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The sea cliffs immediately south of Cape Blanco, Oregon, contain four formations representing three geologic epochs. The oldest of these is the Myrtle formation (Cretaceous), a gray sandy shale containing an exclusive microfauna. The next youngest representative is the Empire formation (Lower Pliocene), a sandstone well cemented with calcium carbonate and containing a characteristic fauna of macrofossils. Immediately overlying this formation stratigraphically is the Elk River formation (Middle Pliocene), a poorly cemented sandstone with an intercalated stratum of blue siltstone in the upper portion, the whole containing numerous fossiliferous strata. Complete compaction and cementation of the Empire formation was accomplished previous to the deposition of the Elk River formation as indicated by the presence at the base of the latter of highly indurated cobbles containing characteristic Empire fossils. Overlying these Pliocene formations with a slight angular unconformity are the only Pleistocene marine fossiliferous deposits known in Oregon. Late Pliocene faulting and slight folding occurred in this area resulting in the juxtaposition of Cretaceous and Pliocene beds.

Correlations of the formations were based upon faunal comparisons with California, temperature conditions as indicated by average faunal ranges, and the various percentages of extinct species. Microfaunas consisting of foraminifera and ostracods were found to occur in all of the above formations excepting that of the Empire. This marks the initial report of ostracods in Oregon paleontology.

INVERTEBRATE PALEONTOLOGY OF CAPE BLANCO

by

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INVERTEBRATE PALEONTOLOGY OF CAPE BLANCO

INTRODUCTION

This thesis is primarily concerned with the invertebrate paleontology of Cape Blanco and secondarily with pertinent geologic considerations.

Cape Blanco, located approximately seven miles north of Port Orford in Curry county, Oregon, forms one of three major Capes on the West Coast of the United States--Cape Flattery, Washington; Cape Blanco, Oregon; and Cape Mendocino, California. It is commonly thought of as the farthest point west in the United States proper but Cape Flattery bears this distinction. The exact locations of these major coastal features may be compared below:

	Latitude	Longitude
Cape Flattery, Washington	48° 27' N	124° 44' W
Cape Blanco, Oregon	42° 50' N	124° 37' W
Cape Mendocino, California	40° 26' N	124° 25' W

The particular section under consideration is the sea cliff extending north and south of Cape Blanco to the mouths of the Sixes and Elk Rivers respectively. This includes many abundantly fossiliferous strata and presents one of the most ideal collecting localities

for the invertebrate paleontologist in Oregon. One stratum contains the only known Pleistocene marine fauna in Oregon (28). The various faunas include abundant micro as well as macro-fossils.

Figure 1.

Pleistocene Schizothaerus Zone

This work was conducted under the helpful supervision of Dr. E. L. Packard whose advice and criticisms have proved invaluable. The writer is also indebted to Dr. I. S. Allison for his constructive criticisms concerning the sedimentology; to former students of advanced paleontology who have collected from this area; and to Mr. D. Johnson of Port Orford, Oregon, for his courteous

extension of hospitality and the resultant furthering of the field work, which was done during the Summer and Fall of 1940.

This area is sparsely populated and includes two nearby towns, Sixes and Port Orford. The 1940 census report places the population of Curry county at 4394, most of which inhabit the coastal plain. East of the coastal plain the valleys are so narrow as to exclude nearly every industry except mining and lumbering.

The precipitation of this coastal region is high--sixty-five to seventy inches annually (26: p. 80)--favoring a dense vegetative covering including heavy underbrush. The extensive coniferous forests include pine, Douglas fir, Port Orford cedar, occasional redwoods, and deciduous trees along the streams.

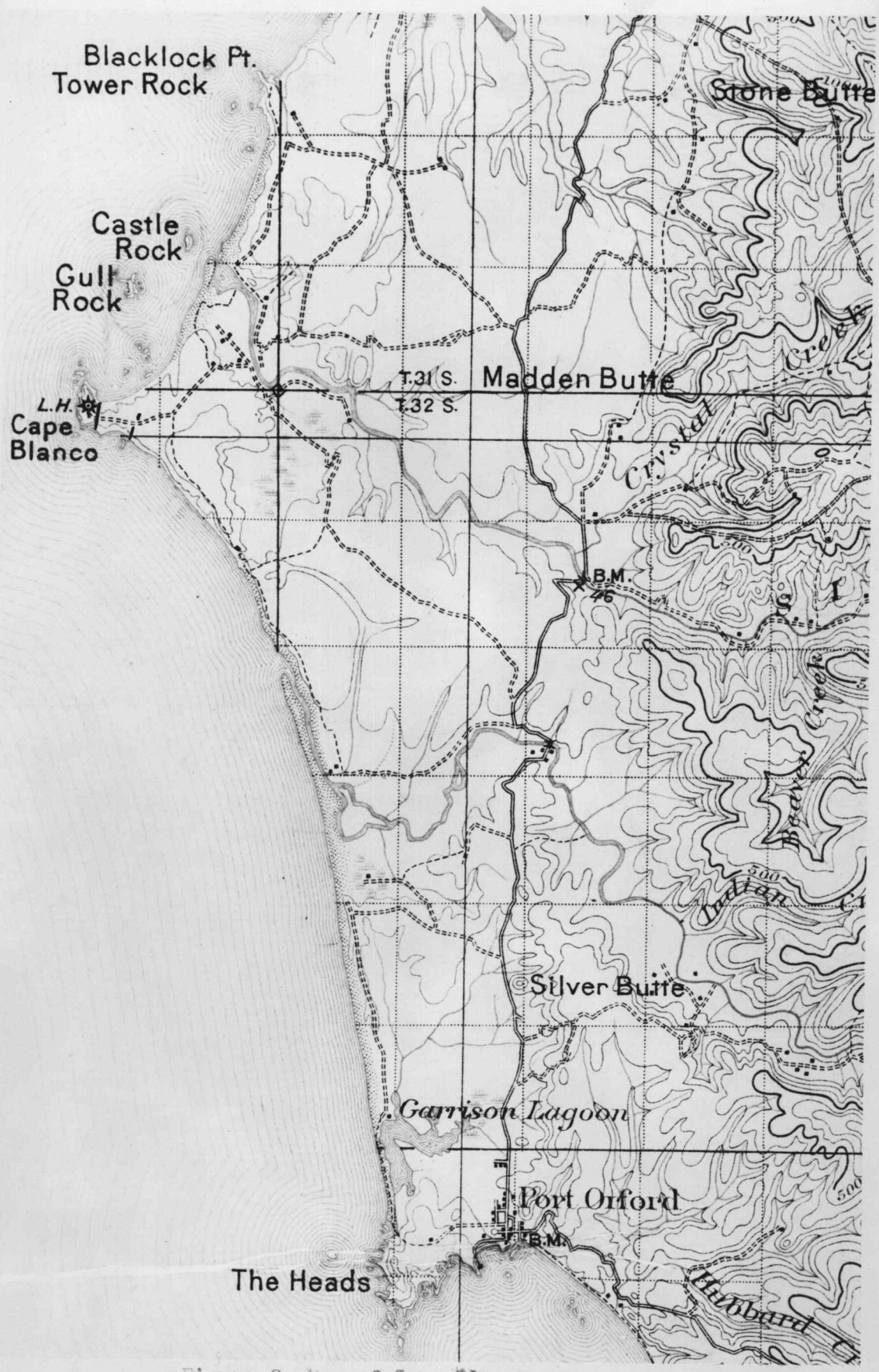


Figure 2. Map of Cape Blanco area.

GENERAL GEOLOGY

A general consideration of the surrounding territory will be given for perspective.

Topography

The area surrounding Cape Blanco and extending inland to the summit of the Coast Range, is readily divisible into three main parts (11: p. 1): the coastal plain and higher marine terraces; the river valleys; and the Klamath plateau.

This coastal plain is exceptionally well defined from Port Orford northward for many miles to the vicinity of Cape Arago. It varies from about one to four miles in width and in general, slopes gently upward toward the east. This uplifted plain is for the most part a terrace due to marine erosion and deposition. A few old stacks of basalt project above the general surface forming prominent landmarks as exemplified by Silver Butte. This coastal region possesses lowland areas, marshes, and lagoons, formed by subsequent erosion by streams which have been blocked by coastal sand bars and dunes. During the winter months the prevailing south-westerly winds result in a northward drift of the near-shore currents which cause a northward

extension of the coastal sand bars. These bars are shortened and modified in the summer months due to a southward drift caused by the prevailing north-westerly winds. North of Cape Blanco are many local prominent ridges of active and fixed dune sand.

Still higher marine terraces are also well defined and are represented in both California and Oregon ranging up to 1500 feet notching many of the more prominent spurs such as the one near Denmark (12: p. 26).

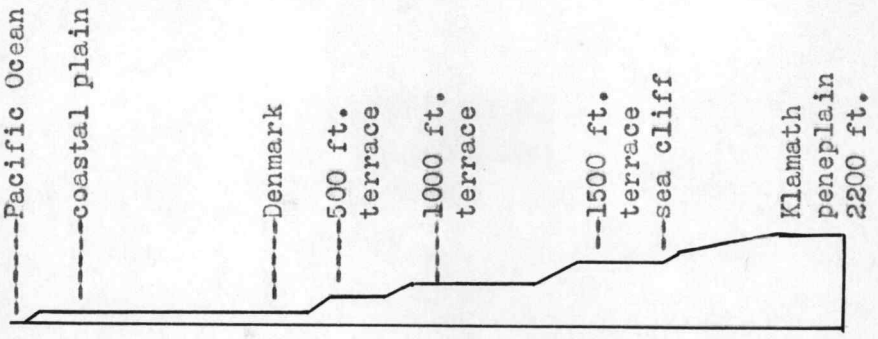


Figure 3.

Profile of Marine terraces at Denmark

Diller (11: p. 1) reports three main terraces, being respectively five hundre, one thousand, and fifteen hundred feet in elevation, with the one thousand foot bench exceptionally well developed.

The river valleys in this district are distinctive in that many of them show two definite stages of erosion,

an earlier and a later stage, with the line of demarcation located approximately at one thousand feet elevation. This is illustrated to the best advantage in those areas in which the canyons and valleys are eroded in more resistant material. A very good example of this may be seen southeast of Cape Blanco near the juncture of the Illinois and Rogue Rivers, where for several miles below the small town of Agness, the stream has cut into basalts. There, below the thousand foot contour, the canyon wall is steep while above, the valley widens out and slopes gently up to the flat topped summits--remnants of the old Klamath plateau. These earlier valleys and the thousand foot terrace are genetically related indicating a corresponding long interval of erosion during which the sea remained at a fairly constant elevation.

The drainage pattern in this general region is mainly dendritic with the streams as a rule youthful, excepting on lower reaches of the larger rivers where they are either mature or old. The steeper walled valleys are subject to frequent, and at times, large scale landslides. One outstanding case of this occurred during the winter of 1893 when large slides filled some of the valleys with gravel and debris to such an

extent that it has not yet been entirely removed.

The Klamath Plateau is a remnant of an old peneplain formed during the Tertiary period. It has been subjected to severe stream dissection but portions of it are now represented in the rounded to flattened summits of most of the mountains in this area. This fact is readily recognized upon studying the topographic map of the Port Orford quadrangle. In general, it slopes westward from an elevation of about thirty-five hundred feet at the crest of the Coast Range down to about two thousand feet.

Geologic History

The oldest geologic record recognized in the Port Orford quadrangle is that represented by the Colebrooke schist (11: p. 2) which is definitely pre-Cretaceous and probably pre-Devonian. In northern California, on the South Fork of the Trinity River, a mica-schist, presumably of the same age as the Colebrooke schist, is overlain by strata containing Devonian fossils.

An unconformity separates the Colebrooke schists from late Mesozoic rocks representing a large interval of time. These younger rocks include slaty shales containing Jurassic fossils (probably upper Jurassic)

along Sucker Creek, which may correspond to the Mariposa slate of the western part of the Sierra Nevada in California. This implies that one or more late Jurassic submergences occurred in the Klamath Mountain region. The sediments deposited in the later sea constitute the lower Knoxville formation.

The Cretaceous period dawned upon an extensive land area in the Klamath Mountain region, the westward margin of which probably coincided with the margin of the continental plateau now submerged beneath the ocean. Throughout most of the Cretaceous, the ocean slowly encroached upon the land, depositing in part the Myrtle Formation (11: p. 1), and later Chico sediments. Near the close of the Chico epoch the region underwent orogeney involving uplift and igneous activity. The period of erosion thus initiated denuded much of the upper Cretaceous sediments excepting a trace near Custer and a larger mass along the coast near Pistol River, where they are now deeply infolded with older strata. The remaining Lower Cretaceous is mostly Paskenta (11: p. 2), and Horsetown (11: p. 2), and along with the Upper Jurassic rocks (lower Knoxville) (11: p. 2), of this area, comprises the widespread Myrtle formation. The name is derived from Myrtle Creek in the Roseburg

quadrangle, which is separated from Port Orford by the Coast Range. The correlation is based upon the lithology, fossils, and stratigraphic sequence (11: p. 2).

The volcanic action which combined with the folding and crushing at the close of the Cretaceous resulted in many resistant masses now forming prominent rock stacks such as Silver Butte.

By Middle Eocene, the land area was again subjected to a slowly encroaching sea which extended over a part of Western Oregon. This Umpqua sea was followed by the Coaledo sea in which a distinct fauna flourished. The sediments deposited at this time have been collectively called the Arago formation and include numerous local coal beds which are usually located in the lower portion of the formation. This clearly indicates a shallow water or even swampy condition in which an abundance of vegetation accumulated. According to J. P. Smith (31: p. 165), the fauna is non-provincial and indicates tropical environs from the equator almost to Alaska, hence, a lack of climatic zoning. The flora substantiates this in California, Oregon, and Washington, while it indicates prevailing warm temperate conditions in Alaska. A moderate elevation of the Coast Range and Klamath Mountains, at the close of the Eocene, initiated another era of extensive erosion, removing all

then existing Eocene strata in Oregon south of Arago.

This condition continued throughout the Oligocene and major portion of the Miocene, obviating any possibility of a fossil record in this immediate area.

Farther north in Oregon the middle Miocene is recorded in the Astoria formation.

The next record is that of the Empire formation which is probably lower Pliocene (3). Tuffaceous beds are quite common indicating volcanic activity. The sediments of this epoch were next subjected to displacement and tilting by a series of faults.

During the late Pliocene and Pleistocene the land emerged in a series of stages as recorded by wave cut terraces. Evidence of the last temporary pause is found in the well developed coastal plain north of Port Orford, which is due more to the presence of underlying uninduated materials rather than indicating an extended period of erosion. The old beach level at this point is at an elevation of approximately 170 feet.

A salient feature in the Pleistocene period is the fluctuation of temperature. In lower Pleistocene, the entire coast from Alaska to San Diego was characterized by a cold northern climate while in the Upper Wisconsin division of this epoch, amelioration of the

climate extended northward to Cape Nome, Alaska, where the temperature of the water was at least eight degrees Fahrenheit (31: p. 167) above what it is now.

There is no evidence of glaciation in this vicinity although records of Alpine glaciers are found at Mt. Ashland and in northern California.

Economic Geology

Coal (11: p. 4), is not found in the immediate vicinity of Cape Blanco but is found at many places farther north where it occurs in the lower portion of the Coaledo formation, with a thick bed of conglomerate below it. It is sub-bituminous to lignitic in character.

Gold and Platinum: Nearly all of the gold and platinum recovered in this quadrangle has been from placers. In this particular area the beach deposits of the marine terraces from sea level up to one thousand feet elevation contain gold and other precious minerals. These deposits are wave-concentrated and are known as black sands because of concentration of dark-colored minerals such as magnetic ilmenite, chromite, etc., with minor amounts of gold and platinum. There is often twenty to sixty feet of "over-burden" above the black sand on the raised terraces. At present there is

a beach placer being operated just south of Cape Blanco known as the Cape Blanco Mine (26: p. 81). The sands are collected in a truck and hauled to a large wooden hopper with three openings at the bottom. A small stream of water washes the sand down and over small riffles and plates. The gold averages 860 in fineness and the recovery probably doesn't exceed fifty per cent.

Throughout the area east of this are numerous low-grade ore deposits. There, the gold is found in quartz veins cutting the Mesozoic and older rocks, and is associated with pyrite, arsenopyrite, and galena.

Because of the low-grade character of the ore and the small size and irregularity of these deposits there is little promise of extensive deposits. The association of chromite with the platinum and gold suggests the serpentinous masses and gabbros as a possible source (29).

GEOLOGY AND PALEONTOLOGY OF CAPE BLANCO

History of Previous Work

The following is a chronological list of the summarized reports of previous workers concerning this area:

1892 Dall and Harris. Reported Neocene deposits between Port Orford and Cape Blanco.

1896 Diller. Designated fossiliferous strata, outcropping in more or less sporadic fashion along the Oregon coast, as the "Empire beds" for their exposure on the beach three miles southwest of Empire City between Pigeon Point and Fossil Point.

1902 Condon. Mentioned an old fossiliferous sea beach at Cape Blanco.

1902 Diller. Worked out the general stratigraphic sequence recognizing two Tertiary formations and one questionably Cretaceous. He separated the lower Empire beds unconformably from the overlying Pleistocene beds which he designated the "Elk River beds". According to Diller this unconformity possibly represents an interval during which the Wildcat and Merced series of California

were deposited.

1913 Merriam, J. C. Described a tapir collected from the Elk River fauna by Bruce Martin.

1913 Arnold and Hannibal. Determined the unconformity as being at the base of the "blue sands". They reported a large fauna from both the Elk River beds and the underlying Empire formation.

1916 Martin. Worked out the general stratigraphy of the beds. He recognized three formations: Cretaceous, (Myrtle formation); Empire (Middle Miocene); and the Elk River beds. This last formation is possibly separable into two divisions. He correlated the upper portion of the Elk River beds with San Pedro and the lowermost beds with the uppermost part of the Wildcat series.

1919 Smith and Packard. Correlated the Elk River beds with San Pedro and the Empire formation with lower Pliocene.

1919 Smith, J. P. Reported several diagnostic species from the Elk River beds which are indicative of a lower temperature environment than is present there now, hence, probable equivalent of the lower San Pedro. On the basis of a few species

he correlates the "blue sandstone" with the Merced of California. Concerning the Empire he merely comments that it is an "incongruous mixture as previously collected" and, if an independent horizon, "corresponds to the interval between the Monterey and Santa Margarita--San Pablo of the California section".

1925 Hertlein and Crickman. Summarized previous work.

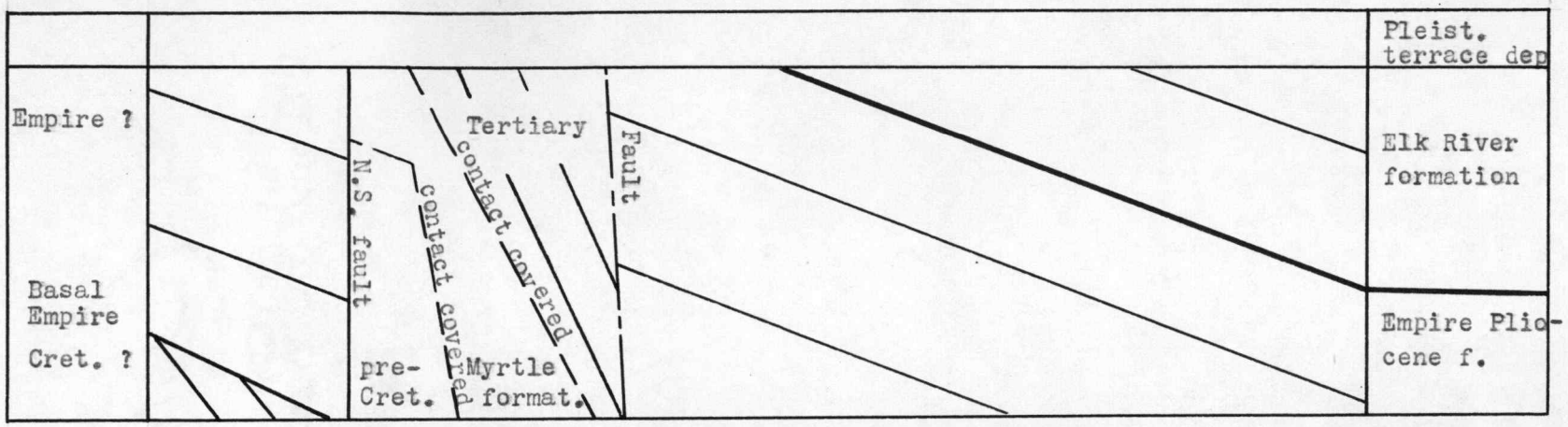
1926 Howe and Smith. Correlated the Elk River formation with upper Pliocene and the Empire with the middle Pliocene.

1927 Schenck. Described one foraminifera from the "Pleistocene" of Cape Blanco.

Structure and Stratigraphic Relations

The following geological divisions are represented in the sea cliff extending from Cape Blanco north and south to the mouths of the Sixes and Elk Rivers respectively: Myrtle formation, Cretaceous; a granule conglomerate, pre-Cretaceous (?); Empire formation, Lower Pliocene; Elk River formation, Upper Pliocene; and Pleistocene marine terrace deposits.

North of the Cape the Myrtle is unconformably overlain by Pleistocene marine terrace deposits. The outer



—— West to end of Cape. Figure 4. Sw. to Elk River ——

Explanation: This figure represents the formational relationships at Cape Blanco with the structure highly exaggerated.

Pleistocene:
- Marine terrace deposits
  - Schizothaerus zone (sta. 114, 115)

Pliocene:
- Elk River formation
  - Psephidia zone (sta. 130, 131)
  - Mitrella zone (sta. 230)
  - Compsomyax zone (sta. 128)
  - Clinocardium zone (sta. 129, 130)
  - Conglomerate
- Empire formation
  - Venus zone (sta. 126, 125)
  - Upper Mytilus zone (sta. 124)
  - Tuffaceous stratum (sta. 123)
  - Lower Mytilus zone (sta. 120)
  - Basal Empire beds (sta. 118)

Cretaceous:
- Myrtle formation
- Granule conglomerate

Pre-Cretaceous:
- Serpentinous mass (?)

portion of the Cape itself is composed of southward tilted Tertiary beds terminated on the east by a north-south post Pliocene-pre-Pleistocene fault, which resulted in the bringing of a serpentinous mass adjacent to these Tertiary beds. The succeeding southward formational occurrences are as follows: Myrtle formation next to the serpentinous mass; Tertiary beds, steeply tilted, their contact with the Myrtle formation covered by slumping; Empire formation faulted against the preceding sediments. The Empire sediments plus later Pliocene sediments, dipping two or three degrees to the south, extend southward to the mouth of the Elk River. The sea cliffs formed of these sediments plus Pleistocene terrace deposits have been modified by much slumping and the presence of two fossil bogs. The bogs occur about midway between the Cape and the mouth of the Elk River, and were, at one time, outlets for the Sixes River, as evidenced by a well defined low marshy area extending from these cliff outcrops inland to the Sixes River.

Cretaceous Beds.

Myrtle Formation. This formation extends continuously from an outcrop just south of Cape Blanco, north-

ward through the Cape and outcrops along the cliffs to the north to the mouth of the Sixes River. It is composed of a fine gray sandy shale. The strike and dip cannot be determined accurately due to the weathered nature and much slumping. A dark basal granule conglomerate on the outer portion of the Cape, cut by innumerable calcite veins, lies unconformably beneath the Empire formation and is referred to the Cretaceous.

A microfauna was obtained from this gray sandy shale, consisting of nine species of foraminifera and at least two different species of ostracods.

Pliocene-Pleistocene Beds.

The mineral content of the various fossiliferous strata representing these epochs is very similar consisting mainly of subangular brilliant to dull grains of quartz with lesser percentages of calcite, decomposed feldspars, hornblende, muscovite, biotite, magnetite, ilmenite, and chromite. Two strata, however, exposed at stations (128 and 230), differ markedly in the presence of a much higher percentage of decomposed feldspars and a much finer size distribution.

Table I is the graphic representation by histograms of the size relationships of the sediments in

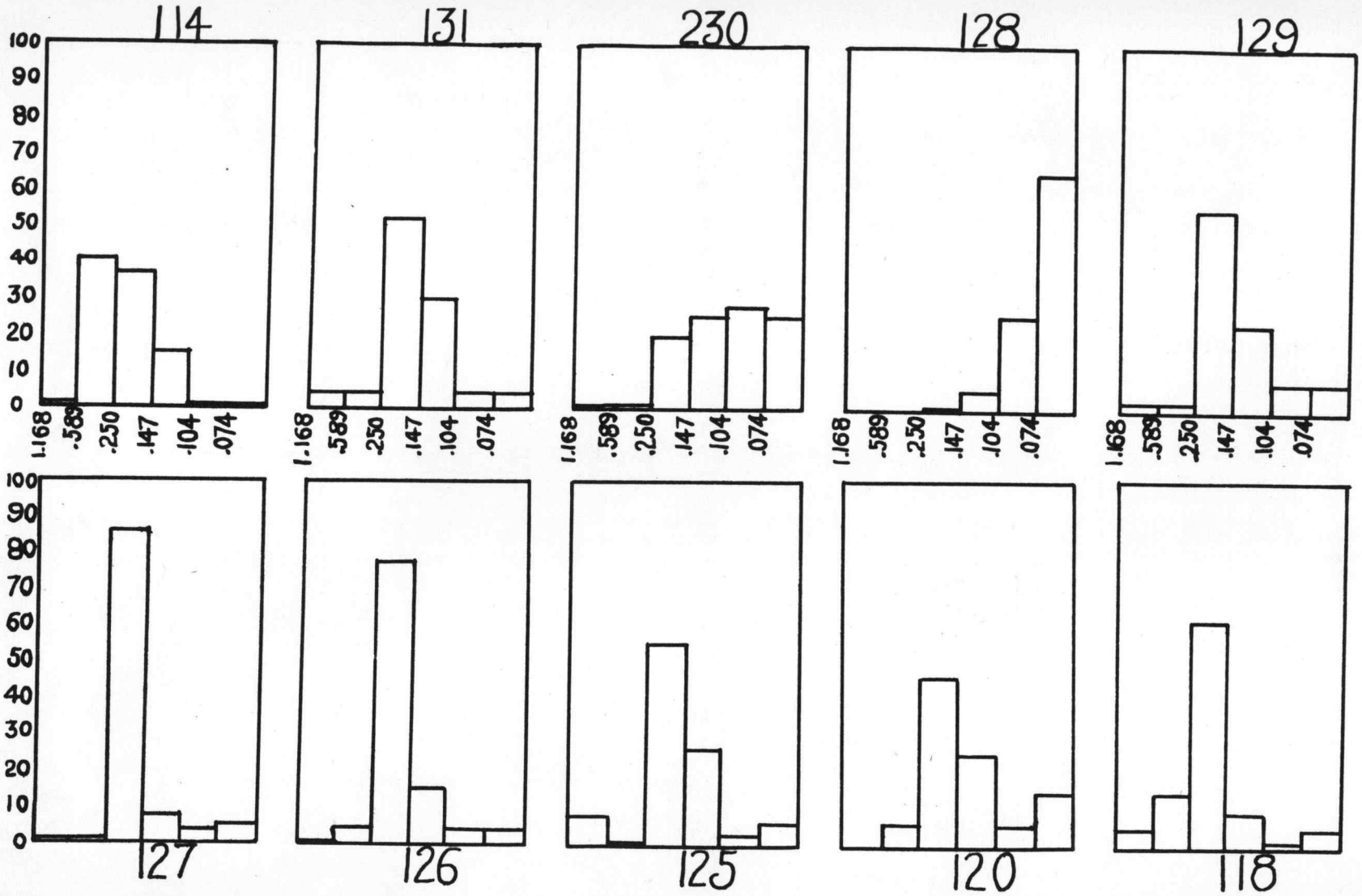

114
131
230
128
129
127
126
125
120
118
100
90
80
70
60
50
40
30
20
10
0
1.168
.589
.250
.147
.104
.074

TABLE I

the various fossiliferous zones. The youngest formation is represented by the histogram in the upper left-hand corner with each successively lower stratigraphic unit placed to the right. The weight percentages are shown on the abscissa and the size distribution in millimeters on the ordinate at the center of the table. The conversion table below gives the Tyler screen sizes with the corresponding size in millimeters and the Wentworth grade term for each.

Mesh	Size in mm.	Wentworth grade term
14	1.168	Very coarse sand
28	.589	Coarse sand
60	.250	Medium sand
100	.147	Fine sand
150	.104	Very fine sand
200	.074	Silt particles

Those sediments representing the fossiliferous zones of the Empire formation (118-126) show a progressively better degree of sorting from bottom to top. This probably is best explained by an environmental change from neritic to littoral conditions.

The sedimentary succession in the Elk River formation includes a lower extremely well sorted sandstone overlain by a less well sorted sandstone grading upward into a fine argillaceous siltstone. The next youngest member, (station 230), very poorly sorted, grades up into a fairly well-sorted sandstone. The succession

just considered indicates a transition of environment from a definitely littoral to a protected condition such as a bay, followed by the advent of unprotected conditions again.

The Pleistocene marine terrace deposits are much coarser and somewhat less sorted indicating continuance of littoral conditions.

Empire Formation. The Empire formation forms the main portion of the sea cliffs from just south of Cape Blanco to the approximate location of the ancient bogs about one and one-half miles further south. It is also present on the outer portion of the Cape where it is unconformably underlain by the (K) granule conglomerate. The Empire beds here have a dip of about fifteen degrees to the southeast and are overlain by gravels which are truncated at the top by the Pleistocene terrace deposits. The lowest member in the cliffs south of the Cape is yellowish sandstone. Overlying this is a layer of tuff containing leaf impressions followed by another layer of sandstone, yellow to gray in color. With the exception of the tuff layer these beds are well cemented with calcium carbonate except where leached and weathered.

Two strata in this series are exceedingly fossil-

iferous and have been given zonal distinction on the basis of the predominating fossils, the Mytilus middendorffi zone, (120), and the overlying Venus securis zone (125), and (126). Station (118) is the fossiliferous representation of the basal Empire series at the outer portion of the Cape, bearing typical Empire species.

Elk River Formation. The hiatus between the Empire and the Elk River formations is evidently located at the base of a thick stratum of conglomerate overlying those beds which are definitely Empire. The first appearance of definitely Elk River formation south of the Cape is about one and one-half miles south of the lighthouse at Cape Blanco and continues southward to the mouth of the Elk River. The lower part is made up of fine-grained brown loosely cemented sand containing many specimens of Clinocardium in its upper portion, (station 127).

Lying conformably upon this bed is a conglomerate layer about one foot thick from which a cobble containing Mytilus middendorffi was collected. This sandstone cobble is well cemented with calcium carbonate indicating that complete induration of the Mytilus middendorffi zone (120) occurred followed by the action of weather-

ing

ing and eroding agents previous to the deposition of the cobble and associated conglomerate. The cobble containing Mytilus middendorffi, along with other sandstone pebbles and cobbles, is weathered to a depth of about one quarter of an inch. This conglomerate is conformably overlain by a brownish-gray fine grained sand, about six to ten feet in thickness. This sand stratum is designated the Clinocardium meekianum zone, (stations 129, and 130), because of the predominance of this species over the associated fauna.

The next youngest stratum in this cliff section is a thick, blue-gray argillaceous siltstone containing many calcareous concretions. The more compact quality of this stratum causes it to occur as more vertical slopes than the overlying less consolidated materials. Some of the concretions of this stratum contain fossils and near the upper part there are local occurrences of fossils with Compsomyax subdiaphana the most characteristic, (station 128).

A thin stratum of a fine sandy siltstone of about the same color as the underlying zone occurs next. This sandy siltstone seems to be very fossiliferous at all points at which it occurred. It contains an abundance of Mitrella carinata variety gausapata, (station

230). The next and uppermost bed of the Elk River formation is composed of a gray fine-grained to very fine-grained sand. This includes rather extensive fossiliferous beds as much as eight feet in thickness with a small clam, Psephidia lordi, constituting by far the predominant species of the fauna, Psephidia zone, (131-132).

Pleistocene Marine Terrace Deposits. The Pleistocene deposits are continuous along the coastal area between the Sixes and Elk Rivers. They are composed mainly of brown medium to fine-grained sandstone grading upward into gravels. Just south of Cape Blanco and at several places still farther south, these deposits are highly fossiliferous near their base containing many large forms such as Schizothaerus nuttallii after which the zone (station 114), is named.

Faunal Correlations and Considerations

Upon comparing these later Cenozoic faunas of the various formations at Cape Blanco with those of California as given by J. P. Smith (31) and Louis N. Waterfall (34), it was found that they correspond most favorably as follows: Empire formation with the "Car-

rizo, Fernando" or Jacalitos, lower Pliocene; Elk River formation with the Wildcat or Etchegoin, Middle Pliocene; and the Pleistocene Schizothaerus deposits with the Lower San Pedro.

Further substantiating evidence is the temperature factor as worked out in Tables II-VIII which indicates the conditions of the present latitude of Cape Mendocino as prevailing through most of the time during which the sediments of the Elk River formation were being laid down. However, the fauna of the uppermost zone (Psephidia) is about seven degrees cooler evidently marking the advent of the cooler water conditions which were present in later Pliocene and Lower San Pedro Pleistocene. The cold-water fauna of the Pleistocene Schizothaerus zone (114-115) definitely eliminates the Upper San Pedro, which was a time of prevailing sub-tropical conditions and indicates the sub-boreal Lower San Pedro as the equivalent.

An approximation of the percentages of extinct molluscan species in each formation has been made and are as follows:

Formation	% extinct
Pleistocene Schizothaerus deposits	0
Elk River Formation	17
Empire Formation	57

The microfossils were found to be absent in the Empire formation but the Myrtle formation (116a), the Elk River formation, and the Pleistocene Schizathaerus zone (114) contain many foraminifera and ostracods, (see check list). Although there are only three different species of foraminifera in the Psephidia zone (131), these occurred in extreme abundance. The Schizothaerus zone (114) also has an abundant microfauna consisting of ten species.

The foraminifera were separated in two different ways which are as follows:

(1) Myrtle formation.

(a) Crushing to granule size.

(b) Exclusion of all -20 mesh material by screening.

(c) Addition of -20 mesh material to bromoform which is of sufficient density to float the entire mass or yield only on a small amount of sediment.

(d) Dilution (slow) with alcohol until sedimentation begins to take place.

The microfauna is found to be fairly well concentrated in this sediment.

(2) Elk River formation and Pleistocene Schizothaerus

Figure 5.- Correlation Chart°

General Time Scale	California	Cape Blanco Formations	Cape Blanco Zonal Divisions
	Upper San Pedro		
Pleistocene	Lower San Pedro	Pleistocene terrace deposits	Schizothaerus zone (114)
	San Pedro Pliocene		
Upper Pliocene	San Joaquin Santa Barbara (Pico-Saugus)°°		
Middle Pliocene	Etchegoin ss San Diego	Elk River formation	Psephidia zone (131) Mitrella zone (230) Compsomyax zone (128) Clinocardium zone (129)
Lower Pliocene	Repetto Jacalitos	Empire formation	Venus securis zone (125) (126) Mytilus midd. zone (120)
Cretaceous		Myrtle formation	
Pre-Cretaceous (?)		Serpentinous mass	

°Modified from that of B. L. Clark (31).
°°Middle and Upper Pliocene--Saugus extends into the Pleistocene.

zone.

(a) Vary from previous method by excluding all plus twenty and minus one hundred and fifty mesh--and addition of sufficient alcohol in the bromoform to sink the main mass.

By this method as used upon these younger unconsolidated sediments, almost perfect separation may be affected with the flotation of the microfauna.

This difference in separation is due to the presence of calcitic filling in the tests of the microfauna of the Myrtle formation--while the tests of the microfauna in the later sediments are without filling, hence floating due to the presence of the included air.

Molluscan Ranges in Latitude

The molluscan ranges on the following tables were derived from Keen's abridged check list (20). The degrees of latitude are given at the top. To aid in the conception of these faunal ranges the approximate latitudes of a few major coastal points are: Panama, 8°; San Diego, 32°; San Francisco, 38°; Cape Mendocino, 40°; Cape Blanco, 42°; Vancouver Island, 49°; and Cook Inlet, 60°. At the right side of each table are the

midpoints with the average for the complete fauna of each respective zone at the bottom.

SCHIZOTHAERUS ZONE (114)	10	20	30	40	50	60	70	Av. Range
Schizothaerus nuttallii pajaroanus			---------					33
Saxidomus nuttalli giganeus				----------				46
Macoma irus				----------	----------			50
Mya truncata					----------	----------		60
Protothaca staminea		----------	----------	----------	----------	----------		48
Saxicava arctica	----------	----------	----------	----------	----------	----------		40
Calliostoma canaliculatum				----------	----------			45
Crepidula nummaria		----------	----------	----------	----------			44
Puncturella galeata				----------				44
Lepeta concentrica					----------	----------		59
Calyptraea mamillaris					-------			52?
Amphissa columbiana				----------	----------			45
Trophon stuarti				----------	----------			44
Margarites pupillus				----------	----------			46
Admete couthouyi				----------	----------	----------		52
							Average	47

TABLE II

PSEPHIDIA ZONE (131)	10	20	30	40	50	60	70	Av. Range
Pandora grandis					---------			51
Pecten giganteus			----------					39
Siliqua patula				----------				48
Spisula polynema voyi					? ----------			58?
Mytilus edulis			----------					51
Nuculana minuta				----------				52
Macoma astori					------?------			
Yoldia scissurata strigata					----------			60
Volsella modiolus			----------					49
Lyonsia pugetensis				----------				48
Psephidia lordi				----------				44
Macoma nasuta			----------					44
Antiplanes perversa			----------					42
Natica clausa					? ----------			63
Thais canaliculata				----------				47
Thais lamellosa				----------				49
Epitonium varicostatum								
Buccinum strigillatum			----------					38
Ranella oregonensis				----------				46
Neptunea lirata				----------				54
Epitonium cooperi		----------						30
Trophon fleenerensis								
Turbonilla hannibali								
Lora viridula					------			52
Neptunea dalmasius								50
Neptunea phoenicea					---------			50
Tegula sp. ?								
					Average			48

TABLE III

MITRELLA ZONE (230)	10	20	30	40	50	60	70	Av. Range
Macoma nasuta kelseyi								48
Macoma astori					----------			56
Cryptomya californica	----------	----------	----------	----------	----------			35
Yoldia scissurata strigata					----------	----------	----------	60
Solen sicarius			----------	----------				39
Mitrella carinata gausapata		----------	----------	----------				43
Nassarius fossatus		----------	----------					38
Colus jordani			----------	----------	----------			48
Clathrodrillia incisa fancherae		----------						30
Cylichnella attonsa			----					33
Turbonilla hannibali								
Olivella biplicata		----------	----------	----------				37
Olivella pedroana		----------	----------	----------	----------			39
Epitonium cooperi		----------	----------					30
Antiplanes perversa			----------	----------	----------			42
Thais canaliculata				----------	----------			47
Thais lamellosa			----------	----------	----------	----------		49
Polinices pallidus				----------	----------	----------	----------	54
Lora pyramidalis								
Mangelia variegata		----------	----------					30
Trophon fleenerensis								
							Average	42

TABLE IV

COMPSOMYAX ZONE (128)	10	20	30-	40	50	60	70	Av.Range
Compsomyax subdiaphana				----------	----------	----------		45
Pecten caurinus					----------	----------		50
Solen sicarius			----------	----------	----------			39
Macoma nasuta kelseyi					--			48
Lucina acutilineata								
Polinices galianoi								
Nassarius fossatus			----------	----------	----------			38
Acteocina culcitella				----------	----------	----------		45
Mitrella carinata gausapata			----------	----------	----------	----------		43
Dentalium neohexagonium	----------	----------	----------					22
Cadulus hepburni				----------	----------	----------	----------	49
Purpura foliata				----------	----------	----------		45
Neptunea tabulata				----------	----------			42
Epitonium cooperi		----------	----------					30
Turbonilla hannibali								
Cidarina cidaris			----------	----------	----------			42
Clathrodrillia incisa fancherae			------					30
						Average		40

TABLE V

CLINOCARDIUM ZONE (129-130)	10	20	30	40	50	60	70	Av.	Range
Taras parilis									
Siliqua patula									48
Clinocardium meekianum									
Schizothaerus nuttalli									33
Macoma nasuta									44
Thracia jacalitosana									
Clinocardium decoratum									
Nassarius fossatus									38
Thais canaliculata									47
Thais lamellosa									49
Olivella biplicata									37
Olivella pedroana									39
Mitrella carinata gausapata									43
Natica clausa (?)					?				63
Trophon stuarti									44
Cidarina cidaris									42
Epitonium cooperi									30
Amphissa versicolor (?)									36
Mangelia variegata									30
Natica russa									42
						Average			41

TABLE VI

VENUS ZONE (125)	10	20	30	40	50	60	70	Av.	Range
Acila blancoensis									
Anadara trilineata									
Venus securis ensifera									
Clinocardium nuttallii				----------	----------	----------			46
Glycimeris grewingki									
Pecten healeyi									
Spisula albaria									
Tellina aragonia									
Siliqua patula				----------	----------	----------			48
Yoldia cooperii			----						35
cf. Sanguinolaria nuttallii			----------						31
Natica clausa					?	----------	----------		63
Sinum scopulosum			----						34
Fusinus coosensis									
Thais canaliculata				----------	----------	----------			47
Neptunea tabulata				----------	----------				42
						Average			43

TABLE VII

MYTILUS ZONE (120)	10	20	30	40	50	60	70	Av. Range
Mytilus middendorffi								
Aloides sp.								
Natica								
Mitrella carinata gausapata (?)			----------	----------	----------	----------		43

CREPIDULA ZONE (118)	10	20	30	40	50	60	70	Av. Range
Spisula albaria								
Spisula polynema voyi					----------	----------		58
Venus securis								
Barbatia								
Clinocardium nuttallii				----------	----------	----------		46
Crepidula praerupta								
Patella (?)								

TABLE VIII

Faunal Check List

Explanation. The following check list includes all species collected in this work along with previously reported species. Those species collected in place are indicated in their respective zones in the vertical columns. Below is an explanation of the numerical designations in the list.

(1). Previously reported Empire species.
(2). Previously reported Elk River species.
(3). Exact position uncertain.

Remarks. The tapir at the end of the check list should be excluded from the fauna of the Compsomyax zone (128). Ostracods were collected at the following stations: (116a), (128), (131), and (114).

Important nomenclatural revisions are recorded in the tables of synonymy--IX and X--which follow this check list.

CHECK LIST of the CAPE BLANCO FAUNA

	CRET.	PLIOCENE								PLEIS.
	MYRT.	EMPIRE F.			ELK RIVER F.					TER. DEP.
	116a	118	120	125 126	127	130 129	128	230	131	114 115
FORAMINIFERA										
Amphistegina sp.	x									
cf. Archaecyclina sp.	x									
Cassidulina sp.										x
Cibicides sp. A.	x									
Cibicides sp. B.										x
Cornuspira sp.	x									
Elphidium hannai Cushman & Grant							x	x	x	x
Elphidium oregonense Cushman & Grant (2)									x	
Elphidium poeyanum (?)							x			
Globigerina bulloides d'Orbigny	x						x	x		x
Lagena sulcata (?) (Walker & Jacob)							x?			x
Nodosaria pauperata d'Orbigny	x?						x			
Nonion sp. A										x
Nonion elongatum (d'Orbigny) Cushman							x	x		
Nonion cf. perforatum (d'Orbigny)Cushman	x									
Nonionella sp.							x			
Quinqueloculina sp. A.	x									
Quinqueloculina sp. B.										x
Quinqueloculina sp. C.										x
Rotalia cf. umbonella Reuss	x									
Rotalia sp. A.						x	x		x	x
Textularia sp. A.							x			
Textularia sp. B.							x			
Uvigerina sp.										x

	116a	118	120	125 126	127	129 130	128	230	131	114
ECHINODERMATA										
Echinarachnius blancoensis Kew (1)										
Echinarachnius gabbi (Remond) (1)										
Anorthoscutum oregonense semigibbosus Howe (1)										
Asteroidea (starfish) (1)										
BRYOZOA									x	x
BRACHIOPODA										
Hemithyris psittacea Lamarch (2)										
PELECYPODA										
Acila blancoensis (Howe) (1)				x						
Aloides			x							
Anadara trilineata (Conrad) (1)				x						
Barbatia		x								
Cardita ventricosa Gould (2)										
Clinocardium decoratum (Grewingk)						x				
Clinocardium meekianum (Gabb) (1)					x	x				
Clinocardium nuttallii (Conrad) (2)		x	x?	x						
Compsomyax subdiaphana (Carpenter) (1)(2)							x			
Cryptomya californica (Conrad) (2)								x		
Glycimeris grewingki Dall (1)		x		x						
Lucina acutilineata Conrad(1)							x			
Lyonsia pugetensis Dall									x	
Macoma astori Dall (2)								x	x	

	116a	118	120	125 126	127	129 130	128	230	131	114
Macoma calcarea Gmelin (1)										
Macoma irus (Hanley) (2)										x
Macoma middendorffi (Dall) (2)										
Macoma nasuta Conrad (2)						x			x	
Macoma nasuta kelseyi (Dall)							x	x		
Mya truncata Linnaeus (2)										x
Mytilus californianus Conrad (2)										
Mytilus edulis Linnaeus (2)									x	
Mytilus middendorffi Grewingk (1)			x							
Nuculana minuta praecursor (Arnold)									x	
Pandora grandis Dall (2)									x	
Pecten caurinus Gould (2)							x			
Pecten giganteus Gray									x	
Pecten healeyi Arnold				x						
Protothaca staminea (Conrad) (2)										x
Psephidia lordi (Baird) (2)									x	
Sanguinolaria nuttallii Conrad				x						
Saxicava arctica Linnaeus										x
Saxidomus nuttalli giganteus Deshayes (2)										x
Schizothaerus nuttallii (Conrad) (2)										x
Siliqua patula (Dixon) (2)				x		x			x	
Spisula polynema voyi (Gabb) (2)		x		x					x	
Spisula albaria (Conrad) (1) (2)		x		x						
Solen sicarius Gould (1)							x	x		
Taras paralis (Conrad) (1)						x				
Teredo Linnaeus (3)										
Tellina aragonia Dall (1)				x						
Thracia jacalitosana Arnold				x?	x	x				
Thracia trapezoides Conrad (2) (3)										
Thyasira bisecta (Conrad) (2) (3)										

	116a	118	120	125 126	127	129 130	128	230	131	114
Venus securis ensifera (1)		x		x						
Volsella modiolus (2) Linnaeus									x	
Volsella rectus (Conrad) (1) (2)										
Yoldia cooperii Gabb				x						
Yoldia scissurata strigata Dall (2)							x	x	x	
GASTROPODA										
Acteocina culcitella (Gould)										
Admete couthouyi (Jay)							x			
Amphissa columbiana Dall (2)										x
Amphissa versicolor Dall (2)						x				x
Antiplanes perversa (Gabb) (1) (2)						x				
Buccinum strigillatum Dall (2)					x			x	x	
Calliostoma canaliculatum (Martyn)									x	
Calliostoma costatum (Martyn) (2)										x
Calyptraea mamillaris Broderip (2)										
Cancellaria crawfordiana Dall (1)										x
Cidarina cidaris (A. Adams) (2)										x?
Colus dalmasius Dall						x				
Colus jordani Dall									x	
Colus halibrectus (Dall) (2)								x?		
Crepidula adunca Sowerby (1)										
Crepidula nummaria Gould										
Crepidula praerupta Conrad		x		x?						x
Cylichnella attonsa Carpenter										
Epitonium cooperi Strong (2)								x		
Epitonium varicostatum (Stearns)						x	x	x	x	
Exilioidea rectirostris Carpenter (2)									x	

	116a	118	120	125 126	127	129 130	128	230	131	114
Fusinus coosensis Dall (1)				x						
Lacuna vincta Mtg. (2)										
Lepeta concentrica (Middendorff)										x
Lora harpa (Dall) (2)										
Lora pyramidalis (Strom)								x		
Lora tabulata (Carpenter) (2)										
Lora viridula (O. Fabricius)									x	
Mangelia variegata Carpenter						x		x		
Margarites pupillus (Gould) (2)										
Mitrella carinata gausapata (Gould) (2)						x	x	x		
Moniliopsis incisa fancherae Dall							x	x		
Nassarius arnoldi (Anderson) (1)										
Nassarius fossatus (Gould) (2)						x	x	x		
Nassarius perpinguis (Hinds) (2)										
Natica clausa Broderip & Sowerby (1) (2)				x		x?			x	
Natica russa Gould						x				
Neptunea lirata (Martyn)(1)									x	
Neptunea phoenicea Dall (2)									x	
Neptunea nodiferous (1)										
Neptunea tabulata (Baird) (2)							x			
Olivella biplicata Sowerby (1) (2)						x		x		
Olivella pedroana (Conrad) (2) (1)						x		x		
Patella sp.		x								
Polinices draconis (Dall) (2)		x								
Polinices galianoi Dall							x			
Polinices lewisii (Gould) (2)										
Polinices pallidus Broderip & Sowerby (2)								x		
Puncturella galeata (Gould) (2)										x
Purpura foliata Martyn (2)							x			
Ranella oregonensis (Redfield) (2)		x?							x	x?

	116a	118	120	125 126	127	129 130	128	230	131	114
Sinum scopulosum Conrad				x						
Tegula sp.									x	
Thais canaliculata (Duclos) (1) (2)				x				x?	x	
Thais lamellosa (Gmelin) (1) (2)						x		x	x	
Thais lima (Martyn) (2)										
Trichotropis cancellata Hinds										
Tritonalia lurida (Middendorff)										
Trophon sp.				x						
Trophon fleenerensis (Martin)						x		x	x	
Trophon multicostatus (Eschscholtz) (2)										
Trophon pacificus (Dall)									x	
Trophon stuarti Smith (2)						x				x
Turbonilla hannibali Bartsch (2)							x	x	x	
SCAPHAPODA										
Cadulus hepburni Dall							x			
Dentalium neohexagonum Sharp & Pilsbury							x			
CRUSTACEA										
Decapod --(claw)									x	
Balanus sp.						x	x	x	x	
Ostracods -- Cytheretta sp. (?)										
VERTEBRATA										
Fish vertebrae									x	
Tapir Merriam (2)							x?			

TABLE IX

Nomenclatural Synonymy of Pelecypods

Thesis	Synonyms
PELECYPODA:	
Acila blancoensis	Nucula b. Acila conradi
Anadara trilineata	Arca trilineata
Cardita ventricosa	Venericardia ventricosa
Clinocardium decoratum	Laevicardium decoratum Cardium decoratum
Clinocardium meekianum	Laevicardium meekianum Cardium meekianum
Clinocardium nuttallii	Laevicardium corbis Cardium corbis
Compsomyax subdiaphana	Clementia subdiaphana Marcia oregonensis
Cryptomya californica	Cryptomya oregonensis
Lucina acutilineata	Phacoides acutilineata
Macoma irus	Macoma inquinata
Pandora grandis	Kennerlia grandis
Pecten caurinus	Chlamys caurina
Pecten giganteus	Hinnites multirugosus Pecten multirugosus
Protothaca staminea	Venerupis staminea Paphia staminea
Saxidomus nuttallii var. g.	Saxidomus giganteus

TABLE IX
(continued)

Thesis	Synonyms
Siliqua patula	Siliqua nuttali
Spisula polynema voyi	Mactra polynema voyi Spisula voyi
Taras paralis	Diplodonta paralis
Volsella modiolus	Modiolus modiolus
Volsella rectus	Modiolus rectus

TABLE X

Nomenclatural Synonymy of Gastropods

Thesis	Synonyms
GASTROPODA:	
Amphissa columbiana	Amphissa corrugata
Antiplanes perversa	Spirotropis perversa Turris impecunia, smithi
Calyptraea mamillaris	Calyptraea fastigiata
Cancellaria crawfordiana	Cancellaria oregonensis
Cidarina cidaris	Solariella cidaris
Colus dalmasius	Neptunea dalmasius
Colus halibrectus	Neptunea halibrectus Sipho halibrectus
Colus jordani	Neptunea jordani
Epitonium cooperi	Epitonium hindsii

TABLE X
(continued)

Thesis	Synonyms
Exilioidea rectirostris	Tritonifusus rectirostris
Lora harpa	Bela harpa
Lora tabulata	Bela tabulata
Mitrella carinata	Columbella gausapata
Moniliopsis incisa f.	Clathrodrillia incisa f.
Nassarius arnoldi	Caesia arnoldi
Nassarius fossatus	Caesia fossatus
Nassarius perpinguis	Caesia perpinguis
Neptunea lirata	Cymatium pacificum
Neptunea phoenicea	Chrysodomus phoenicea
Neptunea tabulata	Chrysodomus tabulata
Ranella oregonensis	Argobuccinum oregonensis
Sinum scopulosum	Sigaretus scopulosus
Thais canaliculata	Nucella decemcostata
Thais lamellosa	Nucella lamellosa
Thais lima	Nucella saxicola

SUMMARY

The following geologic divisions are represented in the sea cliff at, and immediately south of, Cape Blanco:

Pleistocene	Marine terrace deposits
Pliocene	Elk River formation Empire formation
Cretaceous (?)	Granule conglomerate beneath basal Empire
Cretaceous	Myrtle formation
Pre-Cretaceous	Serpentinous mass

Late Pliocene faulting occurred at Cape Blanco resulting in the juxtaposition of Cenozoic and Mesozoic formations.

A large fossil fauna of approximately one hundred and fifty species occurs in the Cretaceous, Pliocene, and Pleistocene sediments. The types of faunas and their occurrences are:

Pleistocene marine terrace deposits	Abundant microfossils and macrofossils
Elk River formation	Abundant microfossils and macrofossils
Empire formation	Extensive macrofauna (no microfossils)
Myrtle formation	Foraminifera, nine species and two species of ostracods (no macrofossils)

Comparisons of these faunas with those in California suggest the following correlations:

Cape Blanco	California
Pleistocene marine deposits	Lower San Pedro
Elk River formation	Etchgoin, Upper Wildcat
Empire formation	Repetto, Jacalitos

Sediments associated with the faunas collected from the Empire formation at Cape Blanco are mostly medium grained sandstones cemented with calcium carbonate. A layer of intercalated tuff indicates volcanic action in Lower Pliocene time.

The most prominent feature of the Elk River formation is a centrally located argillaceous siltstone. This grades both upward and downward into medium grained poorly cemented sandstone.

The Pleistocene deposits, associated with the fauna, are usually coarse grained unindurated sands well cemented locally.

The average median ranges in latitude, as worked out for the various faunas, indicate the following isothermic variations in this area (based upon ranges of existing species):

Pleistocene marine terrace deposits	Cold water conditions

Elk River Pliocene	Cold water conditions in uppermost zone-warmer in lower zones
Empire Pliocene	Slight northward displacement of isotherms

PART II

SYSTEMATIC CATALOG

with

DISCUSSIONS OF SPECIES

FORAMINIFERA

Family MILIOLIDAE

Cornuspira sp. (indet.)

Slide C. B. 1

Test planispiral; simple continuous coil; sutures distinct in the saggital section (only specimen); five to six whorls in the incomplete test, the last two increasing more rapidly in size than the preceeding ones. Cretaceous, Myrtle formation.

Quinqueloculina sp. A.

Slide C. B. 2

Test thickened, 1/5 longer than wide; chambers rather indistinct in the perfect specimens; sutures in most specimens very distinct due to erosion; wall smooth; length up to 1 mm.; breadth up to 0.8 mm.; thickness 0.7 mm. Cretaceous, Myrtle formation.

Quinquiloculina sp. B.

Slide C. B. 3

Test elongate-ovate; chambers distinct, angular, apertural end prominent; sutures distinct; wall with prominent longitudinal costae, 14 on the visible portion of the last chamber; aperture round, terminal,

with small simple tooth. Length up to 9.85 mm.; breadth 0.6 mm. Pleistocene, Schizothaerus zone (114).

Quinqueloculina sp. C.

Slide C. B. 4

Test ovate-elliptical; chambers rapidly increasing in size; distinct; wall smooth. Length 1 mm.; breadth 1 mm. Pleistocene, Schizothaerus zone (114).

FAMILY TEXTULARIIDAE

Textularia sp. A.

Slide C. B. 5

Test broader than long, thick, obtuse apical angle; chambers indistinct, few; wall coarsely arenaceous; aperture indefinite groove at the base of the inner margin of the last-formed chamber; color gray. Compsomyax zone (129).

Textularia sp. B.

Slide C. B. 6

Test elongate, three to one ratio of length to breadth, compressed, periphery oblong on later portion, triangular tendency of first part; chambers mostly indistinct; wall coarsely arenaceous with much cement,

roughly finished; aperture a slit at the base of the inner margin of the last-formed chamber; color gray. Length about 1 mm. Compsomyax zone (128).

Family NODOSARIIDAE

Nedosaria pauperata d'Orbigny

Slide C. B. 7

Test straight excepting near the apertural end; round in section; chambers sound; sutures distinct, shallow at first and becoming deeper anteriorly; wall smooth, finely perforate; aperture terminal, round, and radiate on short external neck. Length about 2.5-3 mms. Variable cosmopolitan form. Compsomyax zone (128).

Some unidentifiable fragments of a Nodosarian were obtained from the Cretaceous "Myrtle formation".

Lagena cf. sulcate (Walker and Jacob)

Slide C. B. 8

Test unilocular; wall with longitudinal costae; ectosolenian aperture.

One large specimen seems referable to this species, however, a great many contemporary forms have fewer ribs than sulcata ss--probably a variant or another

species. Pleistocene Schizothaerus zone (114) and Compsomyax zone (128).

Family NONIONIDAE

Nonion sp. A.

Slide C. B.9

Test close-coiled, planispiral, periphery rounded; about 8 tumic chambers in the last formed coil; sutures moderately depressed on the later portion, indistinct on the earlier part; umbilical region filled; wall smooth, finely perforate; aperture a very narrow slit at the base of the apertural face, indistinct on most specimens. Diameter 0.65 mm.; thickness about 0.20 mm.

Common in the Schizothaerus zone (114). It is very close to Nonion germanicum (Ehrenberg) Cushman, a common species in the north eastern Atlantic.

Nonion elongatum (D'Orbigny) Cushman

Slide C. B. 10

Nonion elongatum (D'Orbigny) Cushman, U. S. G. S. Prof. Pap. (191), p. 11, pl. 3, figs. 4-6, 1939.

Test longer than broad, entirely involute, biumbilicate; chambers distinct, 12 in adult coil, increasing

rapidly in breadth in later portion, slightly inflated; sutures distinct slightly depressed, somewhat curved posteriorly, especially toward the periphery; wall smooth, finely perforate; aperture a low narrow opening at the base of the apertural face. Length 0.80 mm.; breadth 0.55 mm. Approaches Nonion fabum closely in description. Mitrella (230) and Compsomyax (128) zones. Miocene and Pliocene of Europe.

Nonion cf. perforatum

Slide C. B. 11

Nonion perforatum (D'Orbigny) Cushman, U. S. G. S. Prof. Pap. 191, p. 12, pl. 3, fig. 3.

Quotation of the original description follows:

> Test involute, compressed, umbilical region depressed and filled with a few small rounded bosses, periphery broadly rounded; chambers distinct, slightly inflated, of rather uniform size and shape, 9 to 10 in the adult coil; sutures distinct slightly depressed, curved, not limbate; wall smooth, coarsely perforate; aperture a low opening at the base of the apertural face. Diameter 0.50 mm.; thickness 0.20-0.20 mm. Oligocene to Pliocene of Europe--types are from the Miocene.

Occurrence at Cape Blanco is in the Myrtle formation of Cretaceous age.

Nonionella sp.

Slide C. B. 12

Test asymmetrical, slightly trochoid, spire flat, periphery broadly elliptical; six to seven chambers, (early ones indistinct) slightly inflated with the last chamber much elongated and inflated on the ventral surface covering the entire umbilicus; sutures distinct near the umbilicus, disappearing toward the periphery; wall smooth, finely perforate; aperture at the base of the last-formed chamber extending ventrally from the periphery. Length 0.40 mm.; breadth 0.30 mm.

This species occurs in the Compsomyax zone (128). It bears some resemblance to Nonion auris (D'Orbigny), a prominent east coast Miocene form and Recent on the west coast of South America.

Elphidium hannai Cushman and Grant

Slide C. B. 13

Elphidium hannai Cushman and Grant. IV, San Diego Soc. Nat. Hist. Trans., vol. 5, no. 6, p. 77. pl. 8, fig. 1.

Test, diameter about twice the thickness, periphery subangular, sides of whorl flattened leading up to broad umbilical region which is flattened or very slightly concave; chambers distinct, 16-17 in the outer whorl, not inflated; sutures limbate, very distinct in many of the specimens with a line of fine pores

somewhat staggered (perhaps a double line), continuing to the umbilical region, the sutures appear as dark lines against the finely perforate white background of the test; aperture consists of small pores along the base of the apertural face with numerous others occurring on the surface of the face. Diameter 0.9 mm.; thickness 0.40 mm.

Occurs abundantly and widely at Cape Blanco being in the following zones: Schizothaerus (114), Psephidia (131), Mitrella (230), and Compsomyax (128). In California they range from Pliocene to Recent.

Elphidium oregonense Cushman and Grant

Slide C. B. 14

Elphidium oregonense Cushman and Grant, IV. San Diego Soc. Nat. Hist. Trans., vol. 5. no. 6, p. 79, pl. 8, fig. 3.

Holotype Mus. Calif. Acad. Sci. no. 2809, locality; 15, Elk River formation.

The following is a quotation of the original description by Cushman and Grant:

> Description--Test comparatively large, complanate, compressed, periphery rounded, umbilical region strongly umbonate with a rounded boss of clear shell material with several large pores; chambers numerous, 20 or more in the adult, slightly inflated; sutures curved, depressed except toward the periphery where they are indistinct, pores

numerous, rounded, except toward the periphery where they become elongate; wall thick; aperture consisting of a low broad opening at the base of the apertural face with circular pores on the middle portion of the lower half of the flattened wall of the apertural face. Length up to 1.8 mm.; breadth 8.60 mm.

The topotypes collected at Cape Blanco are restricted to the Psephidia zone (131). Both Elphidium oregonense and Elphidium hannai are exceptionally abundant in this stratum. Pliocene.

Elphidium cf. poeyanum (D'Orbigny)

Slide C. B. 15

Elphidium poeyanum (D'Orbigny), Cushman, W. S. G. S. Prof. Paper 191, p. 54, pl. 14, figs. 25, and 26.

Test compressed, biumbilicate, periphery broadly rounded; chambers about nine in the outer whorl, slightly inflated, distinct; sutures somewhat depressed with retral processes; wall smooth, thin, transpicuous, finely perforate; aperture consists of small round openings on the apertural face. Diameter up to 0.80 mm.; thickness 0.20 mm.

The specimens from Blanco are very closely allied to the species referred to, possibly being of varietal distinction. Elphidium poeyanum (D'Orbigny) is an

east coast subtropical form living in the West Indies and dating from the Miocene. Occurs in the Compsomyax zone (128).

Family ROTALIIDAE

Rotalia cf. umbonella Reuss

Slide C. B. 16

Eponides umbonella (Reuss), Cushman and Church, Proc. Calif. Acad. Sci., 4th ser., vol. 18, no. 16, p. 515, pl. 41, figs. 7, 8, and 9.

Test trochoid, biconvex, 7 chambers in the last whorl, periphery acute, chambers distinct, tumid ventrally; sutures distinct on dorsal side coincident with periphery, oblique to periphery, nearly radial on ventral surface; aperture ventral. Umbilical boss on ventral surface indicated in one of the larger specimens. Diameter 0.40 mm.

Rotalia umbonella is reported from the upper Cretaceous of California. It is comparable to this specimen in most respects--the last chamber in Rotalia umbonella seems to be larger and more inflated and there is no ventral umbonal boss.

Cretaceous (Myrtle formation) at Cape Blanco.

Rotalia sp. A.

Slides C. B. 17-18

Test trochoid, dorsal side strongly convex, ventral side slightly convex, with a plug in the umbilicate region; periphery angular, keeled; chambers flush with the surface dorsally, slightly inflated ventrally; wall smooth, translucent, finely perforate; aperture at base of last chamber on the ventral chamber on the ventral surface. Diameter 0.35 mm.

Clinocardium zone (130) rare. Insufficient specimens for determination of exact character. Numerous forms occurring in the Compsomyax zone (128), Psephidia zone (131), and Schizothaerus zone (114) are referred to this same species.

Cibicides sp. A.

Slide C. B. 19

Test plane-convex, totalois, spire visible on the dorsal side, only last whorl visible on the ventral surface; ventral side very convex, somewhat umbilicate, periphery acutely anulated; chambers numerous, appressed; sutures distinct; wall coarsely perforate; aperture a slit at base of the last chamber on the ventral side

and extending slightly on the dorsal side. Diameter, 0.60 mm. Cretaceous (Myrtle formation).

Cibicides sp. B.

Slide C. B. 20

Differs from sp. A. in a more rounded periphery and dorsal side and the penultimate chamber has a tendency to be much enlarged. Pleistocene (Schizothaerus zone) (114).

cf. Archaecyclina sp.

Slide C. B. 21

Incomplete specimens with chamber formation similar to this genus. Cretaceous "Myrtle formation".

Family ASTERIGERINIDAE

Amphistegina sp.

Slide C. B. 22

Test lenticular, planispiral, biumbonate, ventral surface less convex than dorsal; chambers numerous; septa simple dorsally, secondary septa present on ventral surface about midway between the umbo and the periphery; wall finely perforate. Diameter, 1 mm. Cretaceous "Myrtle formation".

Family ORBULINIDAE

Globigerina bulloides

Slide C. B. 23

Test composed of globules with plaispiral arrangement; chambers distinct, about six in number; wall very coarsely perforate; aperture large opening into the umbilicus. Diameter about 0.60 mm.

Some of these from the Cretaceous possibly possess an extra chamber.

Pleistocene Schizothaerus zone (114), Mitrella zone (230), Compsomyax zone (128), and the Cretaceous Myrtle formation.

Family CASSIDULINIDAE

Cassidulina sp.

Slide C. B. 24

Test planispiral, involute; chambers numerous; sutures distinct; wall hyaline, finely perforate, smooth with keel. Diameter approximately 0.75 mm. Pleistocene Schizothaerus zone (114).

Family UVIGERINIDAE

Uvigerina sp.

Slide C. B. 25

Test elongate, tapering from narrow base to the greatest breadth somewhat above the middle, lobulate periphery; chambers distinct, inflated; sutures depressed; wall ornamented with 18 to 20 axial ribs, the last formed chamber smooth; apertural end incomplete. Length approximately 0.75 mm.

Occurs exclusively in the Pleistocene Schizothaerus zone (114).

ECHINODERMATA

Asteroidea

Portions of the ambulacral areas of a starfish were found in the Empire formation.

Echinoidea

Echinarachnius blancoensis Kew

Scutella blancoensis Kew (1920), pp. 64-65, pl. 11, figs. 1a, 1b, 1c.
Echinarachnius blancoensis Kew, Grant-Hertlein (1938), p. 57, pl., 26, figs. 5, 6, and 7.

Type locality: "Basal sandstone, sea cliffs north of lighthouse, Cape Blanco, Oregon. Empire formation Pliocene.

One topotype collected, formation.

Echinarachnius gabbii Remond

Clypeaster gabbii Remond (1863) p. 53, 1863.
Echinarachnius gabbii Remond, Grant-Hertlein (1938), p. 59, pl. 20, figs. 2 and 3.

Reported from the Empire formation of Cape Blanco by Arnold and Hannibal. Miocene of Washington, California and Mexico.

Anorthoscutum oregonense semigibbosus Howe

Dendraster (Calaster) oregonensis Clark ver. semigibbosus Howe (1922), p. 102, pl. 7, fig. 3.

Anorthoscutum oregonense semigibbosus Howe,
Grant-Hertlein (1938), p. 93.

Type locality: Empire formation, Cape Blanco, Oregon.

Exceedingly abundant locally, forming the major portion of the rock. Empire Pliocene.

PELECYPODA

Family NUCULIDAE

Acila blancoensis (Howe)

Plate 1, figure 1

Nucula (Acila) conradi, Dall (1909), p. 102, pl. 12, figs. 4 and 5.

Nucula (Acila) blancoenses (Howe), Grant and Gale (1931) p. 117.

This species is closely allied to Acila castrensis differing only in two respects: "Acila conradi (Acila Castrensis)". Has twenty boomerang-shaped anterior teeth, four large, nearly straight, and five to seven small, nearly straight, posterior teeth, while Acila blancoensis, as listed by Dall, has twenty-four and fourteen resepctively," (18: p. 95) and a more rounded posterior end.

Due to the indurated matrix, the dentition is obscured on all of the specimens collected. Occurs exclusively at (station 126).

Family NUCULANIDAE

Nuculana minuta praecursor (Arnold)

Plate 1, figure 2

Leda minuta Fabricius var. praecursor Arnold, (1903), p. 9, pl. 17, fig. 6.
Nuculana minuta (Fabricius) subspecies praecursor (Arnold), Grant and Gale (1931) p. 122.

Arnold describes this species as rare in the Lower San Pedro series of Deadman Island and San Pedro. At Cape Blanco only a few specimens have been found and those occur exclusively in the Psephidia zone (131) of the Elk River formation.

Arnold and Hannibal have listed Leda acuta from the Elk River beds in, "The Marine Tertiary Stratigraphy of the North Pacific Coast of America".

Yoldia cooperi Gabb

Yoldia cooperi Gabb, (1865) p. 189; Grant and Gale (1931) p. 128, pl. 1, fig. 13, pl. 14, fig. 3.

Very common in the Venus Zone (126). No perfect specimens have been obtained but evidence from various fragments assure its identity with Yoldia cooperi. In the largest preserved specimen the anterior portion of the right valve is nearly complete, its greatest dorsal-ventral distance is at least thirty-eight mm.s. This form is quite easily distinguished from Yoldia oregona (Shumard) in possessing a much shorter rostrum. Pliocene to Recent. Range: 33-38° latitude.

Yoldia scissurata strigata Dall

Plate 1, figures 3, 3a

Yoldia (Cnesterium) strigata Dall, (1909), pp. 18, 104, pl. 14, figs. 9. 9a.
Yoldia scissurata Dall variety strigata Dall, Grant and Gale (1931), p. 131.

Incised sculpture oblique to incremental lines. This variety is prominent in the Miocene and questionably extends to the Recent according to Grant. It is common and occurs in both the Mitrella zone (230) and the Psephidia zone (131) of the Elk River formation. Miocene, Pliocene, Recent(?).

Family ARCIDAE Dall

Glycimeris grewingki Dall

Plate 1, figures 4, 4a

Glycimeris grewingki Dall, (1909), p. 107, p. 12, fig. 13.

Occurs in Miocene and Pliocene of Oregon and California. Found in the Venus zone (126) of the Empire formation at Cape Blanco, fairly common.

Anadara trilineata (Conrad)

Plate 1, figures 5, 5a

Arco trilineata Conrad, (1856), p. 314
Anadara trilineata (Conrad), Schenck and Keen (1940) pl. 1, fig. 6, pl. 50, fig. 1, 2.

The numerous radial ribs are subdivided by three impressed lines resulting in four subribs. Occurs abundantly and exclusively (?) in the lower member of the Venus zone (125). Miocene to Pliocene.

Barbatia (?)

A single indeterminable specimen was collected at (station 118), in the Empire formation.

Family PECTINIDAE

Pecten (Hinnites) giganteus Gray

Plate II, figure 2

Lima gigantea Gray, Ann. Phil., New Series, vol. 9, p. 139, 1825.
Hinnita gigantea Gray, Ann. Phil., New Series, vol. 12, p. 103, 1826.
Not Pecten giganteus Munster in Goldfuss, Petrifacta Germaniae, Ed. 1. Vol. 2, pt. 4, p. 48, pl. 90, fig. 14, 1834.
Pecten (Pecten) multirugosus Gale, Grant and Gale (1931), p. 159, pl. 11, fig. 5a, 5b.
Hinnites multirugosus (Gale), Keen (1937) p. 21.

Conforming to the principles set forth in Article 35 in the "Rules of Zoological Nomenclature" in reference to this species, the specific name of giganteus has priority and should result in the rejection if its use in connection with the Pecten of Munster in 1834.

One large well preserved specimen was found in

the Psephidia zone (131). Hinge area still retains the characteristic purplish color, valve exceptionally distorted and bored by various organisms. Dimensions: altitude, 120 mm.; length, 102 mm.; convexity of valve, 22 mm. Middle Miocene to Recent. Range: 25-54° latitude.

Pecten (Patinopecten) caurinus Gould

Plate II, figures 1, 1a

?Pecten propatulus Conrad, (1849), p. 726, pl. 18, figs. 13, 13a.
Pecten caurinus Gould (1850), p. 345.
Pecten (Patinopecten) caurinus Gould, Grant and Gale, (1931), p. 194, pl. 6, fig. 4.

Occurrence in upper portion of Compsomyax or blue shale zone (128). Commonly in concretions. Miocene (?), Pliocene, and Recent. Range: 41-57° latitude.

Pecten (Patinopecten) healeyi Arnold

?Pecten propatulus Conrad
Pecten expansus Dall (1879), vol. 1, p. 14.
Pecten (Patinopecten) healeyi Arnold, Grant and Gale (1931), p. 196, pl. 6, figs. 2a, 2b.

In the specimens collected, the hinge area is either missing or obscured by matrix. However, enough of the right valve is accessible to identify it at least tentatively as Pecten healeyi. It differs from

Pecten caurinus in having split ribbing on the right valve. Occurs at (station 126). Pliocene of California.

Family MYTILIDAE

Mytilus (Mytilus) edulis Linnaeus

Mytilus edulis Linnaeus (1758), p. 705.
Mytilus (Mytilus) edulis Linnaeus, Grant and Gale (1931), p. 344.

Several small specimens occurring exclusively in the Psephidia zone (131). Miocene (?) to Recent. Range: 28-74° latitude.

Mytilus (Mytilus) californianus Conrad

Mytilus californianus Conrad (1837), p. 242, pl. 18, fig. 15.
Mytilus (Mytilus) californianus Conrad, Grant and Gale (1931) p. 245, pl. 12, fig. 6.

Reported from the Elk River formation by Arnold and Hannibal. Range: 18-54° latitude.

Mytilus middendorffi Grewingk

Plate II, figures 3, 3a

Mytilus middendorffi Grewingk, (1850) pp. 167, 171, 360, pl. 7, figs. 3a-c; Grant and Gale (1931), p. 247.

This species is reported from the Miocene of Alaska by Grewingk and Dall. Dall states that it is

represented in Oregon Pliocene by Mytilus condoni but the description of this species is not available. One of the best specimens was determined by Dr. Clark and Dr. Weaver of the University of California as Mytilus middendorffi. However, Mr. I. K. Nicols compared it with the original and reports that Mytilus middendorffi appears more robust and to have a more pronounced plication. Later Dr. Clark agreed that it may possibly deserve varietal rank.

Volsella modiolus (Linnaeus)

Mytilus modiolus Linnaeus (1758), p. 706.
Volsella modiolus (Linnaeus) Grant and Gale (1931), p. 249.
Modiolus modiolus (Linnaeus) Keen (1937), p. 22.

This species occurs exclusively in the Psephidia zone (131) of the Elk River formation. Pliocene to Recent. Range: 27-72° latitude.

Volsella rectus (Conrad)

Modiola recta Conrad, (1837), p. 243, pl. 19. fig. 1.
Volsella recta (Conrad), Grant and Gale (1931), p. 249.
Modiolus rectus Conrad, Keen (1937) p. 22.

Reported by Arnold and Hannibal from the Elk River formation. Oligocene (?) to Recent. Range: 25-38° latitude.

Family THRADIIDAE

Thracia (Thracia) trapezoides Conrad

Plate III, figure 1

Thracia trapezoides Conrad, (1849) p. 723, pl. 17, fig. 6a.
Thracia (Thracia) trapezoides Conrad, Grant and Gale (1931) p. 257. pl. 13, fig. 8.

Two well preserved specimens were collected from the Empire formation (?) at the Cape. It may be easily distinguished from other species by its well defined radial sulcation extending from the umbonal area to the posterior dorsal margin. Oligocene to Recent.

Tracia (Thracia) cf. jacalitosana Arnold

Plate III, figures 2, 2a

Thracia jacalitosana Arnold (1910) p. 68, pl. 16, fig. 4.
Thracia (Thracia) jacalitosana Arnold, Grant and Gale (1931) p. 258.

This form is very fragile but it is common at (stations 127, 129, and 130). The specific determination is difficult due to the imperfect preservation of the holotype (?) and the fact that the hinge and interior are unknown. Pliocene "Jacalitos" formation of California.

Family PANDORIDAE Gray

Pandora grandis Dall

Plate III, figures 3, 3a

Pandora (Kennerlia) grandis Dall, (1877), p. 5.
Pandora grandis Dall, Grant and Gale (1931), p. 261, pl. 13., 3, figs. 5a, 5b.

This odd plano-convex form is fairly common in the Psephidia zone (131) of the Elk River formation. Miocene to Recent. Range: 45-57° latitude.

Family LYONSIIDAE

Lyonsia pugetensis Dall

Plate III, figures 4, 4a

Lyonsia pugetensis Dall, Oldroyd (1924), vol. 1, p. 91, pl. 28, fig. 2.

Due to the fragile character of the shell only a few complete right valves were obtained. Indication of the fine radial lines which ornament the periostracum in modern forms. Occurs in the Psephidia zone (131). Range: 42-55° latitude.

Family CARDITIDAE Gill

Cardita ventricosa Gould

Cardita ventricosa Gould (1850), p. 276.
Venericardia castor Dall (1909), p. 116, pl. 11. figs. 1, 3.

Reported by Arnold and Hannibal from the Elk River formation. Miocene to Recent. Range: 32-55° latitude.

Family THYASIRIDAE

Thyasira bisecta (Conrad)

Venus bisecta T. A. Conrad. (1849) p. 724. pl. 17.
Thyasira bisecta (Conrad). Grant and Gale (1931) p. 281, cf. pl. 13. fig. 15.
Thyasira disjuncta (Gabb), Keen (1937), p. 26.

Reported from the Elk River formation by J. P. Smith. Oligocene to Recent. Range: 44-36° latitude.

Family CODAKIIDAE

Lucina (Myrtea) acutilineata Conrad

Plate III, figure 5.

Lucina acutilineata T. A. Conrad (1849) p. 725.
Lucina (Myrtea) acutilineata Conrad, Grant and Gale (1931), p. 286, pl. 14, figs. 22a, 22b.

This genus is also commonly known as Phacoides. Only a few specimens were found at the Cape and these occurred in the Compsomyax zone (128). Oligocene to Recent.

Family UNGULINIDAE

Taras parilis (Conrad)

Loripes paralis Conrad (1846), p. 432, fig. 7.
Taras paralis (Conrad). Grant and Gale (1931), p. 294.

Found exclusively at (station 130). Much smaller in size than typical adult form. Miocene to Recent.

Family CARDIIDAE

Clinocardium nuttallii (Conrad)

Cochlea corbis Martyn (1788), Vol. 2, fig. 80.
Clinocardium nuttallii (Conrad), Keen (1937), p. 19.

Common at (stations 118, 125, and 126). Costae poorly preserved. Less prosogyrous than Clinocardium meekianum. Miocene to Pliocene. Range: 33-60^{0} latitude.

Clinocardium decoratum (Grewingk)

Plate IV, figure 2.

Cardium decoratum Grewingk (1848), (1849), p. 347, pl. 47. figs. 3a-g, 1850; Grant and Gale (1931), p. 308.

This form is very close to Clinocardium nuttallii (Conrad) but is much smaller with narrower ribs--twenty-eight to thirty--flat-topped and about as wide as the interspaces. Clinocardium zone (129). Miocene to Recent.

Clinocardium meekianum (Gabb)

Plate IV, figures 1, 1a.

Cardium meekianum Gabb (1866) p. 27, pl. 7, fig. 46.
Clinocardium meekianum (Gabb). Schenck and Keen (1940), pl. 6.

Very abundant at (station 130). This is a very large form with extremely prosogyrous beaks. It is associated with Clinocardium nuttallii (Conrad) differing in possessing thirty ribs instead of thirty seven as in nuttallii and having a more oblique shell.

Family VENERIDAE Leach

Venus (Chione) securis ensifera Dall

Plate IV, figures 3, 3a.

Venus lamellifera Conrad (1849), p. 724, pl. 17, figs. 12, 12a.
Venus (Chione) securis Shumard var. ensifera, Grant and Gale. (1931), p. 320, pl. 17, figs. 2a, 2b, 3.

According to Grant and Gale this variety and the typical variety (securis) commonly intergrade. This form occurs abundantly at (stations 118, 125, and 126). Middle and Upper Miocene.

Protothaca staminea (Conrad)

Plate IV, figures 4, 4a.

Venus staminea Conrad (1837), p. 250, pl. 19. fig. 15.
Protothaca staminea (Conrad), Keen (1937). p. 24.

Keen refers the varietal names of this species to the type species. Occurrence is in the Schizothaerus zone (114-115) exclusively. Miocene to Recent. Range: 23-73° latitude.

Compsomyax subdiaphana (Carpenter)

Plate V, figures 1, 1a.

Clementia subdiaphana Carpenter (1863), p. 602, 607, and 640.
Compsomyax subdiaphana, Keen (1937), p. 19.

This form is very characteristic of the zone at (station 128), hence, the generic name has been applied to it. The occurrence is usually in calcareous concretions. This species has often been referred to as Marcia oregonensis but this name has been rejected. Miocene to Recent. Range: 34-56° latitude.

Psephidia lordi (Baird)

Plate V, figure 2.

Chione lardi Baird (1863), p. 69.
Psephidia lordi (Baird). Grant and Gale (1931), p. 336, pl. 15. figs. 567a, 7b.

Small ovate-triangular shell, concentrically grooved and with minutely crenulate margins. Exceedingly abundant at (stations 131 and 132) forming the major species in the fossiliferous zone, hence, the derivation of "Psephidia zone". Pliocene to Recent. Range: 33-55° latitude.

Saxidomus nuttalli giganteus (Deshayes)

Plate V, figure 3.

Venerupis gigantea Deshayes, (1839), p. 359.
Saxidomus nuttalli Conrad variety giganteus (Deshayes), Grant and Gale (1931), p. 342, pl. 18, figs. 4, and 10.

This form constitutes one of the most abundant forms in the Schizothaerus zone (114-115). It varies markedly in thickness of shell and is on the whole crude and distorted. This is probably due to environmental conditions.

Grant and Gale classified giganteus as a variety of Conrads typical nuttalli in view of the fact that this specimen merely is a cooler water variety. Pliocene to Recent. Range: 37-56° latitude.

Family TELLINIDAE

Tellina aragonia Dall

Tellina aragonia Dall (1909), pp. 18, 124, 125, pl. 14, fig. 3.

Due to induration of the matrix, this horizon presents very difficult collecting conditions. Portion of one fairly large specimen found--large size precludes (?) its being oregonensis Conrad. Occurrence is at (station 126) in the Venus zone. Miocene to Pliocene.

Macama nasuta (Conrad)

Plate VI, figures 1, 1a.

Tellina nasuta Conrad (1837), p. 150, 124, 125, pl. 14.
Macoma nasuta (Conrad). Grant and Gale (1931), p. 365. pl. 20, figs. 11a, 11b.

The strongly recurved posterior end of this species immediately distinguishes it. Widespread stratigraphically, occurring at (stations 129, 130, (?), and 230). Miocene to Recent. Range: 28-60° latitude.

Macoma nasuta kelseyi (Dall

Plate VI, figure 2

Macoma kelseyi Dall (1900), p. 1052, pl. 49 fig. 7.

Macoma nasuta (Conrad), var. kelseyi Dall, Grant and Gale (1931), p. 366.

Several large well preserved specimens collected in the Compsomyax zone (128) and overlying Mitrella

zone (230). Differs from typical nasuta in being larger, more elongate, with less flexure of the posterior end. Pliocene to Recent. Range: (?) 48° latitude.

Macoma irus (Hanley)

Plate V, figures 4, 4a.

Tellina inquinata Deshayes, 1854, p. 357.
Macoma irus (Hanley), Keen (1937), p. 22.

Slightly less ventricose perhaps than the type of irus but in view of the anomalous character of the contemporary fauna this is probably due to environmental conditions. Occurs in Schizothaerus zone (114-115). Pliocene to Recent. Range: 37-64° latitude.

Macoma astori Dall

Plate V, figures 5, 5a.

Macoma astori Dall (1909), p. 128, pl. 14. figs. 1, II.

A large sub-ovate species with a very heavy shell. This form and Macoma brota lipara seem to be synonymous. Macoma astori occurs abundantly at (stations 230 and 131). Some of the younger forms are similar to Macoma calcarea differing mainly in proportion of longitude to altitude and heavy shell in the case of Macoma astori. The adult Macoma calcarea is also very much smaller than

the same stage of Macoma stori. Dimensions: Longitude 68, altitude 53, convexity 11 mm. Miocene and Pliocene.

Macoma calcarea (Gmelin)

Tellina calcarea Gmelin (1791) p. 3236.
Macoma calcarea (Gmelin), Grant and Gale (1931) p. 369.

Reported from Cape Blanco by Arnold and Hannibal. Possibly neanic stage of Macoma astori Dall. Oligocene to Recent. Range: 37-72° latitude.

Macoma middendorffii Dall

Tellina edentula Middendorffi (1850), p. 259, in part, pl. 21, fig. 1 only.
Macoma middendorffii Dall, Grant and Gale (1931) p. 372.

One right valve found which seems referable to this species. Horizon (?). Miocene to Recent. Range: 55-65° latitude.

Family SANGUINOLARIIDAE

cf. Sanguinolaria nuttallii Conrad

Sanguinolaria nuttallii Conrad (1837), Vol. 7, p. 230, pl. 17, fig. 6; Grant and Gale (1931), p. 383, pl. 20, figs. 15a, and 15b.

A very large but incomplete specimen found in the Venus zone (126) referred to this species. Altitude

At least 90 mm., valves very flat, longitude indterminable due to loss of a portion of the anterior and posterior ends. Miocene to Recent. Range: 25-37° latitude.

Family SOLENIDAE

Solen sicarius Gould

Solen sicarius Gould, (1850), p. 214; Grant and Gale (1931), p. 385, pl. 21, fig. 4

Shell very fragile, occurs in Compsomyax (128) and Mitrella (230) zones. Miocene to Recent. Range: 30-49° latitude.

Siliqua patula (Dixon)

Plate VI, figure 3

Solen patulus Dixon (1789), p. 355, fig. 2.
Siliqua patula (Dixon), Grant and Gale (1931), p. 387, cf. pl. 21, fig. 9.

Shell large, thin, and occurs at (stations 126, 129, 130?, 131, and 132). The specimen found at (126) is a young form which might be mistaken for Siliqua lucida. It differs in ratio of altitude to longitude and has a longer anterior extremity. Upper Miocene to Recent. Range: 37-59° latitude.

Family MACTRIDAE

Spisula polynema voyi (Gabb)

Plate VI, figures 4, 4a

Callista voyi Gabb (1866), p. 24, pl. 5, fig. 41.
Spisula polynema Stimpson var. voyi (Gabb), Keen (1937), p. 25.

This large spectacular form is found abundantly in the Psephidia zone (131). Other indeterminable species which seem to be smaller and possibly referable to Spisula falcata occur at (stations 118, and 126). Pliocene to Recent. Range: 48-69° latitude.

Spisula albaria (Conrad)

Plate VI, figure 5.

Mactra albaria Conrad (1848), p. 432, fig. 1.
Mactra (Spisula) albaria Conrad, Grant and Gale (1931), p. 395, pl. 23, figs. 3a, 3b.

Occurs abundantly in the Empire formation, (stations 118, 125, and 126). Largest specimens average approximately 45 mms. in length. It probably should be given varietal distinction. Oligocene to Recent.

Schizothaerus nuttallii pajaroanus (Conrad)

Plate VII, figure 1.

Venus pajaroana Conrad (1857), p. 192, pl. 4, figs. 1, and 2.

Schizothaerus nuttallii (Conrad) var. pajaroanus (Conrad). Grant and Gale (1931) p. 405, pl. 22, figs. 6a, 6b, and 8.

The Pleistocene terrace fossiliferous zone is composed mainly of two forms. This variety of Schizothaerus and Saxidomus. It is distinguished from the typical Schizothaerus nuttallii in its smaller size, less ventricose valves, and usually the more anterior position of the umbones. It's rough crude character is probably due to lack of optimum environmental conditions. Miocene to Pliocene. Range: 28-38° latitude.

Family MYACIDAE

Mya (Mya) truncata Linnaeus

Plate VII, figures 2, 2a.

Mya truncata Linneaus (1758), p. 670.
Mya (Mya) truncata Linnaeus, Grant and Gale (1931) p. 414.

Extremely variant in ratios of length to height. Similar to other contemporary forms in the Schizothaerus zone (114) regarding crudeness of character. Miocene to Recent. Range: 48-72° latitude.

Cryptomya californica (Conrad)

Sphaenia californica Conrad (1837), p. 234, pl. 17, fig. 11.
Cryptomya californica (Conrad), Grant and Gale (1931), p. 417, pl. 21, figs. 7, 8a, 8b. 11, 14, 14a, and 14b.

Small with chondrophore normal to plane of the valves as in Mya truncata. Occurrence--exclusively in transition zone (230) between lower Compsomyax zone (128) and the overlying Psephidia zone of the Elk River formation. Upper Miocene to Recent. Range: 11-59° latitude.

Family CORBULIDAE

Aloidis

Plate VII, figure 3.

Aloidis Mergerle von Muhlfeldt, Keen (1937) p. 18.

Abundant forms occurring at (station 120) are tentatively assigned to this genus.

Family SAXICAVIDAE

Saxicava arctica (Linnaeus)

Mya arctica Linnaeus (1767), p. 1113.
Saxicava arctica (Linnaeus), Grant and Gale (1931), p. 427.

Rather rare occurring exclusively in the Pleistocene terrace zone (114-115). One right and one left

valve collected illustrating presence of one tooth and two teeth respectively. Miocene to Recent. Range: 8-72° latitude.

Family TEREDINIDAE

Teredo Linnaeus 1753

Fragments of sandstone containing these occur on the beach, none were found in place.

SCAPHOPODA

Family Dentaliidae

Dentalium neohexagonum (?) Sharp and Pilsbury

Plate VII, figure 4.

"Dentalium hexagonum Sowerby", Carpenter (1864), p. 612, 648.
Dentalium neohexagonum Sharp and Pilsbury, Grant and Gale (1931), p. 436.

Found in the Compsomyax zone (128) only. Simple hexagonal form with no notch or slit in the orfice. Pliocene to Recent. Range: 8-37° latitude.

Family CADULIDAE

Cadulus hepburni Dall

Cadulus hepburni Dall (1897), p. 12, pl. 1, fig. 13; Oldroyd (1927), vol. 2, pt. 1, p. 15, pl. 1, fig. 13.

Shell small white, smooth, jajor diameter approximately one-third distance from anterior end; apertural margins simple. Associated with Dentalium neohexagonum in the Compsomyax zone (128). Pleistocene to Recent. Portion of a specimen referred to this species found in the Mitrella zone (230). Range: 37-61° latitude.

GASTROPODA

Family RETUSIDAE (ACTEOCINIDAE)

Acteocina culcitella (Gould)

Bulla (Akera) culcitella Gould, (1853) p. 377, 378, pl. 14, fig. 8.
Retusa (Acteocina) culcitella (Gould), Grant and Gale (1931) p. 447, pl. 24, fig. 13.
Acteocina culcitella (Gould), Keen (1927), p. 28.

Few specimens collected in Compsomyax zone (128). Small form at one time designated by the specific name of cerealis but now included in the culcitella group. These give way in the immediately superimposed beds to a closely related form--Cylichnella attonsa (?). Pliocene to Recent. Range: 33-58° latitude.

Cylichnella attonsa Carpenter

Plate VII, figure 5.

Cylichna (?) cylindracea, var. attonsa Carpenter (1863), p. 537.
Cylichna attonsa Carpenter, Grant and Gale (1931) p. 454.
Cylichnella attonsa (Carpenter), Keen (1937), p. 34.

Common form in Mitrella zone (230) only. Sudden appearance of this form in the Mitrella zone and complete disappearance of Acteocina culcitella (Gould was accompanied by a progressively more unprotected environment

as indicated by the increase in coarser sediments. Pleistocene to Recent. Range: 33° latitude.

Family TURRIDAE

Lora viridula (O. Fabricius)

Plate IX, figure 3.

Tritonium viridulum O. Fabricius (1780) p. 402.
Lora viridula (O. Fabricius), Grant and Gale (1931), p. 514, pl. 32, figs. 39, 40, and 41.

Small delicate form with tabulate whorls, illustrated in better preserved specimens--ribs numbering 21-25. Similar to Lora turricula (Montagu) differing mainly in more acute apical angle, smaller size, and more numerous axial ribs. Occurs in Psephidia zone (131) and Schizothaerus zone (114). Pliocene to Recent. Range: 40-55° latitude.

Lora tabulata (Carpenter)

Mangelia tabulata Carpenter (1864) p. 628, 658.
Lora tabulata (Carpenter), Grant and Gale (1931) p. 520.

Reported from Elk River formation by Arnold and Hannibal and J. P. Smith. Pliocene to Recent. Range: 37-57° latitude.

Lora pyramidalis (Stroom)

Plate VII, figure 6.

Buccinum pyramidale Strom (1788), vol. 3, p. 297, fig. 22.
Lora pyramidalis (Strom), Grant and Gale (1931), p. 528, pl. 32, figs. 36, 37, and 38.

This specie occurs in the Mitrella zone (230). Ribs number from 16 to 21, slightly more than the type. Differs from Lora turricula in smaller apical angle and according to the figure in Grant and Gale of Lora turricula, where is a well-defined transverse sulcus on the columells. Similar to Lora viridula varying only in not having tabulate whorls and with fewer axial costae. ? Recent.

Lora harpa (Dall)

Bela harpa Dall (1884), vol. 7, p. 523.
Lora harpa (Dall), Grant and Gale (1931) p. 531.

Reported from the Elk River formation by J. P. Smith. Pliocene to Recent. Range: 55-72° latitude.

Mangelia (Bela) variegata Carpenter

Plate VIII, figure 1.

Mangelia variegata Carpenter (1864), p. 658.
Mangelia (Bela) variegata Carpenter, Grant and Gale (1931), p. 590.

Shell high spired with whorls angulated on the upper portion, 11 to 14 axial ribs. Height averages approximately 10 mm. Occurs in the Mitrella (230) and Clinocardium (129) zones. Pleistocene to Recent. Range: 23-37° latitude.

Antiplanes perversa (Gabb)

Plate VIII, figure 2.

Pleurotoma (Surcula) perversa Gabb (1865) p. 183.
Antiplanes perversa (Gabb), Keen (1937), p. 30.

This distinctive form occurs at (stations 127, 230, and 131). Sinistral habit illustrated in majority of the specimens. Keen (19) has grouped all of the varieties together because the environment is the only factor in the variations of this species. Upper Miocene to Recent. Range: 30-55° latitude.

Moniliopsis incisa fancherae Dall

"Drillia inermis Hinda," Arnold (1903), vol. 3, p. 205, pl. 5. fig. 10.
Moniliopsis incisa (Carpenter) variety fancherae (Dall), Grant and Gale (1931), p. 567.

Few small specimens collected in the Mitrella zone (230), and Compsomyax zone (128). Distinctive ornamentation of this variety immediately differentiates it from the others. Upper Pliocene to Recent. (Moniliop-

sis halcyonis is included in the variety according to Grant and Gale, which has a range of from 27° to 49° latitude).

Family CANCELLARIIDAE

cf. Cancellaria crawfordiana Dall

Cancellana crawfordiana Dall (1891), p. 182, pl. 8, fig. 1.

Small specimen obtained in Schizothaerus zone (114) ? referred to this species. Reported from Empire formation by Arnold and Hannibal. Miocene to Recent. Range: 33-38° latitude.

Admete couthouyi (Jay)

Plate VIII, figure 3.

Cancellaria couthouyi Jay (1839), p. 77.
Admete couthouyi (Jay), Grant and Gale (1931), p. 622.

Rare (?) in Schizothaerus zone (114). Pliocene to Recent. Range: 33-72° latitude.

Family OLIVIDAE

Olivella biplicata (Sowerby)

Oliva biplicata Sowerby (1825), p. 33.
Olivella biplicata (Sowerby), Grant and Gale (1931), p. 625, pl. 24, fig. 15.

Distinguished from pedroana by larger size, two

plaits on the columella, and less elevated spire. Occurs at (stations 129, 130, and 230). Pliocene to Recent. Range: 25-49° latitude.

Olivella pedroana (Conrad)

Plate VIII, figure 4.

Strephona pedroana Conrad (1855), p. 17.
Olivella pedroana (Conrad), Grant and Gale p. 626, pl. 24, fig. 10,

Small form very similar to boetica Carpenter. Abundant and widespread stratigraphically at Cape Blanco--stations 127, 129, 130, and 230). Miocene to Recent. Range: 23-55° latitude.

Family FASCIOLARIIDAE

Fusinus (Buccinofusus) coosensis Dall

Fusinus (Buccinofus) coosensis Dall (1909), p. 41, pl. 2, fig. 1.

One specimen found with body whorl and penultimate whorl intact--assigned to this genus and specie until further evidence is found. Venus horizon (126). Pliocene--(Empire formation of Coos Bay).

Family NEPTUNEIDAE

Neptunea (Neptunea) lirata (Martyn)

Plate VIII, figure 7.

Buccinum liratus Thomas Martyn (1784), Table 2, pl. 43.
Neptunea (Neptunea) lirata (Martyn), Grant and Gale (1931), p. 654.

Found exclusively in the Psephidia zone (131) of the Elk River formation. Approximately one-third of last body whorl absent on best specimen. Miocene (?) to Recent. Range: 37-71° latitude. According to Oldroyds figures this species is exceedingly variable--pl. 11, figs. 1 and 3 are nearest to the specimen found at Cape Blanco. Miocene to Recent. Range: 37-71° latitude.

Neptunea (Sulcosipho) tabulata (Baird)

Plate VIII, figure 5.

Chrysodomus tabulatus Baird (1863), p. 66.
Neptunea (Sulcosipho) tabulata (Baird: Grant and Gale (1931), p. 658.

Occurs in Compsomyax zone (128) and (station 125). This high spired species is characterized by uniform spiral ribbing and a broad tabulation bordered by a raised rib on the upper portion of each whorl. Miocene to Recent. Range: 33-51° latitude.

Neptunea phoenicea Dall

Plate VIII, figure 6.

Chrysodomus phoeniceus Dall, Oldroyd (1927), pl. 1, p. 231, pl. 25, fig. 1.
Neptunea phoenicea Dall, Keen (1937), p. 41.

Two large specimens occurring in the Psephidia zone (131) assigned to this species. Approaches the round-whorled Neptunea lirata. Length 50 mms.; breadth, 31 mms. Pliocene (?) Pleistocene, Recent. Range: 45-55° latitude.

Colus halibrecta (Dall)

Reported from the Elk River formation by Arnold and Hannibal. Pliocene to Recent. Range: 55° latitude.

Colus jordani Dall

Plate VIII, figure 8.

Tritonofusus jordani Dall (1913), vol. 45, p. 588.
Colus jordani (Dall), Keen (1937), p. 33.

Resembles Buccinum strigillatum but has smaller apical angle and different aperture. Occurrence--Mitrella zone (230). Pliocene (?) to Recent. Range: 37-60° latitude.

Colus dalmasius Dall

Plate VIII, figure 9

Colus dalmasius Dall, Oldroyd (1927), p. 227. pl. 13, fig. 9.

Fragile shell, outer lip thickened, sinuous, axial sculpture of irregularly spaces, feeble incremental lines. Larger apical angle than Colus-jordani Dall. Pliocene (?) Pleistocene to Recent. Range: 50° latitude.

Exilioidea rectirostris Carpenter

Chrysodomus rectirostris Carpenter (1864), p. 603. 664.
Exilioidea rectirostris (Carpenter), Grant and Gale (1931), p. 665, pl. 28, fig. 5.

Reported from Elk River formation by Arnold and Hannibal. Pleistocene to Recent. Range:

Family BUCCINIDAE

Buccinum strigillatum Dall

Plate VIII, figure 10.

Buccinum strigillatum Dall (1891), p. 186; Grant and Gale (1931), p. 669.

This fragile species is of rather common occurrence in the Psephidia zone (131). Upper Pliocene to Recent. Range: 29-48° latitude.

Family NASSARIIDAE

Nassarius (Schizopyga) perpinguis (Hinds)

Nassa perpinguis Hinds (1844), p. 36, pl. 9. figs. 12, and 13.
Nassarius (Schizopyga) perpinguis (Hinds), Grant and Gale (1931), p. 673, pl. 26, figs. 51, and 52.

Reported from the Elk River formation by Arnold and Hannibal. Miocene (?) to Recent. Range: 28-48° latitude.

Nassarius (Schizopyga) fossatus (Gould)

Plate VIII, figures 11, 11a.

Buccinum elegans Reeve (1843), p. 199.
Nassarius (Schizopyga) fossatus (Gould), Grant and Gale (1931), p. 675, pl. 26, figs. 55, and 56.

Extremely abundant at (stations 130 and 230). Wide range in size--largest is 47 mms. in length. Miocene to Recent. Range: 27-49° latitude.

Nassarius (Uzita) arnoldi (Anderson)

Nassa arnoldi Anderson (1905), p. 204, pl. 16, figs. 70 and 71.
Nassarius (Uzita) arnoldi (Anderson), Grant and Gale (1931).

Reported from the Empire formation by Arnold and Hannibal. Miocene.

Family PYRENIDAE

(COLUMBELLIDAE)

Mitrella carinata gausapata (Gould)

Plate IX, figure 1.

Columbella gausapata Gould (1851), p. 170.
Mitrella carinata (Hinds) variety gausapata (Gould), Grant and Gale (1931), p. 693. plate 26, fig. 45, (not 44).

Small unornamented variety. Zone at (station 230) designated "Mitrella zone" due to their extreme abundance. Also occurs at (stations 127, 128, 129, and 130). Miocene (?) Pliocene to Recent. Range: 27-60° latitude.

Amphissa columbiana Dall

Plate IX, figure 2.

Buccinum corrugatum Reeve (1847), Buccinum sp. 10;
Amphissa columbiana Dall, Grant and Gale (1931), p. 701, pl. 26, fig. 39.

Many perfect specimens obtained from (stations 114, 115 and 130). Pliocene to Recent. Range: 34-55° latitude.

Amphissa versicolor Dall

Amphissa versicolor Dall (1871), p. 113, pl. 13, figs. 2; pl. 14, fig. 2; pl. 16, figs. 10, and 11; Grant and Gale (1931), p. 702, pl. 26, fig. 53.

Reported from Elk River formation by Arnold and Hannibal. Pleistocene to Recent. Range: 28-44° latitude.

Family MURICIDAE

Purpura (Purpura) foliata Martyn

Plate IX, figure 4.

Purpura foliata Martyn (1784), pl. 66 and explanatory table.
Purpura (Purpura) foliata Martyn, Grant and Gale (1931), p. 705.

Partially eroded specimen collected in the Compsomyax zone (128) of the Elk River formation. Open canal due to erosion. Pliocene to Recent. Range: 33-57° latitude.

Tritonalia lurida (Middendorff)

Tritonium (Fusus) luridum Middendorff (1848). p. 244.
Tritonalia lurida (Middendorff), Grant and Gale (1931), p. 711.

Reported from Elk River formation by Arnold and Hannibal. Pliocene to Recent. Range.

Thais (Nucella) lamellosa (Gmelin)

Plate IX, figures 6, 7.

Buccinum plicatum Martyn (1788), pl. 44; not Buccinum plicatum Linnaeus, (1758).
Thais (Nucella) lamellosa (Gmelin), Grant and Gale (1931), p. 716, pl. 32, figs. 14, 26.

An extremely variable species which exemplifies individual variation excellently. Occurs at (stations 129, 130, and 131). One of those collected at (131) fits the varietal description of franciscana (Fig. 6). Upper Miocene to Recent. Range: 34-65° latitude.

Thais (Nucella) lima (Martyn)

Buccinum lima Martyn (1788), pl. 46.
Thais (Nucella) lima (Martyn) Grant and Gale (1931) p. 717, pl. 32, fig. 15.

This is another species of varying individuality. (See Thais canaliculata). Reported from Cape Blanco.

Thais (Nucella) canaliculata (Duclos)

Plate IX, figure 5.

Purpura canaliculata Duclos (1832), p. 104, pl. 1, fig. 1.
Thais (Nucella) precursor Dall (1909), p. 51, pl. 4. fig. 4.
Thais (Nucella) canaliculata Duclos, Oldroyd (1927), Vol. 2, pt. 2, p. 46, pl. 35, figs. 3 and 4.

This species varies from a fairly high spired type (Oldroyds figures) to a very low spired habit (Dall's figure). Upon comparing these it is plainly evident that the costal ornamentation is undependable as a determinative factor in aspublished material to date is concerned. Only with difficulty was this form differentiated from Thais lima and this was principally

upon the deeper, narrower character of the canal and the more pronounced angulation between the inner lip and the canal--as consistently illustrated in all figures consulted of Thais canaliculata. Occurs at (stations 126, 127, 129, 130, and 131). Pliocene to Recent. Range: 35-57° latitude.

Trophon (Boreotrophon) fleenerensis (Martin)

Plate VIII, figure 19.

Boreotrophon fleenerensis Martin (1914) p. 191, pl. 22, figs. 3a, 3b, and 3c.
Trophon (Boreotrophon) fleenerensis (Martin), Grant and Gale (1931), p. 722

Closely related to Trophon pacificus (Dall, differs in having angulated whorls and spiral sculpture. Many specimens collected in the Psephidia zone (131) and one at (station 129, and 230) respectively which conform exactly to the type description. Pliocene, "upper Wildcat" of California.

Trophon (Boreotrophon) multicostatus (Eschscholtz)

Murex multicostatus Eschscholtz (1829), p. 11, pl. 4, fig. 4.
Trophon (Boreotrophon) multicostatus (Eschscholtz), Grant and Gale (1931), p. 722.

See Trophon (Boreotrophon) pacificus (Dall). Trophon multicostatus was reported by Arnold and Hannibal.

Trophon (Boreotrophon) pacificus (Dall)

Plate VIII, figure 20.

Trophon (Boreotrophon) pacificus (Dall), Grant and Gale (1931), p. 723.

Few small specimens from Psephidia zone (131) lacking spiral sculpture and with rounded whorls. Arnold has figured this species as Trophon multicostatus and Trophon scalariformis according to Grant and Gale. Pliocene (?) Pleistocene, Recent. Range: 17-72° latitude.

Trophon (Boreotrophon) stuarti Smith

Plate IX, figures 8, 8a.

Trophon stuarti E. A. Smith (1880), p. 481, pl. 48, fig. 6.
Trophon (Boreotrophon) stuarti Smith, Grant and Gale (1931), p. 724.

Easily confused with Trophon orpheus Gould, differs in having fewer but more accentuated ribs. Two large specimens from (station 130) and two small ones at 114 are included in this species. Pliocene to Recent. Range: 33-55° latitude.

Family CYMATIIDAE

Ranella (Priene) oregonensis (Redfield)

Plate IX, figure 9.

?Triton calcellatum Lamarck, (1816).
Triton oregonense Redfield (1846), p. 165, pl. 11, fig. 2.
Ranella (Priene) oregonensis (Redfield), Grant and Gale (1931), p. 737, pl. 27, fig. 12.
Argobuccinum oregonense (Redfield), Keen (1937). p. 30.

This large hirsute spectacular species is common in the Psephidia zone (131). It also occurs at (stations 130, (?), 118, and 114). Pliocene to Recent. Range: 33-59° latitude.

Family TRICHOTROPIDAE

Trichotropis cancellata Hinds

Trichotropis cancellata Hinds (1843), pl. 11, figs. 11, 12.

Reported from the Elk River formation by Arnold and Hannibal.

Family LACUNIDAE

Lacuna vincta Mtg.

Reported from the Elk River formation by Arnold and Hannibal.

Family CREPIDULIDAE

Crepidula adunca Sowerby

Crepidula adunca Sowerby (1825), p. 7; Grant and Gale (1931), p. 791.

Reported from Cape Blanco "Empire formation" by Arnold and Hannibal; probably Crepidula praerupta Conrad.

Crepidula nummaria Gould

Plate IX, figure 10.

Crepidula nummaria Gould (1846), p. 160; Grant and Gale (1931) p. 792.

Two small specimens were found in the Schizothaerus zone. Pliocene to Recent. Range: 23-65° latitude.

Crepidula praerupta Conrad

Crepidula (Credidula) praerupta Conrad, Etherington (1931), p. 92, pl. 11, figs. 2, 15.

Specimens badly eroded, beaks appressed to the body whorl which lacks the ventricosity of Crepidula princeps, lip eroded down to the level of the septum. Occurs at (station 118). Evidently confused with Crepidula adunca by various authors, differs in parallel reflection of beak and less ventricose shell. Miocene and Pliocene.

Family CALYPTRAEIDAE

Calyptraea mamillaris Broderip

Plate IX, figures 11, 11a.

Calyptraea mamillaris Broderip (1834), p. 38; Grant and Gale (1931) p. 794, pl. 32, figs. 24a, 24b.

Abundant in the Pleistocene terrace zone (114), (115), and (118). Highly variable in general shape, graduations running from convex sides to concave sides. This distortion is due to the fact that Calyptraea mamillaris s. s. is a southern form and it was present in a cold sea as indicated by the majority of the fauna from this zone. Dimensions: diameter, 33 mms.; height, 17 mm.; (largest specimen). Miocene to Present.

Family NATICIDAE

Natica (Tectonatica) clausa B and S.

Natica clausa Broderip and Sowerby (1829), p. 360.
Natica (Tectonatica) clausa Broderip and Sowerby, Grant and Gale (1931), p. 797, text fig. 11.

Globose form with abutting sutures, funicle completely enclosing the umbilicus. Occurs abundantly in zones (126), (129), (130), and (131). Miocene to Recent. Range: 54-72° latitude.

Natica (Tectonatica) russa Gould

Natica russa Gould (1859), p. 43.
Natica (Tectonatica) russa Gould, Grant and Gale (1931), p. 798.

Recent specimens of this form have a characteristic brown color. These collected at Cape Blanco are brown and somewhat mottled. This form is distinct from Natica calusa in that it is of larger size with a larger funicle which, excepting for a slight notch, is continuous with the parietal callus. Clinocardium zone (130). Pliocene to Recent. Range: 33-71° latitude.

Polinices pallidus Broderip and Sowerby

Plate IX, figure 12.

Polinices pallida Broderip and Sowerby, Oldroyd (1927), p. 126, pl. 97, fig. 9.
Polinices pallidus Broderip and Sowerby, Keen (1927), p. 44.

Globose form which might be mistaken for Natica clausa in poorly preserved fossil form. Essential distinguishing character is the narrow umbilicus present in Polinices pallidus. Occurs in the Mitrella zone (230) abundantly. Range: 37-72° latitude.

Polinices (Euspira) lewisii (Gould)

Natica lewisii Gould (1847) p. 239.
Polinices (Euspira) lewisii (Gould), Grant and Gale (1931), p. 804, text figs. 15a, 15b.

Reported from Elk River beds by J. P. Smith. Probably confused with the species galianoi which seems to be the only large Polinices found in this formation.

Polinices draconis (Dall)

Lunatia draconis Dall (1903), p. 174, (see Packard, p. 351.
Polinices draconis (Dall), Packard (1918), p. 324, pl. 38, figs. 2a, and 2b.

Reported by Arnold and Hannibal (2) from Elk River formation--probably same as Polinices galianoi Dall.

Polinices (Euspira) galianoi Dall

Plate IX, figure 13.

Polinices (Euspira) galianoi Dall (1909), p. 88, pl. 5, figs. 12, 13.

This form is prominent form in the Compsomyax zone (128). Distinguished from Polinces lewisii in lacking (1) concave flexure on side of whorl, parallel to the suture and (2) tendency for callous to encroach upon the umbilicus. Differs from Polinices draconis

in being higher spired and lacking a flattened base. Miocene to Pleistocene.

Sinum scopulosum (Conrad)

Plate IX, figure 14.

Sigaretus scopulosus Conrad (1849), p. 727, pl. 19, figs. 6, 6a only.
Sinum scopulosum (Conrad), Grant and Gale (1931) p. 806.

Occurs in Venus zone (126) of Empire formation, exclusively. Aperture obscured due to indurated matrix. Ogligocene to Recent. Range: 32-37° latitude.

Family LEPETIDAE

Lepeta concentrica (Middendorff)

Plate IX, figures 15, 15a.

Patella (Cryptobranchia) caeca, var. concentrica Middendorff (1851), vol. 2, p. 183, pl. 16, fig. 6.
Lepeta concentrica (Middendorff), Grant and Gale (1931), p. 809.

Simple cap shaped shell with anterior apex. Anterior terminations of the muscle scar are posterior to the apex. Common locally in Schizothaerus zone (114) and (115) and Psephidia zone (131). Pliocene (?) Pleistocene and Recent. Range: 48-70° latitude.

Family TROCHIDAE

Tegula sp.

Small umbilicate form found in the Psephidia zone. Ornamentation lacking excepting very faint axial ribbing on the early whorls, growth lines, and very faint spiral striae. Occur exclusively in the Psephidia zone (131).

Calliostoma canaliculatum (Martyn)

Plate VIII, figure 12.

Trochus canaliculatus Martyn (1784), table 1, pl. 32.
Calliostoma canaliculatum (Martyn), Grant and Gale (1931), p. 833, pl. 32, fig. 23.

Small form with flattened body whorl, the base of which is angulated. Occurs in the Pleistocene zone (114-115). Pliocene to Recent. Range: 33-57° latitude.

Calliostoma costatum (Martyn)

Trochus costatus Martyn (1784), table 1, pl. 34, not Trochus costatus Gmelin, (1788).
Calliostoma costatum (Martyn), Grant and Gale (1931), p. 833, pl. 32, fig. 25.

Closely allied to Calliostoma canaliculatum (Martyn) differing mainly in having a much stronger shell, a rounded body whorl, and in being much smaller.

Reported from Elk River beds. Pliocene to Recent. Range: 33-57° latitude.

Cidarina cidaris (A. Adams)

Plate VIII, figure 14.

Margarita cidaris A. Adams (1863), p. 653.
Cidarina cidaris (A. Adams), Grant and Gale (1931), p. 838, pl. 32, fig. 22.

One good specimen obtained at (station 130), possibly occurring at (128) also. Pliocene (?) to Recent. Range: 30-55° latitude.

Margarites (Pupillaria) pupillus (Gould)

Plate VIII, figure 13.

Trochus pupillus Gould (1849), Vol. 3. p. 91.
Margarites (Pupillaria) pupillus (Gould), Grant and Gale (1931), p. 840.

Small fragile form resembles Calliostoma costatum, differs in possessing an umbilicus. Occurs in Schizothaerus zone (114-115) exclusively. Pliocene to Recent. Range: 34-60° latitude.

Family FISSURELLIDAE

Puncturella galeata (Gould)

Plate VIII, figure 15.

Rimula galeata Gould (1846) Vol. 2, p. 159.
Puncturella galeata (Gould), Grant and Gale (1931), p. 851.

This small form well preserved, occuring in the Schizothaerus zone (115-114), showing the two conical pits on each side of the septum within the apex. Pleistocene to Recent. Range: 34-54° latitude.

Family EPITONIIDAE

Epitonium (Opalia) varicostatum (Stearns)

Plate VIII, figure 16.

Opalia varicostata Stearns (1875), p. 463, pl. 27, figs. 2 and 5.
Epitonium (Opalia) varicostatum (Stearns), Grant and Gale (1931), p. 853, pl. 24, fig. 20.

The specimen found at Cape Blanco (Psephidia zone) is incomplete having about nine complete whorls with the remaining anterior portion missing. Spiral ornamentation is entirely lacking, transverse ornamentation consists of about six or seven vari-like ribs which decrease in prominence with increase in size. This suggests the possibility of its being a gradational form between Epitonium varicostatum and the variety anomatum. The main prohibitive factor in respect to Epitonium varicostatum is that the number of ribs in the specimen found at Cape Blanco has only six ribs while the typical form has ten to eleven.

The species is known only from the middle Pliocene,

San Diego horizon of California.

Epitonium (Nitidiscala) cooperi Strong

Plate VIII, figures 17, 17a.

"Scala tincta Carpenter", Arnold (1903), p. 265, pl. 5, fig. 3., not of Carpenter, (1864).
"Epitonium hindsil Carpenter," Packard (1918) p. 319, pl. 36, figs. 14a, 14b.
Epitonium (Nitidiscala) cooperi Strong, (1930), pp. 189, 194, pl. 20, figs. 6a, 6b. 7, 8a, 8b.

The specimens found at Cape Blanco conform to the type of Epitonium cooperi in every particular excepting in the presence of twelve to fifteen varices instead of eleven to twelve as in the type. It might be confused with Epitonium sawinae but that species has approximately twenty ribs and a minute umbilicus which may be concealed by the reflected basal lip. It differs from Epitonium tinctum in that tinctum has a larger apical angle with fused varices. It occurs rarely at (stations 130) and (station 128). Abundant in Mitrella zone (230). Pliocene to Recent. Range: 23-37° latitude.

Family PYRAMIDELLIDAE

Turbonilla (Pyrgolampros) hannibali Bartsch

Plate VIII, figures 18, 18a.

Turbonilla (Pyrgolampros) hannibali Bartsch (1917), p. 645, pl. 43, fig. 7; Grant and Gale (1931) p. 870.

Many well preserved topotypes excepting for decollation of nuclear whorls, found along with several in which the ribbing is partially or completely obliterated due to poor preservation. Costae seem to vary between eighteen and twenty-three in number. Spiral sculpture consists of very fine striae.

Differs from Turbonilla oregonensis in more acute apical angle and better defined ribbing--Turbonilla lituyana in more flattened ribbing. Bartsch has stated that Turbonilla lituyana Dall has stronger ribs and is larger but he evidently had access only to very few specimens because some of those from the Mitrella zone (230) are from 12 to 14 mms. in length while Turbonilla lituyana is about 11½ mms. long. The ratio of diameter to height is approximately the same in both of these forms. These facts suggest that Turbonilla hannabali is synonymous to, or at most a variety of Turbonilla lituyana Dall. Occurs in Compsomyax (128), Vitrella (230), and Psephidia (131) zones. Pliocene.

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PLATES I-IX

PLATE I

All figures on this plate two-thirds natural size.

Fig. 1. Acila blancoensis (Howe)
Fig. 2. Nuculana minuta praecursor (Arnold)
Fig. 3. Yoldia scissurata strigata Dall-Exterior of
Fig. 3a. Yoldia scissurata strigata Dall-Interior of
Fig. 4. Glycimeris grewingki Dall
Fig. 4a. Glycimeris grewingki Dall Dentition
Fig. 5. Anadara trilineata (Conrad)
Fig. 5a. Anadara trilineata (Conrad)

PLATE I

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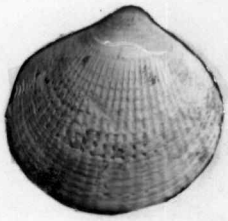

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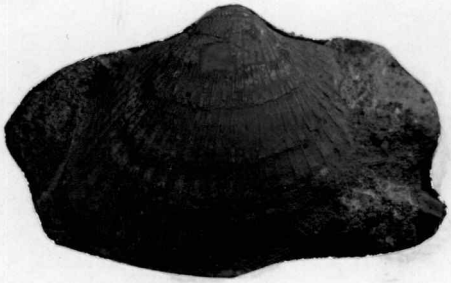

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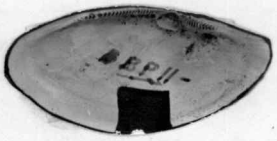

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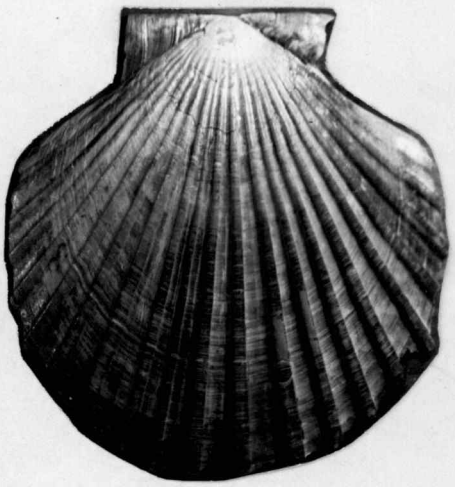
PLATE II

All figures on this plate two-thirds natural size unless otherwise indicated.

Fig. 1.	Pecten caurinus Gould. Right exterior valve.
Fig. 1a.	Pecten caurinus Gould. Left exterior valve.
Fig. 2.	Pecten giganteus Gray. (2/5).
Fig. 3.	Mytilus middendorffi Grewingk. Ventral view.
Fig. 3a.	Mytilus middendorffi Grewingk. Right exterior valve.

PLATE II



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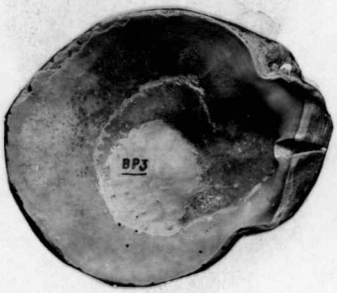

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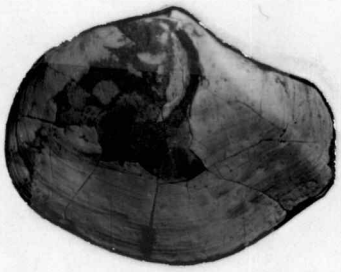
PLATE III

All figures on this plate two-thirds natural size.

Fig. 1. Thracia trapezoides Conrad.
Fig. 2. Thracia jacalitosana Arnold. Right valve.
Fig. 2a. Thracia jacalitosana Arnold. Left valve.
Fig. 3. Pandora grandis Dall. Left exterior valve.
Fig. 3a. Pandora grandis Dall. Interior of right valve.
Fig. 4. Lyonsia pugetensis Dall. Exterior of right valve.
Fig. 4a. Lyonsia pugetensis Dall. Interior of right valve.
Fig. 5. Lucina acutilineata Conrad.

PLATE III



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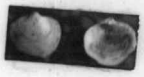

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PLATE IV

All figures on this plate two-thirds natural size.

Fig. 1. Clinocardium meekianum (Gabb). Exterior left valve.

Fig. 1a. Clinocardium meekianum (Gabb). Interior of left valve.

Fig. 2. Clinocardium decoratum (Grewingk). Exterior.

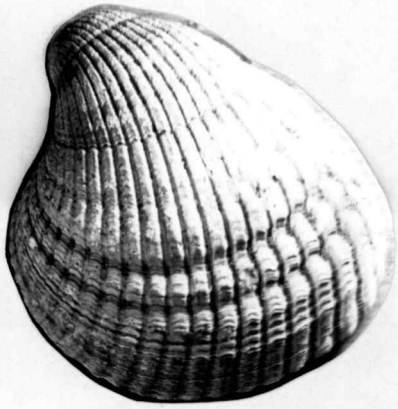
Fig. 3. Venus securis ensifera Grant and Gale (?). Left exterior.

Fig. 3a. Venus securis ensifera Grant and Gale. Dentition of right valve.

Fig. 4. Protothaca staminea (Conrad). Exterior of right valve.

Fig. 4a. Protothaca staminea (Conrad). Interior of right valve.

PLATE IV



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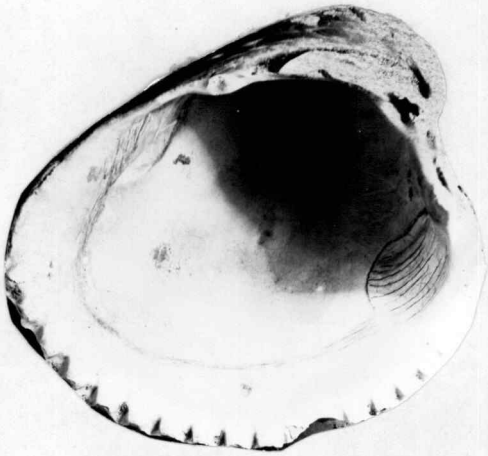

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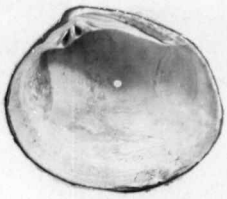

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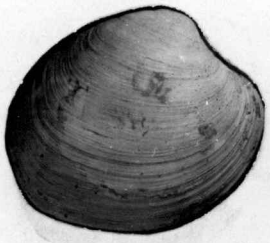
PLATE V

All figures on this plate two-thirds natural size.

Fig. 1. Compsomyax subdiaphana (Carpenter). Exterior of right valve.
Fig. 1a. Compsomyax subdiaphana (Carpenter. Interior of right valve.
Fig. 2. Psephidia lordi (Baird).
Fig. 3. Saxidomus nuttalli giganteus (Deshayes). Interior left valve.
Fig. 4. Macoma irus (Hanley). Exterior right valve.
Fig. 4a. Macoma irus (Hanley). Interior left valve.
Fig. 5. Macoma astori Dall. Exterior right valve.
Fig. 5a. Macoma astori Dall. Interior left valve.

PLATE V



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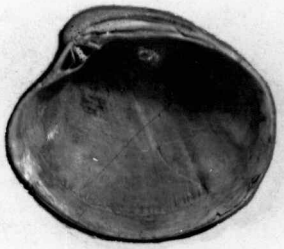

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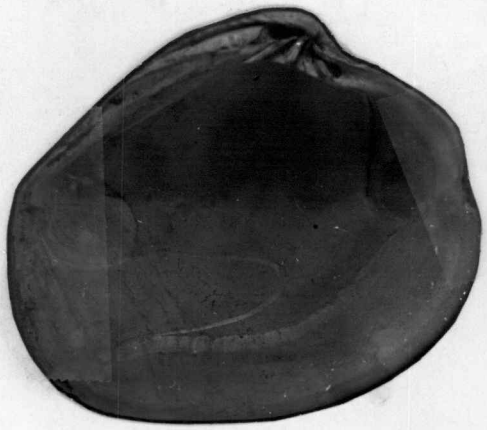

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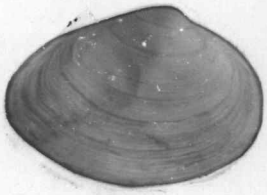

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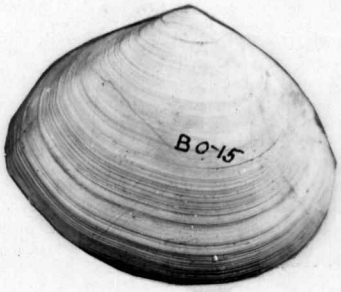

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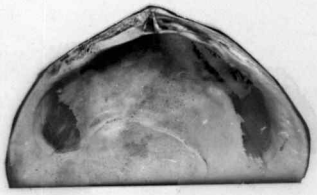

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PLATE VI

All figures on this plate two-thirds natural size unless otherwise indicated.

Fig. 1. Macoma nasuta (Conrad). Exterior right valve.

Fig. 1a. Macoma nasuta (Conrad). Interior left valve.

Fig. 2. Macoma nasuta kelseyi (Dall). Exterior left valve.

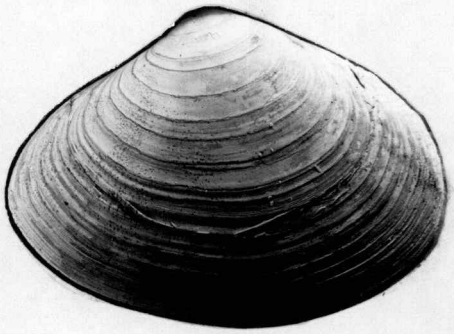
Fig. 3. Siliqua patula (Dixon). Interior Left valve.

Fig. 4. Spisula polynema voyi (Gabb). Exterior left valve ($\frac{1}{2}$).

Fig. 4a. Spisula polynema voyi (Gabb). Interior right valve. ($\frac{1}{2}$).

Fig. 5. Spisula albaria (Conrad). Exterior left valve.

PLATE VI



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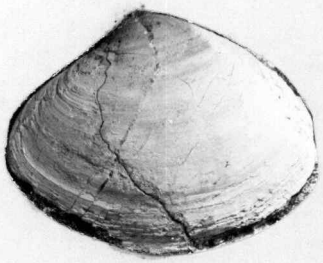

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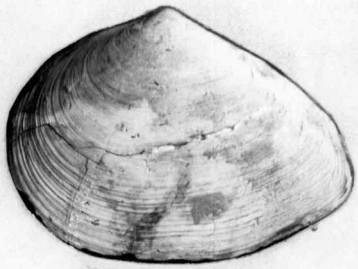

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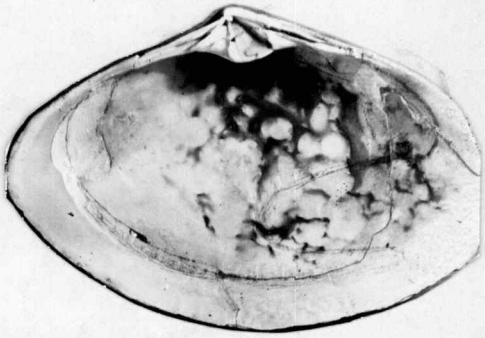

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PLATE VII

All figures natural size unless otherwise indicated.

Fig. 1. Schizothaerus nuttallii pajoroanus (Conrad). Interior left valve. (3/5).
Fig. 2. Mya truncata Linnaeus. Exterior left valve. (2/3)
Fig. 2a. Mya truncata Linnaeus. Dorsal view showing chondrophore. (2/3).
Fig. 3. Aloides.
Fig. 4. Dentalium neohexagonum Sharp and Pilsbury.
Fig. 5. Cylichnella attonsa Carpenter.
Fig. 6. Lora pyramidalis (Strom).

PLATE VII

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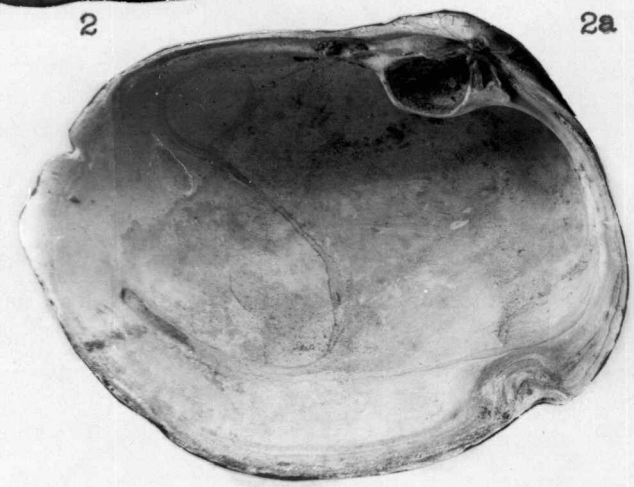

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PLATE VIII

All figures natural size.

Fig. 1. Mangelia variegata Carpenter
Fig. 2. Antiplanes perversa (Gabb)
Fig. 3. Admete couthouyi (Jay)
Fig. 4. Olivella pedroana (Conrad)
Fig. 5. Neptunea tablulata (Baird)
Fig. 6. Neptunea phoenicea Dall
Fig. 7. Neptunea lirata (Martyn)
Fig. 8. Colus jordani Dall
Fig. 9. Colus dalmasius Dall
Fig. 10. Buccinum strigillatum Dall
Fig. 11. Nassarius fossatus (Gould)
Fig. 11a. Nassarius fossatus (Gould) Apertural view
Fig. 12. Calliostoma canaliculatum (Martyn)
Fig. 13. Margarites pupillus (Gould)
Fig. 14. Cidarina cidaris (A. Adams)
Fig. 15. Puncturells galeata (Gould)
Fig. 16. Epitonium varicostatum (Stearns)
Fig. 17. Epitonium cooperi Strong
Fig. 17a. Epitonium cooperi Strong
Fig. 18. Turbonilla hannibali Bartsch
Fig. 18a. Turbonilla hannibali Bartsch
Fig. 19. Trophon fleenerensis (Martin)
Fig. 20. Trophon pacificus (Dall)

PLATE VIII

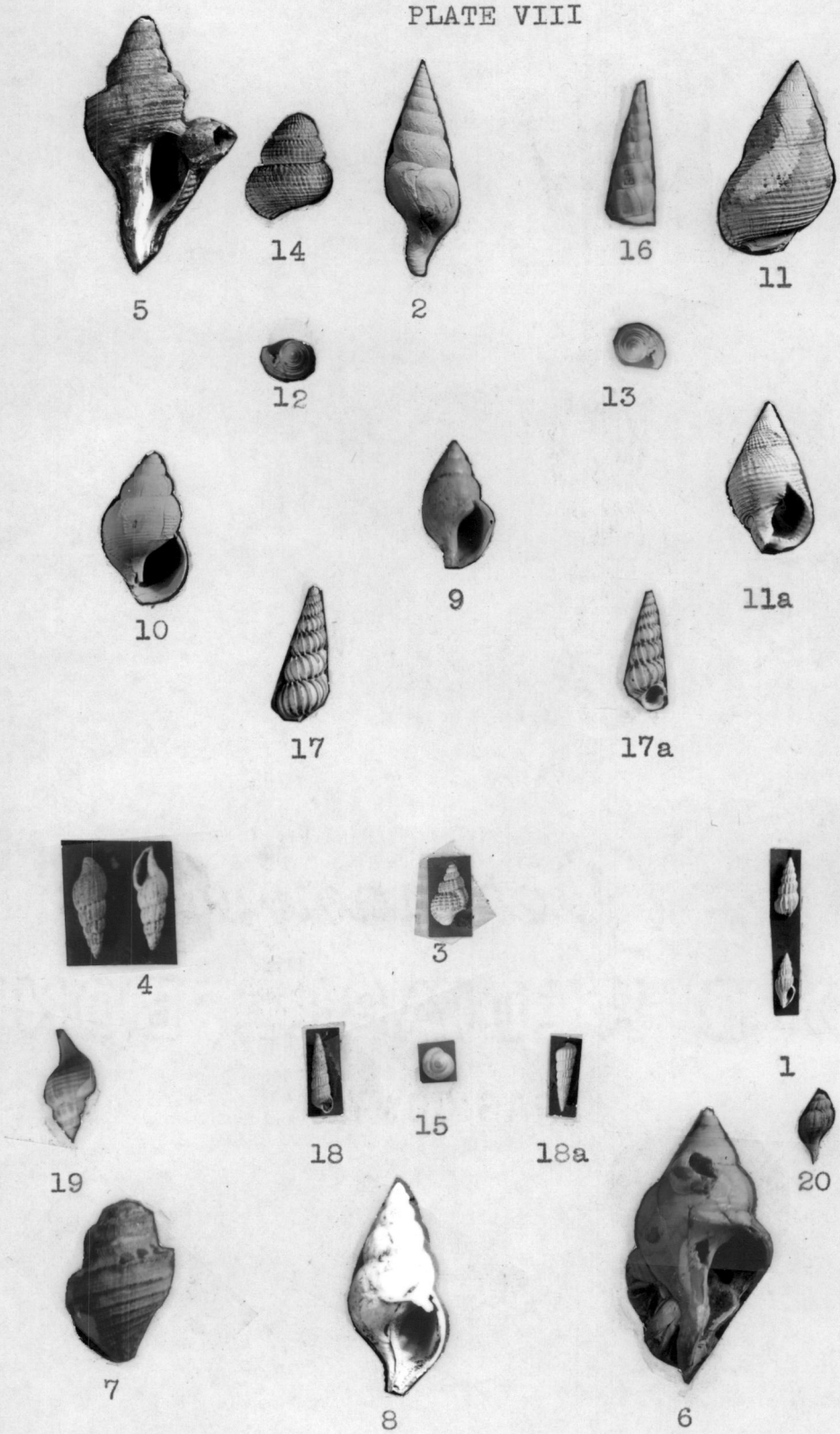
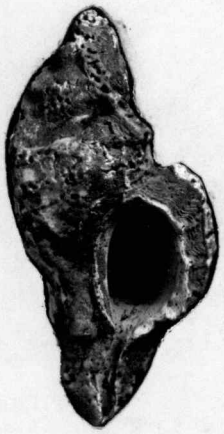


PLATE IX

All figures approximately natural size unless otherwise indicated.

Fig. 1. Mitrella carinata gausapata (Gould)
Fig. 2. Amphissa columbiana Dall
Fig. 3. Lora viridula (O. Fabricius)
Fig. 4. Purpura foliata Martyn
Fig. 5. Thais canaliculata (Duclos)
Fig. 6. Thais lamellosa franciscana
Fig. 7. Thais lamellosa (Gmelin)
Fig. 8. Trophon stuarti Smith. Apertural view
Fig. 8a. Trophon stuarti Smith. Apertural view
Fig. 9. Ranella oregonensis (Redfield)
Fig. 10. Crepidula nummaria Gould (½)
Fig. 11. Calyptraea mamillaris Broderup
Fig. 11a. Calyptraea mamillaris Broderip. Apertural view.
Fig. 12. Polinices pallidus Broderip and Sowerby
Fig. 13. Polinices galianoi Dall
Fig. 14. Sinum scopulosum (Conrad)
Fig. 15. Lepeta concentrica (Middendorff)
Fig. 15a. Lepeta concentrica (Middendorff) APertural view.

PLATE IX



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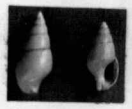

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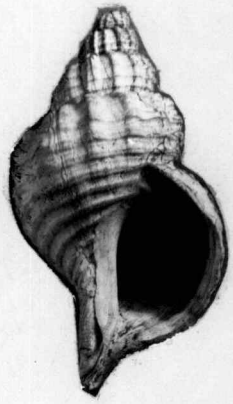

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