REPORT ON REFERRED FOSSILS

Stratigraphic range: Eocene

Kinds of fossils: Foraminifera

General locality: Washington

Shipment No.: C-51-12

Referred by: Robert A. Leroy

Branch: Outside of Survey Date: April 30, 1951

Report prepared by: R. R. Todd

Date: July 24, 1951

#100 - (3 slides)--OK, Karreriella washingtonensis Rau.
#101 - Pulvinulina? sp. These do not seem to be arenaceous.
#165 - We have no primary types for comparison, probably pacifica but hard to be certain of species.
#166 - Ammodiscus OK, but hard to tell if new. Many more specimens should be available before describing as new.
#161, 162 - Both are probably the same species of Quinqueloculina.
#163 - OK, Triloculina
#164 - OK, Textularia, or if more and complete specimens were found, they might prove to be Vulvulina.

To me, the genus Robulus and allied genera are about the most difficult to separate into species, and specimens do actually show complete gradation from one species to another, so that the separation into species is an artificial, not natural, separation. Nevertheless, extremes may be chosen that are quite distinct. It seems best, therefore, to set up a list of factors, such as:

number of chambers
sutures - straight or curved
radial or tangential
depressed or limbate
periphery - keeled or not; if keeled, blunt or sharp and serrate
entire or lobulated
umbo - prominent or indistinct
raised or depressed
aperture - protruding or not
apertural face convex or ~~not~~ concave
ornamentation
and you may think of still other factors.

When ornamentation is present, it is usually a good method of separating species, but it is more often lacking. When such a list is made you may find that most of the forms present fit into several groupings of these factors, but there are still borderline cases.

I think your reference to R. arcuato-striatus (Hantken), var. carolinianus Cushman is good for those forms which have few chambers (6+), rather strongly curved and tangential sutures, a prominent umbo, and a blunt keel. The types of this variety, however, are larger than any of your specimens referred to it.

Robulus alato-limbatus (Gümbel) should differ in having an even larger umbo and the sutures straight instead of curved, and in not being sharply keeled.

Your specimens with more numerous chambers, curved and limbate sutures, and serrate keel may be close to *R. articulatus* (Reuss), var. *texanus* (Cushman and Applin).

The specimen referred questionably to *R. welchi* Church (slide #173) is not typical. That species is not completely involute.

#104 - Because of its strongly compressed form, I would place this in *Planularia*.
#160 - Probably *Saracenaria*, but hard to be certain about the genus from this broken specimen.
#170 - OK, *Pseudoglandulina conica* (Neugeboren).
#169, 171 - OK, *Pseudoglandulina inflata* (Bornemann).
#107, 108 - These seem to be young forms of *Sigmomorphina* or *Sigmoidella*.
#109 - I think this is not enough compressed to be *Globulina landesi*.
#105 - *Guttulina* but probably not *frankei*.
#106 - OK, *Guttulina hantkeni* Cushman and Ozawa.
#110 - (2 slides)—OK, *Sigmomorphina cubensis* Cushman and Bermudez.
#111 - Not *S. vaughani*; but may be close to *S. jacksonensis* (Cushman).
#112 - OK, *Nonion planatum* Cushman and Thomas.
#113 - (2 slides)—These are probably what has been called *N. umbilicatulum*, but are probably not that species which may not even be a *Nonion*. These do belong in *Nonion* and may be undescribed. Note that a specimen of *Gyroidina* is included on one slide. I remounted it separately in the lower left corner.
#168 - It is difficult to be sure but the aperture appears radiate rather than elongate and, if so, this would probably be some genus in the Lagenidae or Polymorphinidae, possibly an initial chamber only.
#114, #115 - OK, *Plectofrondicularia garzaensis* Cushman and Siegfus.
#116, #117 - OK, *Plectofrondicularia packardi* Cushman and Schenck.
#118, #119 - OK, *Plectofrondicularia packardi* Cushman and Schenck, var. *multilineata* Cushman and Simonson.
#120 - (2 slides)—OK, *Bulimina macilenta* Cushman and Parker.
#124, 125 - OK, *Uvigerina garzaensis* Cushman and Siegfus.
#122, 123 - (2 slides)—No, these seem closer to *U. rustica* Cushman and Edwards.
#121 - No, these are not typical. They are more elongate than *U. garzaensis*, and are more strongly ornamented.
#126 - (2 slides)—OK, *Uvigerina* cf. *gallowayi* Cushman.
#127 - (2 slides), 128, 129, 130 (2 slides)—These are larger than types of *Gyroidina soldanii* d'Orbigny, var. *octocamerata* Cushman and G.D.Hanna but I believe most of them could be included in that variety. A few with more angular periphery along the dorsal side may belong in *G. orbicularis* d'Orbigny, var. *planata* Cushman.
#167 - OK, *Gyroidina orbicularis* d'Orbigny, var. *planata* Cushman.
#131, 132 (2 slides), 133, 134 - These appear to belong in either *Pseudoparrella* or *Alabamina*. Further study of the apertural area is needed to determine which. These may be new.
#135, 136, 137, 138 - OK, *Eponides umbonata* (Reuss).
#139 - No, this is another species of *Eponides*.
#140, 141 - Not *Cancris sagra*, but may be a new species. Fairly close to *C. cocoaensis* Cushman.
#142 - Probably *Cassidulina galvinensis* Cushman and Frizzell, but a poor and small specimen.

#143, 144, 145 - I believe these could be included in Cassidulina globosa Hantken although they are smaller than usual for that species.

#146 - OK, Pullenia eocenica Cushman and Siegfus.

#147, 148 - These are not identical with topotypes of this species from the Adriatic Sea, although they may be the same as what has been called G. bulloides.

#149, 150 - These are very close to types of Globigerina triloculinoides Plummer, in having the same type of cancellated wall surface, and, when well preserved, the same projecting lip over the aperture. Even though these are larger than the types I believe they could be called the same.

#151, 152, 153, 154 - No, from comparison with paratypes these are not Cibicides elmaensis Rau. Possibly these are too poor to identify with certainty.

#155, 156, 157, 158, 159 - These are much smaller and more involute than topotypes of Cibicides pseudowuellerstorfi Cole and, if the same, are probably immature specimens.

M. R. Todd

GEOLOGY OF THE CRESCENT BAY AREA
OLYMPIC PENINSULA WASHINGTON

by

ROBERT AHLBERG LONEY

A thesis submitted in partial fulfillment for the degree of

MASTER OF SCIENCE

UNIVERSITY OF WASHINGTON

1951

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OLYMPIC PENINSULA WASHINGTON

ABSTRACT

Early Tertiary sequence of the Crescent Bay area of the northern Olympic Peninsula, Clallam County, Washington, comprises about 5200 feet of volcanic and sedimentary rocks, folded into a broad, northwest-trending syncline.

From base upward, the revised stratigraphic sequence includes: the middle Eocene Crescent formation, about 1800 feet in thickness, consisting of a lower, predominantly volcanic (Metchosin) member, and an upper, Boundary shale member; 1800 feet of Lyre conglomerate; the upper Eocene (?) Twin River formation, comprising an exposed 1400 feet of siltstone and graywackes.

Megafossils (chiefly molluscs) of the Crescent formation, and Foraminifera of the Twin River formation are described and figured.

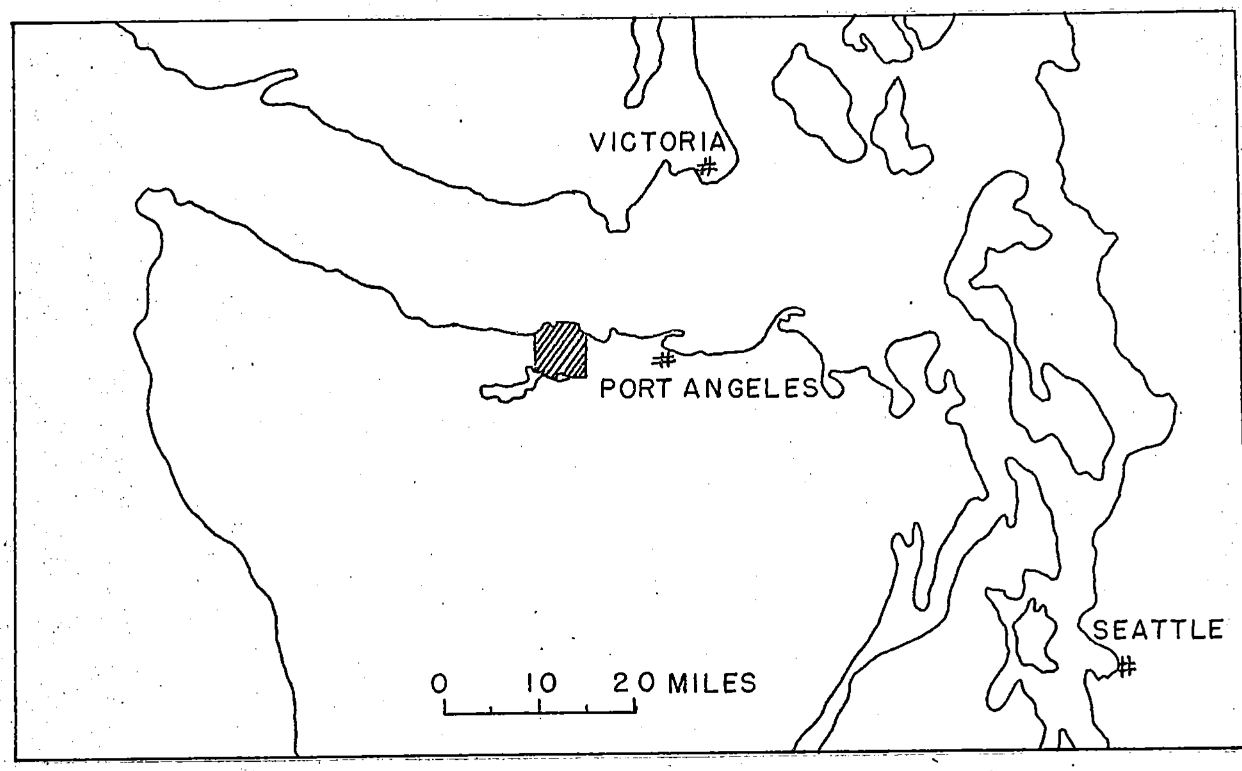

Figure 1

Index Map

INTRODUCTION

General Statement

Since Arnold's (1906) original work in the Crescent Bay area of the Olympic Peninsula several investigators have made studies of a reconnaissance nature. With this in mind it is the writer's purpose to undertake a more detailed study of this area. Accordingly, detailed mapping and collecting have been carried out where exposures permit.

The basaltic sediments of the middle Eocene Crescent formation at Crescent Bay contain a fossil fauna that represents the only basis for determining the age of the upper part of this volcanic and sedimentary sequence. Several previous authors (Arnold 1906, Weaver 1912, Arnold and Hannibal 1913, Weaver 1916-a, Berthiaume 1938, Durham 1942, Weaver 1942) have published lists of this fauna. The present paper is the initial attempt to describe and figure the Crescent fauna as such and correlate it with that of other early Tertiary strata.

The Foraminifera of the upper Eocene (?), lower Twin River formation have been studied in an attempt to correlate them with those of formations of previously determined age. The results of this study are presented in this paper.

The initial field work revealed that some of the formations, as defined by previous writers, are not amenable to mapping as lithologic units. For this reason a suggested revision of the stratigraphic nomenclature of the north Olympic Peninsula is presented herein under the co-authorship of W. L. Danilchek, who is working in a nearby area.

Because of the dense vegetation of the map area, together with the limitations of time in the field, the present study is less definitive than the writer had originally hoped. Therefore, both the areal mapping and the stratigraphic treatment presented in this paper should be regarded as somewhat tentative in character.

Location and Area

The Crescent Bay area is located along the north coast of the Olympic Peninsula in northwestern Washington, about 15 miles west of Port Angeles. The area mapped is bounded on the north by the Strait of Juan de Fuca and on the south by U.S. Highway 101, which runs through a rather narrow, deep valley containing Lake Crescent and Lake Sutherland. The eastern boundary extends eastward as far as Observatory Point on Freshwater Bay, and the western boundary extends westward to the mouth of Whisky Creek.

The area comprises approximately 40 square miles including most of townships 30 and 31 north, range 8 west.

Field Work

The beach section was mapped on aerial photographs with an approximate scale of 400 feet to the inch. In the remainder of the area the mapping was done of the Lake Crescent and Port Crescent quadrangle maps of the U.S. Army Corps of Engineers (1942 editions), enlarged to scale of 800 feet to the inch. Where suitable outcrops exist, detailed sections were measured by tape and Brunton compass. In areas of few outcrops pacing and Brunton compass traverses were made.

Previous Work

The previous work in the area is discussed in a later section under the heading "Stratigraphic Nomenclature."

Acknowledgments

The writer is indebted to Professor Charles E. Weaver for guidance during field studies and paleontological research, and to Professor Harry E. Wheeler for his encouragement and helpful criticism during the preparation of the manuscript and plates. Thanks are also due Professors J. Hoover Mackin and Julian D. Barksdale for their helpful advice on physiography and structure respectively.

GENERAL GEOLOGY

Physiography

The topography of the Crescent Bay area is the result of pre-glacial fluviatile and glacial erosion. During the Vashon glacial epoch the Juan de Fuca Lobe of the Cordilleran ice sheet overrode the north side of the Olympic Peninsula to an elevation of approximately 5000 feet as indicated by the presence of granitic erratics on the highest ridges (Bretz 1920, p. 338).

The northernmost part of the area consists of a rather discontinuous series of northwesterly trending strike ridges which vary greatly in altitude along the trend. This belt is an ill-defined, composite cuesta formed by resistant beds on the north limb of the Clallam syncline. The north and steeper side of the cuesta is further steepened by wave action forming rugged sea cliffs up to 400 feet in height.

The resistant strata forming the cuesta are not everywhere the same. In the area northwest of Salt Creek between Tongue and Observatory Points the ridge is well defined and reaches an altitude of over 1000 feet. In this section the crest is formed by the resistant Metchosin volcanic sequence. The Metchosin is also partly responsible for the rugged sea cliffs of the headland between Agate and Crescent Bays. The low ridge paralleling Striped Peak on the south bank of Salt Creek is formed by the Lyre conglomerate. This ridge trends northwest until it reaches Crescent Bay, where it follows the coast westward forming sea cliffs. About a mile east of Whisky Creek the softer siltstone of the Twin River formation is the cliff-former.

The rolling lowland to the south, formed in the Twin River siltstone, averages about two miles in width and 350 feet in elevation.

South of this lowland is a prominent west-to-northwest-trending ridge rising to a maximum elevation of 2500 feet in the vicinity of the headwaters of Whisky Creek and declining to a minimum of 900 feet in the saddle near the southeastern border of the map area. The resistant strata comprising this ridge are the Lyre conglomerate, the Twin River siltstone, and the Crescent volcanics. These formations alternate as ridge formers (see Plate I).

To the south this ridge descends steeply into the narrow east-west valley containing Lakes Crescent and Sutherland. The floor of the valley, which averages about 500 feet in elevation, is covered by glacial gravels, landslide materials from the surrounding slopes, and stream deposits. The south side of the valley rises steeply onto the north flank of Baldy Ridge of the Olympic Mountains.

The Clallam syncline in this area is asymmetrical with the steeper limb on the south. This asymmetry is more pronounced in the eastern part where dips average about 25° on the north limb and about 70° on the south. In the Western part of the area, where the asymmetry is less prominent, the north limb dips average 25°, while on the south they average 35°. Because of the scarcity of outcrops in the southwestern portion of the map area, information is projected into this quarter from the adjacent area to the west (Weaver 1937).

On the basis of present local data it is not possible to determine accurately the age of the folding in this area. All beds except the Pleistocene glacial deposits are involved in the deformation. Weaver (1937) postulated a late Miocene diastrophism to account for the present northwest-trending folds involving Tertiary strata in western Washington.

Because of the scarcity of outcrops, detailed information concerning faulting in the area is lacking. However, stratigraphic and topographic evidence occurs in the immediate vicinity of Crescent Bay. Two probable faults, striking at near right angles to the trend of the folding, are indicated.

In the saddle occupied by the west Crescent Bay road, as it descends to the beach, a probable fault zone strikes about N. 40° E. Detailed mapping shows the Lyre conglomerate to have an apparent horizontal displacement along this fault zone of 2000 to 3000 feet. Field study of the Lyre conglom-

The pre-glacial drainage was probably of the trellis type consisting of subsequent streams flowing parallel to the regional strike and northward flowing streams which were probably consequent.

A study of the elevations in the floor of the Valley occupied by Lakes Crescent and Sutherland indicates that the original drainage was probably to the east via Indian Creek, which is a tributary of the Elwha River. However, today the Lyre River, which is a short, steep-gradient, northward flowing stream, drains Lake Crescent directly into the Strait of Juan de Fuca.

This rather anomalous drainage pattern is interpreted by the writer as follows: The Lake Crescent-Lake Sutherland valley was formed originally by an eastward flowing tributary to the Elwha River. During the Pleistocene the Juan de Fuca Lobe overrode the area and in general widened and deepened the valley. That part of the valley east of Lake Sutherland apparently was not gouged by the overriding, westerly moving ice. As the ice front began to retreat eastward along the valley, a lake was formed to the west in its wake. When the ice front had retreated eastward to a point beyond the present position of Piedmont, the water of this lake was high on the valley sides. Overflow from this lake into the headwaters of the Lyre River resulted in the present position of the outlet of Lake Crescent.

Following the withdrawal of the ice to the present position of Lake Sutherland, huge landslides from glacially oversteepened valley sides separated the lake into two smaller ones and prevented further drainage between them. The position of Lake Sutherland is determined by the east end of the glacially scoured valley. Further withdrawal of the glacier was without significant modification of the valley to the east.

Wave-cut cliffs and terraces at various elevations indicate recent changes in sea level. These changes may be due to recent uplift of the land or actual changes in water level. The lowest and most recent of the terraces is the broad flat, about ten feet in elevation, extending from the mouth of Salt Creek to the area between Crescent and Agate Bays. This lowland is bordered on the south by a wave-cut sea cliff of Lyre conglomerate. Today, the only locality in which this cliff is being actively eroded by the sea is the area west of Agate Bay. Another terrace, 25 feet in elevation, occurs at Tongue Point. Its surface is rather flat and its soil contains a considerable amount of recent marine invertebrate remains. On the north slope of Striped Peak are several probable terraces between 50 to 100 feet in elevation, but these contain no marine fossils and are too eroded to be identified with certainty.

Structure

The principal structure in the Crescent Bay area is the west-to-northwest-trending Clallam syncline. In the eastern part of the area the axial plane of this fold has a westerly trend; about a half mile east of Ramapo it swings northwesterly for about three miles and strikes about N. 60° W. In the vicinity of Joyce the axial plane again trends to the west. The trace of the axial plane as indicated on Plate I is only approximate, because dense undergrowth and cover prevent precise location.

Most of the evidence indicating the plunge of the Clallam syncline to the northwestward occurs to the east of the area mapped. The conclusions presented are based on the work of McMichael (1946) and reconnaissance by the writer.

Near the middle of the eastern border of the map (Plate I) a ridge consisting of Lyre conglomerate diverges from the general trend and strikes northeastward for a distance of two miles; it then swings northwestward and abruptly terminates. The strata comprising this horseshoe-shaped feature dip inward toward the middle of the fold. It is further observed that this ridge is the eastward limit of the Twin River formation in the immediate area. These facts indicate that the Clallam syncline is plunging westerly at this point.

erate shows that it is a rather unreliable marker due to extreme variations in thickness and lithology along the strike. The above figure for the displacement must necessarily be approximate. An examination of the strike of the Crescent formation outcropping in the neck of land between Agate and Crescent Bays bears out the hypothesis that a fault of considerable displacement exists in this locality.

Another probable fault parallels Salt Creek near fossil locality 3501 (Plate I) south of Striped Peak. This fault appears to truncate the eastward extension of the Lyre conglomerate. Additional evidence of this fault, and indications that it may have considerable extent, may be seen both to the north and to the south. To the north the contours on both sides of Striped Peak are sharply flexed; to the south the ridge in section 35 of T. 31 N., R. 8 W., is abruptly truncated, and Salt Creek east of Ramapo seems properly aligned.

STRATIGRAPHY

Stratigraphic Nomenclature*

Subsequent to Arnold's (1906) division of the Tertiary formations on the north border of the Olympic Peninsula, several writers have made modifications and additions to his nomenclature. The principal contributors to this nomenclature, together with their stratigraphic subdivisions, are listed in tabular form on Plate IV.

After attempting to recognize and correlate the formations of this area in accordance with the concepts of previous authors, we conclude that most of these formations cannot be recognized as mappable units in the field. A study of the reasons behind the previous subdivisions of the sequence finds that most of these "formations" were defined on the basis of faunal zones and that lithology and mappability have been given minimum consideration.

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*Written in collaboration with Walter L. Danilchek.

The decision to revise the nomenclature on the north side of the Olympic Peninsula comes from the need for a satisfactorily applicable stratigraphic nomenclature. Thus several of these formations are here redefined on the basis of lithology and mappability in compliance with the "Stratigraphic Code" (Committee on Stratigraphic Nomenclature, Ashley et al. 1933).

Arnold (1906) was the first to make a complete subdivision of the Tertiary sequence of the northern border of the Olympic Peninsula. He defined the oldest Tertiary formation on page 460:

> The oldest formation of definitely known age on the Olympic Peninsula is a 1,200 foot series of black basalt and greenish basalt tuffs and tuffaceous sands found in the vicinity of Port Crescent and here designated as the Crescent formation.

Arnold referred to the conglomerates, sandstones, and shale unconformably overlying the Eocene and older rocks as the Clallam formation, which he regarded as undifferentiated Oligocene-Miocene age.

In his paper on the geology of the Olympic Peninsula, Reagan (1909) used the stratigraphic terminology established by Arnold; but in a footnote on page 163 he comments about the Clallam formation:

> Following Doctor Arnold, it is deemed best to use the above term [Clallam formation], as the separation of the two members (Oligocene and Miocene) of the group will necessarily have to be made on paleontological grounds, and the writer does not feel that material enough has been collected to make that possible at the present time.

Arnold and Hannibal (1913) retained Arnold's (1906) definition of the Crescent formation. They did, however, revise Arnold's Clallam formation. For the lower portion of the old Clallam formation, which they believed to be Oligocene, the name Astoria series was proposed. This "Astoria series" was then divided into three faunal zones: the "San Lorenzo formation," the "Seattle formation," and the "Twin River formation." The name Clallam was restricted to the "conglomerates unconformable on the Seattle beds between West Clallam and the Hoko River." They correlated the restricted Clallam with the Monterey formation of California on the basis of faunas.

Weaver (1916-a) referred to the volcanic rocks and interbedded sediments as "the Eocene formation at Crescent Bay." Although he did not call these rocks the Crescent formation, he acknowledged Arnold's (1906) type section on the east shore of Crescent Bay, and his description of the lithology indicates that he was referring to the same lithologic unit.

The conglomerates and interbedded sandstones comprising the later designated Lyre conglomerate are not mentioned specifically by Weaver, and there is some question as to whether he included them in the Eocene "formation" (Crescent) or within the overlying Clallam. A study of his lithologic descriptions suggests that he placed these rocks in the Clallam formation, although his geologic map of the area places part of the Lyre in the Crescent and part in the Clallam.

The Clallam formation was redesignated by Weaver to include only the "Oligocene marine deposits." The Miocene rocks exposed between Pysht and Clallam Bay were therefore excluded, and were referred to the Arca montereyana zone or the Wahkiakum horizon.

Weaver (1916-b, p. 26), in reference to the Arnold and Hannibal (1913) stratigraphic revision, states that, "In the opinion of the writer, it would be preferable to refer to these divisions as faunal zones rather than formations."

Hertlein and Crickmay (1925), in their summary of the stratigraphic nomenclature of this area, regarded Weaver's (1916-a) restriction of the Clallam formation as invalid because it had been previously restricted by Arnold and Hannibal (1913). They did agree with Weaver (1916-b) that until Washington formations were better known it would be best to refer to them by local names.

Weaver (1937) correlated the lower unfossiliferous part of the volcanic sequence at Crescent Bay with the Metchosin volcanics of southeastern Vancouver Island (Clapp, 1912 and 1917). The Crescent formation was accordingly restricted by Weaver to what he regarded as the upper and fossiliferous part of the effusive and sedimentary sequence at Crescent Bay.

At Boundary Creek, near Piedmont on Lake Crescent, Weaver (1937, pp. 123-126) recognized and named a lithologic unit composed of "brownish gray sandy and clay shales" as the Boundary shale, and on page 124 refers to this shale as the "uppermost portion of the middle Eocene Crescent formation."

Because of geographic distance to the type section in California, Weaver (1937, p. 118) did not apply the term San Lorenzo formation of Arnold and Hannibal (1913) to the lowest portion of Arnold's (1906) original Clallam formation. Instead, he introduced the term Lyre formation, which he defined as follows (p. 123):

> The lower 1,450 feet of the more firmly cemented gray sandstones and sandy shale, together with the basal 750 feet of conglomerate and massive sandstone are designated as the Lyre formation and possess a total thickness of 2,200 feet at the type section in Lyre River Canyon.

The name Seattle formation, as applied by Arnold and Hannibal (1913) to the middle beds of their "Astoria series," was changed by Weaver (1937, p. 117) to Lincoln formation on the basis of priority, and because of faunal and lithologic similarity. He likewise correlated the Twin River formation of Arnold and Hannibal with the Blakeley formation on the basis of fauna and, since the name Blakeley has priority over the term Twin River, he referred to this unit as the Blakeley formation.

The Clallam formation as used by Arnold and Hannibal was accepted by Weaver in 1937 with the recommendation that when the fauna was more thoroughly known the term Astoria formation should be used.

The latest revision of the stratigraphic nomenclature of the north Olympic Peninsula area was made by Weaver et al. (1944). In this work the terms Metchosin and Crescent remained as employed by Weaver in 1937, with the exception of the Boundary shale, which was not mentioned. The term Lyre formation of Weaver (1937) was modified to Lyre conglomerate, and the name "Lincoln formation" was retained.

Weaver's (1937) Blakeley formation on the north side of the Olympics was regarded as equivalent in age to the type Blakeley at Restoration Point. He later found, however, that only the lower part of this formation was equivalent in age to type Blakeley, the upper part being younger. Therefore, Weaver et al. (1944) restored the name Twin River formation to these rocks.

These authors also correlated the Clallam formation of Arnold and Hannibal with the Astoria formation in northwestern Oregon on the basis of fauna, and therefore substituted the name Astoria formation for the term Clallam.

The stratigraphic nomenclature employed in this paper is fundamentally a refinement of that proposed by Arnold in 1906. No new names are proposed.

Our field work at the Crescent formation type section at Crescent Bay and in other areas to the west shows Arnold's (1906) definition of this formation to be valid. Weaver (1937, p. 29) restricted the name Crescent to the chiefly detrital rocks at the top of Arnold's Crescent. Weaver applied the term Metchosin to the predominantly volcanic rocks below his restricted Crescent. However, our field study between Crescent and Freshwater Bays reveals a large thickness of sedimentary detrital rocks within the Metchosin as mapped and employed by Weaver. Moreover, to the west of the type section, the entire Tertiary sequence beneath the Boundary shale is overwhelmingly volcanic in character. Thus neither locally nor regionally does there appear to be an acceptable basis for subdivision of Arnold's Crescent. Therefore, on the basis of both priority and applicability, the Crescent formation as originally defined by Arnold (1906) is accepted.

Weaver's Boundary shale is a distinct lithologic unit that can be recognized at many localities above the underlying volcanics or as interbeds within the uppermost part of the volcanic sequence. Therefore, the term Boundary shale should be retained for this member of the Crescent; and the well-established term Metchosin may be appropriately applied to the more dominantly volcanic part of the formation. Although it is not possible to trace these rocks to the Metchosin type section on Vancouver Island, written descriptions (Clapp 1912, 1917) and the work by Weaver (1937) indicate that it is reasonable to correlate this chiefly volcanic sequence with the type Metchosin.

The gray conglomerates and interbedded gray sandstones overlying the Crescent formation were designated by Weaver (1937) as the Lyre formation. As a valid cartographic unit, the Lyre is retained.

The Twin River formation of Arnold and Hannibal is accepted, but is extended to include the underlying "Seattle formation." Arnold and Hannibal originally defined both the Seattle and Twin River formations on the basis of fauna, as did later authors. There is apparently no lithologic basis for such a subdivision, as both "formations" consist of the same gray siltstone with minor amounts of gray sandstone.

Arnold's original Clallam formation was restricted by Arnold and Hannibal to the massive sandstones, conglomerates, and interstratified shales overlying the Twin River. Since this unit would otherwise be without designation, the term Clallam is accepted.

<table>
<tr><th colspan="2">This Paper</th><th>1906 Arnold</th><th>1909 Reagan</th><th colspan="2">1913 Arnold & Hannibal</th><th>1916 Weaver</th><th colspan="2">1925 Hertlein & Crickmay</th><th colspan="2">1937 Weaver</th><th>1944 Weaver et al.</th></tr>
<tr><td colspan="2">Clallam fm.</td><td rowspan="4">Clallam fm. or Oligocene-Miocene (undiff)</td><td rowspan="4">Clallam fm.</td><td colspan="2">Monterey or Clallam fm.</td><td>Arca Montereyana zone or Wahkiakum horizon</td><td colspan="2">Clallam fm.</td><td colspan="2">Clallam fm.</td><td>Astoria fm.</td></tr>
<tr><td colspan="2" rowspan="2">Twin River fm.</td><td rowspan="3">Astoria series</td><td>Twin River fm.</td><td rowspan="3">Clallam fm.</td><td rowspan="3">Astoria series</td><td>Twin River fm.</td><td colspan="2">Blakeley fm.</td><td>Twin Rivers fm.</td></tr>
<tr><td>Seattle fm.</td><td>Seattle fm.</td><td colspan="2">Lincoln fm.</td><td>"Lincoln fm."</td></tr>
<tr><td colspan="2">Lyre fm.</td><td>San Lorenzo fm.</td><td>San Lorenzo fm.</td><td colspan="2">Lyre fm.</td><td>Lyre congl.</td></tr>
<tr><td rowspan="2">Crescent fm.</td><td>Boundary Shale mem.</td><td rowspan="2">Crescent fm.</td><td rowspan="2">Crescent fm.</td><td colspan="2" rowspan="2">Crescent fm.</td><td rowspan="2">Eocene fm. at Crescent Bay</td><td colspan="2" rowspan="2">Crescent fm.</td><td>Crescent fm</td><td>Boundary Shale mem.</td><td>Crescent fm.</td></tr>
<tr><td>Metchosin member</td><td colspan="2">Metchosin volcanics</td><td>Metchosin volcanics</td></tr>
</table>

Comparative Nomenclature of the Tertiary Sequence of the Northern Olympic Pennisula. Plate I V

Crescent Formation

Lithology

The Crescent formation consists of approximately 2500 feet of light gray to dark gray volcanics and associated sediments. The above stratigraphic thickness was measured in the type section on the east shore of Crescent Bay and eastward to Observation Point. The base is not exposed at this locality. The Crescent is here divided into two members. The lower, the Metchosin member, consists chiefly of volcanics and associated medium to coarse-grained clastics; the upper, the Boundary shale member, consists chiefly of dark gray to medium brownish-gray, silty shale with an occasional thin flow of basalt.

Metchosin Member

The Metchosin member consists of many rock types, but these may be divided into two general phases: the basaltic phase, and the andesitic phase.

Basaltic phase: The basaltic phase consists of approximately 50 per cent irregular basalt flows and flow breccias. The borders of these flows are poorly defined and grade into coarse, basalt, flow breccias with angular fragments up to 6 feet in diameter.

The basalts vary from black and aphanitic to dark gray and fine grained, and weather brown to reddish-brown.

All variations are usually porphyritic with plagioclase and augite occurring as the principal phenocrysts. A few vesicular and amygdaloidal basalts are present in the sequence. The amygdalesare spherical to ellipsoidal and consist of quartz, chalcedony, calcite, chlorite, and zeolites; they average about 1/8 inch in diameter.

Within about 300 feet of the base of the beach section east of Crescent Bay, pillow basalts become common. The pillows average about 3 feet in diameter; they are convex on top and roughly concave on the bottom, with a short neck projecting downward. The pillows show a concentric structure and become slightly vesicular near the margins. The interstices between adjacent pillows contain fine, altered, basalt fragments.

Microscopically the basalt commonly shows phenocrysts of labradorite ($Ab_{45}An_{55}$) and augite. The plagioclase is partly altered to kaolin, and the augite to antigorite and chrysotile. Magnetite and apatite form accessory minerals. The groundmass is usually felty and contains little or no glass.

The basalt breccias contain the same type of basalt as the flows. These breccias may be divided into two types which grade into each other. One type consists of a flow breccia in which the matrix is of the same material (basalt) as the fragments themselves; the other type is a sedimentary breccia in which the matrix consists of dark green graywacke. In this last type, although the fragments are predominantly angular, some are slightly rounded by transport.

Several small, intrusive bodies of unknown shape occur on the south limb near the east end of Lake Sutherland. They exhibit several grain sizes from medium to coarse. The composition varies between a diorite containing calcic andesine plagioclase and a gabbro with sodic labradorite plagioclase. The other important mineral is pigeonite. All rocks show typical ophitic texture.

Approximately 45 per cent of the basaltic phase consists of dark greenish-gray, fine to coarse graywackes* which are derived almost entirely from the erosion of the basalt. The graywackes are usually massive, but bedding is sometimes suggested by fine pebble layers (Figure 2). Sorting is poor and the rock grades both vertically and horizontally into conglomerates and breccias. Calcite veins are very common and in some places develop into gray and pink limy veins up to three feet in thickness; these veins do not conform to the bedding. Veins of this type are very common in the upper part of the Metchosin as exposed on the west side of Crescent Bay (Figure 3). Associated with these lime zones are breccias consisting of very angular fragments of

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*All sedimentary rock classifications according to Pettijohn (1944) unless otherwise noted.

Figure 2

Coarsely bedded graywacke at the type section of the Crescent formation, east shore of Crescent Bay

Figure 3

A calcareous vein in the Crescent formation, west shore of Crescent Bay graywacke averaging 6 inches in diameter with a matrix of gray, limy mudstone (Figure 4).

Microscopically the graywacke consists almost entirely of the alteration products of the original basalt fragments. About 40 per cent of the rock consists of a grass-green, isotropic mineral with an index of refraction of 1.59±. This mineral could not be positively identified, but it is probably a hydrous magnesium iron silicate close to greenolite and glauconite. Small amounts of chlorite occur with this mineral. The green mineral is replacing a pyroxene, probably augite. Little quartz was found, but an isotropic form of silica with an index of refraction of 1.490-1.500, probably metacristobolite, makes up 30 per cent of the rock. The remaining mineral constituents consist of calcite, magnetite, and fine argillaceous material. Due to the high degree of alteration, no feldspar is present.

The above description agrees with Pettijohn's (1949) definition of a graywacke.

Andesitic phase: The andesitic phase makes up about 30 per cent of the Metchosin. It occurs near the middle of the section between Tongue Point and Observatory Point. The rocks of this phase are pyroclastics ranging from fine tuff to medium breccia. The rocks display great variation in form, but the general color is light to medium green, gray, and red. Andesine plagioclase ($Ab_{67}An_{33}$), chert, and andradite garnet

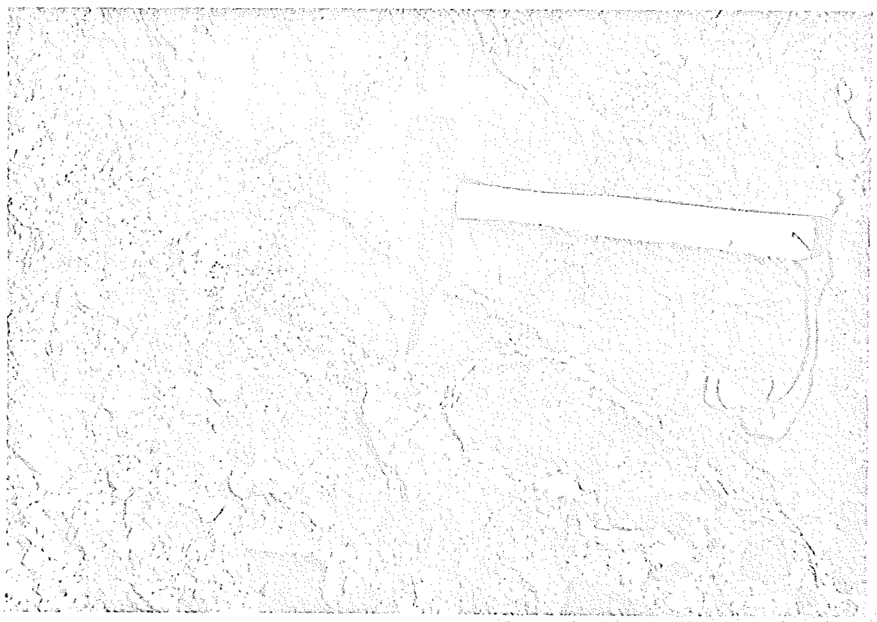

Figure 4

Coarse, graywacke breccia cut by calcite veinlets, west shore of Crescent Bay are common constituents. Little glass is present, as the tuffs are largely recrystallized into a fine ground mass of spherulitic, feldspathic microlites. Finely banded, buff to light greenish-gray chert is found in thin beds, and is also an important constituent of the fragmental rocks.

The andesitic phase differs from the basaltic in that finely bedded rocks are common and no flows are present. This phase occurs at several horizons with the basaltic phase intervening. It is excellently exposed near Observatory Point on Freshwater Bay.

Boundary Shale Member

The Boundary shale consists of dark grayish-brown to medium brownish-gray silty shale. It is not well exposed in the map-area, but is widespread in the south limb of the Clallam Syncline farther west. Two small outcrops occur in the map-area; one on the north bank of lower Salt Creek, and another in the U.S. Highway 101 road cut south of the east end of Lake Crescent. These outcrops are not of sufficient size or excellence to allow a detailed description of this member. The reader is referred to Weaver (1937) for a more detailed discussion.

Distribution

The Crescent formation is widespread in this region. Rocks comparing closely in lithology have been described on all sides of the Olympic Mountains except the western (Weaver 1937). The Crescent formation has been mapped in Washington largely as Metchosin volcanics. However, the name Crescent has priority over Metchosin and is used in this paper for the entire volcanic and associated sedimentary sequence. The name Metchosin, however, is widely used and is therefore retained for the dominantly volcanic member of the Crescent formation (see section on Stratigraphic Nomenclature).

The sea cliffs in the vicinity of Crescent Bay and eastward to Observation Point contain the best exposures of the Crescent formation in the area mapped. The top of the formation is exposured in the sea cliff in the first cove east of Agate Bay. At the type section on the east side of Crescent Bay neither the top nor the bottom is exposed. The exposed top east of Agate Bay exhibits an irregular erosion surface with a slight angular discordance between the Crescent and the overlying coarse conglomerates of the Lyre formation.

On the south limb the chief outcrops are in the road cuts of U.S. Highway 101 near the east end of Lake Sutherland and along the south shore of Lake Crescent. Exposures also occur in the hills in the southeast portion of the area.

Age and Correlation

The graywackes of the Crescent formation contain an abundant fossil fauna consisting chiefly of mollusks. The fossils occur in two horizons: One is about 300 feet stratigraphically below the top of the formation where it has a thickness of about 60 feet. This fossiliferous horizon is represented by fossil localities 3493, 3499, and 3500,* and is exposed in the sea cliffs between Crescent and Agate Bays. The other horizon is about 1150 feet below the top of the formation and is approximately 250 feet in thickness. It is represented by fossil localities 3491, 3492, and 3495 in the sea cliffs near Tongue Point.

The Crescent fauna is closely related to that of the Umpqua formation of Oregon and the Domengine formation of California. Eleven species are found in common with the Umpqua (Turner 1938), and 12 species in common with the Domengine (Vokes 1939). This means that 25 per cent of the known Crescent fauna occurs in formations that have been correlated with the Capay and Domengine stages of the west coast middle Eocene (Weaver et al. 1944). Plate VII shows the occurrence of elements of the Crescent fauna in selected west coast formations.

Several investigators in the past have correlated the Crescent formation on various bases. Clark and Vokes (1936, p. 856) on the basis of megafossils considered it to

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*Unless otherwise indicated, all fossil locality numbers are those of the University of Washington.

be the equivalent of the Domengine stage of California. Berthiaume (1938, p. 495) correlated the orbitoid-bearing beds at Freshwater Bay with the Capay stage of California. Durham (1942, p. 85) collecting in the same area states that ". . . the writer has found . . . a coral, Archohelia clarki Vaughan? which is very close to a Meganos species; and, in a still different area of supposedly the same formation, are found Turritellas close to type Tejon (upper Eocene) species."

Lithologically the Crescent is quite similar to the Metchosin formation of the south end of Vancouver Island as reported by Clapp (1912, 1917). It is highly probable that these two formations are the same lithologic unit (Weaver 1937). Weaver also states that a middle Eocene fauna has been found in the type Metchosin.

Depositional Environment

The heterogeneous rock types of the Crescent formation make the interpretation of the depositional environment difficult. However, certain facts are clear; the existence of pillow basalt and marine fossils indicates a marine environment. Angular fragments and unstable minerals indicate rapid sedimentation from a nearby source. The above facts together with the considerable thickness of the sequence indicate a strongly subsiding, at least partially, marine basin.

The abundant occurrence of mollusks points to the neritic zone as the scene of deposition. Durham (1942, p. 85), after studying a collection of corals from the Crescent formation, interpreted the depth of the environment to be about 74 meters, with a temperature of 22.8°C.

Section

BEACH SECTION EASTWARD FROM WHISKY CREEK

	Feet
Graywacke: dark greenish-gray, massive, conglomeratic, medium grained with very sparse basalt pebbles from subrounded to angular and averaging about 3/4" in diameter; rock contains many light gray calcareous veinlets	18
Breccia: dark greenish-gray, massive made up of angular fragments of graywacke averaging 1/4" in diameter with light gray calcareous, matrix	12
Breccia: dark greenish-grey, similar to above but with finely bedded graywacke fragments averaging 3" in diameter	12
Breccia: similar to above but with subrounded basalt pebbles	63
Breccia: dark gray, massive consisting of angular basalt fragments containing calcite amygdales averaging 2 mm. in diameter in a light gray, calcareous matrix; matrix about 25%	115
Graywacke: dark greenish-gray, massive to coarsely bedded, conglomeratic, medium grained with basalt pebbles averaging 1" in diameter	19
Graywacke: dark greenish-gray, massive, weathering brown, slightly pebbly (basalt 1" in diameter) containing numerous small molluscan fossils; fossil locality 3499	18

	Feet
Graywacke: dark greenish-gray, weathering brown, massive, medium grained with interbedded dark gray, fine graywacke; 50% of each type. Fine graywacke contains molluscan fossils; fossil locality 3500	30
Graywacke: dark greenish-gray, massive, fine grained, containing molluscan fossils; fossil locality 3493	36
Breccia: dark greenish-gray, massive consisting of angular fragments of medium graywacke averaging about 1" in diameter in a matrix of light gray, calcareous material cut by cream colored, calcareous veins	27
Limestone; light gray to cream, vein almost parallel to bedding.	2
Graywacke: dark greenish-gray, massive, medium grained	37
Breccia: dark gray, massive made up of angular fragments of basalt averaging 3" in diameter in a matrix of basalt and gray and cream colored calcareous material	155
Basalt: dark gray, massive, fractured, spheroidally weathered becoming finely vesicular in lowest 18'; small number of calcite veinlets	166
Breccia: dark gray, massive, flow-type with angular basalt fragments averaging 2-1/2" in diameter in a matrix of same basalt; rock cut by gray and cream colored calcite veinlets	31
Basalt: dark gray, massive, sparsely and finely vesicular, weathered spheroidally with a few gray calcite veinlets	21
Total thickness	762

End of section at water's edge on point of land between Agate Bay and Crescent Bay.

BEACH SECTION EASTWARD FROM SALT CREEK

	Feet
Basalt: dark gray, massive, with amygdals of calcite averaging 3 mm. in diameter	6
Covered	20
Basalt: dark gray, massive, amygdaloidal, porphyritic with amygdals of calcite averaging 3 mm. and phenocrysts of feldspar averaging 2 mm. in diameter; this rock appears to be an irregular mixture of flow and coarse breccia	50
Covered	17
Basalt: dark gray, massive, slightly vesicular with a very few calcite amygdals and fine veins	77
Covered	10
Basalt: poorly exposed, dark gray, weathered brown, massive	12
Covered	10
Breccia: dark gray, massive, coarse, containing angular fragments of basalt averaging 1' in diameter and coarse graywacke matrix. Grading irregularly into a flow downward	48
Covered	53
Basalt: dark gray, massive with a few calcite veinlets	4
Covered	10
Basalt: dark gray, massive, fractured with fractures filled with calcite	13
Breccia: dark greenish-gray, massive, coarse with angular fragments of basalt averaging 3" in diameter and up to 4' in diameter; 40% coarse graywacke matrix	12

	Feet
Basalt: dark gray, crudely columnar jointed, becoming finely vesicular near top and grading downward into coarse, basalt breccia with irregular patches of coarse graywacke	73
Breccia: dark gray, massive, coarse, containing basalt fragments averaging 2' in diameter; matrix consists of partly coarse graywacke and partly basalt	9
Basalt: dark gray, massive	10
Covered	30
Graywacke: dark brownish-gray, finely bedded, sparsely conglomeratic, medium grained containing many small mollusks; fossil locality 3491	12
Graywacke: dark brownish-gray, finely bedded, conglomeratic, medium grained with subrounded basalt pebbles averaging 1" in diamter and containing fine particles of calcite, and 6" lenses of green altered material; bed becomes more massive downward	89
Graywacke: dark greenish-gray, weathering brown, massive, conglomeratic, coarse grained with subrounded to rounded basalt fragments averaging 1" in diameter up to 4" in diameter	18
Breccia: dark gray, massive, coarse grained, made up of basalt fragments averaging 1' in diameter containing mollusk and brachiopod fossils in a graywacke matrix; fossil locality 3492	7
Breccia: dark brownish-gray, massive made up of basalt fragments averaging 1/4" in diameter in a matrix of medium graywacke; basalt fragments vesicular with some calcite amygdals	11
Graywacke: dark brownish-gray, finely bedded, conglomeratic, coarse grained containing subangular basalt pebbles averaging 1/2" in diameter	7
Graywacke: dark greenish-gray, massive, coarse grained, conglomeratic containing subangular, irregularly bedded basalt pebbles averaging 1" in diamter	13

	Feet
Breccia: dark gray, massive, coarse made up of basalt fragments in a small amount of graywacke matrix; fragments average 1' in diameter	35
Graywacke: dark greenish-gray, massive, conglomeratic, coarse grained containing sparse subrounded basalt pebbles averaging 1" in diameter and calcite veinlets	10
Basalt: dark gray massive	5
Graywacke: dark greenish-gray, massive, conglomeratic with subangular basalt fragments averaging 4" in diameter	25
Basalt: dark gray, massive	3
Graywacke: dark greenish-gray, massive, conglomeratic containing subanguler, vesicular basalt fragments averaging 1' in diameter and numerous calcite veinlets	7
Alternating thin lenses of dark gray, finely vesicular basalt and dark, greenish-gray, medium-grained graywacke; lenses averaging 4" in thickness	8
Graywacke: dark greenish-gray, massive, conglomeratic, coarse grained containing sub-rounded basalt fragments averaging 1' in diameter. Abundantly fossiliferous; fossil locality 3495	9
Basalt: dark gray, weathered brownish-yellow with crudely columnar jointing containing a few irregular lenses of dark greenish-gray, medium graywacke averaging 2' in thickness	28
Basalt: dark gray, massive with calcite veinlets	24
Graywacke: greenish-gray, massive, conglomeratic, coarse containing subanguler basalt fragments averaging 1' in diameter	7
Basalt: dark gray, massive	4
Breccia: dark greenish-gray, massive, coarse containing angular fragments of basalt averaging 1' in diameter with a coarse graywacke matrix	10

	Feet
Basalt: dark gray, massive	3
Graywacke: dark greenish-gray, massive, medium grained with calcite veinlets	2
Graywacke: dark greenish-gray, massive, conglomeratic, coarse grained containing angular fragments of basalt and calcite veinlets	4
Breccia: dark brownish-gray, massive, made up of angular fragments of highly vesicular to scoriaceous basalt in a matrix of basalt and coarse graywacke	150
Graywacke: medium grayish-green, tuffaceous, irregularly finely bedded with fine particles of jasper scattered throughout having worm tube-like structures on the upper surface of the bedding planes (1/2" diameter by 1' length)	28
Graywacke: medium grayish-green, tuffaceous, irregularly finely bedded, coarse grained containing jasper particles	170
Graywacke: same as above but no jasper and more massive containing lenses of conglomeratic, coarse, tuffaceous graywacke	62
Graywacke: medium grayish-green, tuffaceous, coarse grained containing 1" lenses of the same medium grained graywacke	28
Graywacke: medium bluish-green, massive, tuffaceous, fine grained	3
Graywacke: medium grayish-green coarse and medium, tuffaceous graywacke interbedded; beds average 1' in thickness. Fifty per cent of each type	40
Graywacke: medium grayish-green, tuffaceous, massive, medium grained	13
Graywacke: same as above with irregular lenses of light greenish-buff volcanic breccia with fragments averaging 2" in diameter	31
Breccia: dark brownish-gray, massive, coarse containing basalt fragments averaging 2" in diameter	8

	Feet
Graywacke: medium grayish-green, tuffaceous, medium grained with interbedded coarse graywacke lenses; 60% medium graywacke	17
Breccia: dark brownish-gray, massive, with basalt fragments averaging 1/2" in diameter and in a medium grained graywacke matrix; 85% basalt fragments	6
Graywacke: medium bluish-green, well indurated, fine grained interbedded with 6" lenses of coarse, tuffaceous graywacke; containing angular light green cherty and felsitic fragments averaging 1/4" in diameter	3
Covered	30
Breccia: medium grayish-green, massive containing angular fragments of chert and scoriaceous felsite averaging 1/2" in diameter, with siliceous veins averaging 1" in thickness	14
Covered	8
Inaccessible cliff exposures but chiefly basalt, basalt breccia with interbedded graywacke	255±
Total thickness	1991±

Lyre Conglomerate

Lithology

The dominant rock type of the Lyre formation is a medium gray, well indurated, polymictric conglomerate (Pettijohn 1949). The conglomerate varies from a conglomeratic graywacke to a coarse, boulder conglomerate, and makes up about 70 per cent of the total section as exposed in the sea cliffs between Whisky Creek and Agate Bay (Figure 5). The remaining portion consists of dark green, graywacke breccia, and interbedded gray, medium grained graywacke and gray siltstone.

The Lyre conglomerate displays considerable variation both in vertical and horizontal extent. Near the base as exposed along the beach northeast of Agate Bay the formation consists of a coarse, boulder conglomerate with lenses of pebbly graywacke. West of Agate Bay toward the middle of the beach section the Lyre contains a considerable amount of interbedded medium graywacke and siltstone which often exhibits graded bedding. Within 200 feet of the top of the section the rock changes into a dark greenish-gray, coarse, graywacke breccia. The rocks of the south limb generally contain a greater percentage of interbedded medium graywacke and siltstone than those of the north limb. These interbedded sediments, which often display graded bedding, occur near the

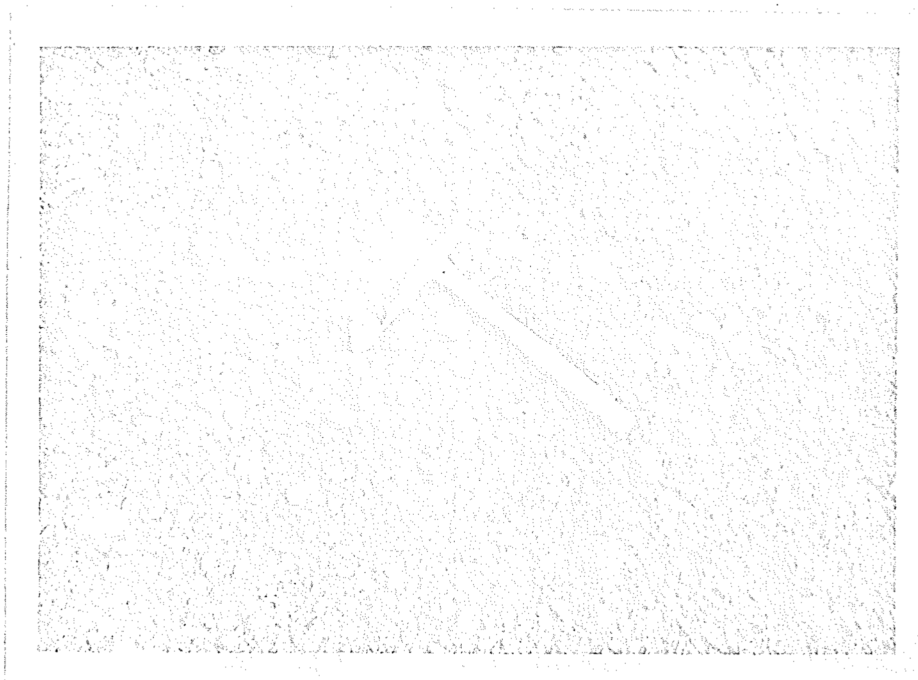

Figure 5

Cobble conglomerate of the Lyre formation at Agate Bay base of the formation at the eastern end of Lake Crescent, although they have also been observed near the top of the section in the road cuts between Piedmont and Joyce.

Conglomerate. The conglomerates of the Lyre are gray in color and consist of rounded to subangular fragments of quartz, metamorphic rock of dioritic composition, amphibolite, aplite, greenshist, greenstone, and basalt. Some of the metamorphic rock fragments are intruded by light colored granitic material. Occasionally angular fragments of dark greenish-gray graywacke and gray siltstone occur in the conglomerate; these fragments range up to boulder size. As a rule the finer material is much more angular than the coarser. The amount of matrix may range from 80 per cent in a pebbly graywacke to less than 20 per cent in a boulder conglomerate. The matrix itself grades from a medium graywacke to a coarse subgraywacke. This tendency of the coarser sand sizes to be more "washed" than is typical of the average graywacke is common in the Lyre. Light gray, impure calcareous and siliceous cement consisting of finely recrystallized calcereous or siliceous mud is common.

Interbedded fine and medium graywacke. This type often displays graded bedding. In all cases observed the grading was upward from coarse to fine with the average cycle about three inches in thickness. The usual cycle grades from coarse sand to silt; however, these cycles may begin or end at any intermediate grade size.

The finer grades tend to contain more matrix than the coarser ones. A typical fine graywacke consists of 60 per cent angular to subangular quartz, 20 per cent angular feldspar (largely altered to kaolin), and 20 per cent fine matrix consisting of secondary quartz, calcite, and argillaceous material. The coarse-grained subgraywackes contain approximately the same minterals as the graywackes but contain less than 5 per cent matrix and cement. The matrix consists of fine, chloritic, argillaceous material, while the cement varies between calcite and quartz. Calcareous and limonitic concretions are rare. The siltstone contains an occasional thin lens of lignite; these lenses average approximately 1/8 inch in thickness and 4 inches in length.

The interbedded graywackes are well exposed in a road cut on U.S. Highway 101 about one-quarter of a mile east of the intersection between Lakes Crescent and Sutherland (Figure 6).

Dark greenish-gray, coarse graywacke breccia. The breccia consists of fragments of dark greenish-gray, medium to coarse graywacke ranging up to 4 feet in diameter. The fragments are sharply angular and are imbedded in a matrix of light gray, fine, calcareous material. The dark graywacke is very similar to that described under the section on the Crescent formation.

Figure 6

Graded bedding in medium graywacke of the Lyre conglomerate in road cut near U.S. Highway 101 east of Lake Crescent

Distribution

The Lyre conglomerate is confined to the north side of the Olympic Peninsula. It has been reported as far eastward as the Quimper Peninsula by Durham (1942) and McMichael (1946), and as far westward as the area south of Pysht (Weaver 1937). Weaver tentatively correlated at least part of the conglomerates of the Cape Flattery region with the Lyre (1937, p. 138). The Lyre River Canyon was designated the type section of this formation by Weaver (1937, p. 123).

The top of the Lyre is exposed in the sea cliffs about a mile east of the mouth of Whisky Creek. At this locality the contact with the overlying Twin River silt is an irregular erosion surface (Figure 7). On the south limb, although exposures are poorer, the boundary between these two formations appears to be gradational. Thus the unconformity is probably of local extent.

The Lyre conglomerate apparently lenses out along the strike in certain localities. On the north limb the conglomerate thins to the eastward along the strike toward fossil locality 3501 on Salt Creek (Plate I). The apparent disappearance of the formation to the east of this locality, while it may be in part attributed to faulting, is probably primarily due to lensing out. This thinning along the strike is indicated in the canyon of Salt Creek where the contact between the Lyre and the Twin River formation follows the

Figure 7

Disconformable contact between the Lyre conglomerate and the overlying Twin River siltstone in sea cliff a mile east of Whisky Creek course of the stream. On the south limb in the area occupied by sections 14 and 15 of T. 30 N., R. 8 W., the Lyre apparently disappears for a distance of two miles along the strike. The Twin River siltstone forms the ridge in this area. This change in character may be due to one or more of the following causes: lensing out of the Lyre conglomerate; gradational change in facies from conglomerate to siltstone; faulting. More definite interpretation of the relationships must await further information.

The chief outcrops of the Lyre occur in the sea cliffs from Crescent Bay westward to Whisky Creek, the lower canyon of Salt Creek, and the road cuts and steep cliffs north of U.S. Highway 101 east of Lake Crescent.

Age and Correlation

To the writer's knowledge, no identifiable fossils have been found in the Lyre formation in the area mapped. Weaver (1937, p. 121) states that a few poorly preserved molluscan fossils were found near Port Discovery Bay which were correlated with the upper Eocene-lower Oligocene Keasey formation of Oregon. Within the map area the age of the Lyre can only be inferred from its stratigraphic position with the underlying middle Eocene Crescent and the overlying upper Eocene Twin River.

Depositional Environment

The following is a summary of the important characteristics of the Lyre formation:

- Appreciable thickness
- Lack of bedding in the coarser grades
- Poor sorting
- Angularity of the detrital fragments (especially in the finer grades)
- Rock types of the graywacke suite
- Graded bedding (cross bedding lacking)
- Channeling common

These characteristics belong to Pettijohn's (1949) orogenic or geosynclinal facies as well as to the geosynclinal association of Krumbein and Sloss (1951).

The graded bedding, common in the finer sediments, may be caused by slumping or unstable accumulations on the margin of the subsiding marine trough into deeper water (Pettijohn 1949, p. 137). Kuenen and Migliorini (1950) showed that this occurrence produces turbidity currents of high density which, upon settling out, form graded bedding. Periodic storms or earthquakes could cause such slumping.

A few poorly preserved marine, molluscan fossils were found by the writer in the Lyre formation. Although they were unidentifiable, they serve to indicate marine deposition for at least part of the formation. On the other hand the presence of small lignite seams suggests environments other than typically marine.

The coarseness of the conglomerate, the lack of rounding, and the unstable rock and mineral constituents suggest that the source of sedimentation was not far and deposition was rapid. The rock types are quite similar to those described from southern Vancouver Island by Clapp (1912). The probability that these rocks made up the source area is further substantiated by the fact that the conglomerate, as well as the Lyre formation in general, coarsens northward.

The above evidence suggests a land mass of high relief to the northward of the present shoreline with a subsiding, partially marine, trough to the south.

Section

BEACH SECTION EASTWARD FROM WHISKY CREEK

Top

	Feet
Breccia: dark greenish-gray, massive, with fragments of dark greenish-gray, medium greywacke averaging 15 mm. in a matrix of light gray, fine, calcareous material	42
Covered	37
Breccia: same as above with a few 1/2" light gray calcareous veinlets	28
Breccia: same as above with numerous white flecks of calcite averaging 2 mm. in diameter	28

	Feet
Covered	14
Breccia: same as above with a few light gray calcareous veinlets	43
Largely covered but a few scattered outcrops indicate some breccia	42
Sandstone: medium gray, coarse, conglomeratic with quartz, dark metamorphic and igneous rock pebbles averaging 1" in diameter	174
Conglomerate: medium gray, with coarse graywacke matrix and subrounded fragments averaging 3" in diameter and up to 1-1/2' in diameter; fragments consist of quartz, dark metamorphic and igneous rock	43
Inaccessible cliff apparently mostly same conglomerate with some interbedded graywacke	588
Sandstone: medium gray, massive, silty, fine	39
Conglomerate: dark gray, massive, boulder with basalt boulders up to 3' in diameter	52
Inaccessible cliff apparently mostly same conglomerate with some interbedded graywacke	57
Graywacke: medium gray, weathered yellow, pebbly, medium grained with sparse pebbles of quartz, dark metamorphic and igneous rocks averaging 1/4" in diameter, also containing small lenses of gray, fine graywacke	16
Conglomerate: medium gray, massive with basalt, dark metamorphic rock and quartz pebbles averaging 1-1/2" in diameter and coarse graywacke matrix	1
Graywacke: medium yellowish-reddish-gray, medium grained, with a few thin gray shale and lignite lenses (1/8")	2
Graywacke: light gray, well indurated, coarse grained, calcareous, concretionary with a few pebbles of dark metamorphics, basalt and quartz averaging 1/4"	3

	Feet
Graywacke: medium gray, massive, medium grained with thin lenses of gray, fine graywacke	5
Graywacke: light gray, well indurated, calcareous, fine grained	1
Graywacke: medium yellowish-reddish-gray, medium grained with thin lenses of gray, fine graywacke and sparse, gray, rounded, calcareous 2" concretions	7
Partly covered but mostly medium gray, massive, medium graywacke with pebbles sparsely scattered throughout averaging 1" in diameter	32
Graywacke: medium gray, conglomeratic, medium grained with 15% pebbles averaging 2" diameter	8
Conglomerate: medium gray, massive with pebbles averaging 1-1/4" in diameter and 60% coarse graywacke matrix	3
Graywacke: medium yellowish-reddish-gray, medium grained with lignite lenses from 1/16" to 1" in thickness	5
Graywacke: light gray, well indurated, calcareous, concretionary, fine grained	4
Graywacke: medium reddish-yellowish-brown, massive, medium grained with thin lenses of gray, fine graywacke and lignite containing light gray, calcareous concretions	11
Graywacke: light gray, well indurated, calcareous, fine grained	1
Graywacke: medium yellowish-brownish-gray, medium grained, thinly interbedded with medium gray, fine graywacke containing light gray, calcareous concretions; all graded bedded with cycles averaging 4" in thickness; 65% medium graywacke	7
Graywacke: light grey, well indurated, siliceous, concretionary medium grained	1
Alternating lenses of gray, fine graywacke, and gray, medium graywacke graded bedded; 50% of each	7

	Feet
Graywacke: medium gray, massive, conglomeratic, medium grained containing very sparse pebbles, averaging 1" in diameter, of quartz, basalt, dark and light metamorphics and light gray calcareous concretions averaging 1' in diameter	23
Conglomerate: partly inaccessible but mostly of medium gray, massive conglomerate with pebbles averaging 1-1/2" in diameter and up to 1-1/2' in diameter	98
Covered	280
Conglomerate: light gray, massive containing 25% subangular to subrounded basalt, dark metamorphic and quartz pebbles averaging 1" in diameter and up to 1-1/2' in diameter	4
Conglomerate: same as above but with boulders up to 3" in diameter interbedded with lenses of yellowish-reddish-gray, medium graywacke averaging 2" in thickness; 80% conglomerate	20
Conglomerate: same as above with medium graywacke matrix and pebbles averaging 1" in diameter and up to 1-1/2' in diameter; pebbles 35%	8
Conglomerate: same as above containing yellowish-reddish-gray, pebbly fine graywacke lenses; 95% conglomerate. Poorly preserved <u>Ostrea</u> occur near top.	44
Graywacke: medium gray, weathering yellow, pebbly fine-grained pebbles very sparse and average 1/2" in diameter; a few poorly preserved pelecypods occur in bed	3
Conglomerate: medium gray, boulder with same pebble types as above and gray coarse graywacke matrix about 50%; boulders average 3" in diameter and up to 2-1/2' in diameter	13
Conglomerate: medium gray, same pebble types as above but with gray, fine graywacke matrix and pebbles averaging 3/4" in diameter	23
Conglomerate: same as above but with angular basalt fragments 10%	2

	Feet
Conglomerate: medium gray, massive with subrounded pebbles averaging 1" in diameter and up to 1' in diameter; basalt 30%, dark metamorphics 40%, and quartz and light metamorphics 30%. Rock contains cream colored, calcite veins	3
Conglomerate: similar to above but with pebbly medium gray, graywacke lenses averaging 3" in thickness; 50% conglomerate	2
Conglomerate: same as above but without graywacke	23
Interbedded conglomerate and graywacke similar to that in 2' bed above but with 1/8" lignite lenses	2
Conglomerate: same as above, but with boulders averaging 6" in diameter	20
Bottom Total thickness	1880

Unconformity

Twin River Formation

Lithology

The Twin River formation consists predominantly of medium gray siltstone interbedded with medium greenish-gray graywacke and silty shale. Light gray, well indurated, calcareous concretions are common throughout the section.

The gray siltstone constitutes approximately 70 per cent of the lower 1400 feet of the formation as exposed in the sea cliffs between Agate Bay and Whisky Creek. The siltstone grades imperceptibly into a very fine graywacke. The sandy siltstone and fine graywacke are well exposed in the hills south of Ramapo where they are quite resistant to erosion. More rarely the siltstone grades into claystone and shale. The average silt consists of angular quartz feldspar, pyrite, and chlorite in addition to fine argillaceous material.

The medium greenish-gray, medium graywacke constitutes about 20 per cent of the lower Twin River. It contains approximately 40 per cent angular quartz, 25 per cent feldspar, and 35 per cent fine matrix of chlorite, biotite, and fine argillaceous material. The graywacke occurs in thin lenses averaging about 6 inches in thickness, and is especially common in the basal 440 feet of the formation.

Light gray, well indurated, calcareous concretions become more numerous in the upper part of the measured section. The concretions are of two types: one roughly spherical, which average about 5 inches in diameter; the other occurs as lenses averaging approximately 6 inches in thickness. The spherical types are usually formed about a nucleus such as a shell fragment. Limonitic concretions occur less frequently.

Distribution

The Twin River has been described throughout the northern Olympic Peninsula. It has been reported as far eastward as the Quimper Peninsula (Weaver 1937, Durham 1944, and McMichael 1946), where correlation is based solely upon lithology and stratigraphic sequence because of intervening glacial deposits. The formation has also been recognized as far west as Clallam Bay (Weaver 1937). In all these cases these rocks have been referred to as either Keasey, Lincoln, or Blakeley formations. Because these divisions are based on fauna, the writer has included them in a single lithologic unit, the Twin River formation (see section on Stratigraphic Nomenclature).

The Twin River occupies the middle of the Clallam syncline in the area mapped. In the area between Salt Creek and Freshwater Bay it overlies the Crescent formation apparently without intervention of the Lyre conglomerate. A similar relationship occurs in the hills northeast of Lake Sutherland where again the Twin River apparently lies directly upon the Crescent. The details of this contact are unknown to the writer. In all other portions of the area mapped, it overlies the Lyre conglomerate.

The Twin River formation, as here redefined, includes the siltstones and medium graywackes exposed in the sea cliffs from one mile east of Whisky Creek westward to Pillar Point. Weaver et al. (1944) estimated the total thickness of the rocks to be 6000 to 7000 feet. Thus the section included in the map area represents approximately the lower one-fifth of the total formation.

Arnold and Hannibal (1913) named the formation for the town of Twin Rivers (now called Twin), but no type section as such was designated.

Age and Correlation

No identifiable megafossils were found within the map area. However, an abundant foraminiferal fauna was collected from two stratigraphic horizons.

The lowest fauna occurs approximately 60 feet above the base of the formation and is represented by fossil localities 3496, 3501, 3497, and 3498. In order to show their estimated relative stratigraphic position these localities are represented on Plate V as being in the Lyre formation. This is due to their projection from their position on the east side of the fault at Salt Creek westward along the strike to the beach section. These fossiliferous beds have a thickness of 50 feet.

The lower Twin River fauna is closely related to that of the Bassendorf formation of the Oregon coast. Eight species are in common with the Bassendorf fauna described by Detling (1946). The Bassendorf was correlated by Weaver et al. (1944) with the upper Eocene-lower Oligocene Keasey stage; Detling simply refers it to either the upper Eocene or lower Oligocene.

The Tumey formation of California, as reported by Cushman and Simonson (1944), contains six species and two closely related forms in common with the lower Twin River. They regarded the Tumey also to be either Oligocene or upper Eocene.

The Kreyenhagen formation of California contains six species and one comparable form in common with this formation. The lower Twin River fauna is related most closely to the Kreyenhagen zones E, F, and G, as defined by Cushman and Siegfus (1942). These zones make up the middle Kreyenhagen and were assigned by Cushman and Siegfus to the upper Eocene.

The lower Twin River has five species and two allied forms in common with the fauna of the Porter shale as described by Rau (1948). He referred the Porter to either the upper Eocene or the Oligocene.

The foregoing provides no basis for determining whether the lower Twin River fauna belongs to the upper Eocene or lower Oligocene. The following tabulation is presented in an attempt to place its time-stratigraphic position more precisely.

3 species and 2 comparable forms reported from lower and middle Oligocene formations only

5 species and 1 comparable form reported from both Oligocene and Eocene formations

10 species and 2 comparable forms reported from upper and middle Eocene formations only

Because of the meagerness of data, the above evidence must be interpreted with caution. However, it does suggest an upper Eocene age for the lower Twin River fauna. Plate VI shows the occurrence of elements of this fauna in key West Coast and Gulf Coast formations.

Depositional Environment

In an attempt to interpret the environment of deposition, two methods of approach are employed. These are, in order of discussion, faunal and lithologic.

Some difficulty is encountered in attempting to interpret environment through the foraminiferal fauna.

Genera are not reliable indicators of environmental zone, either depth or thermal (Galloway 1933). Considerable data have been compiled on the Gulf and Atlantic Coasts concerning bathymetric environments of living species, but few are in common with the lower Twin River fauna.

Natland (1933) reported on the depth and thermal distribution of the recent Foraminifera of southern California. His report revealed that Nonion umbilicatulum (Montague), Eponides umbonatus (Reuss), and Gyroidina soldanii D'Orbigny are characteristic of his zone V which was defined as 6500 feet to 8340 feet with a temperature of $\pm 4^{\circ}$C. to $\pm 2.4^{\circ}$C. He regarded temperature as the most significant factor in determining the foraminiferal assemblage of any environment. Thus little significance is placed on the depth of these forms. However, it is likely that they were adjusted to a small yearly temperature change and would not occur in shallow water (epineritic) where thermal ranges are greater. The above named species are common in the lower Twin River formation.

Parker (1948), in a similar study on the north Atlantic Coast, listed Gyroidina soldanii D'Orbigny as being confined to his zone 3 (90 meters to 300 meters with 7°C. to 10°C. range at 300 meters). His figure indicates that this form is identical to G. soldanii var. octocamerata Cushman and G. D. Hanna of the Twin River fauna. He also reported

Eponides umbonata (Reuss) as occurring in both zone 3 and zone 4 (300 meters to 1000 meters with 5°C. to 8°C. range). The above species are common in the lower Twin River.

This evidence suggests that the Foraminifera of the lower Twin River were adjusted to cold water (2.4°C. to 10°C.) with little annual range in temperature. The last indicates moderately deep water (infraneritic to upper bathyal). The paucity of molluscan remains tends to substantiate this view (Krumbein and Sloss 1951).

The great thickness of relatively homogeneous silt which comprises the Twin River formation suggests rapid subsidence and sedimentation. The angularity of the mineral grains, the high percentage of feldspar, and the poor sorting indicate rapid burial (Pettijohn 1949). An environment fulfilling these requirements would probably occur in a rapidly subsiding, marine trough near a land mass with rather high relief and ample rainfall (Twenhofel 1939). The lower Twin River formation probably accumulated for the most part in the deeper neritic-shallow bathyal zone.

Section

BEACH SECTION EASTWARD FROM WHISKY CREEK

Top Deep Creek Cr.

	Feet
Covered	88(?)
Siltstone: medium gray, weathered brown	8
Covered	107
Siltstone: medium gray, weathered brown, with sparse, rounded, dark-brown concretions averaging 6" in diameter	23
Covered	63
Siltstone: medium to olive gray with shell fragments and bits of carbonized wood; contains Foraminifera; location 3494	28
Sandstone: light gray, well indurated, calcareous, fine-grained	3
Siltstone: medium gray	19
Sandstone: light gray, well indurated, calcareous	1
Siltstone: medium gray	14
Sandstone: light gray, nodular, calcareous; nodules averaging 4" in diameter	1
Siltstone: medium gray	9
Covered	13
Sandstone: light gray, well indurated, calcareous, fine	1
Siltstone: medium gray	28
Shale: medium gray, silty	1
Siltstone: medium gray, with numerous light gray, rounded, calcareous concretions, averaging 1' in diameter	9

	Feet
Siltstone: same as above but fewer concretions	43
Covered	26
Siltstone: medium to olive gray, slightly shaley with light gray, calcareous concretion averaging 10" in length	111
Sandstone: light gray, fine, calcareous, containing fossil shell fragments	19
Siltstone: medium gray, with light gray, calcareous concretions averaging 6" in length	153
Siltstone: same as above, but with light gray, concretionary lenses (calcareous) up to 2' in thickness by 6' in length	19
Graywacke: medium brownish-gray, coarse, poorly sorted with grains of dark metamorphic and igneous rock fragments	6
Siltstone: medium gray with sparse light gray, rounded calcareous concretions	20
Shale: medium gray, silty with 1" lenses of medium greenish-gray, medium graywacke and rounded, calcareous concretions	4
Siltstone: medium gray, with light gray, calcareous concretions	23
Shale: medium gray, silty with equal amount of medium gray, medium graywacke in lenses averaging 4" in thickness	12
Siltstone: medium gray, with medium graywacke lenses as above averaging 3" in thickness; siltstone 80% containing calcareous concretions	26
Siltstone: medium gray	133
Siltstone: same as above but with 1" lenses of medium gray, medium graywacke; 95% siltstone	193
Covered	43

	Feet
Shale: medium gray, silty with gray, medium graywacke lenses averaging 2" in thickness; 95% shale	14
Shale: same as above but graywacke increased to 20%	5
Shale: same as above with graywacke decreased to 10%	56
Shale: same as above with graywacke increased to 25%	9
Siltstone: medium gray with greenish-gray, medium graywacke in irregular lenses averaging 1" in thickness; siltstone 85%	28
Covered	24
Graywacke: medium greenish-gray, finely bedded, medium grained	8
Partly covered: chiefly medium gray, medium grained graywacke with silty shale lenses	19
Total thickness	1410

Disconformity

PALEONTOLOGY

University of Washington Fossil Localities

3491 NE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 21, T. 31 N., R. 8 W.: sea cliffs on the east side of Crescent Bay, Clallam County, Washington, 800 feet south along shore from Tongue Point; in dark brownish-gray, finely bedded, sparsely conglomeratic, medium graywacke 1076 feet stratigraphically below the exposed Lyre formation conglomerate

3492 NE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 21, T. 31 N., R. 8 W.: sea cliffs on the east shore of Crescent Bay, Clallam County, Washington, 320 feet south along shore from Tongue Point; in dark gray, massive coarse, basalt breccia with a dark greenish-gray, medium graywacke matrix 1189 feet stratigraphically below the exposed Lyre formation conglomerate

3493 NW$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 20, T. 31 N., R. 8 W.: sea cliffs on the west shore of Crescent Bay, Clallam County, Washington, 740 feet southwest along shore from eastward projecting point of land; in dark gray, massive, conglomeratic, medium graywacke 275 feet below the contact with the overlying Lyre formation

3494 SE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 24, T. 31 N., R. 9 W.: low sea cliff at mouth of small stream 2400 feet east of mouth of Whisky Creek, Clallam County, Washington; in medium gray to olive gray, massive, fine silty sandstone 930 feet stratigraphically above contact with the underlying Lyre formation

3495 SE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 21, T. 31 N., R. 8 W.: sea cliff east of Crescent Bay and 200 feet east of Boundary Marker at Tongue Point; in dark greenish-gray, massive, conglomeratic, medium graywacke 1320 feet stratigraphically below the lowest exposed Lyre formation conglomerate.

3496 NW¼, NE¼, Sec. 35, T. 31 N., R. 8 W.: exposed 40 feet from north end of roadcut on east side of Camp Haydon Road 1.45 miles north from intersection with Piedmont Highway; in medium gray, massive siltstone about 60 feet stratigraphically above the highest Crescent formation exposure in immediate vicinity

3497 NW¼, NE¼, Sec. 35, T. 31 N., R. 8 W.: 100 feet south of the north end of road cut on the east side of the Camp Hayden Road 1.45 miles north of intersection with the Piedmont Highway; in medium gray, massive siltstone 18 feet stratigraphically above U.W. location 3496

3498 NW¼, NE¼, Sec. 35, T. 31 N., R. 8 W.: 150 feet south of the north end of road cut on the east side of the Camp Hayden road 1.45 miles north of intersection with Piedmont Highway; in medium gray, massive siltstone 15 feet stratigraphically above U.W. location 3497

3499 NW¼, SE¼, Sec. 20, T. 31 N., R. 8 W.: in sea cliff on northwest side of second point of land east of Agate Bay; in dark brownish-gray, massive, slightly conglomeratic, medium graywacke 230 feet stratigraphically below contact with the overlying Lyre formation

3500 NW¼, SE¼, Sec. 20, T. 31 N., R. 8 W.: in sea cliff on northwest side of second point of land east of Agate Bay; in dark brownish-gray, fine, shaley graywacke, 10 feet stratigraphically below U.S. location 3499 and 243 feet stratigraphically below contact with overlying Lyre formation

3501 NE¼, NE¼, Sec. 34, T. 31 N., R. 8 W.: exposed on west bank of Salt Creek, 1650 feet downstream (northward) from logging road that intersects the Camp Hayden Road 1.2 miles north of the Camp Hayden Road-Piedmont Highway intersection; in medium gray, siltstone with light gray calcareous concretions approximately 60 feet stratigraphically above the Crescent formation contact and is thus the approximate stratigraphic equivalent of U.W. location 3496

PLATE VI

TWIN RIVERS FORMATION
FAUNAL CHECK LIST

X=PRESENT K=COMPARABLE SPECIES

A=ABUNDANT 26+ C=COMMON 16—25 F=FEW 6-15 R=RARE 1-5

	PORTER SH.	COWLITZ FM.	LINCOLN FM.	BASSENDORF FM.	COALEDO FM.	KEASEY FM.	POWAY CONGL.	KREYENHAGEN SH.	POISON OAK CAÑON	TUMEY FM.	TEJON FM.	COOK MTN. FM.	JACKSON FM.	SALT MTN. FM.	COOPER MARL	"OLIGOCENE" S. AM.	LOCALITIES	3494	3496	3497	3498	3501
KARRERIELLA WASHINGTONENSIS	X																	A				R
ROBULUS CF. R. ALATO-LIMBATUS								K		K		K	K					A				R
LENTICULINA SP.																		R				
GUTTILINA CF. G. FRANKEI	K		K															R				
CF. G. HANTKENI	K						K											R				
G. IRREGULARIS	X	X		X						X		X	X					F		R		
GLOBULINA LANDESI		X					X				X							R				
SIGMOMORPHINA CUBENSIS			X															R				
CF. S. VAUGHANI												K						R				
NONION PLANATUM		X					X					X								R		
N. UMBILICATULUM				X		X												A				
PLECTOFRONDICULARIA GARZAENSIS								X		X								F		R		
P. PACKARDI			X	X	X					X								R		F		
P. PACKARDI MULTILINEATA	X			X	X					X									R	C		
BULIMINA MACILENTA									X									C				
UVIGERINA CF. U. GALLOWAYI																K		A				
U. GARZAENSIS								X		X								F	R	A	F	A
GYROIDINA SOLDANII OCTOCAMERATA				X			X	X				X		X				A	R	C		R
EPONIDES MINIMUS		X									X				X				A	A	F	R
E. UMBONATUS								X		K			X					C	R	R	R	R
CANCRIS SP.																		R				C
CASSIDULINA GALVINENSIS	X		X															R				
C. GLOBOSA		X		X	X			X		X	X				X				R	C	F	
PULLENIA EOCENICA								X						X				R				
GLOBIGERINA BULLOIDES													X					R		R		
G. TRILOCULINOIDES		X		X	X						X			X				F		R		
CIBICIDES ELMAENSIS	X																	F	R	R	R	
C. PSEUDOWUELLERSTORFI				X	X		X					K						R	R	F	R	R

PLATE VII

CRESCENT FORMATION FAUNAL CHECK LIST

X=PRESENT C=COMPARABLE SPECIES

	COWLITZ FM.	LOWER UMPQUA	UPPER UMPQUA	ARAGO (COALEDO)	LOWER LLAJAS	UPPER LLAJAS	DOMENGINE	CAPAY	LOCALITIES	3491	3492	3493	3495	3499	3500
ANTHOZOA															
MADRACIS CRESCENTENSIS													X		
ARTICULATA															
TEREBRATULINA TEJONENSIS WARINGI					X	X		X			X				
PELECYPODA															
GLYCYMERIS CRESCENTENSIS		X	X							X			X	X	
OSTREA IDRIAENSIS?	X		X				X	X			X				
PTERIA PELLUCIDA							X							X	
VENERICARDIA CRESCENTENSIS													X		
MEGACARDITA (VENERICOR) HORNII CLARKI	X			X						X			X	X	
?PACHYDESMA KELLOGGENSIS MCLURENSIS							X							X	
MACROCALLISTA (COSTACALLISTA) CONRADIANA		X	X				X			X				X	
M. (COSTACALLISTA) CONRADIANA MEGANOS.		X	X										X	X	
NITIDAVENUS TEJONENSIS		C					X						X		
CORBULA PARILIS		X	X											X	
C. TORREYENSIS														X	
GASTROPODA															
ACMAEA SP.														X	
TEGULA SP.													X		
SOLARIELLA CRESCENTENSIS													X	X	
NERITA SP.										X					
LIOTA SP.													X		
LOXOTREMA TURRITA		X	X		X									X	
KEILOSTOMA CALIFORNICA							X							X	
TURRITELLA UVASANA SSP.														X	X
AMAURELLINA (EUSPIROCROMMIUM) CLARKI		X	X		X	X	X							X	
CERNINA (EOCERNINA) HANNIBALI		X	X		X	X	X					X			
CROMMIUM ANDERSONI			X				X							X	
POLINICES (EUSPIRA) NUCIFORMIS	X	X	X	X	X	X	X	X						X	
?COWLITZIA PROBLEMATICA													X		X
PSEUDOLIVA SP.														X	
KLEINACTEON MOODYI		C					X						X		

Systematic Paleontology

Phylum PROTOZOA

Family Valvulinidae

Genus Karreriella Cushman 1933

Karreriella washingtonensis Rau

Plate VIII, Figures 1, 2

Karreriella washingtonensis Rau 1948, Jour. Paleontology, vol. 22, no. 2, p. 158, pl. 27, figs. 5, 6.

Dimensions. Average mature specimens length, .87 mm.; width, 45 mm.

Figured specimens. Nos. 100, 101; locality 3493.

Occurrence. Porter shale, Washington.

Remarks. Two types of specimens were found: a larger one tending to become biserial in last whorl, and a smaller one being entirely triserial. It is probable that the smaller type is the immature form of the larger; however, it is more numerous than the larger type.

Family Lagenidae

Genus Robulus Montfort 1808

Robulus cf. R. alato-limbatus (Gümbel)

Plate VIII, Figure 7

Robulina alato-limbata Gümbel 1868 (1870), K. bayer. Akad. Wiss. Munchen, cl. 2, Abh., vol. 10, p. 641, pl. 2, figs. 70a, b.

Cristellaria alato-limbata (Gümbel), Cushman and Applin, 1926, Bull. Am. Assoc. Petroleum Geologists, vol. 10, no. 9, p. 171, pl. 8, figs. 8a, b.

Robulus alato-limbatus (Gümbel) Cole 1927, Bull. Am. Paleontology, vol. 14, no. 51, p. 18, pl. 4, fig. 1; ------ Howe 1939, Dept. Cons. Louisiana Geol. Surv., Bull. 14, p. 40, pl. 4, fig. 18.

Dimensions. Average: diameter .75 mm.; thickness .30 mm.

Figured specimen. No. 102; locality 3493.

Occurrence. Eocene Kreyenhagen formation of California.

Remarks. Specimens average slightly larger than most described forms; they are closest to Howe's (1939) fig. 18, pl. 4.

Genus Lenticulina Lamarck 1804

Lenticulina sp.

Plate VIII, Figure 8

Description. Test large, moderately compressed, later chambers tending to uncoil, periphery with irregularly lobate keel; chambers six in last whorl, increasing rapidly in size as added; sutures slightly depressed, indistinct, moderately limbate, curved; wall thick, calcareous, smooth, finely perforate; aperture radiate, protruding upward at peripheral angle, apertural face convex.

Dimensions. Length, 1.16 mm.; width .85 mm.; thickness .30 mm.

Figured specimen. No. 104; locality 3494.

Remarks. A single specimen is apparently unlike any figured specimen the writer has examined. Probably a new species.

Family Polymorphinidae

Genus Guttulina, d'Orbigny 1839

Guttilina cf. G. frankei Cushman and Ozawa

Plate IX, Figure 1

Guttilina frankei Cushman and Ozawa 1930, U.S. Nat. Mus. Proc., vol. 77, art. 6, p. 28, pl. 4, fig. 1.

----- Cushman and Frizzel 1943, Cushman Lab. Foram. Res. Contr., vol. 19, pt. 4, p. 84, figs. 17, 18. ----- Rau 1948, Jour. Paleontology, vol. 22, no. 2, p. 170, pl. 30, figs. 17,18. ----- Cushman and Todd 1948, Cushman Lab. Foram. Res. Contr., vol. 24, pt. 1, pl. 1, fig. 7.

Dimensions. Length .65 mm.; width .42 mm.; thickness .26 mm.

Figured specimen. No. 105; locality 3494.

Occurrence. Porter shale and Lincoln formation of Washington.

Remarks. Two specimens are similar to this species.

Guttilina cf. G. hantkeni

Cushman and Ozawa 1930

Plate IX, Figure 2

Guttilina hantkeni Cushman and Ozawa 1930, U.S. Nat. Mus. Proc., vol. 77, art. 6, p. 33, pl. 5, figs. 4-6. ----- Rau, 1948, Jour. Paleontology, vol. 22, no. 2, p. 169, pl. 30, figs. 11, 12. ----- Cushman and Todd 1948, Cushman Lab. Foram. Res. Contr., vol. 24, pt. 2, p. 56, pl. 10.

Dimensions. Length .90 mm.; width .65 mm.; thickness .50 mm.

Figured specimen. No. 106, locality 3494.

Occurrence. Porter shale of Washington and Poway conglomerate of California.

Remarks. One specimen probably referrable to this species.

Guttilina irregularis d'Orbigny 1846

Plate VII, Figure 3

Globulina irregularis d'Orbigny 1846, Foram. Foss. Bass. Tert. Vienne, p. 226, pl. 13, figs. 9, 10.

Guttilina irregularis (d'Orbigny), Cushman and Ozawa 1930, U.S. Mus. Proc., vol. 77, art. 6, pl. 3, figs. 4, 5, pl. 7, figs. 1, 2. ----- Rau 1948, Jour. Paleontology, vol. 22, no. 2, p. 169, pl. 30, figs. 7, 8.

Dimensions. Length .50 mm.; width .35 mm.; thickness .27 mm.

Figured specimen. No. 107; locality 3494.

Occurrence. Widely spread in Eocene and Oligocene formations.

Remarks. At least two early stages are represented by specimens; one of which has a small spine at middle of base.

Genus Globulina d'Orbigny 1839

Globulina landesi G. D. Hanna and M. A. Hanna 1924

Plate VIII, Figure 6

Polymorphina landesi G. D. Hanna and M. A. Hanna 1924, Univ. Wash. Publ. Geol., vol. 1, no. 4, p. 60, pl. 13, figs. 16, 17.

Globulina landesi Cushman and Ozawa 1930, U.S. Nat. Mus. Proc., vol. 77, art. 6, p. 71, pl. 15, figs. 9a, b. ------ Beck 1943, Jour. Paleontology, vol. 17, no.6, p. 603, pl. 103, figs. 14, 16.

Dimensions. Length .41 mm.; width .32 mm.; thickness .28 mm.

Figured specimen. No. 109; locality 3494.

Occurrence. Cowlitz formation of Washington and the Eocene Kreyenhagen formation of California.

Remarks. A single specimen very close to type descriptions.

Genus Sigmomorphina Cushman and Ozawa 1928

Sigmomorphina cubensis Cushman and Bermudez 1937

Plate VIII, Figure 4

Sigmomorphina cubensis Cushman and Bermudez 1937, Cushman Lab. Foram. Res. Contr., vol. 13, p. 12, pl. 1, fig. 41. ------ Cushman and Frizzell 1942, Cushman Lab. Foram. Res. Contr., vol. 19, p. 85, pl. 14, fig. 20.

Dimensions. Average: length .92 mm.; width .67 mm.; thickness .30 mm.

Figured specimen. No. 110; locality 3494.

Occurrence. Lincoln formation of Washington.

Remarks. Somewhat similar to S. schenki Cushman and Ozawa (1930) but more asymmetrical; it is, however, very close to S. cubensis Cushman and Bermudez (1937) as figured by Cushman and Frizzell (1943, pl. 14, fig. 20) without a basal spine.

Sigmomorphina cf. S. vaughani Cushman and Ozawa 1930

Plate VII, Figure 5

Sigmomorphina vaughani Cushman and Ozawa 1930, U.S. Nat. Mus. Proc., vol. 77, art. 6, pl. 38, figs. 2a, b, c.

Dimensions. Length .81 mm.; width .63 mm.; thickness .27 mm.

Figured specimen. No. 111; locality 3494.

Occurrence. Eocene Cook Mountain formation of Gulf Coast.

Remarks. Very close to holotype, but test more asymmetrical and sutures not noticeably depressed.

Family Nonionidae

Genus Nonion Montfort 1808

Nonion planatum Cushman and Thomas 1930

Plate X, Figure 6

Nonion planatum Cushman and Thomas, 1930, Jour. Paleontology, vol. 4, p. 37, pl. 3, figs. 5a, b. ----- Beck 1943, Jour. Paleontology, vol. 17, p. 603, pl. 107, figs. 12, 13.

Dimensions. Diameter .35 mm.; thickness .16 mm.

Figured specimen. No. 112; locality 3497.

Occurrence. Cowlitz formation, Washington; Poway conglomerate, California; Cook Mountain formation, Louisiana; Kreyenhagen formation, California; type Tejon formation, California.

Remarks. A single specimen found.

Nonion umbilicatulus (Montagu) 1803

Plate X, Figure 2

Nautilus Umbilicatulus Montagu 1803, Testacea Britannica, p. 191; Suppl. 1808, p. 78, pl. 18, fig. 1.

Nonionina umbilicatula (Montagu), Parker, Jones, and H. B. Brady 1871, Amer. Mag. Nat. His., ser. 4, vol. 8, p. 242, pl. 12, fig. 157.

Nonion umbilicatulus (Montagu) Cushman and Schenck 1928, Univ. Calif. Publ. Geol. Sci., vol. 17, p. 310, pl. 44, figs. 2a, b. ----- Detling 1946, Jour. Paleontology, vol. 20, no. 4, p. 355, pl. 48, fig. 13.

Dimensions. Average: diameter .40 mm.

Figured specimen. No. 113; locality 3494.

Occurrence. Bassendorf and Keasey formations of Oregon.

Remarks. Abundant at one locality.

Family Heterohelicidae

Genus Plectofrondicularia Liebus 1903

Plectofrondicularia garzaensis Cushman and Siegfus 1939

Plate X, Figure 11

Plectofrondicularia garzaensis Cushman and Siegfus 1939, Cushman Lab. Foram. Res. Contr., vol. 15, pt. 2, p. 26, pl. 6, fig. 9.

Figured specimen. No. 114; locality 3494.

Occurrence. Kreyenhagen and Tumey formations of California.

Plectofrondicularia packardi, Cushman and Schenck 1928

Plectofrondicularia packardi Cushman and Schenck 1928, Univ. Calif. Publ. Geol. Sci., vol. 17, p. 311, pl. 43, figs. 14, 15.

Dimensions. Average: length .86 mm.; width .48 mm.

Specimen. Nos. 116, 117; localities 3494, 3497.

Occurrence. Bassendorf and Coaledo formations of Oregon; Lincoln formation of Washington; Tumey formation of California.

Remarks. Sutures tend to be more sharply chevron-shaped than type.

Plectofrondicularia packardi multilineata Cushman and Simonson 1944

Plectofrondicularia packardi multilineata Cushman and Simonson 1944, Jour. Paleontology, vol. 18, p. 197, pl. 32, figs. 2-4. ----- Detling 1946, Jour. Paleontology, vol. 20, p. 335, pl. 49, figs. 3, 5. ----- Rau 1948, Jour. Paleontology, vol. 22, no. 2, p. 171, pl. 30, fig. 19.

Dimensions. Maximum: length 1.69 mm.; width .94 mm.

Specimen. Nos. 118, 119; localities 3496, 3497.

Occurrence. Porter shale of Washington; Coaledo and Bassendorf formations of Oregon; Tumey formation of California.

Family Buliminidae

Genus Bulimina d'Orbigny 1826

Bulimina macilenta Cushman and Parker 1939

Plate X, Figure 1

Bulimina macilenta Cushman and Parker 1939, Cushman Lab. Foram. Res. Contr., vol. 15, p. 93. ----- Cushman and Parker 1947, U.S. Geol. Surv. Prof. Paper 210-D, p. 98, pl. 23, figs. 2, 3.

Dimensions. Average: length .35 mm.; width .28 mm.

Figured specimen. No. 120; locality 3494.

Occurrence. "Martinez" formation, Poison Oak Canyon, California.

Remarks. Abundant at one locality.

Genus Uvigerina d'Orbigny 1826

Uvigerina garzaensis Cushman and Siegfus 1939

Plate IX, Figure 9

Uvigerina garzaensis Cushman and Siegfus 1939, Cushman Lab. Foram. Res. Contr., vol. 15, pt. 2, p. 28, pl. 6, figs. 15a, b. ----- Detling 1946, Jour. Paleontology, vol. 20, p. 357, pl. 50, fig. 8.

Dimensions. Average: length .60 mm.; width .27 mm.

Figured specimen. No. 125; locality 3501.

Occurrence. Kreyenhagen shale of Oregon, Tumey formation of California.

Remarks. Abundant in all localities.

Uvigerina cf. U. gallowayi Cushman 1929

Plate IX, Figure 8

Uvigerina alata Galloway and Morrey (not Cushman and Applin) 1929, Bull. Amer. Pal., vol. 15, no. 55, p. 38, fig. 1.

Uvigerina gallowayi Cushman 1929, Cushman Lab. Foram. Res. Contr., vol. 5, p. 94, pl. 13, figs. 33, 34. -----Cushman and Edwards 1938, Cushman Lab. Foram. Res. Contr., vol. 14, pt. 4, p. 75, pl. 13, figs. 8, 9.

Dimensions. Average: length .61 mm.; width .40 mm.

Figure specimen. No. 126; locality 3494.

Occurrence. "Oligocene" of Ecuador and Venezuela.

Remarks. This species is abundant in one locality. The specimens are similar to U. cocoensis Cushman 1925, but have more costae and are much shorter and fatter. They are closer to U. jacksonensis Cushman 1925 but are shorter and quite close to figure 9 of Cushman and Edwards (1937).

Family Rotaliidae

Genus Gyroidina d'Orbigny 1826

Gyroidina soldanii var. octocamerata Cushman and G. D. Hanna 1927

Plate IX, Figures 3, 6

Gyroidina soldanii d'Orbigny var. octocamerata Cushman and G. D. Hanna 1927, Calif. Acad. Sci. Proc., ser. 4, vol. 16, p. 223, pl. 14, figs. 16-18. -----Cushman and Schenck 1928, Univ. Calif. Publ., Dept. Geol. Bull., vol. 17, p. 312, pl. 44, figs. 3-5.

Dimensions. Average: length .53 mm.; width .50 mm.; thickness .40 mm.

Figured specimen. No. 127; locality 3494.

Occurrence. Bassendorf formation of Oregon, Poway conglomerate and Eocene Kreyenhagen formation of California, Cook Mountain formation of Louisiana, and the Salt Mountain formation of Alabama.

Remarks. The specimens seem more inflated than the type.

Genus Eponides Montfort 1808

Eponides minima Cushman 1933

Plate IX, Figure 7

Eponides minima Cushman 1933, Cushman Lab. Foram. Res. Contr., vol. 9, pt. 1, p. 17, pl. 2, figs. 8a, b, c. ----- Beck 1943, Jour. Paleontology, vol. 17, no. 6, p. 606, pl. 108, figs. 16, 17, 19.

Dimensions. Average: diameter 40 mm.; thickness .17 mm.

Figured specimen. No. 132; locality 3497.

Occurrence. Cowlitz formation of Washington, Tejon formation of California, Cooper Marl, South Carolina.

Remarks. Numerous in all localities.

Eponides umbonatus (Reuss) 1851

Plate IX, Figure 4

Rotalina umbonata Reuss 1851, Zeitschr. d. Deutsch. Geol. Gessellsch., vol. 3, p. 75, pl. 5, figs. 35a-c.

Pulvinulina umbonata Reuss 1866, Denkschi. d. K. Akad. Wiss. Wien, vol. 25, p. 206.

Eponides umbonatus (Reuss) Cole 1928, Bull. Amer. Pal., vol. 14, no. 53, p. 15, pl. 2, fig. 6.

Dimensions. Average: diameter .30 mm.; thickness .21 mm.

Figured specimen. No. 135; locality 3494.

Occurrence. Eocene Kreyenhagen and Tumey formations of California, Cooper Marl of South Carolina.

Remarks. A numerous species in all but one locality.

Genus Cancris Montfort 1808

Cancris sp.

Plate IX, Figure 5

Description. Test medium in size, compressed, developing blunt keel anteriorly, dorsal side much flattened, ventral side inflated-convex; chambers five to six in last whorl, increasing in size as added, small concavity on ventral side of last chamber near periphery; sutures distinct, depressed, nearly straight; wall smooth, calcareous; aperture obscure.

Dimensions. Range from length .45 mm.,width, .33 mm.,thickness, .20 mm. to length .70 mm., width .55 mm., thickness .25 mm.

Figured specimen: No. 141; locality 3501.

Remarks. A fairly numerous species closely resembling C. sp. Cushman and Todd (1942, p. 90, pl. 23, fig. 5) from the Miocene of Los Sauces Creek, California. C. sp. Cushman and Todd was tentatively referred to C. sagra Cushman and Laiming (1931) but the writer's specimens do not. It is probable, therefore, that these specimens represent a new species.

Family Cassidulinidae

Genus Cassidulina d'Orbigny 1826

Cassidulina galvinensis Cushman and Frizzell 1940

Plate IX, Figure 4

Cassidulina galvinensis Cushman and Frizzell 1940, Cushman Lab. Foram. Res. Contr., vol. 16, pt. 2, p. 43, pl. 8, figs. 10a, b, c. ----- Rau 1948, Jour. Paleontology, vol. 22, no. 2, p. 173, pl. 31, figs. 9, 10, 11.

Dimensions. Diameter .22 mm., thickness .08 mm.

Figured specimen. No. 142; locality 3494.

Occurrence. Porter shale and type Lincoln formation of Washington.

Remarks. A single specimen much smaller than holotype with the sutures being not quite as perpendicular.

Cassidulina globosa Hantken

Plate X, Figure 7

Cassidulina globosa Hantken 1875 (1876), Magy. Kir. foldt. int. Evkonyve, vol. 4, p. 54, pl. 16, fig. 2. ----- Beck 1943, Jour. Paleontology, vol. 17, no. 6, p. 609, pl. 108, figs. 7, 13, 14.

Dimensions. Average: diameter .25 mm., thickness .20 mm.

Figured specimen. No. 144; locality 3497.

Occurrence. Cowlitz formation of Washington; Bassendorf and Coaledo formations of Oregon; Eocene Kreyenhagen shale, Tejon and Tumey formations, all of California; and the Cooper Marl of South Carolina.

Remarks. An abundant species.

Family Chilostomellidae

Genus Pullenia Parker and Jones 1862

Pullenia eocenica Cushman and Siegfus 1939

Plate X, Figure 3

Pullenia eocenica Cushman and Siegfus 1939, Cushman Lab. Foram. Res. Contr., vol. 15, p. 31, pl. 7, fig. 1; 1942 Trans. San Diego Soc. Nat. Hist., vol. 9, p. 420, pl. 18, fig. 2. ----- Cushman and Todd 1943, Cushman Lab. Foram. Res. Contr., vol. 19, pt. 1, p. 10, pl. 2, fig. 2.

Dimensions. Length .32 mm., width .29 mm., thickness .32 mm.

Figured specimen. No. 146; locality 3494.

Occurrence. Eocene Kreyenhagen shale of California; Salt Mountain formation of Alabama.

Remarks. A single specimen differs slightly from the type in that it has only four and one-half chambers in last whorl.

Family Globorinidae

Genus Globigerina d'Orbigny 1826

Globigerina bulloides d'Orbigny 1826

Plate III, Figure 8

Globigerina bulloides d'Orbigny 1826, Ann. Sci. Nat. Paris, ser. 1, tome 7, p. 277. ----- Cushman 1941, Cushman Lab. Foram. Res. Contr., vol. 17, pt. 2, p. 38, pl. 10, figs. 1-13.

Dimensions. Average: length .26 mm., width .09 mm.

Figured specimen. No. 148; locality 3497.

Occurrence. Jackson formation in Louisiana.

Remarks. A small, sparse species in these localities.

Globigerina triloculinoides Plummer 1927

Plate X, Figure 10

Globigerina triloculinoides Plummer 1927, Texas Univ. Bull. 2644, p. 134, pl. 8, figs. 10a, b, c. -----Rau 1943, Jour. Paleontology, vol. 17, no. 6, p. 609, pl. 108, figs. 2, 3.

Dimensions. Average: length .43 mm., width .26 mm.

Figured specimen. No. 149; locality 3494.

Occurrence. Cowlitz formation of Washington; Dassendorf and Coaledo formations of Oregon; Salt Mountain formation of Alabama.

Remarks. A common species here; quite close to holotype.

Family Anomalinidae

Genus Cibicides Montfort 1808

Cibicides elmaensis Rau 1948

Plate X, Figure 5

Cibicides elmaensis Rau 1948, Jour. Paleontology, vol. 22, no. 2, p. 173, pl. 31, figs. 18-26.

Dimensions. Average: diameter .45 mm., thickness .15 mm.

Figured specimen. No. 151; locality 3494.

Occurrence. Porter shale of Washington.

Remarks. A common species in these localities. The specimens show the gradation from the plano-convex form with flattened dorsal side to the double-convex form with a large plug on dorsal side; a plano-convex form is figured in this report.

Cibicides pseudowuellerstorfi Cole 1926

Plate X, Figure 9

Cibicides pseudowuellerstorfi Cole 1926, Bull. Am. Pal., vol. 14, no. 51, p. 30, pl. 1, figs. 13, 14. ----- Howe 1939, Louisiana Geol. Survey, Geol. Bull. no. 14, p. 88, pl. 13, figs. 1-3. ----- Cushman and Applin 1943, Cushman Lab. Foram. Res. Contr., vol. 19, pt. 2, p. 46, pl. 8, fig. 13.

Dimensions. Average: diameter .27 mm., thickness .22 mm.

Figured specimen. No. 156; locality 3496.

Occurrence. Bassendorf and Coaledo formations of Oregon, Poway conglomerate of California, Cook Mountain formation of Louisiana.

Remarks. A common species here; some variance in convexity and prominence of ventral plug, but close to holotype.

Phylum COELENTERATA

Class ANTHOZOA

Genus Madracis Milne Edwards and Haime 1849

Madracis crescentensis Durham 1942

Madracis crescentensis Durham 1942, Jour. Paleontology, vol. 16, no. 1, p. 95, figs. 1, 10.

Dimensions. Fragment of branch, length 5 mm.; diameter 3 mm.; diameter of calyces 1 mm.

Figured specimen. No. 160; locality 3495.

Remarks. One fragment of a branch is quite close to holotype.

Phylum BRACHIOPODA

Class ARTICULATA

Genus Terebratulina d'Orbigny

Terebratulina tejonensis waringi Hertlein and Grant 1944

Plate XI, Figure 1

Terebratulina tejonensis Stanton 1906, U.S.G.S. Prof. Paper 47, p. 53.

Terebratulina tejonensis waringi Hertlein and Grant 1944, Pubs. U.C.L.A. in Math. and Physical Sci., vol. 3, p. 77, figs. 12-16, 21.

Dimensions. Length 12.0 mm., width 13.5 mm., thickness 8.0 mm.

Figured specimen. No. 161; locality 3492.

Geologic Age. Middle Eocene.

Remarks. A single specimen referrable to this species.

Phylum MOLLUSCA

Class PELECYPODA

Family Arcidae

Genus Glycymeris Da Costa 1778

Glycymeris crescentensis Weaver and Palmer 1922

Plate XI, Figure 3

Glycymeris crescentensis Weaver and Palmer 1922, Univ. of Wash. Publ. Geol., vol. 1, no. 3, p. 11, pl. 8, figs. 10, 12.

Dimensions. Average length 8 mm., height 7.5 mm., width 5 mm.

Figured specimen. No. 162; locality 3491.

Geologic Age. Middle Eocene.

Remarks. This species is very numerous.

Family Ostreidae

Genus Ostrea Linnaeus 1758

Ostrea idriaensis? Gabb 1869

Ostrea idriaensis Gabb 1869, Geol. Surv. Calif. Paleon., vol. 2, pp. 203, 252, pl. 33, figs. 103b, c, d; pl. 34, fig. 103.

Dimensions. Length 66.0 mm., height 55.0 mm. (right valve).

Specimen. No. 165; locality 3492.

Geologic Age. Middle and upper Eocene.

Remarks. One and one-half poorly preserved right valves seem to be questionably referrable to this species.

Family Pteriidae

Genus Pteria Scopoli 1777

Pteria pellucida (Gabb)

Plate XI, Figure 4

Avicula pellucida Gabb 1864, Paleontology: Calif. Geol. Surv., vol. 1, p. 186, pl. 25, fig. 172.

Pteria pellucida (Gabb) Vokes 1939, Annals N.Y. Acad. Sci., vol. 38, p. 50, pl. 2, figs. 1, 4, 7, 8.

Dimensions. Length 15 mm. (inc.), height 10 mm. (inc.).

Figured specimen. No. 166; locality 3499.

Geologic Age. Middle Eocene.

Remarks. A single broken specimen is close to description and figure by Vokes (1939); the angle between hinge line and umbonal ridge is 41 degrees.

Family Carditidae

Genus Venericardia Lamarck 1801

Venericardia crescentensis Weaver and Palmer 1922

Plate XI, Figure 2

Venericardia crescentensis Weaver and Palmer 1922, Univ. Wash. Publ. Geol., vol. 1, no. 3, pp. 19, 20, pl. 10, fig. 9.

Dimensions. Length 22 mm. (inc.), height 25 mm.

Figured specimen. No. 167; locality 3495.

Geologic Age. Middle Eocene.

Remarks. Two broken specimens are close to holotype, although slightly larger.

Genus Megacardita Sacco 1899

Subgenus Venericor Stewart 1930

Megacardita (Venericor) hornii clarki (Weaver and Palmer)

Plate XI, Figure 5

Venericardia planicosta Lamarck, Arnold 1907, U.S.G.S. Bull. 321, pl. 9, fig. 3.

Venericardia planicosta hornii (Gabb) Dickerson 1915, Calif. Acad. Sci., Pr., 4th ser., vol. 5, p. 49.

Venericardia clarki Weaver and Palmer 1922, Univ. Wash., Publ. Geol., vol. 1, no. 3, p. 19, pl. 9, figs. 4, 5, pl. 10, fig. 8.

Venericardia hornii subsp. clarki Weaver and Palmer, Stewart 1930, Phila. Acad. Nat. Sci., Spec. Publ. 3, p. 169.

Megacardita hornii subsp. clarki (Weaver and Palmer) Vokes 1939, Annals N.Y. Acad. Sci., vol. 38, p. 70.

Dimensions. Length 104 mm., height 103 mm., thickness 75 mm.

Figured specimen. No. 168; locality 3499.

Geologic Age. Middle to upper Eocene.

Remarks. A rather rare species in the Crescent formation.

Family Veneridae

Genus Pachydesma Conrad 1854

?Pachydesma kelloggensis (Clark and Woodford) melurensis Vokes 1939

Plate XI, Figure 6

Pachydesma kelloggensis (Clark and Woodford) melurensis Vokes 1939, Annals N.Y. Acad. Sci., vol. 38, p. 78, pl. 11, figs. 13, 16, 18.

Dimensions. Average: length 15 mm., height 10 mm., thickness 6 mm.

Figured specimen. No. 173; locality 3499.

Geologic Age. Middle Eocene.

Genus Macrocallista Meek 1876

Subgenus Costacallista Palmer 1927

Section Microcallista Stewart 1930

Macrocallista (Costacallista) conradiana (Gabb) 1864

Plate XI, Figure 8

Tapes conradiana Gabb 1864, Geol. Surv. Calif., Paleont., vol. 1, p. 169, pl. 32, fig. 282.

Macrocallista conradiana (Gabb) Arnold and Hannibal 1913, Am. Philos. Soc., Pr., vol. 52, p. 572.

Microcallista conradiana (Gabb) Stewart 1930, Phila. Acad. Nat. Sci., Publ. 3.

Macrocallista (Costacallista) conradiana (Gabb) Turner 1938, Geol. Soc. Am. Spec. Paper 10, p. 55, pl. 10, figs. 11, 12, 13, 14.

Dimensions. Average: length 17 mm., height 8 mm., thickness 8 mm.

Figured specimen. No. 177; locality 3491.

Geologic Age. Middle Eocene.

Remarks. Common in Crescent formation. All specimens are smooth, having only fine growth lines.

Macrocallista (Costacallista) conradiana (Gabb)

var. meganosensis Clark and Woodford

Plate XI, Figure 11

Macrocallista meganosensis Clark and Woodford 1927, Univ. Calif. Publ., Bull. Dept. Geol., vol. 17, p. 98, pl. 17, figs. 5,6.

Macrocallista (Costacallista) conradiana (Gabb) meganosensis Clark and Woodford, Turner 1938, Geol. Soc. Am., Spec. Paper, no. 1, p. 56, pl. 10, figs. 15, 16.

Dimensions. Length 18 mm. (inc.), height 15 mm., thickness 6 mm.

Figured specimen. No. 179; locality 3499.

Geologic Age. Middle Eocene.

Remarks. The ratio of length to height averages 1.3+.

Genus Nitidavenus Vokes 1939

Nitidavenus tejonensis (Waring) 1917

Isocardia tejonensis Waring 1917, Calif. Acad. Sci., Pr. 4th ser., vol. 7, p. 93, pl. 15, fig. 14.

Nitidavenus tejonensis (Waring) Vokes 1939, Annals N.Y. Acad. Sci., vol. 38, p. 83, pl. 12, figs. 11, 13, 14, 15, 16.

Dimensions. Length 24 mm., height 21 mm., thickness 10 mm.

Figured specimen. No. 180; locality 3495.

Geologic Age. Middle Eocene.

Remarks. One partly crushed specimen with most of ornamentation missing; however, enough characteristics remain to refer it to this species.

Family Corbulidae

Genus Corbula Bruguiere 1797

Corbula parilis Gabb 1864

Plate XI, Figure 7

Corbula parilis Gabb 1864, Geol. Surv. Calif., Paleont., vol. I, p. 150, pl. 29, figs. 239, 239a.

Dimensions. Average; length 9 mm., height 6 mm., thickness 5.5 mm.

Figured specimen. No. 181; locality 3499.

Geologic Age. Middle Eocene.

Remarks. Two perfectly preserved specimens are very close to this species.

Corbula torreyensis M. A. Hanna 1927

Plate XI, Figure 10

Corbula torreyensis M. A. Hanna 1927, Univ. Calif. Publ., Bull. Dept. Geol., vol. 16, p. 296, pl. 44, figs. 6-10, 15, 16.

Dimensions. Length 8 mm., height 5 mm., thickness 4 mm.

Figured specimen. No. 182; locality 3499.

Geologic Age. Middle Eocene.

Remarks. Very close to types.

Class GASTROPODA

Family Acmaeidae

Genus Acmaea Eschscholtz 1830

Acmaea sp.

Plate XI, Figure 9

Description. Shell small, of moderate height; surface marked by about twenty sharp, prominent radial ribs which are triangular with a broad base in cross-section and interspaces of one-half the width containing a faint radial rib; these ribs are crossed by one to two broad but indistinct lines of growth; the apex is nearly central.

Dimensions. Length 14 mm. (inc.), width 10 mm., height 5 mm.

Figured specimen. No. 183; locality 3499.

Remarks. One specimen, partially broken; the prominent sharp ribbed ornamentation does not resemble any previously described species as far as the writer can determine.

Tegula sp.

Plate XII, Figure 9

Description. Shell very small; spire low, apical angle large; whorls three, body whorl sharply biangulate, upper surface convex with two equal, strongly nodose spiral ribs, sides of body whorl smooth and flat in outline with strong carinae at posterior and anterior shoulders, under surface convex, smooth except for a nodose spiral rib at extreme anterior margin. The entire surface is covered with fine growth lines which make up the only ornamentation on earlier whorls.

Dimensions. Diameter of base 1.5 mm., height 1 mm.

Figured specimen. No. 184; locality 3495.

Remarks. A single specimen in perfect preservation; the distinctive ornamentation is apparently unlike other figured *Tegula's*, probably a new species.

Genus Solariella S. Wood 1842

Solariella crescentensis Weaver and Palmer 1922

Plate XII, Figure 2

Solariella crescentensis Weaver and Palmer 1922, Univ. Wash. Publ., Geol., vol. 1, no. 3, p. 28, pl. 12, fig. 11.

Dimensions: Average: altitude 4 mm., width of body whorl 5 mm.

Figured specimen. No. 188; locality 3495.

Geologic Age. Middle Eocene.

Remarks. A common species in the Crescent formation.

Family Neritidae

Genus Nerita Linnaeus 1758

Nerita sp.

Plate XII, Fig. 10

Description. Shell medium in size, subglobose; spire absorbed by body whorl; aperture crescent-shaped, with seven or eight moderately coarse teeth on inner lip, outer lip smooth with a sharp ridge at edge, inner lip in crescent-shaped depression equal in size to aperture; callus large; surface ornamentation obscured.

Dimensions. Length of body whorl 24 mm., width of body whorl 20 mm., altitude 12 mm.

Figured specimen. No. 189; locality 3491.

Remarks. A single specimen appears to be a new species.

Genus Liota Gray 1847

Liota sp.

Plate XII, Figure 12

Description. Shell small, planorboid whorls three and one-half, increasing uniformly in size; first two and one-half whorls form a nearly flat plane surface with body whorl dropping slightly below; earlier whorls smooth, upper surface of body whorl convex with a spiral line of well developed nodes in middle; side of body whorl slightly convex with a strong nodose carina at posterior shoulder, a slightly more prominent nodose carina in middle, and a strong, smooth carina at the anterior shoulder. The above nodes are cup-shaped, with the open end toward the anterior; the lower surface of the body whorl is smooth. The entire surface is covered with fine growth lines.

Dimensions. Diameter of body whorl 1.4 mm., height .9 mm.

Figured specimen. No. 190; locality 3495.

Remarks. Only one minute specimen found. Its fewer spiral ribs and lack of longitudinal ribbing separates it immediately from *Liota weaveri* Effinger 1938. It is probably a new species.

Family Thiaridae (Melaniidae)

Genus Loxotrema Gabb 1868

Loxotrema turrita Gabb 1868

Plate XII, Figure 1

Loxotrema turrita Gabb 1868, Amer. Jour. Conch., vol. 4, p. 147, pl. 14, fig. 21.

Dimensions. Length 17 mm., diameter 8 mm. (average).

Figured specimen. No. 191; locality 3499.

Geologic Age. Middle Eocene.

Remarks. Fairly numerous in one locality. Specimens average smaller than types.

Family "Rissoinidae"

Genus Keilostoma Deshayes 1848

Keilostoma californica Vokes 1939

Plate XII, Figure 8

Keilostoma californica Vokes 1939, Annals N.Y. Acad. Sci., vol. 38, p. 160, pl. 20, figs. 12, 13.

Dimensions. Length 11 mm., diameter 4 mm.

Figured specimen. No. 192; locality 3499.

Geologic Age. Middle Eocene.

Remarks. One mature and two immature specimens were found; the mature specimen was very close to this species.

Family Turritellidae

Genus Turritella Lamarck 1799

Turritella uvasana Conrad 1914

Plate XII, Figures 4, 6

Turritella uvasana Conrad, Dickerson 1914, Calif. Acad. Sci., Pr., 4th ser., vol. 4, p. 115.

Turritella uvasana Conrad ssp.

Description. The surface of the mature whorls is covered with numerous fine riblets. At the posterior margin of the mature whorls is a rounded carina, about one-sixteenth the height of the width; it is covered by about seven fine riblets. Anterior of this carina is a concavity about one-half as wide as the posterior carina; its anterior edge is occupied by one or two strong spiral ribs with interspaces of twice the width. Anteriorally the ribs and interspaces become gradually finer as the profile terminates in a narrow constriction with a carina about one-half the size of the posterior one; its surface is covered with fine riblets and its anterior side slopes to the channeled suture. The posterior carina is not well defined on the adolescent whorls; the anterior carina is not always well defined, especially on the earlier adult whorls.

Dimensions. No. 193: length 50 mm. (inc.), diameter 12 mm. (inc.).

No. 194: length 29 mm. (inc.), diameter 10 mm. (inc.).

Figured specimens. Nos. 193, 194; locality 3499.

Remarks. No complete specimens were found, but the ornamentation was well preserved on all. Merriam (1941, p. 91): "_Turritella uvasana_ found recently at Port Crescent, Clallam Co., Washington (U.C. Locs. A-1547, A-1550, A-1551), shows affinity to both _aedificata_ and _hendoni_; the adult sculpturing consists of very fine threads. The form is probably subspecifically distinct, but certainly should be classified close to the Domengine and Umpqua subspecies named." This description agrees with the above specimens and it is probable that these are the forms referred to. *T. uvasana* ssp. differs from *T. uvasana aedificata* Merriam 1941 in that the posterior constriction with the spiral fold is much more strongly developed in the later adult whorls; also, the smaller anterior groove is more prominent. The principal difference, however, is that the surface is sculptured by very fine spiral ribs instead of the fewer, coarser ribs of *T. uvasana aedificata*. In general, form *T. uvasana* ssp. is similar to class 2 of *T. uvasana hendoni* Merriam 1941, p. 91, but again the numerous fine ribs and the constriction with fold posteriorly differ from any form of *T. uvasana hendoni* figured. It is very probable, therefore, that the above form is a new subspecies.

Family Ampullospiridae

Genus Amaurellina "Bayle" Fischer 1885

Amaurellina (Euspirocrommium) clarki Stewart 1926

Plate XII, Figure 7

Amauropsis alveata (Conrad) Arnold 1909, U.S. Geol. Surv., Bull. 396, p. 13, pl. 4, fig. 21.

Amaurellina (Euspirocrommium) clarki Stewart 1926, vol. 78, p. 330, pl. 26, figs. 8, 9.

Dimensions. Length, 9 mm. (inc.), width 6.5 mm. (inc.).

Figured specimen. No. 195; locality 3499.

Geologic Age. Middle Eocene.

Remarks. A single broken specimen is close to the type of this species but much smaller.

Genus Cernina Gray 1840

Cernina (Eocernina) hannibali (Dickerson)

Plate XII, Figure 5

Natica hannibali Dickerson 1914, Calif. Acad. Sci., Proc., ser. 4, vol. 4, p. 119, pl. 12, figs. 5a, 5b.

Natica (Cryptonatica) hannibali Dickerson, Waring, 1917, Calif. Acad. Sci., Proc., ser. 4, vol. 7, pl. 15, figs. 21-23.

Ampullina hannibali (Dickerson) M. A. Hanna 1927, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 16, p. 306, pl. 48, figs. 1, 2, 3, 10.

Globularia hannibali (Dickerson) Stewart 1926, Acad. Nat. Sci. Phila., Proc., vol. 78, p. 331.

Gernina (Eocernina) hannibali (Dickerson) Turner 1938, Geol. Soc. Am., Spec. Paper no. 10, pp. 87, 88, pl. 19, fig. 3.

Dimensions. Length 60 mm., width of body whorl 52 mm.

Figured specimen. No. 196; locality 3493.

Geologic Age. Middle Eocene.

Remarks. A single well preserved specimen.

Genus Crommium Cossman 1888

Crommium andersoni (Dickerson)

Plate XII, Figure 3

Amauropsis andersoni Dickerson 1914, Calif. Acad. Sci., Pr. 4th ser., vol. 4, p. 120, pl. 12, fig. 2a, b.

Ampullina (Crommium) andersoni (Dickerson) Turner 1938, Geol. Soc. Am., Spec. Pap. no. 1, p. 87, pl. 19, figs. 1, 2, 4, 5.

Crommium andersoni (Dickerson) Vokes 1939, Annals N.Y. Acad. Sci., vol. 38, p. 171, pl. 21, figs. 22, 23.

Dimensions. Length 25 mm., width 20 mm.

Figured specimen. No. 197; locality 3499.

Geologic Age. Middle Eocene.

Remarks. One complete specimen and two other incomplete ones of about the same dimensions. Specimens are especially close to Vokes' (1939, pl. 21, figs. 22, 23) figures.

Family Naticidae

Genus Polinices Montfort 1810

Subgenus Euspira Agassiz 1839

Polinices (Euspira) nuciformis (Gabb)

Lunatia nuciformis Gabb 1864, Calif. Geol. Surv., Paleont., vol. 1, p. 107, 224, pl. 28, fig. 218.

Euspira nuciformis (Gabb) Stewart 1926, Phila. Acad. Nat. Sci., vol. 78, p. 323, pl. 30, fig. 16.

Polinices (Euspira) nuciformis (Gabb) Turner 1938, Geol. Soc. Am., Spec. Pap. no. 10, p. 88, pl. 20, figs. 4, 5.

Dimensions. Height 4.5 mm., width 5 mm. (average).

Figured specimen. No. 198; locality 3499.

Geologic Age. Middle and upper Eocene.

Remarks. Several specimens apparently close to this species, but much smaller.

Family Strombididae

Genus Cowlitzia Clark and Palmer 1923

?Cowlitzia problematica M. A. Hanna 1927

Plate XII, Figure 13

Cowlitzia problematica M. A. Hanna 1927, Univ. Calif. Publ. Geol. Sci., vol. 16, no. 8, p. 313, pl. 50, figs. 9, 10, 12.

Dimensions. Length 6 mm. (inc.), width 3 mm.

Figured specimen. No. 200; locality 3500.

Geologic Age. Middle Eocene.

Remarks. Four broken specimens were found, the best of which is figured. The specimens are somewhat similar to C. problematica, but both anterior and posterior canals are missing on all specimens, making definite identification impossible. The details of the ornamentation are very similar, the only important difference being the lack of axial ribbing on all whorls except the last two. This difference, however, may be due to the immaturity of these specimens.

Stewart (1926, pp. 366-368) recognized that the genus Cowlitzia was very close to the genus Ectinochilus Cossman 1889 and therefore made Cowlitzia a subgenus of Ectinochilus. Since then most of the species formerly described under Cowlitzia have been re-described as Ectinochilus. It is probable that C. problematica should be placed under Ectinochilus, but the fragmentary nature of the evidence here makes this impossible.

This species was described by Hanna (1927) from the La Jolla formation of California.

Family Buccinidae

Genus Pseudoliva Swainson 1840

Pseudoliva sp.

Description. Shell small; whorls about four, fragment of ornamentation remaining on body whorl shows strong, rounded, flat spiral ribs with interspaces one-half as wide. The body whorl forms about three-fourths of total height. Suture linear. Well developed medial spiral groove just below middle of whorl. Aperture and canal missing.

Dimensions. Length (inc.) 6.5 mm., width 5 mm.

Figured specimen. No. 201; locality 3499.

Remarks. A single broken specimen lacking most of the ornamentation and the anterior canal; it most closely resembles P. inornata Dickerson (1915, p. 62, pl. 7, fig. 1) but differs in that it is smaller and has well developed spiral formation, while P. inornata is smooth.

Family Acteonidae

Genus Kleinacteon Vokes 1939

Kleinacteon moodyi (Dickerson)

Plate XXI, Figure 11

Acteon moodyi Dickerson 1916, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 9, p. 488, pl. 38, figs. 10a, b.

Kleinacteon moodyi (Dickerson) Vokes 1939, Annals N.Y. Acad. Sci., vol. 38, p. 109, pl. 16, fig. 24.

Dimensions. Length 2 mm., width 1.5 mm.

Figured specimen. No. 202; locality 3495.

Geologic Age. Middle Eocene.

Remarks. A partially broken specimen is apparently close to species, but much smaller.

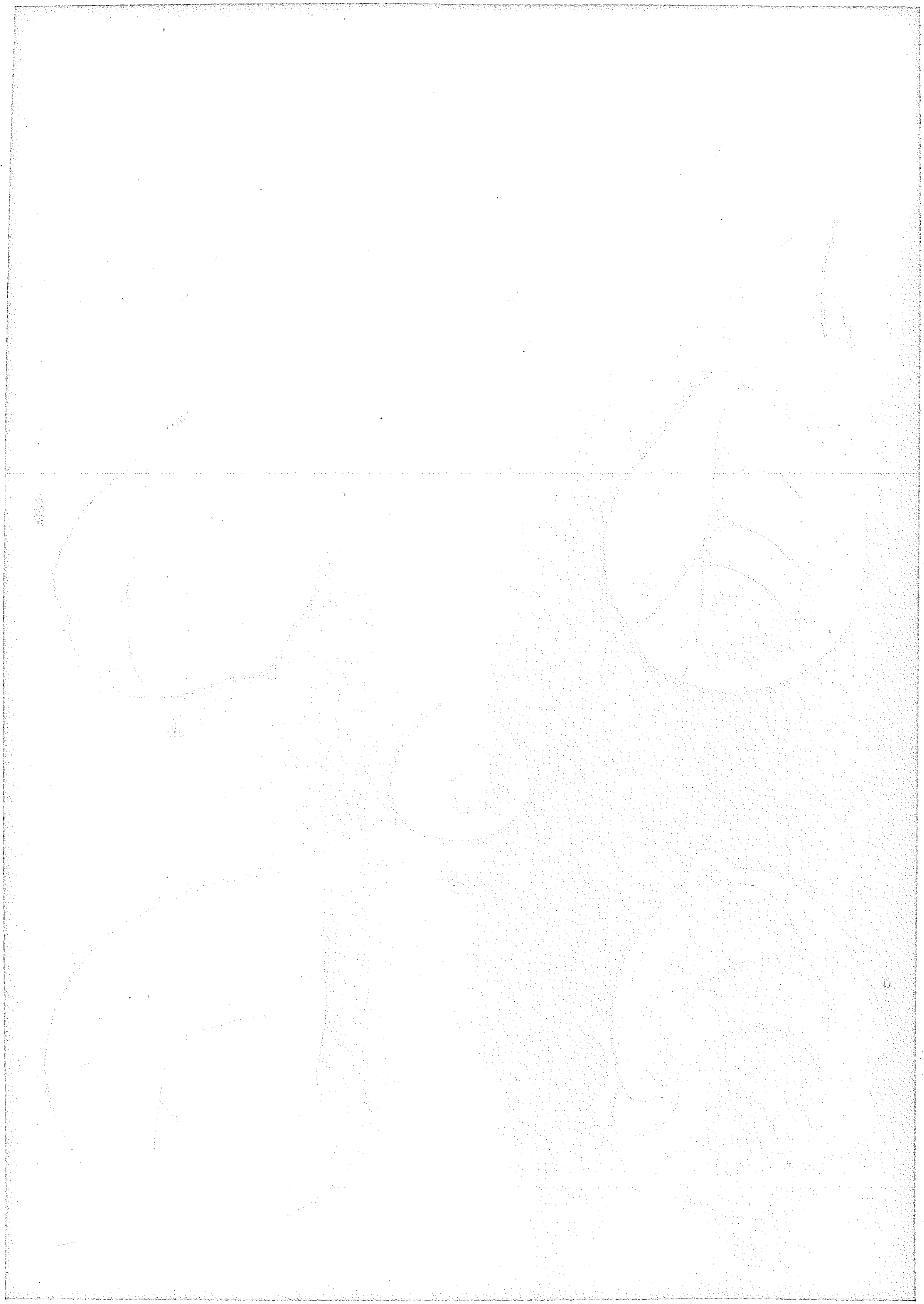

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PLATE IX

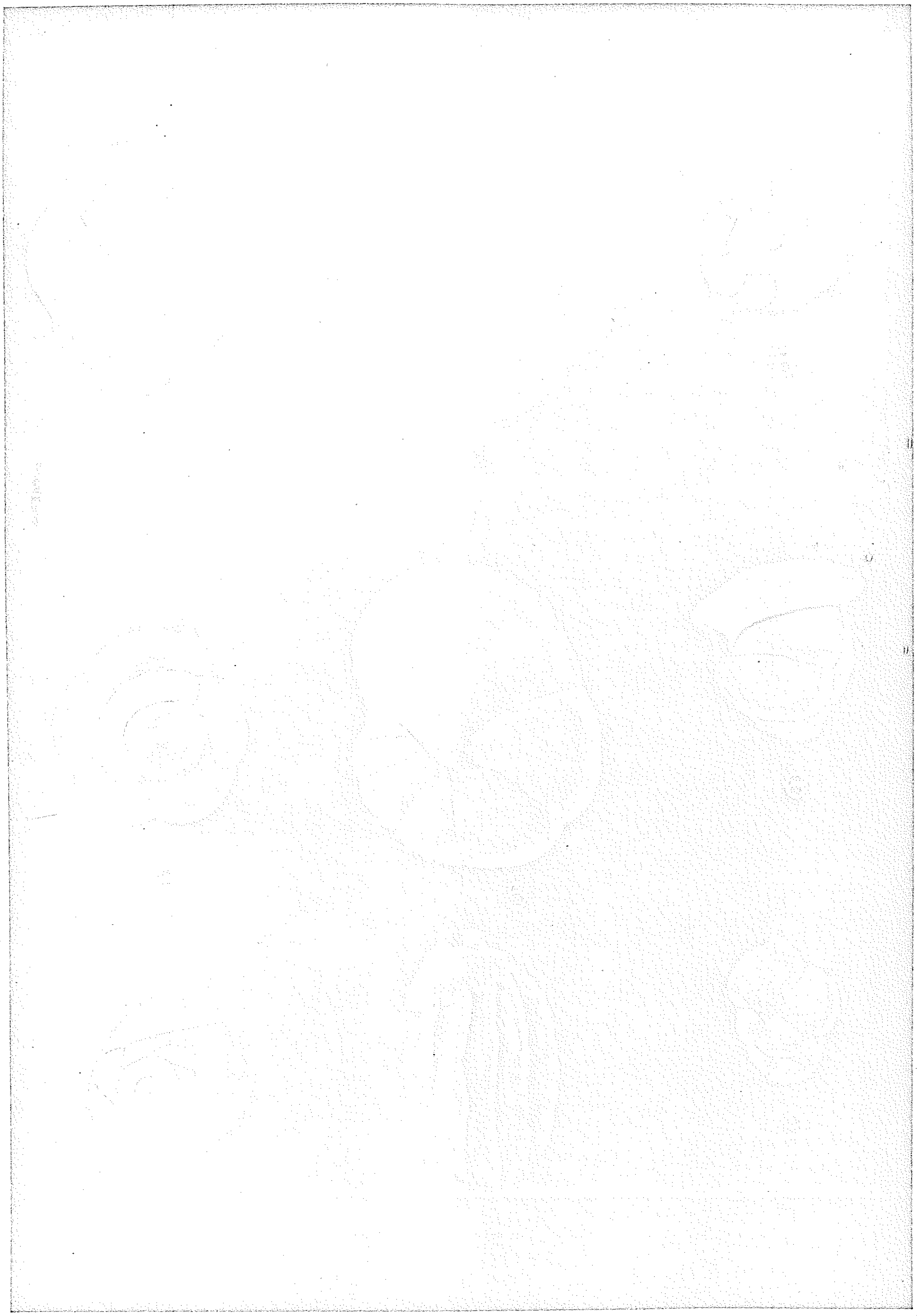

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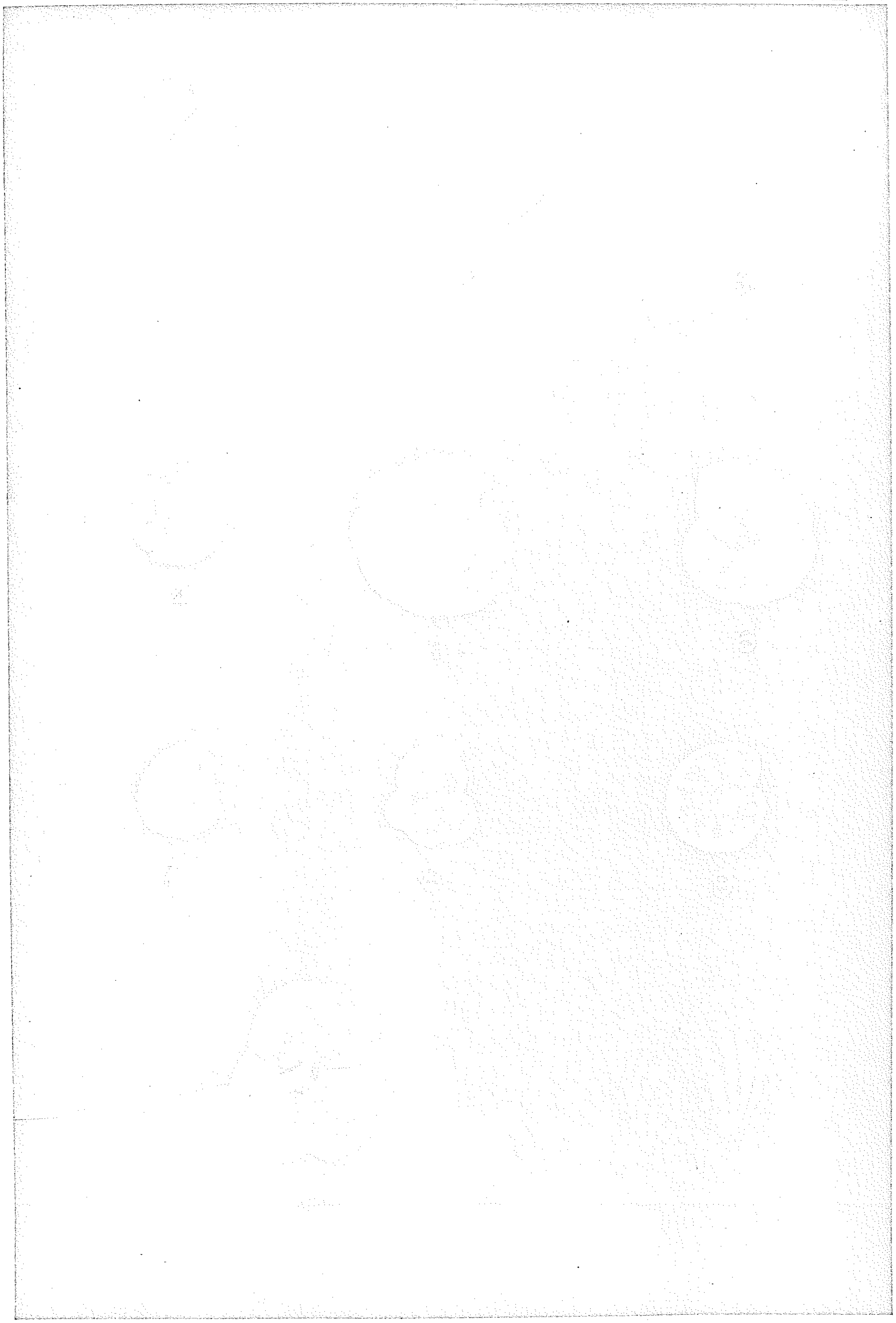
PLATE X



Original Plate in the Museum copy

PLATE XI

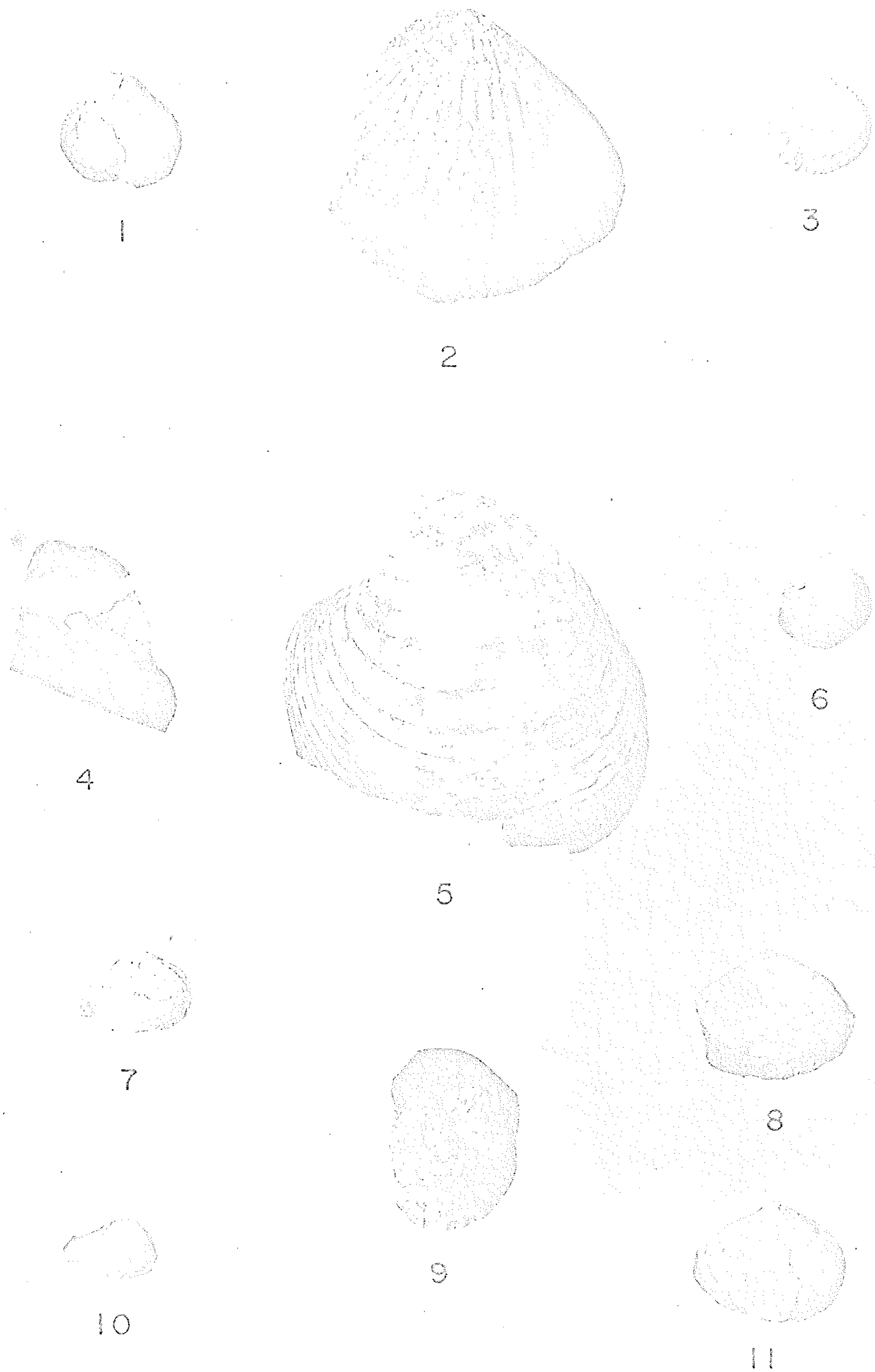


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PLATE XII

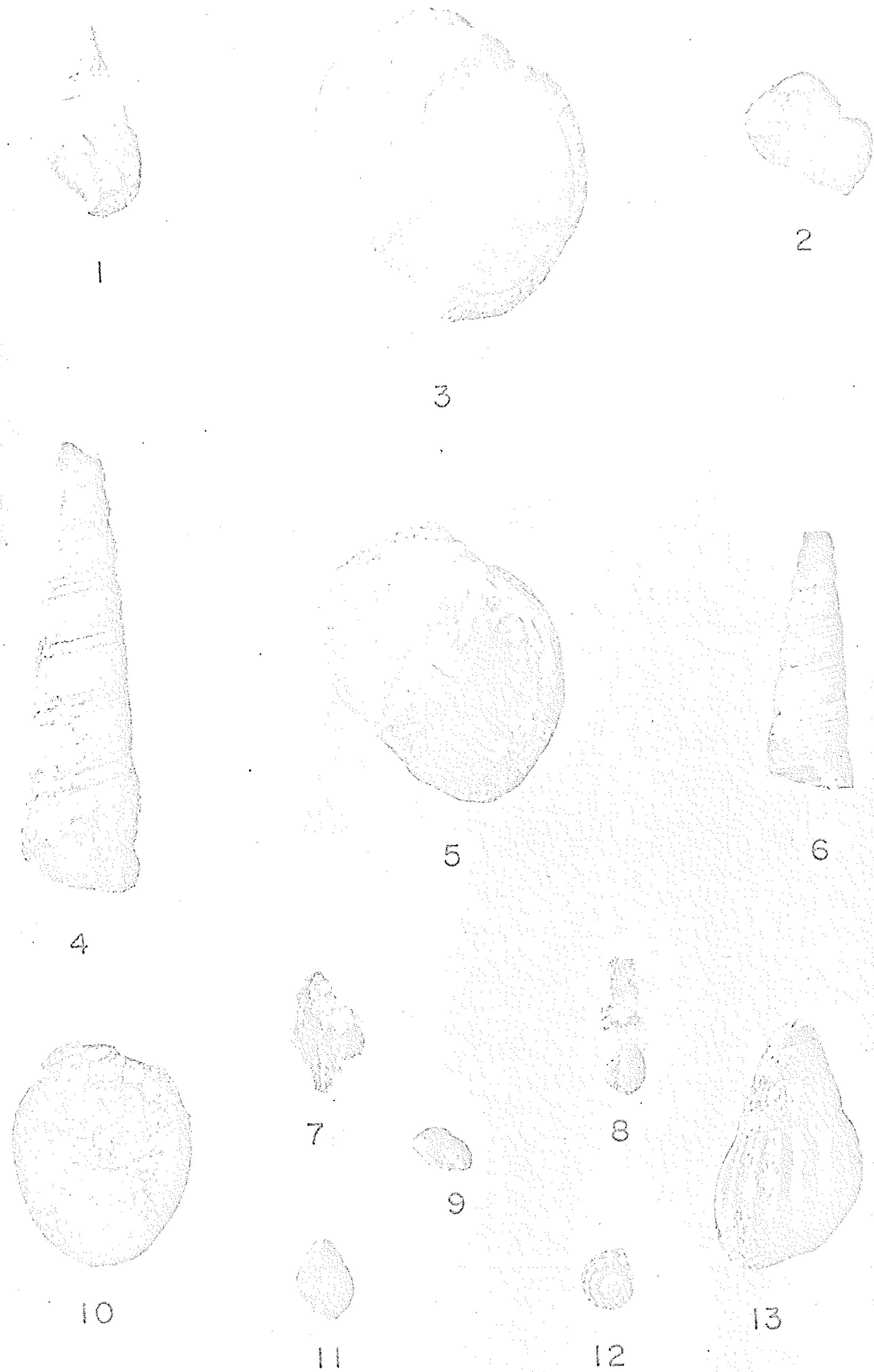

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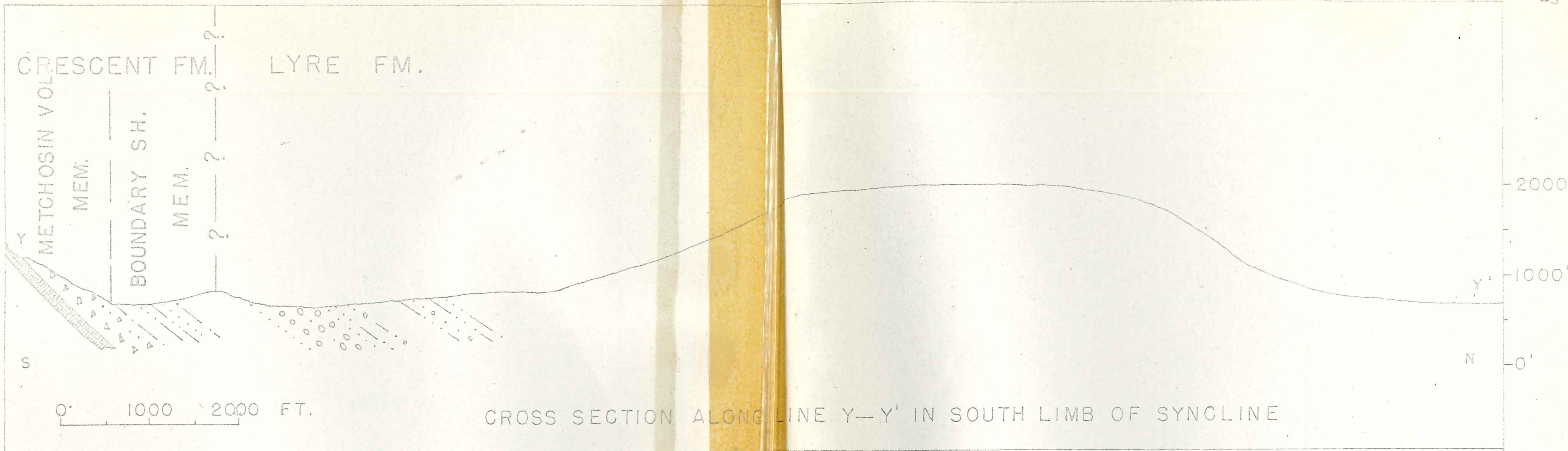
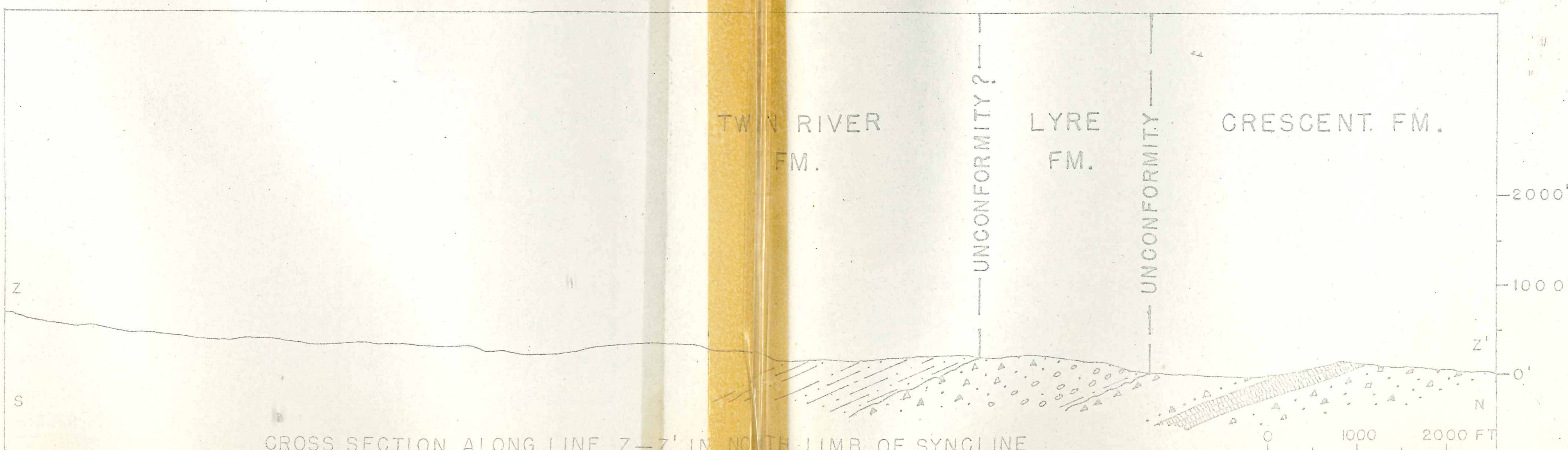
PLATE III



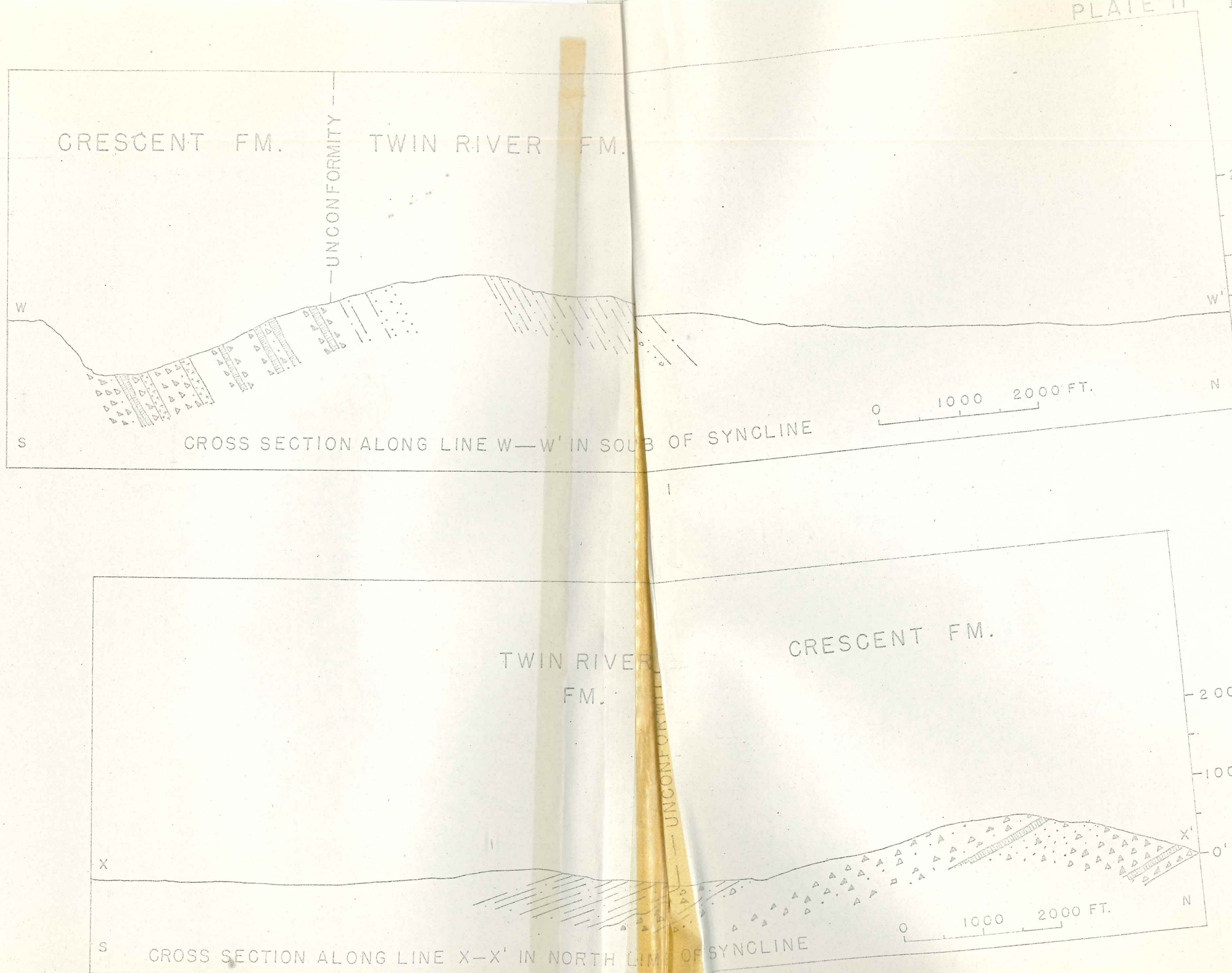
CROSS SECTION ALONG LINE Y—Y' IN SOUTH LIMB OF SYNCLINE

FIGURE 1



CROSS SECTION ALONG LINE Z—Z' IN NORTH LIMB OF SYNCLINE

FIGURE 2



CROSS SECTION ALONG LINE W—W' IN SOUTH LIMB OF SYNCLINE

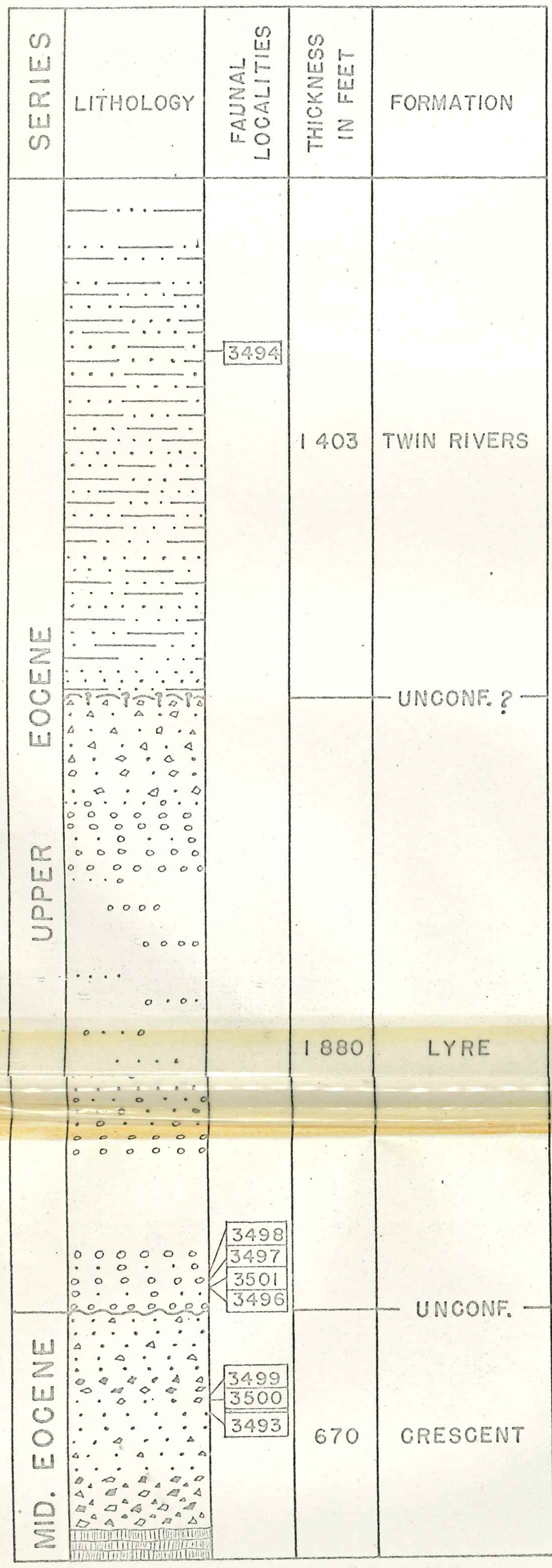
CROSS SECTION ALONG LINE X—X' IN NORTH LIMB OF SYNCLINE

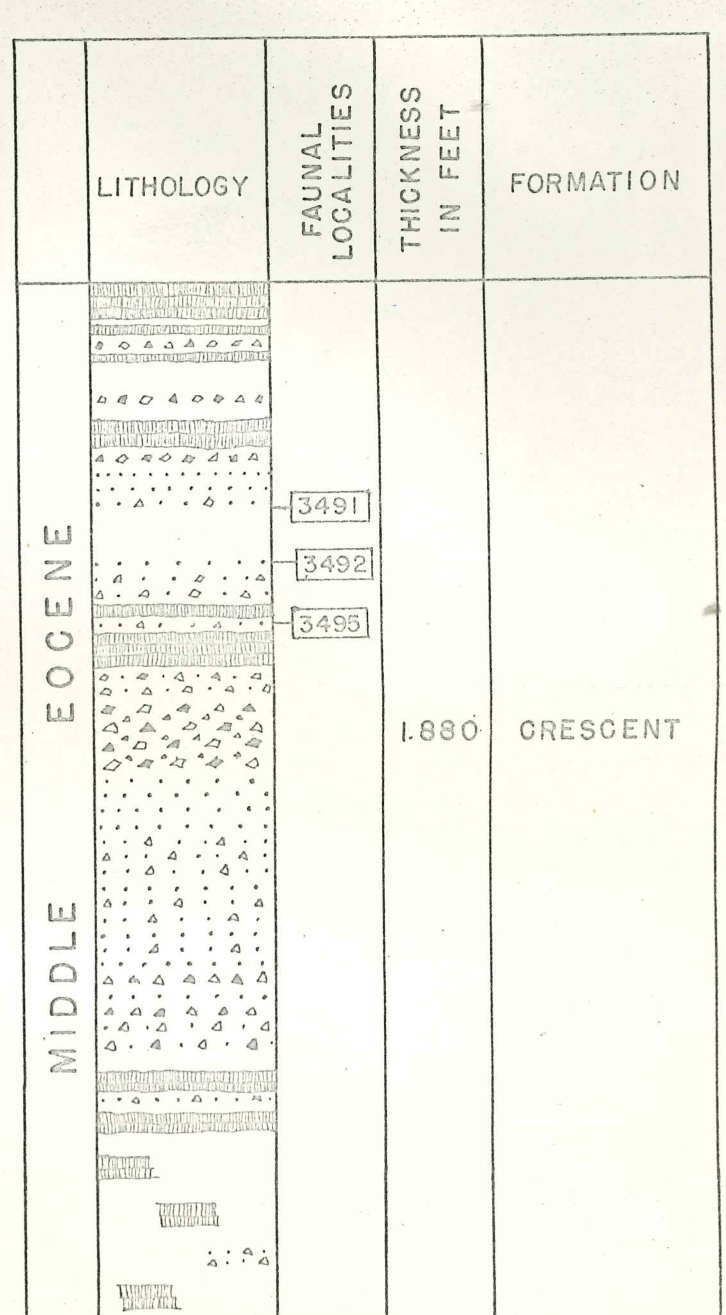
FIGURE 2

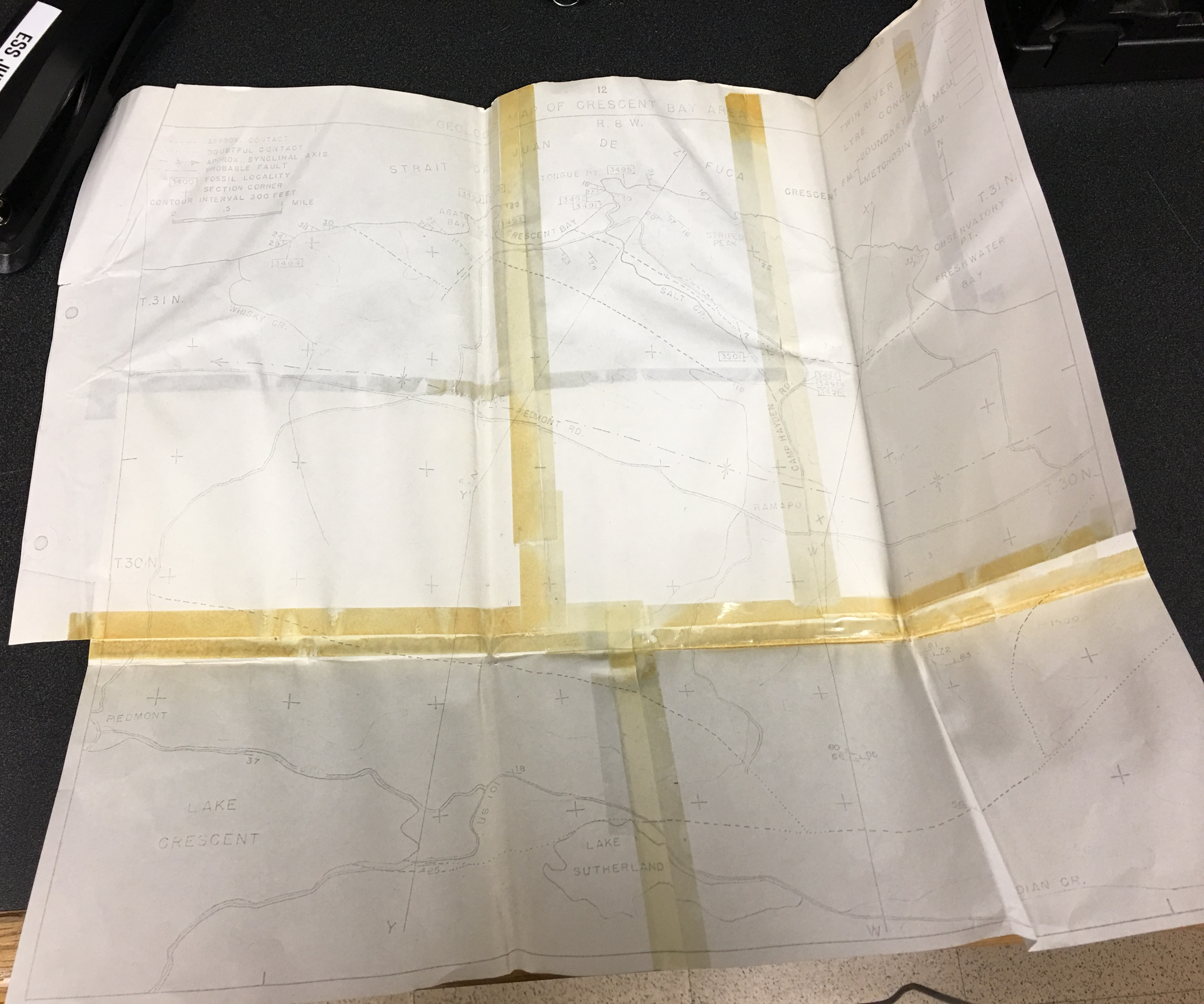
PLATE V

COLUMNAR SECTION

ALONG BEACH IN CRESCENT BAY AREA






12
GEOLOGIC MAP OF CRESCENT BAY AREA
PLATE
R. 8 W.
APPROX. CONTACT
DOUBTFUL CONTACT
APPROX. SYNCLINAL AXIS
PROBABLE FAULT
3400 FOSSIL LOCALITY
SECTION CORNER
CONTOUR INTERVAL 300 FEET
0 .5 1 MILE
TWIN RIVER FM.
LYRE CONGL.
CRESCENT FM.
BOUNDARY SH. MEM.
METCHOSIN MEM.
N
STRAIT OF JUAN DE FUCA
TONGUE PT.
3495
3492
3491
3493
3494
3501
AGATE BAY
CRESCENT BAY
STRIPED PEAK
SALT CR.
WHISKY CR.
OBSERVATORY PT.
FRESHWATER BAY
T. 31 N.
T. 30 N.
PIEDMONT RD.
CAMP HAYDEN RD.
RAMAPO
PIEDMONT
LAKE CRESCENT
LAKE SUTHERLAND
US 101
DIAN CR.
X
X'
Y
Y'
Z'
W