiliferous float block found above high-tide level on the beach southeast of Cape Blanco directly below ledge-forming fossiliferous sandstone of the restricted Empire Formation yielded many specimens of *Scutella blancoensis*. This block contained mollusks diagnostic of the Wishkahan Stage (early late Miocene); there is little doubt that it broke off from one of the thin ledges of fossiliferous calcareous sandstone on the near-vertical cliffs forming the basal part of the restricted Empire Formation in this area. Several late Miocene mollusks also were recovered from this block (USGS loc. M2141). The echinoid is characterized by extremely fine tubercules on the aboral surface and an anteriorly eccentric apical system. Similar specimens from the underlying late early or middle Miocene *Mytilus middendorffi* beds (pl. 2, fig. 9) have fewer and much larger tubercules; these specimens seem to represent the small early or middle Miocene subspecies *Kewia blancoensis etheringtoni* (Weaver, 1942) from the Astoria Formation of southwestern Washington. Presumably, Durham's (1953) record of *K. blancoensis* from the *Mytilus middendorffi* beds southeast of Cape Blanco is of this pre-late Miocene subspecies. His later record from the middle Miocene (Durham, 1953, fig. 34d) is from Stanford University collection NP26, a stratigraphically mixed collection from both the sandstone of Floras Lake and the restricted Empire Formation. A later collection in the University of California Museum of Paleontology (UCMP colln. B7511) containing *K. blancoensis* is not from the sandstone of Floras Lake. The specimen in question occurs in a waterworn sandstone boulder that contains mollusks indicative of a Wishkahan (late Miocene) age: *Molopophorus bogachieli* (Reagan), *Siliqua* sp., a large coarse-ribbed specimen of *Clinocardium*, and fragments of a large concentrically sculptured *Tellina*. This assemblage indicates derivation from the lower part of the restricted Empire Formation.

The small echinoids with fine tubercules from the restricted Empire Formation are believed to be *Kewia*

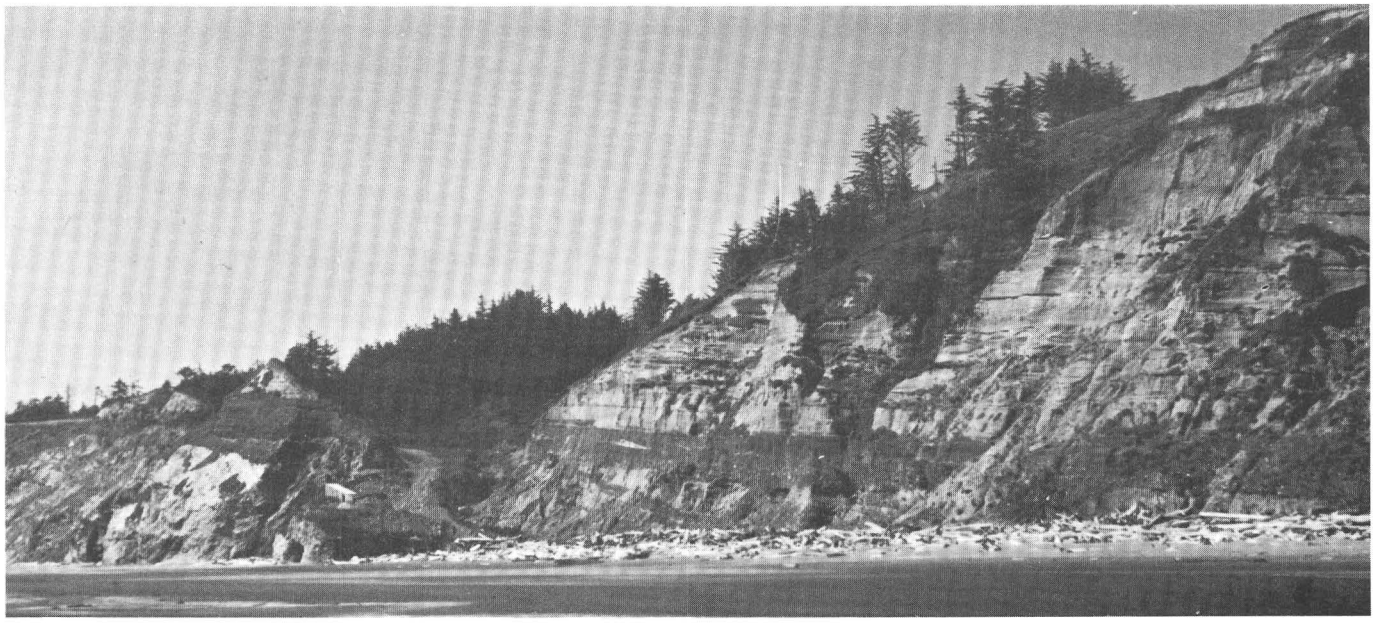


FIGURE 11.—Unconformable contact between the upper Miocene restricted Empire Formation and the overlying lower Pleistocene Port Orford Formation of Baldwin (1945) exposed immediately west of Goldwasher's Gully (left center of photograph). Conglomerate and sandstone of the Port Orford contrast sharply with underlying massive white diatomaceous siltstone and silty sandstone of the restricted Empire Formation. Angular unconformity between conglomerate and sandstone unit of the Port Orford ("Goldwasher's Gully member"; R. J. Janda, written commun., 1978) and overlying 7- to 8-m-thick fluvial conglomerate that marks base of the Elk River Formation is apparent to east of Goldwasher's Gully. View northwestward.

blancoensis (Howe) s.s. Those from the underlying sandstone of Floras Lake, which differ by having relatively coarse tubercules, may represent a closely related subspecies, *K. blancoensis etheringtoni* (Weaver).

FIGURE 12.—*Psephidia* beds in upper part of the Port Orford Formation of Baldwin (1945) exposed near mouth of Elk River, about 2½ km southeast of Goldwasher's Gully.

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INDEX

[Italic page numbers indicate major reference]

A

Acila blancoensis, 13; pl. 3
  conradi, 3
Acmaea sp., 13
Actinoptychus minutus, 14
  vulgaris monicae, 14
acutilineata, Lucinoma, 13
adunca, Crepidula, 13; pl. 3
alaskensis, Cancellaria, 9; pls. 1, 2
albaria coosensis, Spisula, 13
  Spisula, 6, 9, 11; pl. 1
Anadara trilineata, 13
andersoni, Nassarius, 13; pl. 3
anglonana, Molopophorus, 11
anglonanus, Molopophorus, 9; pl. 1
angustifrons, Katherinella, 9, 11; pl. 2
annulata, Lucinoma, 7
aragonia, Tellina, 13
Arca sp., 13
arnoldi, Nassarius, 3, 9, 11; pl. 2
Astoria Formation, 2, 11

B

Balanus, 3, 4, 10, 11
  tintinnabulum coosensis, 13
  sp., 9
Blacklock Point, 2, 3, 9, 10, 11
blancoensis etheringtoni, Kewia, 9, 15, 16; pl. 2
  Acila, 13; pl. 3
  Kewia, 13, 15; pl. 3
  Scutella, 2, 3, *14*, 15
  Scutella (*Kewia*), 14
bodegensis, Tellina, 13
bogachieli, Molopophorus, 13, 15; pl. 3
Bruclarkia, 10
  oregonensis, 9, 11; pl. 1
(*Bruclarkia*) *stanfordensis, Fusus*, 3

C

calcarea, Macoma, 7
californica, Rouxia, 14
californicum, Lithodesmium, 14
Calliostoma cammani, 3, 13; pl. 3
cammani, Calliostoma, 3, 13; pl. 3
canaliculata, Nucella, 13
Cancellaria alaskensis, 9; pls. 1, 2
  ocoyana, 9, 11
  oregonensis, 3
  n. sp., 9; pls. 1, 2
Cardium (*Clinocardium*) *meekianum*, 3
carnerosensis, Yoldia, 11; pl. 1
  Yoldia (*Kalayoldia*), 9
caurina, Terebratalia transversa, 13
caurinus, Patinopecten, 14
Chlamys, 4
  hodgei, 13; pl. 3
  sp., 11; pl. 3
Clallam Formation, 2
clarki, Natica, 9, 11; pl. 1
clausa, Cryptonatica, 13
Clinocardium, 15
  meekianum 13; pl. 3
(*Clinocardium*) *meekianum, Cardium*, 3
Cnesterium scissurata, 7, 13
Compsomyax subdiaphana, 7
conradi, Acila, 3
  Solen, 9, 11; pl. 1
cooperi, Yoldia, 9, 13
Coos Bay, 1, 12
Coos Conglomerate Member, 7, 12, 14
coosensis, Balanus tintinnabulum, 13
  Patinopecten, 12
  Spisula albaria, 13
Coscinodiscus lineatus leptopus, 14
  temperi, 14
Crepidula adunca, 13; pl. 3
  onyx, 13
  praerupta, 9, 11; pl. 2
  princeps, 11, 13
  rostralis, 9, 11; pl. 1
Cryptonatica clausa, 13
  oregonensis, 9, 11; pl. 2
  sp., 11

D, E

Dentalium, 10, 11
  hustedtii, 14
  sp., 9
Diodora sp., 13
Distephanus pseudofibula, 14
  speculum pseudocrux, 14
Dosinia, 9
emacerata, Tellina, 9, 11; pls. 1, 2
Empire Formation, 1, 2, 4, 7, 12, 13, 14
  restricted, *11*
etchegoinensis, Nucella, 13
etheringtoni, Kewia blancoensis, 9, 15, 16; pl. 2

F, G

Felaniella parilis, 13; pl. 3
Fin Rock, 4, 13
flagleri, Macoma, 9, 11; pl.2
Floras Lake, 2, 3
Fusus (*Bruclarkia*) *stanfordensis*, 3
gabbi, Glycymeris, 13
giganteus, Saxidomus, 11, 13
Glycymeris gabbi, 13
  grewingki, 13; pl. 3
Goldwasher's Gully, 8, 13, 14
Graysian Stage, 9
grewingki, Glycymeris, 13; pl. 3

H, I, J

hodgei, Chlamys, 13; pl. 3
hoquiamensis, Nassarius, 13
Hunters Cove Formation, 3
hustedtii, Denticula, 14
indentata, Macoma, 13
ischnon, Olivella, 9, 11; pl. 2
Juanian Stage, 9
(*Kalayoldia*) *carnerosensis, Yoldia*, 9
  sp., *Yoldia*, 11
Katherinella, 10, 13
  angustifrons, 9, 11; pl. 2
Kewia, 11
  blancoensis, 13, 15; pl. 3
    etheringtoni, 9, 15, 16; pl. 2
(*Kewia*) *blancoensis, Scutella*, 14

L

leptopus, Coscinodiscus lineatus, 14
lima, Nucella, 13, pl. 3
lincolnensis, Polinices, 9; pl. 1
lineata, Thalassiosira, 14
lineatus leptopus, Coscinodiscus, 14
Liomesus sulcatus, 13
Liracassis, 10
  sp., 9; pl. 1
Lithodesmium californicum, 14
Littorina petricola, 13
lucida, Siliqua, 13; pl. 3
Lucinoma acutilineata, 13
  annulata, 7
lyrata, Neptunea, 13

M

Macoma, 10
  calcarea, 7
  flagleri, 9, 11; pl. 2
  indentata, 13
  secta, 9, 13; pl. 2
  spp., 12
matthewi, Molopophorus, 8, 9, 11; pl. 1
medialis, Priscofusus, 9, 11; pls. 1, 2
Mediargo sp., 13
meekianum, Cardium (*Clinocardium*), 3
  Clinocardium, 13; pl. 3
Megasurcula sp., 9; pl. 1
merriami, Tellinella, 13
middendorffi, Mytilus, 3, 9, 10, 11, 15; pl. 2
minutus, Actinoptychus, 14
Mizuhopecten n. sp., 13
Modiolus sp., 13
Mohnian Stage, 14
Molopophorus anglonana, 11
  anglonanus, 9; pl. 1
  bogachieli, 13, 15; pl. 3
  matthewi, 8, 9, 11; pl. 1
  sp., 3
monicae, Actinoptychus vulgaris, 14
Montesano Formation, 14
Mytilus, 10, 11
  middendorffi, 3, 9, 10, 11, 15; pl. 2

N

Nassarius andersoni, 13; pl. 3
  arnoldi, 3, 9, 11; pl. 2
  hoquiamensis, 13
Natica clarki, 9, 11; pl. 1
Neptunea, 13
  lyrata, 13
Newportian fauna, 11
Newportian Stage, 2, 3, 8, 9
Nitzschia praereinholdii, 14
North Pacific Diatom Zone 11, 14
Nucella, 6, 10, 11
  canaliculata, 13
  etchegoinensis, 13
  lima, 13; pl. 3
  packi, 3, 9, 11; pl. 1
  n. sp. A, pls. 1, 2
  n. sp. B, pl. 2
  sp. A, 9
  sp. B, 9
Nuculana sp., 7

O

Ocenebra sp., 13

ocoyana, Cancellaria, 9, 11
Olivella ischnon, 9, 11; pl. 2
sp., 11, 13
olympicensis, Ophiodermella, 9, 11; pl. 1
onyx, Crepidula, 13
Opalia wishkahensis, 13; pl. 3
Ophiodermella olympicensis, 9, 11; pl. 1
oregonensis, Cancellaria, 3
Cryptonatica, 9, 11; pl. 2
Scutellaster, 12
Otter Point Formation, 3

P

packi, Nucella, 3, 9, 11; pl. 1
pajaroanus, Tresus, 13
Pandora sp., 13
parilis, Felaniella, 13; pl. 3
Patinopecten, 7, 11, 14
caurinus, 14
coosensis, 12
Pecten Point, 12
petricola, Littorina, 13
Pillarian Stage, 9
Polinices lincolnensis, 9; pl. 1
victorianus, 11
sp., 13
Port Orford Formation, 3, 14
Portlandia sp., 7
praecursor, Spisula, 13
praereinholdii, Nitzschia, 14
praerupta, Crepidula, 9, 11; pl. 2
precursor, Thais, 3
princeps, Crepidula, 11, 13
Priscofusus medialis, 9, 11; pls. 1, 2
Psephidia, 14, 16
Pseudocardium sp., 12
pseudocrux, Distephanus speculum, 14
pseudofibula, Distephanus, 14

R, S

rostralis, Crepidula, 9, 11; pl. 1
Rouxia californica, 14
Sandstone of Floras Lake, 1, 3, 4, 6, *8*, 9, 11, 16
Saxidomus giganteus, 11, 13
schenckii, Stephanopyxis, 14
scissurata, Cnesterium, 7, 13
Scutella blancoensis, 2, 3, *14*, 15
(*Kewia*) *blancoensis*, 14
Scutellaster oregonensis, 12
secta, Macoma, 9, 13; pl. 2
Securella, 4
securis, 7, 11, 12, 13, 14; pl. 3
sp., 9; pl. 2
securis, Securella, 7, 11, 12, 13, 14; pl. 3
selbyensis, Spisula, 9, 11; pl. 2
Siliqua lucida, 13; pl. 3
Solen conradi, 9, 11; pl. 1
speculum pseudocrux, Distephanus, 14
Spisula, 10, 11
albaria, 6, 9, 11; pl. 1
coosensis, 13
praecursor, 13
selbyensis, 9, 11; pl. 2
sp., 11
stanfordensis, Fusus (*Bruclarkia*), 3
Stephanopyxis schenckii, 14
stuarti, Trophonopsis, 13; pl. 3
subdiaphana, Compsomyax, 7
sulcatus, Liomesus, 13

T

Tellina, 15
aragonia, 13
bodegensis, 13
emacerata, 9, 11; pls. 1, 2
Tellinella merriami, 13
Temblor Stage, 9
temperi, Coscinodiscus, 14
Terebratalia transversa caurina, 13
Thais precursor, 3
Thalassiosira lineata, 14
tintinnabulum coosensis, Balanus, 13
transversa caurina, Terebratalia, 13
Tresus pajaroanus, 13
trilineata, Anadara, 13
Trochita n. sp., 13
Trophonopsis stuarti, 13; pl. 3
sp., 13; pl. 3

V, W, Y

victorianus, Polinices, 11
vulgaris monicae, Actinoptychus, 14
Wishkahan Stage, 2, 9, 14, 15
wishkahensis, Opalia, 13; pl. 3
Yoldia carnerosensis, 11; pl. 1
cooperi, 9, 13
(*Kalayoldia*) *carnerosensis*, 9
sp., 11

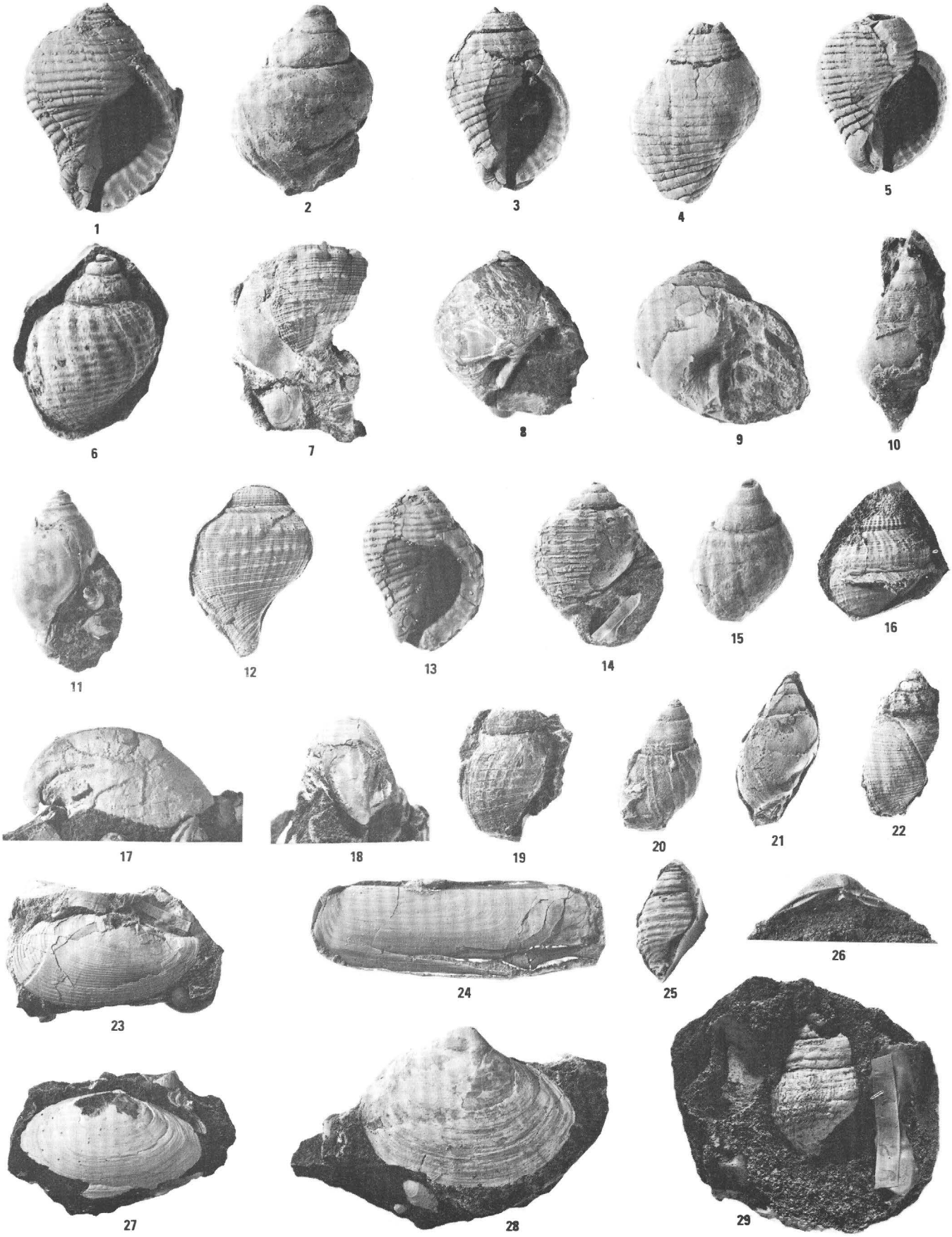
PLATES 1-3

[Contact photographs of the plates in this report are available, at cost, from the U.S. Geological Survey Photographic Library, Federal Center, Denver, Colorado 80225]

PLATE 1

Macroinvertebrate fossils from the sandstone of Floras Lake. All specimens natural size unless otherwise indicated.

FIGURE 1. *Nucella packi* (Clark). USNM 245694. USGS loc. M4129. ×2.
2. *Bruclarkia oregonensis* (Conrad). UO F-29713. UO loc. F2011.
3, 4. *Nucella packi* (Clark). USNM 245695. USGS loc. M3637. ×1½.
5. *Nucella packi* (Clark). USNM 245696. USGS loc. M4131. ×1½.
6. *Cancellaria* n. sp.? aff. *C. alaskensis* Clark. USNM 245697. USGS loc. M4136. ×3, a rubber cast.
7. *Brucklarkia oregonensis* (Conrad). USNM 245698. USGS loc. M4135.
8. *Polinices lincolnensis* (Weaver). USNM 245699. USGS loc. M4126.
9. *Natica* cf. *N. clarki* Etherington. USNM 245700. USGS loc. M4126. ×2.
10. *Priscofusus* cf. *P. medialis* (Conrad). USNM 245701. USGS loc. M4126. ×1½.
11. *Molopophorus matthewi* Etherington. USNM 245702. USGS loc. M2142. ×1½.
12. *Bruclarkia oregonensis* (Conrad). USNM 245703. USGS loc. M4690, a rubber cast.
13. *Nucella packi* (Clark). USNM 245704. USGS loc. M4129. ×2.
14. *Liracassis* sp. USNM 245705. USGS loc. M4132.
15. *Molopophorus* cf. *M. anglonanus* (Anderson). USNM 245706. USGS loc. M2142. ×2.
16. *Bruclarkia oregonensis* (Conrad). USNM 245707. USGS loc. M2142. ×1½, a rubber cast.
17, 18. *Crepidula rostralis* (Conrad). USNM 245708. USGS loc. M2142. ×1½.
19. *Megasurcula* sp. USNM 245709. USGS loc. M4132.
20. *Molopophorus matthewi* Etherington. USNM 245710. USGS loc. M4132.
21. *Molopophorus matthewi* Etherington. USNM 245711. USGS loc. M4690, a rubber cast.
22. *Nucella* n. sp. A. UO F-29714. UO loc. F2011.
23. *Yoldia* cf. *Y. carnerosensis* Clark. USNM 245712. USGS loc. M4126.
24. *Solen conradi* Dall. USNM 245713. USGS loc. M4126.
25. *Ophiodermella* cf. *O. olympicensis* Addicott. USNM 245714. USGS loc. M4690. ×2, a rubber cast.
26. *Spisula albaria* (Conrad). USNM 245715. USGS loc. M4135. ×3, a rubber cast.
27. *Tellina emacerata* Conrad. USNM 245716. USGS loc. M4126.
28. *Spisula albaria* (Conrad). USNM 245717. USGS loc. M2142.
29. *Ophiodermella* cf. *O. olympicensis* Addicott. USNM 245718. USGS loc. M4126. ×2.

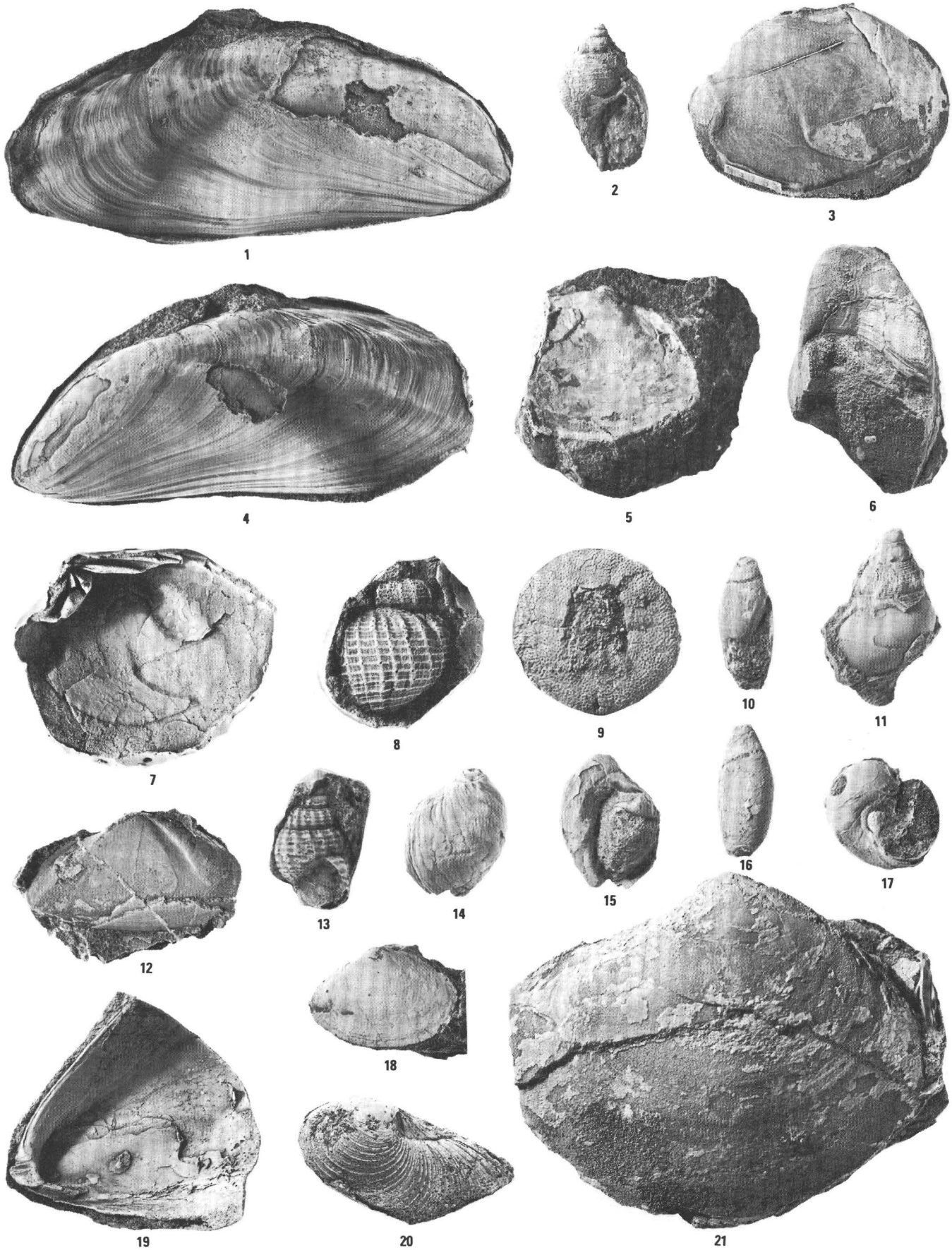


MACROINVERTEBRATE FOSSILS FROM THE SANDSTONE OF FLORAS LAKE

PLATE 2

Macroinvertebrate fossils from the sandstone of Floras Lake. All specimens natural size unless otherwise indicated.

FIGURE 1. *Mytilus middendorffi* Grewingk. USNM 64706. USGS loc. M4130, a rubber cast.
2. *Nucella* n. sp. A. UO F-29714. UO loc. F2011.
3. *Katherinella angustifrons* (Conrad). USNM 245719. USGS loc. M41332, an internal mold showing pallial sinus.
4. *Mytilus middendorffi* Grewingk. USNM 245720. USGS loc. M4130, a rubber cast.
5. *Macoma* cf. *M. secta* (Conrad). USNM 245721. USGS loc. M2142.
6. *Crepidula praerupta* Conrad. USNM 245722. USGS loc. M4136.
7. *Katherinella angustifrons* (Conrad). USNM 245723. USGS loc. M4132, a rubber cast.
8. *Cancellaria* n. sp.? aff. *C. alaskensis* Clark. USNM 245724. USGS loc. M4136. ×2, a rubber cast.
9. *Kewia* cf. *K. blancoensis etheringtoni* (Weaver). USNM 245725. USGS loc. M4126. ×1½.
10, 16. *Olivella* cf. *O. ischnon* Keen. USNM 245726. USGS loc. M4126. ×4.
11. *Priscofusus* cf. *P. medialis* (Conrad). USNM 245701. USGS loc. M4126. ×1½.
12. *Tellina emacerata* Conrad. USNM 245726. USGS loc. M4126.
13. *Nassarius arnoldi* (Anderson). USNM 245727. USGS loc. M4690. ×4, a rubber cast.
14, 15. *Nucella*, n. sp. B. UO F-29715. UO loc. F2011.
17. *Cryptonatica oregonensis* (Conrad). USNM 245727. USGS loc. M4126. ×1½.
18. *Macoma* cf. *M. flagleri* Etherington. USNM 245728. USGS loc. M2142.
19. *Mytilus middendorffi* Grewingk. USNM 647060. USGS loc. M4130, a rubber cast.
20. *Securella* sp. USNM 245729. USGS loc. M4136, a rubber cast.
21. *Spisula* cf. *S. selbyensis* Packard. USNM 245730. USGS loc. M4136.

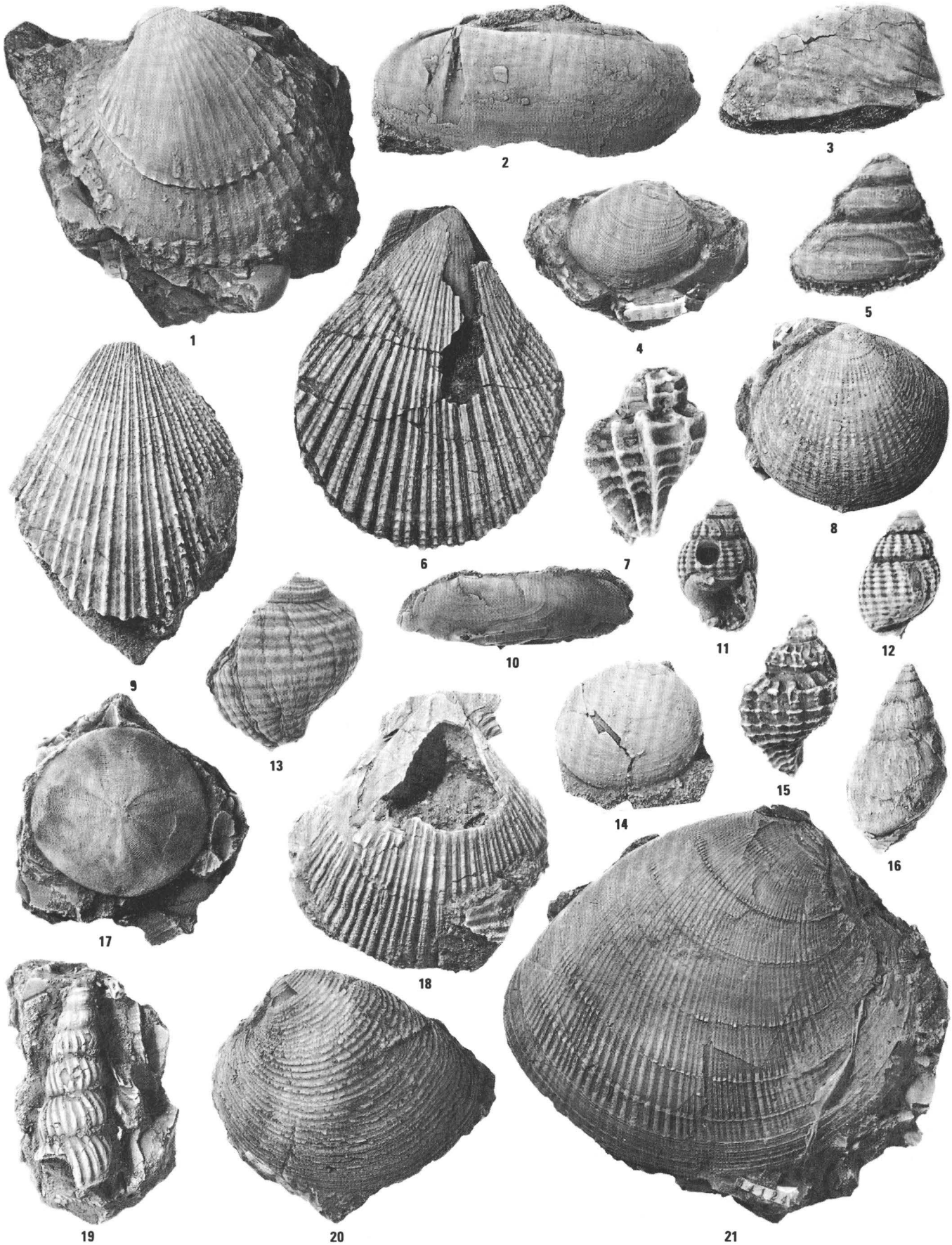


MACROINVERTEBRATE FOSSILS FROM THE SANDSTONE OF FLORAS LAKE

PLATE 3

Macroinvertebrate fossils from the restricted Empire Formation. All specimens natural size unless otherwise indicated.

FIGURE 1. *Clinocardium meekianum* (Gabb). USNM 264129. USGS loc. M2141.
2. *Siliqua* cf. *S. lucida* (Conrad). USNM 264114. USGS loc. M4125. ×1½.
3. *Crepidula adunca* Sowerby. USNM 264116. USGS loc. M3965. ×1½.
4. *Acila blancoensis* Howe. USNM 264131. USGS loc. M2140.
5. *Calliostoma cammani* Dall. USNM 264132. USGS loc. M7369. ×3.
6. *Chlamys hodgei* (Hertlein), right valve. USNM 252508. USGS loc. M3965.
7. *Trophonopsis* cf. *T. stuarti* (Smith). USNM 264133. USGS loc. M7369. ×2.
8. *Glycymeris grewingki* Dall. USNM 264118. USGS loc. M2139.
9. *Chlamys hodgei* (Hertlein). USNM 264134. USGS loc. M7395.
10. *Siliqua* cf. *S. lucida* (Conrad). USNM 264135. USGS loc. M4225.
11, 12. *Nassarius andersoni* (Weaver). USNM 264123. USGS loc. M7369. ×3.
13. *Nucella lima* (Gmelin). USNM 264136. USGS loc. M7369. ×2½.
14. *Felaniella parilis* (Conrad). USNM 264124. USGS loc. M7369.
15. *Trophonopsis* sp. USNM 264137. USGS loc. M7369. ×2.
16. *Molopophorus bogachieli* (Reagan). USNM 264126. USGS loc. M4125.
17. *Kewia blancoensis* (Kew). USNM 264127. USGS loc. M4121. ×1½.
18. *Chlamys* sp. USNM 264138. USGS loc. M7395.
19. *Opalia wishkahensis* Durham. USNM 264120. USGS loc. M4134. ×1½.
20. *Securella securis* (Shumard). USNM 264128. USGS loc. M4125.
21. *Securella securis* (Shumard). USNM 264130. USGS loc. M4124.



MACROINVERTEBRATE FOSSILS FROM THE EMPIRE FORMATION (RESTRICTED)

Shorter Contributions to General Geology

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CONTENTS

[Letters designate the separately published chapters]

(A) Reconnaissance geology of the northern Yukon-Koyukuk province, Alaska, by William W. Patton, Jr.

(B) Hetch Hetchy Reservoir quadrangle, Yosemite National Park, California—analytic data, by Ronald W. Kistler

(C) Mount Abbot quadrangle, central Sierra Nevada, California—analytic data, by John P. Lockwood

(D) Shaver Lake quadrangle, central Sierra Nevada, California—analytic data, by Paul C. Bateman and John P. Lockwood

(E) The Uyaijah ring structure, Kingdom of Saudi Arabia, by F. C. W. Dodge

(F) Biostratigraphy and paleoecology of the upper Miocene (Messinian) and lower Pliocene(?) Cerro de Almendral section, Almería Basin, southern Spain, by Richard Z. Poore and Sean Murphy Stone

(G) Biostratigraphy of the marine Neogene sequence at Cape Blanco, southwestern Oregon, by Warren O. Addicott

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