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Parts VI–VIII, pp. 113–208, plates 14–22, figures 5–7, table 1

Part VI

Upper Eocene Foraminifera from the Toledo Formation,
Toledo, Lincoln County, Oregon, by Joseph A. Cushman,
Roscoe E. Stewart, and Katherine C. Stewart.

PART VII

Quinault Pliocene Foraminifera from Western Washington, by
Joseph A. Cushman, Roscoe E. Stewart, and Katherine C. Stewart.

Part VIII

Local Relationships of the Mollusca of the Wildcat Coast Section,
Humboldt County, California, with Related Data on the Foraminifera
and Ostracoda, by Roscoe E. Stewart and Katherine C. Stewart.

Parts VI and VII Prepared Under a Joint Project of the
State Department of Geology and Mineral Industries
and the
United States Geological Survey

OCTOBER 1949

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In Memoriam

Dr. Joseph Augustine Cushman, Director of the Cushman Laboratory for Foraminiferal Research, Lecturer at Harvard University, and Geologist with the United States Geological Survey, died on the evening of Saturday, April 16th, 1949.

Probably no man has ever stood more in the forefront of any field of science than he, nor left that field more enriched and in better order as a result of his work and leadership. His interests were not confined to his own personal research. His cooperation with other micro-paleontologists has resulted in a long list of publications, a large majority of which probably would never have been completed without his assistance. Such are all of our foraminiferal papers.

We are very grateful for the inspiring privilege of working with so great a scientist, so fine a gentleman, and so true a friend as Dr. Cushman.

Roscoe E. Stewart

Katherine C. Stewart

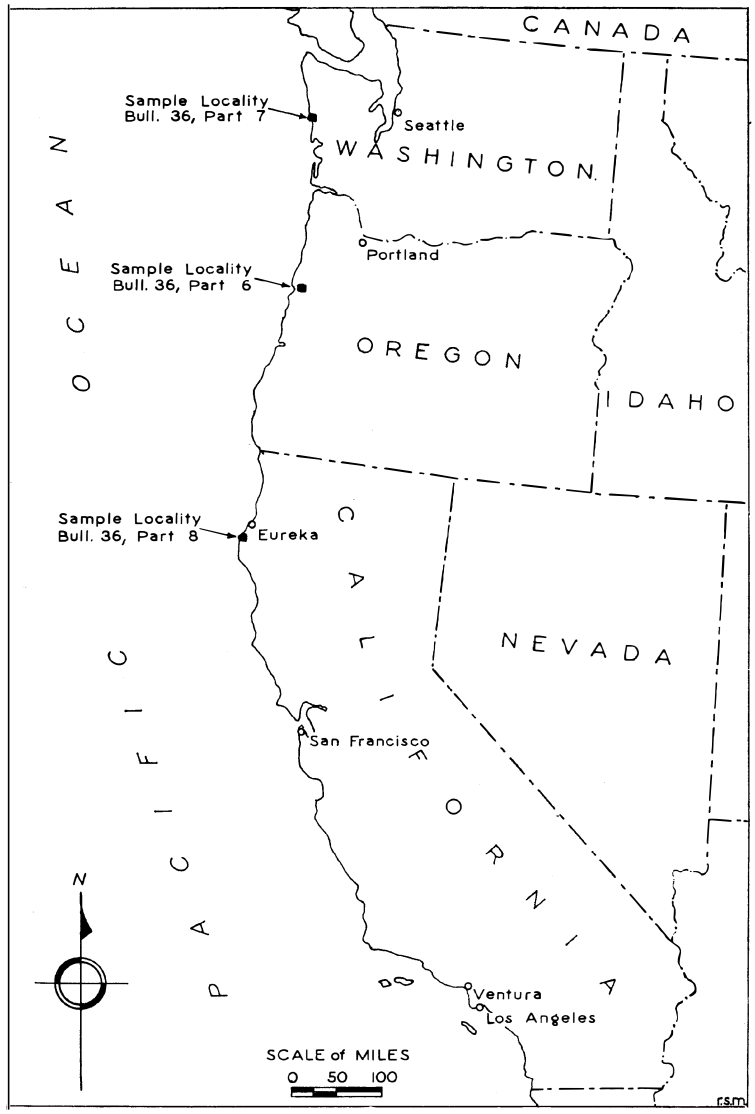

Figure 5. Map showing sample localities for Bulletin 36, Parts VI, VII, and VIII.

CONTENTS

		Page
Index of Foraminifera recorded in Bulletin 36, Parts I–VIII		119
Part VI	Upper Eocene Foraminifera from the Toledo formation, Toledo, Lincoln County, Oregon, by Joseph A. Cushman, Roscoe E. Stewart, and Katherine C. Stewart	126
Part VII	Quinault Pliocene Foraminifera from western Washington, by Joseph A. Cushman, Roscoe E. Stewart, and Katherine C. Stewart	147
Part VIII	Local relationships of the Mollusca of the Wildcat coast section, Humboldt County, California, with related data on the Foraminifera and Ostracoda, by Roscoe E. Stewart and Katherine C. Stewart	165

ILLUSTRATIONS

		Page
Figure 5	Map showing sample localities for Bulletin 36, Parts VI, VII, and VIII	116
Figure 6	Chart showing Weaver's 1942 correlation of the Quinault formation	148
Figure 7	Map of northern California showing Humboldt County and, within it, the general area of the Wildcat coast section and Lawson's type section of the Wildcat series (See also Plate 19)	166
Table 1	Table showing occurrences of molluscan species in the faunal zones and subzones	193
Plates 14-16	Upper Eocene Foraminifera from Toledo, Lincoln County, Oregon	137
Plates 17-18	Quinault Pliocene Foraminifera from Grays Harbor County, Washington	159

		Page
Plate 19	Map showing locations of the Wildcat coast section, Lawson's type section of the Wildcat series, and Hanna's Cretaceous fossil locality	In pocket
Plate 20	Range chart, Wildcat coast section Mollusca and Cirripedia	In pocket
Plate 21	Graphic representation of order of first and last appearance of species of Mollusca, Foraminifera, and Crustacea in the Wildcat coast section	In pocket
Plate 22	Range chart, Wildcat coast section Foraminifera and Ostracoda	In pocket

Grateful appreciation is due Miss Ruth Todd, Research Associate, Cushman Laboratory for Foraminiferal Research, for proofreading parts VI and VII of this bulletin.

INDEX OF FORAMINIFERA

RECORDED IN BULLETIN 36, PARTS I–VIII

Numbers following the species names indicate the part or parts of this bulletin in which they have been recorded.

The ages of the formations covered by the various parts are considered to be as follows:

Part I	Middle Miocene. Astoria formation.
Part II	Middle Miocene. Astoria formation.
Part III	Upper Eocene. Upper member of Coaledo formation.
Part IV	Upper Eocene. Lower member of Coaledo formation.
Part V	Upper Eocene. Helmick formation, approximately equivalent to Moody shale member of Toledo formation.
Part VI	Upper Eocene. Moody shale member of Toledo formation, approximately equivalent to Helmick formation.
Part VII	Pliocene. Quinault formation.
Part VIII	Pliocene. Wildcat formation.

Ammobaculites cf. *hockleyensis* Cushman and Applin 3

Angulogerina astoriensis Cushman and R. E. and K. C. Stewart 1
carinata Cushman 8
cooperensis Cushman 4
hannai Beck 5
cf. *hannai* Beck 3

Anomalina glabrata Cushman 1

Bathysiphon eocenica Cushman and G. D. Hanna 5

Bolivina advena Cushman 1
astoriensis Cushman and R. E. and K. C. Stewart 2
basisenta Cushman and Stone 3, 5, 6
basisenta Cushman and Stone, var. *oregonensis* Cushman and R. E. and K. C. Stewart 6
cf. *kleinpelli* Beck 3
marginata Cushman, var. *adelaidana* Cushman and Kleinpell 1
pisciformis Galloway and Morrey 8
subadvena Cushman, var. *acuminata* Natland 7
subadvena Cushman, var. *spissa* Cushman 8

Bolivinita angelina Church 8

INDEX OF FORAMINIFERA—Continued

Bulimina alligata Cushman and Laiming 1
(Desinobulimina) auriculata (Bailey) 7
fossa Cushman and Parker 7
inflata Seguenza 8
ovata d'Orbigny 1, 2, 8
pagoda Cushman, var. *hebespinata* R. E. and K. C. Stewart 7
rostrata H. B. Brady 8
schencki Beck 3, 5
subacuminata Cushman and R. E. Stewart 8
subcalva Cushman and K. C. Stewart 8

Buliminella bassendorfensis Cushman and Parker 2
elegantissima d'Orbigny 2, 8
subfusiformis Cushman 1

Cancris cancriformis (Kleinpell) 1

Cassidulina californica Cushman and Hughes 7
cushmani R. E. and K. C. Stewart 8
globosa Hantken 4, 5, 6
cf. *globosa* Hantken 1
laevigata d'Orbigny, var. *carinata* Cushman 1
limbata Cushman and Hughes 7
modeloensis Rankin 1
quadrata Cushman and Hughes 7

Cassidulinoides parkeriana (H. B. Brady) 8

Chilostomella cf. *czizeki* Reuss 7

Cibicides cicatricosa (Schwager) 8
concentricus (Cushman), var. *washingtonensis* Cushman and R. E. and K. C. Stewart 7
cf. *cooperensis* Cushman 3
floridanus (Cushman) 1
howei Cushman and Todd 6
natlandi Beck, var. *olequaensis* Beck 4
pseudoungeriana (Cushman) 8
warreni Cushman and R. E. and K. C. Stewart 5, 6

Clavulina communis d'Orbigny 8
communis d'Orbigny, var. *pallida* Cushman 8

INDEX OF FORAMINIFERA—Continued

Cyclammina cf. *acutidorsata* (Hantken) 5
cancellata H. B. Brady 8
cf. *constrictimargo* R. E. and K. C. Stewart 7
incisa Stache 1
pacifica Beck 4

Dentalina cf. *approximata* Reuss 4
communis d'Orbigny 4, 5
cf. *communis* d'Orbigny 6
dusenburyi Beck 4
insecta (Schwager) 8
pauperata d'Orbigny 1
quadrulata Cushman and Laiming 1

Dentalina (?) sp. (pt. 3, pl. 7, fig. 4) 3

Discorbis cf. *samanicus* (W. Berry) 6

Ellipsonodosaria sp. (pt. 4, pl. 11, fig. 5) 4
sp. (pt. 5, pl. 12, figs. 8, 9) 5
sp. A. (pt. 6, pl. 15, fig. 10) 6
sp. B. (pt. 6, pl. 15, fig. 11) 6

Ehrenbergina compressa Cushman 8

Elphidium hannai Cushman and Grant 8
hughesi Cushman and Grant 8
hughesi Cushman and Grant, var. 8
oregonensis Cushman and Grant 8

Eponides ellisorae Garrett 4
healdi R. E. and K. C. Stewart 1
mansfieldi Cushman, var. *oregonensis* Cushman and R. E. and K. C. Stewart 2
minimus Cushman 3, 5, 6
tenera (H. B. Brady) 8
umbonatus (Reuss) 1

Gaudryina pliocenica Cushman and R. E. and K. C. Stewart 7
sp. A. (pt. 4, pl. 11, fig. 1) 4
sp. B. (pt. 4, pl. 11, fig. 2) 4
triangularis Cushman 8

Glandulina laevigata (d'Orbigny), var. *ovata* Cushman and Applin 4, 5

INDEX OF FORAMINIFERA—Continued

Globobulimina pacifica Cushman 7
pacifica Cushman, var. *oregonensis* Cushman and R. E. and K. C. Stewart 6

Globorotalia crassula Cushman and R. E. Stewart 8

Gyroidina cf. *planulata* Cushman and Renz 3, 5
scalata Garrett 6
soldanii d'Orbigny 8
cf. *soldanii* d'Orbigny 4
soldanii d'Orbigny, var. *altiformis* R. E. and K. C. Stewart 8
sp. (pt. 3, pl. 8, fig. 11) 3

Haplophragmoides sp. (pt. 6, pl. 14, fig. 1) 6

Lagena cf. *acuticosta* Reuss 5
cf. *costata* (Williamson) 5, 6
hexagona (Williamson) 8
substriata Williamson 8

Lenticulina cf. *theta* Cole 4

Marginulina cf. *dubia* Neugeboren 1
subbullata Hantken 6
cf. *subbullata* Hantken 4, 5

Nodogenerina advena Cushman and Laiming 1
lepidula (Schwager) 8
sp. (pt. 1, pl. 2, figs. 9, 10) 1
sp. (pt. 7, pl. 17, fig. 12) 7

Nodosaria anomala Reuss 1
chirana Cushman and Stone 6
hochstetteri Schwager, var. *spinicosta* Koch 8
koina Schwager 8
cf. *longiscata* d'Orbigny 5
parexilis Cushman and K. C. Stewart 1, 8
tosta Schwager 8

Nonion applini Howe and Wallace 3, 4, 5
barleeanum (Williamson) 8
cf. *belridgense* Barbat and Johnson 1
costiferum (Cushman) 2
danvillense Howe and Wallace 4
florinense Cole 5, 6
cf. *inexcavatum* (Cushman and Applin) 3
scapha (Fichtel and Moll) 8
sp. (pt. 3, pl. 7, fig. 8) 3
umbilicatula (Montagu) 8

INDEX OF FORAMINIFERA—Continued

Nonionella jacksonensis Cushman 3, 5
miocenica Cushman 2

Planularia tolmani Cushman and Simonson 6

Planulina astoriensis Cushman and R. E. and K. C. Stewart 1
cf. *haydoni* Cushman and Schenck 4
mexicana Cushman 1
ornata (d'Orbigny) 7, 8

Plectofrondicularia californica Cushman and R. E. Stewart 1, 8
miocenica Cushman, var. *directa* Cushman and Laiming 1
oregonensis Cushman and R. E. and K. C. Stewart 4, 5
packardi Cushman and Schenck 5
searsi Cushman and R. E. and K. C. Stewart 4, 6
cf. *searsi* Cushman and R. E. and K. C. Stewart 3
sp. (pt. 1, pl. 2, fig. 4) 1
vokesi Cushman and R. E. and K. C. Stewart 6

Polymorphina charlottensis Cushman 8

Pseudoglandulina laevis (d'Orbigny) 7

Pullenia cf. *bulloides* (d'Orbigny) 7
sphaeroides (d'Orbigny) 8

Pseudoparrella subperuviana Cushman 7

Pulvinulinella parva Cushman and Laiming .... 2†

Pyrgo sp. (pt. 2, pl. 5, fig. 2) 2

Quinqueloculina imperialis G. D. and M. A. Hanna 4
cf. *minuta* Beck 3
cf. *seminuda* Reuss 7
cf. *vulgaris* d'Orbigny 2

Robulus articulatus (Reuss), var. *texanus* (Cushman and Applin) 4
cf. *calcar* (Linné) 1
chiranus Cushman and Stone 5, 6
inornatus (d'Orbigny) 3, 4, 5, 6
nikobarensis (Schwager) 1
cf. *orbicularis* (d'Orbigny) 2
sp. (pt. 1, pl. 1, fig. 4) 1
sp. (pt. 2, pl. 5, fig. 4) 2
welchi Church 5, 6

† This is now *Pseudoparrella parva* (Cushman and Laiming). See Cushman and ten Dam, Cushman Lab. Foram. Research Contr., vol. 24, pt. 3, 1948, p. 49.

INDEX OF FORAMINIFERA—Continued

Saracenaria cf. *acutauricularis* (Fichtel and Moll) 1
sp. (pt. 1, pl. 1, fig. 6) 1
sp. (pt. 6, pl. 15, fig. 3) 6

Sigmoilina celata (Costa) 8

Sigmomorphina semitecta (Reuss) 5

Siphogenerina branneri (Bagg) 1
kleinpelli Cushman 1

Sphaeroidina bulloides d'Orbigny 7
chilostomata Galloway and Morrey .... 1,* 8 *

Textularia ? sp. (pt. 6, pl. 14, fig. 2) 6

Uvigerina garzaensis Cushman and Siegfus 6
peregrina Cushman 8
peregrina Cushman, var. *latalata* R. E. and K. C. Stewart 7
proboscidea Schwager 8
senticosa Cushman 7, 8
subperegrina Cushman and Kleinpell 1, 7
aff. *tenuistriata* (Reuss) 8

Valvulineria araucana (d'Orbigny) 1, 7
chirana Cushman and Stone 6

Virgulina californiensis Cushman 2
nodosa R. E. and K. C. Stewart 8
punctata d'Orbigny 2
cf. *zetina* Cole 5

* Originally assigned to *S. bulloides* d'Orbigny. See Cushman, J. A. and Todd, Ruth, The genus *Sphaeroidina* and its species: Cushman Lab. Foram. Research Contr., vol. 25, pt. 1, p. 18 (synonymy), March 1949.

Part VI

UPPER EOCENE FORAMINIFERA FROM THE TOLEDO FORMATION. TOLEDO, LINCOLN COUNTY, OREGON

UPPER EOCENE FORAMINIFERA

From the Toledo Formation, Toledo, Lincoln County, Oregon*

by

Joseph A. Cushman,[1] Roscoe E. Stewart,[2] and Katherine C. Stewart [3]

The Toledo formation was named and described by Harrison and Eaton[4] in 1920. They called it "the lowermost member of the Oligocene," but stated that it ". . . . may not all be of Oligocene age but possibly transitional between the Eocene and Oligocene." The type locality was designated as " . . . three miles south of Toledo in Lincoln County," and the thickness given as 2,800 feet. Attention was called to " . . . a lack of fossil life in the Toledo" and the possibility that this is due to the tuffaceous character of the deposition. On plate 4 of their report the lower Oligocene was shown in fault contact with the Eocene.

Smith[5] in 1924 gave 3,000 feet as the thickness of the Toledo formation; stated that it is ". . . . quite barren of evidence of life"; and indicated the presence of some life by giving *Thracia* as a typical fossil.

In 1927 Schenck[6] divided the Toledo formation into two members, with an estimated 1,200 feet of shale at the base and 1,000 feet of sandstone above, the attitudes in each being similar. The term Moody shale was proposed for the lower member, ". . . . with type locality at the railroad cuts at Moody Station, Southern Pacific Railroad, Lincoln County, between Yaquina and Toledo." Available evidence was considered insufficient to place the Moody shale in fault contact with the underlying Eocene Burpee formation, as shown in plate 4 of

* Published by permission of the Director, U. S. Geological Survey.

(1) Geologist, U. S. Geological Survey.

(2) Geologist, Oregon Department of Geology and Mineral Industries, Portland, Oregon.

(3) Geologist, Portland, Oregon.

(4) Harrison and Eaton. Report on investigation of oil and gas possibilities of western Oregon: Oregon Bur. Mines and Geology, Mineral Resources of Oregon, vol. 3, no. 1, pp. 6-7, 12-13, 29, March 1920.

(5) Smith, W. D., Petroleum possibilities of western Oregon: Econ. Geology, vol. XIX, no. 5, table 1 on p. 458, August 1924.

(6) Schenck, H. G., Marine Oligocene of Oregon: California Univ., Dept. Geol. Sci., Bull., vol. 16, no. 12, pp. 455-459, March 1927.

the Harrison-Eaton report, and there was believed to be no angular unconformity between the Toledo formation and the overlying Oligocene Yaquina sandstone. Like previous authors, Schenck noted a scarcity of fossils in the shale. He listed *"Turris" clalamensis* Weaver, *Acila, Pecten, Leda, Macoma,* and Foraminifera, and tentatively called the Moody shale lower Oligocene.

In a more comprehensive study of western Oregon Oligocene formations published in 1928, Schenck[7] restated the belief that the Toledo formation is of lower Oligocene age, but did not entirely discard the possibility of its being at least in part Eocene. Since " . . . the fauna is not sufficiently complete to render paleontologic correlation conclusive," the assignment of the Toledo formation to the lower Oligocene is based largely upon its stratigraphic position between the Eocene Burpee and the middle Oligocene Yaquina formations. The Toledo formation is said to overlie the Burpee unconformably, and, in figure 7, page 23 of Schenck's paper, angular unconformity is indicated between it and both the underlying Burpee and the overlying Yaquina.

Weaver[8] in 1937 referred briefly to the Toledo formation and the Moody shale and apparently regarded them as of lower Oligocene age. The Toledo formation, containing occasional marine invertebrate fossils, is said to be approximately 2,400 feet thick and to rest unconformably upon the Eocene Burpee formation along a contact which cannot be ascertained definitely but which appears to exist in a hill about 1 mile northeast of Toledo. The Moody shale member, containing a few well-preserved specimens of pelecypods and gastropods as well as occasional Foraminifera, is said to include the lower 1,400 feet of the Toledo formation and to rest with probable conformity upon the Burpee formation along an unobservable contact which lies along Yaquina River and extends northward into the hills east of Toledo.

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[7] Schenck, H. G., Stratigraphic relationships of western Oregon Oligocene formations: California Univ., Dept. Geol. Sci., Bull., vol. 18, no. 1, pp. 23–27, 30, 44, table 1, November 1928.

[8] Weaver, C. E., Tertiary stratigraphy of western Washington and northwestern Oregon: Washington Univ. (Seattle) Pub. in Geology, vol. 4, pp. 104, 106, 108, pl. 15B, June 1937.

In a correlation chart published by Weaver[9] in 1942 the Toledo formation is confined to the lower Oligocene, but in another chart[10] published in 1945 it is extended downward to include the upper portion of the upper Eocene as well as the lower Oligocene.

As announced in 1946,[11] the foraminiferal assemblage recorded in the present paper substantiates the upper Eocene age of at least a portion of the Moody shale member of the Toledo formation. It has affinities so close as to be almost identical with an upper Eocene assemblage recorded by the authors[12] in 1948 from Helmick Hill, sec. 13, T. 9 S., R. 5 W., Polk County, Oreg., and it has several rather distinctive species in common with another assemblage recorded by Cushman and Stone[13] in 1947 from the Eocene Chira shale of Peru.

The apparent Eocene age of the lower portion of the Moody shale member lends added interest to the nature of the contact between the Toledo and Burpee formations and to the nature of the transition from Eocene to Oligocene in northwestern Oregon. It is believed that Schenck's Bastendorf (spelling corrected from Bassendorf) shale, like the Toledo formation, is in part transitional between the Eocene and the Oligocene.

The material for this paper is from a sample rich in Foraminifera collected by H. E. Vokes and Parke D. Snavely, Jr., of the United States Geological Survey. The sample was taken from a hillside cut beside Minnie's Sunset Cafe on U. S. Highway No. 20 in Toledo, Lincoln County, Oreg. The following tabular data, based upon speedometer readings from the intersection of U. S. Highway No. 20 and Main Street, Toledo,

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[9] Weaver, C. E., Paleontology of the marine Tertiary formations of Oregon and Washington: Washington Univ. (Seattle) Pub. in Geology, vol. 5, pt. III, correlation chart preceding p. 629, December 1942.

[10] Weaver, C. E., Geology of Oregon and Washington and its relation to occurrence of oil and gas: Am. Assoc. Petroleum Geologists Bull., vol. 29, no. 10, table V on p. 1402, October 1945.

[11] Eocene age assigned shales at Toledo, Oregon: Oregon Dept. Geology and Min. Industries Ore.-Bin, vol. 8, no. 12, p. 88, December 1946.

[12] Cushman, J. A., and Stewart, R. E. and K. C., Five papers on Foraminifera from the Tertiary of western Oregon, Part V—Eocene Foraminifera from Helmick Hill, Polk County, Oregon: Oregon Dept. Geology and Min. Industries Bull. 36, pt. V, pp. 93–111, pls. 12, 13, July 1947 (May 1948).

[13] Cushman, J. A., and Stone, Benton, An Eocene foraminiferal fauna from the Chira shale of Peru: Cushman Lab. Foram. Research, Special Pub. 20, pp. 1–27, pls. 1–4, April 1947.

should facilitate the finding of this locality. These readings are taken in the direction from Toledo to Newport.

Street, road or highway	Side road or street	Dist. between points *Miles*	Cumulative dist. *Miles*
Main St. (Toledo) and U. S. Hwy. 20	Intersection	0.00	0.00
Run Bottom Road	To right	0.15	0.15
MINNIE'S SUNSET CAFE. County road to Federal Housing Project on Toledo Terrace	To right	0.25	0.40
Road past C. D. Johnson Mill to Yaquina and Newport	To left	0.05	0.45
Toledo city limits	To left	0.10	0.55
French Avenue	To right	0.00+	0.55+
U. S. 20 and U. S. (Ore.) 229 highways	Junction	0.85	1.40

Family LITUOLIDAE

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES sp. (Pl. 14, fig. 1)

Several specimens in this collection are referred to this genus, but most of the specimens are crushed and it is difficult to determine the true specific characters. A few of the specimens suggest *Trochammina* but this also will remain doubtful until better specimens can be obtained.

Family TEXTULARIIDAE

Genus TEXTULARIA Defrance, 1824

TEXTULARIA ? sp. (Pl. 14, fig. 2)

There are numerous specimens of the form figured in the material from the Toledo formation. The wall is thin and all specimens are considerably compressed and distorted. Some of the specimens in the early stages suggest that they may be a *Gaudryina* but sufficiently well preserved specimens were not found to give the needed information.

Family LAGENIDAE

Genus ROBULUS Montfort, 1808

ROBULUS INORNATUS (d'Orbigny) (Pl. 14, figs. 4, 5)

(For references and figures, see Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 3, p. 60, pl. 7, fig. 3; pt. 4, p. 74, pl. 11, fig. 6; pt. 5, p. 97, pl. 13, fig. 2.)

This species has already been recorded from the upper and lower parts of the Coaledo formation and from the Helmick formation. Specimens from the Toledo formation are very well preserved and show their characters well.

ROBULUS CHIRANUS Cushman and Stone (Pl. 14, fig. 3)

Robulus chiranus Cushman and Stone, Special Pub. 20, Cushman Lab. Foram. Res., 1947, p. 5, pl. 1, fig. 15.—Cushman, Stewart, and Stewart, Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 5., p. 98, pl. 12, fig. 5.

This species recently described from the Eocene—Chira shale—of Peru and recorded from the Helmick formation of Oregon, occurs in typical form in the Toledo formation. It is easily distinguished by its open umbilical region and very strongly curved sutures.

ROBULUS WELCHI Church (Pl. 14, fig. 8)

Robulus welchi Church, Rep't State Min. Calif., 1931, p. 212, pl. C, figs. 13, 14; Calif. Div. Mines, Bull. 118, pt. 2, 1941, p. 182.—Cushman and Siegfus, Trans. San Diego Soc. Nat. Hist., vol. 9, 1942, p. 404, pl. 15, fig. 22.—Beck, Jour. Pal., vol. 17, 1943, p. 596, pl. 102, figs. 4, 8.—Kelley, Bull. Amer. Assoc. Petr. Geol., vol. 27, 1943, p. 11 (list.)—Cushman and Simonson, Jour. Pal., vol. 18, 1944, p. 195, pl. 30, fig. 11.—Cushman, R. E. and K. C. Stewart, Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 5, p. 97, pl. 12, fig. 4.

Our specimens from the Toledo formation are identical with the type figure and topotype specimens with which they have been compared. From the figures, specimens which have been referred to this species by later authors are not all typical. The types are from the Eocene—Kreyenhagen shale—of California.

Genus PLANULARIA Defrance, 1824

PLANULARIA TOLMANI Cushman and Simonson (Pl. 14, fig. 9)

Planularia tolmani Cushman and Simonson, Jour. Pal., vol. 18, 1944, p. 195, pl. 30, figs. 13, 14.—Cushman and Stone, Special Pub. 20, Cushman Lab. Foram. Res., 1947, p. 5, pl. 1, fig. 12.

This species was described from Atwill's Oligocene Tumey formation of California and occurs in typical form in the Eocene

—Chira shale—of Peru. Specimens from the Toledo formation seem to belong to this species.

Genus MARGINULINA d'Orbigny, 1826

MARGINULINA SUBBULLATA Hantken (Pl. 14, fig. 10)

(For references, see Cushman and Siegfus, Trans. San Diego Soc. Nat. Hist., vol. 9, 1942, p. 408.)

Typical specimens of this widely distributed species occur in the Toledo formation. These are more typical than the ones referred to it from the lower part of the Coaledo formation and the Helmick formation (Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 4, p. 76, pl. 9, fig. 4; pt. 5, p. 98).

Genus DENTALINA d'Orbigny, 1826

DENTALINA cf. COMMUNIS d'Orbigny (Pl. 15, fig. 2)

Specimens similar to that figured seem to be enough like d'Orbigny's species to be referred to it, but are not entirely typical. They are much like the specimens referred to it from the lower part of the Coaledo formation and the Helmick formation (Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 4, p. 76, pl. 9, fig. 9; pt. 5, p. 98).

Genus NODOSARIA Lamarck, 1812

NODOSARIA CHIRANA Cushman and Stone (Pl. 15, fig. 1)

Nodosaria chirana Cushman and Stone, Special Pub. 20, Cushman Lab. Foram. Res., 1947, p. 6, pl. 1, figs. 18–21.

Specimens identical with this species recently described from the Eocene Chira shale of Peru occur in our material from the Toledo formation. Specimens are easily broken as the portion connecting the chambers is very delicate.

Genus SARACENARIA Defrance, 1824

SARACENARIA sp. (Pl. 15, fig. 3)

Specimens of the species figured are very rare in the material from the Toledo formation. It is difficult to assign this form to a definite species without more specimens. In the one figured the last-formed chambers failed to cover the aperture of one of the earlier chambers and an opening is left at the base near the peripheral margin.

Genus LAGENA Walker and Jacob, 1798

LAGENA cf. COSTATA (Williamson) (Pl. 14, fig. 6)

Very rare specimens from the Toledo formation resemble this species which is widely recorded. Specimens have also been found in the Helmick formation (Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 5, p. 98, pl. 12, fig. 6).

Family NONIONIDAE

Genus NONION Montfort, 1808

NONION FLORINENSE Cole (Pl. 14, fig. 7)

(For references, see Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 5, p. 99.)

Specimens from the Helmick formation have already been referred to this species and those from the Toledo formation are also very similar to the types from the Eocene of Mexico.

Family HETEROHELICIDAE

Genus PLECTOFRONDICULARIA Liebus, 1903

PLECTOFRONDICULARIA SEARSI Cushman and R. E. and K. C. Stewart (Pl. 15, fig. 5)

Plectofrondicularia searsi Cushman and R. E. and K. C. Stewart, Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 4, p. 78, pl. 10, fig. 5; pl. 11, fig. 8.

This species, recently described from the lower part of the Coaledo formation, occurs in typical form in the Toledo formation.

PLECTOFRONDICULARIA VOKESI Cushman and R. E. and K. C. Stewart, n. sp. (Pl. 15, fig. 4)

Test elongate, about 3 times as long as broad, very strongly compressed, periphery acute or slightly keeled; chambers numerous, distinct, very slightly inflated, the earlier ones biserial, later ones uniserial, increasing gradually in height as added but very little in width; sutures distinct, slightly depressed; strongly curved; wall smooth; aperture narrowly elliptical, terminal. Length 0.75-1.00 mm.; breadth 0.22-0.27 mm.; thickness 0.04-0.06 mm.

Holotype (Cushman Coll. No. 56725) and paratypes (Oregon State Dept. Geology and Min. Industries Coll. No. 229 and Stewart Coll. No. 229) from the Eocene, Toledo formation, Minnie's Sunset Cafe, Toledo, Oreg.

This species differs from *P. oregonensis* Cushman and R. E. and K. C. Stewart in the smaller size, more elongate test, and smooth surface.

Family BULIMINIDAE

Genus GLOBOBULIMINA Cushman, 1927

GLOBOBULIMINA PACIFICA Cushman, var. OREGONENSIS Cushman and R. E. and K. C. Stewart (Pl. 15, fig. 6)

Globobulimina pacifica Cushman, var. *oregonensis* Cushman and R. E. and K. C. Stewart, Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 5, p. 101, pl. 12, fig. 13; pt. 3, p. 61, pl. 8, fig. 6; pt. 4, p. 78, pl. 11, fig. 4.

This variety, recently described from the Helmick formation and recorded from the upper and lower parts of the Coaledo formation, occurs in typical form in the Toledo formation.

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA BASISENTA Cushman and Stone (Pl. 15, fig. 8)

Bolivina basisenta Cushman and Stone, Special Pub. 20, Cushman Lab. Foram. Res., 1947, p. 15, pl. 2, fig. 20.—Cushman and R. E. and K. C. Stewart, Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 3, p. 61, pl. 8, fig. 7; pt. 5, p. 102, pl. 13, fig. 6.

Typical specimens of this species recently described from the Eocene Chira shale of Peru occur in the Toledo formation. It has also been recorded from the upper part of the Coaledo formation and the Helmick formation.

BOLIVINA BASISENTA Cushman and Stone, var. OREGONENSIS Cushman and R. E. and K. C. Stewart, n. var. (Pl. 15, fig. 7)

Variety differing from the typical form in the narrower test, more rounded periphery, and the chambers almost entirely lacking the basal spinose projections.

Holotype of variety (Cushman Coll. No. 56728) and paratypes (Oregon State Dept. Geology and Min. Industries Coll. No. 232 and Stewart Coll. No. 232) from the Eocene, Toledo formation, Minnie's Sunset Cafe, Toledo, Oreg.

In our material this variety seems to be distinct from the typical form.

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA GARZAENSIS Cushman and Siegfus (Pl. 15, fig. 9)

Uvigerina garzaensis Cushman and Siegfus, Contr. Cushman Lab. Foram. Res., vol. 15, 1939, p. 28, pl. 6, fig. 15; Trans San Diego Soc. Nat. Hist., vol. 9, 1942, p. 414, pl. 17, fig. 5.—Kelley, Bull. Amer. Assoc. Petr. Geol., vol. 27, 1943, p. 11 (list).—Curran, l. c., pp. 1378, 1381 (lists).——Cushman and Simonson, Jour. Pal., vol. 18, 1944, p. 199, pl. 32, figs. 20, 21.—Detling, l. c., vol. 20, 1946, p. 357, pl. 50, fig. 8.

This species has been recorded from the Eocene and Oligocene of California and the Eocene of Oregon. Specimens are common in the Toledo formation.

Family ELLIPSOIDINIDAE

Genus ELLIPSONODOSARIA A. Silvestri, 1900

ELLIPSONODOSARIA sp. A (Pl. 15, fig. 10)

Specimens of this species are abundant in the Toledo formation but are badly broken; it does not seem possible to refer them to a definite species. It is very easily broken and the figured specimen is one of the most nearly complete ones found.

ELLIPSONODOSARIA sp. B (Pl. 15, fig. 11)

The figured specimen gives the general shape of this species but the ornamentation of the surface is quite variable from nearly smooth to fairly spinose. Specimens are very common in the material from the Toledo formation.

Family ROTALIIDAE

Genus DISCORBIS Lamarck, 1804

DISCORBIS cf. SAMANICUS (W. Berry) (Pl. 16, fig. 1)

The types of this species are from the Eocene, Lobitos shale, of Peru. It has recently been recorded from the Eocene, Chira shale, of Peru. The original figure is a line drawing but from the description the present specimens seem to be close to this species.

Genus VALVULINERIA Cushman, 1926

VALVULINERIA CHIRANA Cushman and Stone (Pl. 16, fig. 2)

Valvulineria chirana Cushman and Stone, Special Pub. 20, Cushman Lab. Foram. Res., 1947, p. 22, pl. 3, fig. 3.

Specimens from the Toledo formation have been compared with the types of this species recently described from the Eocene, Chira shale, of Peru, and they seem identical.

Genus GYROIDINA d'Orbigny, 1826

GYROIDINA SCALATA Garrett (Pl. 15, fig. 13)

Gyroidina scalata Garrett, Jour. Pal., vol. 12, 1938, p. 316, pl. 40, figs. 12, 13.—Cushman and Ellisor, Contr. Cushman Lab. Foram. Res., vol. 15, 1939, p. 10, pl. 2, fig. 1.—Ellisor, Bull. Amer. Assoc. Petr. Geol., vol. 24, No. 3, 1940, pl. 2, fig. 8.

Specimens from the Toledo formation have been compared with types of this species from the Tertiary of Texas and Louisiana and seem identical. Specimens from Atwill's Tumey formation of California recorded as "*Gyroidina* cf. *G. soldanii* d'Orbigny" by Cushman and Simonson (Jour. Pal., vol. 18, 1944, p. 201, pl. 34, fig. 1) are also probably to be placed in this species.

Genus EPONIDES Montfort, 1808

EPONIDES MINIMUS Cushman (Pl. 15, fig. 12)

(For references, see Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 5, p. 103.)

This species is widely distributed in the upper Eocene. It has already been recorded from the Helmick formation and the specimens from the Toledo formation are identical.

Family CASSIDULINIDAE

Genus CASSIDULINA d'Orbigny, 1826

CASSIDULINA GLOBOSA Hantken (Pl. 16, fig. 3)

(For references and figures, see Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 4, p. 79, pl. 10, fig. 10; pt. 5, p. 103, pl. 12, fig. 14.)

Specimens of this species, which is widely distributed in the Eocene, occur in the Toledo formation. It has already been recorded from the lower part of the Coaledo formation and the Helmick formation.

Family ANOMALINIDAE

Genus CIBICIDES Montfort, 1808

CIBICIDES WARRENI Cushman and R. E. and K. C. Stewart (Pl. 16, fig. 5)

Cibicides warreni Cushman and R. E. and K. C. Stewart, Bull. No. 36, Oregon Dept. Geol. and Min. Ind., 1947 (1948), pt. 5, p. 104, pl. 13, fig. 11.

Specimens of this species recently described from the Helmick formation occur in typical form in the Toledo formation.

CIBICIDES HOWEI Cushman and Todd (Pl. 16, fig. 4)

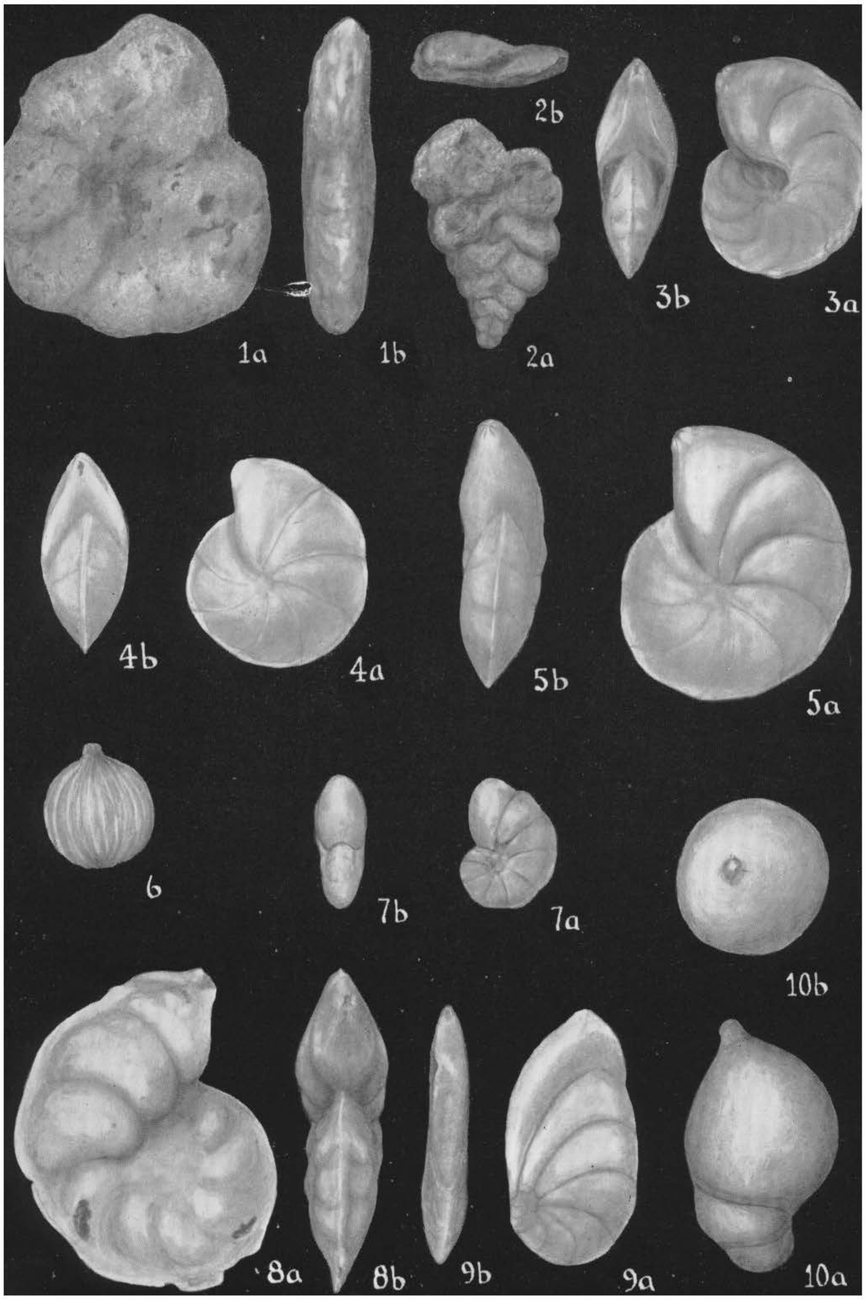
Cibicides howei Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 21, 1945, p. 20, pl. 4, fig. 21.

Specimens from the Toledo formation are very similar to the types of this species described from the Eocene of Alabama.

Explanation of Plate 14

Fig.		Page
1.	*Haplophragmoides* sp. X 70. *a,* side view; *b,* peripheral view	129
2.	*Textularia* ? sp. X 70. *a,* front view; *b,* apertural view	129
3.	*Robulus chiranus* Cushman and Stone. X 70. *a,* side view; *b,* apertural view	130
4, 5.	*Robulus inornatus* (d'Orbigny). X 70. *a, a,* side views; *b, b,* apertural views	130
6.	*Lagena* cf. *costata* (Williamson). X 70.	132
7.	*Nonion florinense* Cole. X 70. *a,* side view; *b,* peripheral view	132
8.	*Robulus welchi* Church. X 70. *a,* side view; *b,* apertural view	130
9.	*Planularia tolmani* Cushman and Simonson. X 70. *a,* side view; *b,* peripheral view	130
10.	*Marginulina subbullata* Hantken. X 70. *a,* side view; *b,* apertural view	131

Figures drawn by Mrs. Vivian Clay.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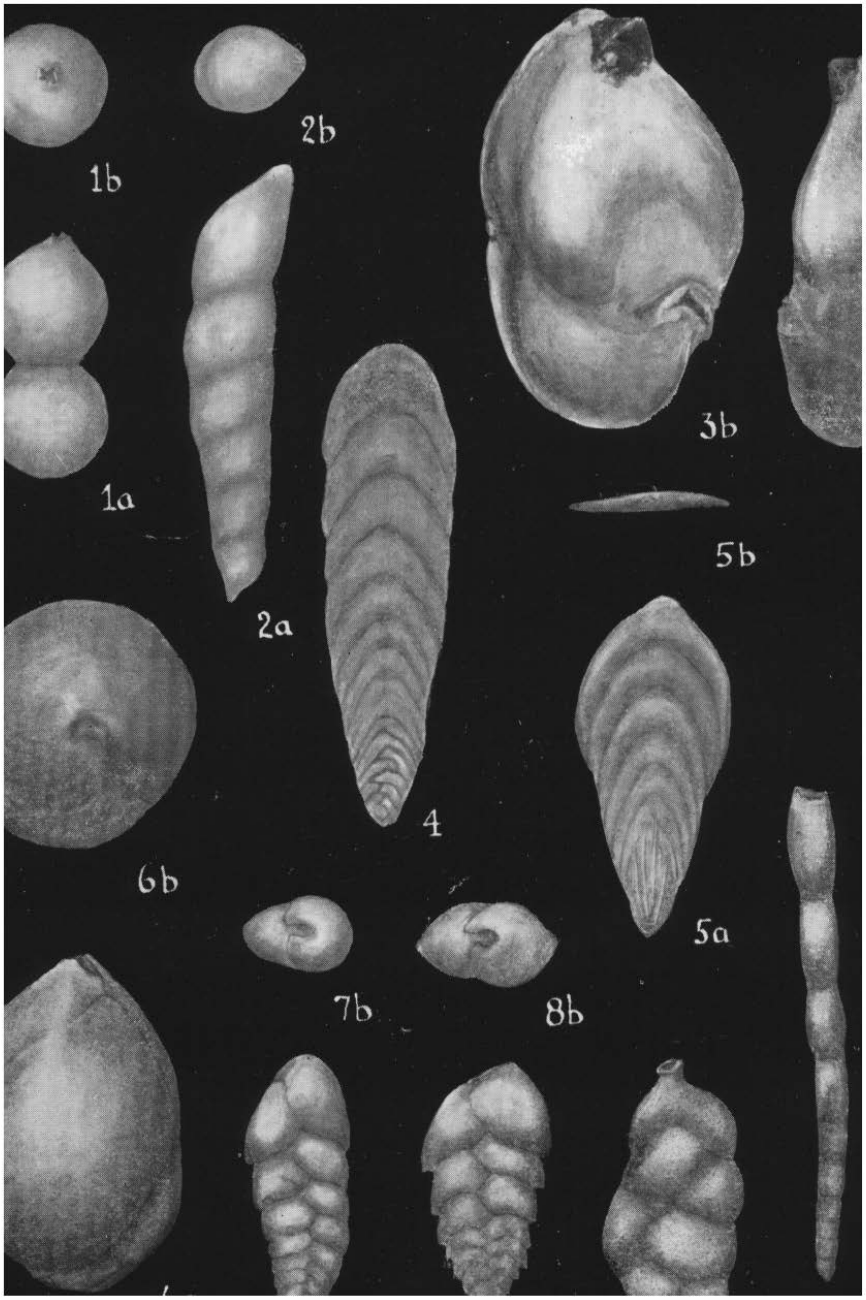
Explanation of Plate 15

Fig.		Page
1.	*Nodosaria chirana* Cushman and Stone. X 70. *a*, front view; *b*, apertural view	131
2.	*Dentalina* cf. *communis* d'Orbigny. X 70. *a*, side view; *b*, apertural view	131
3.	*Saracenaria* sp. X 70. *a*, side view; *b*, oblique front view	131
4.	*Plectofrondicularia vokesi* Cushman and R. E. and K. C. Stewart, n. sp. Holotype. X 70.	132
5.	*Plectofrondicularia searsi* Cushman and R. E. and K. C. Stewart. X 70. *a*, front view; *b*, apertural view	132
6.	*Globobulimina pacifica* Cushman, var. *oregonensis* Cushman and R. E. and K. C. Stewart. X 70. *a*, side view; *b*, apertural view	133
7.	*Bolivina basisenta* Cushman and Stone, var. *oregonensis* Cushman and R. E. and K. C. Stewart, n. var. X 70. Holotype. *a*, front view; *b*, apertural view	133
8.	*Bolivina basisenta* Cushman and Stone. X 70. *a*, front view; *b*, apertural view	133
9.	*Uvigerina garzaensis* Cushman and Siegfus. X 70.	133
10.	*Ellipsonodosaria* sp. A. X 70.	134
11.	*Ellipsonodosaria* sp. B. X 70.	134
12.	*Eponides minimus* Cushman. X 140. *a*, dorsal view; *b*, ventral view; *c*, peripheral view	135
13.	*Gyroidina scalata* Garrett. X 70. *a*, dorsal view; *b*, ventral view; *c*, peripheral view	134

Figures drawn by Mrs. Vivian Clay.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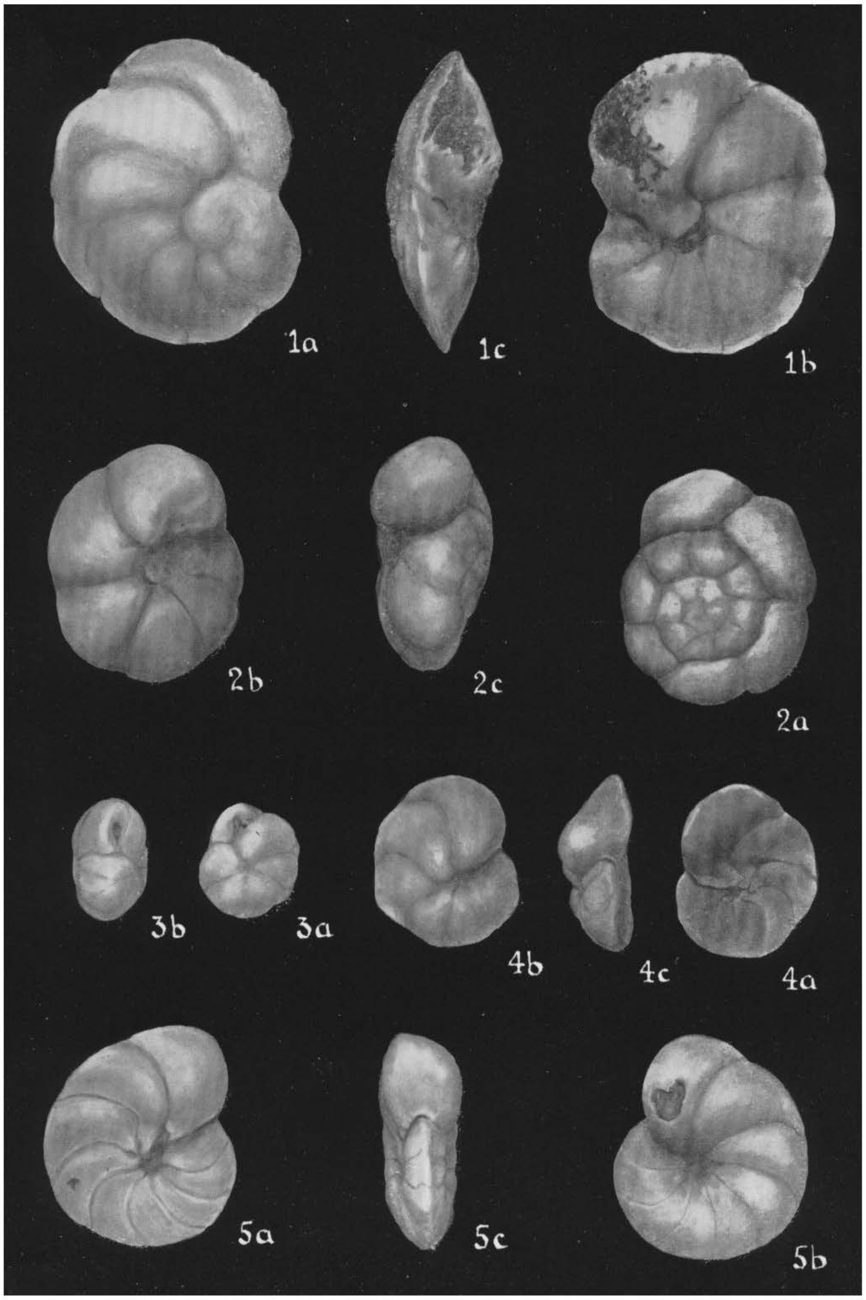
Explanation of Plate 16

Fig.		Page
1.	*Discorbis* cf. *samanicus* (W. Berry). X 70. *a,* dorsal view; *b,* ventral view; *c,* peripheral view	134
2.	*Valvulineria chirana* Cushman and Stone. X 70. *a,* dorsal view; *b,* ventral view; *c,* peripheral view	134
3.	*Cassidulina globosa* Hantken. X 70. *a,* ventral view; *b,* peripheral view	135
4.	*Cibicides howei* Cushman and Todd. X 70. *a,* dorsal view; *b,* ventral view; *c,* peripheral view	135
5.	*Cibicides warreni* Cushman and R. E. and K. C. Stewart. X 70. *a,* dorsal view; *b,* ventral view; *c,* peripheral view	135

Figures drawn by Mrs. Vivian Clay.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PART VII

QUINAULT PLIOCENE FORAMINIFERA FROM WESTERN WASHINGTON

QUINAULT PLIOCENE FORAMINIFERA
From Western Washington*

by

Joseph A. Cushman, Roscoe E. Stewart, and
Katherine C. Stewart

The Quinault formation occupies a small synclinal area on the Quinault Indian Reservation in the northwest corner of Grays Harbor County, Wash. It is best exposed along the coast of the Pacific Ocean, north and south of the mouth of Quinault River, from a point about a mile north of Cape Elizabeth southward to Point Grenville. Point Grenville itself is of basaltic rocks.

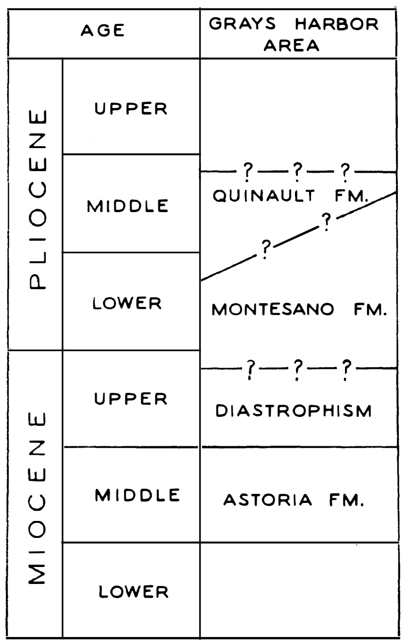


Figure 6. Chart showing Weaver's 1942 correlation of the Quinault formation.

Arnold[1] named and described the Quinault formation in 1906, giving the age as Pliocene. In 1916 Weaver[2] considered it to be upper Miocene, but in 1937[3] stated that it is probably late middle and early late Pliocene closely allied to the Merced formation of California. By 1942[4] Weaver appears to have revised

* Published by permission of the Director, U. S. Geological Survey.

[1] Arnold, Ralph, Geological reconnaissance of the coast of the Olympic Peninsula, Washington: Geol. Soc. America Bull., vol. 17, pp. 451–468, 1906.

[2] Weaver, C. E., Tertiary formations of western Washington: Washington Geol. Survey Bull. No. 13, pp. 225–226, pl. 26, 1916.

[3] Weaver, C. E., Tertiary stratigraphy of western Washington and northwestern Oregon: Washington Univ. (Seattle) Pub. in Geology, vol. 4, p. 192, 1937.

[4] Weaver, C. E., Paleontology of the marine Tertiary formations of Oregon and Washington: Washington Univ. (Seattle) Pub. in Geology, vol. 5, pt. III, correlation table facing p. 628, 1942.

his opinion again, for in a correlation chart published in December of that year he indicates a questionable range for the Quinault from the upper part of the lower Pliocene to the upper part of the middle Pliocene. Figure 6 is taken from his correlation chart solely for the purpose of illustrating the stratigraphic relationships indicated by Weaver in 1942.

The Foraminifera from the two samples used for this paper have a close affinity with the lower Pliocene (Repetto) phase of Lawson's Wildcat formation of northern California and are suggestive of the middle portion of that Repetto section, but this correlation should be considered somewhat tentative pending study of a more complete set of samples from the Quinault.

The two samples from which the Foraminifera recorded in this paper were obtained were collected by E. M. Baldwin and R. E. Stewart, of the Oregon State Department of Geology and Mineral Industries, at localities about a quarter of a mile apart along the coast in the S½ sec. 12, T. 21 N., R. 13 W., which is just south of the midpoint between Point Grenville and the mouth of Quinault River.

The occurrence of the Foraminifera in these samples is as follows:

Sample A

Bulimina (Desinobulimina) auriculata (Bailey)

Cassidulina californica Cushman and Hughes

Cibicides concentricus (Cushman), var. *washingtonensis* Cushman and R. E. and K. C. Stewart, n. var.

Cyclammina cf. *constrictimargo* R. E. and K. C. Stewart

Gaudryina pliocenica Cushman and R. E. and K. C. Stewart n. sp.

Globobulimina pacifica Cushman

Planulina ornata (d'Orbigny)

Sample B

Bolivina subadvena Cushman, var. *acuminata* Natland
Bulimina (Desinobulimina) auriculata (Bailey)
B. *fossa* Cushman and Parker
B. *pagoda* Cushman, var. *hebespinata* R. E. and K. C. Stewart
Cassidulina limbata Cushman and Hughes
C. *quadrata* Cushman and Hughes
Chilostomella cf. *czizeki* Reuss
Globobulimina pacifica Cushman
Nodogenerina sp. (Pl. 17, fig. 12)
Pseudoglandulina laevigata (d'Orbigny)
Pseudoparrella subperuviana (Cushman)
Pullenia cf. *bulloides* (d'Orbigny)
Quinqueloculina cf. *seminuda* Reuss
Sphaeroidina bulloides d'Orbigny
Uvigerina peregrina Cushman, var. *latalata* R. E. and K. C. Stewart
U. *senticosa* Cushman
U. *subperegrina* Cushman and Kleinpell
Valvulineria araucana (d'Orbigny)

Family LITUOLIDAE

Genus CYCLAMMINA H. B. Brady, 1876

CYCLAMMINA cf. CONSTRICTIMARGO R. E. and K. C. Stewart (Pl. 17, fig. 1)

Cyclammina constrictimargo R. E. and K. C. Stewart, Jour. Pal., vol. 4, 1930, p. 62, pl. 8, fig. 1.

This species was described from the Pliocene, lower part of the Pico formation, of California. The specimens from the Quinault formation are not very well preserved but, as far as the characters can be distinguished, seem to be similar to the type of this species with which they have been compared.

Family VERNEUILINIDAE

Genus GAUDRYINA d'Orbigny, 1839

GAUDRYINA PLIOCENICA Cushman and R. E. and K. C. Stewart, n. sp. (Pl. 17, fig. 2)

Test elongate, early triangular portion pointed at the apex, the sides slightly convex, periphery subacute to slightly rounded, biserial portion forming a large part of the test, sides flat, periphery angled, slightly rounded; chambers only slightly inflated, about 3 or 4 pairs in the adult biserial portion; sutures rather indistinct, very slightly depressed; wall finely arenaceous with a large proportion of cement, the exterior smooth and polished; aperture a low opening at the base of the apertural face of the last-formed chamber. Length 1.35 mm.; breadth 0.60 mm.; thickness 0.50 mm.

Holotype (Cushman Coll. No. 56688) and paratypes (Oregon State Dept. Geology and Min. Industries Coll. No. 252 and Stewart Coll. No. 252) from the Pliocene, Quinault formation, near mouth of Quinault River, Quinault Indian Reservation, Grays Harbor County, Wash.

This species differs from *G. arenaria* Galloway and Wissler in the very finely arenaceous wall, smooth surface, larger size, and broader test, and from *G. triangularis* Cushman in the smooth surface, less inflated chambers, and less depressed sutures.

Family MILIOLIDAE

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA cf. SEMINUDA Reuss (Pl. 17, fig. 3)

A few specimens somewhat resembling this species occurred in the Quinault material. It was also recorded from the Pliocene of Timms Point, Calif.

Family LAGENIDAE

Genus PSEUDOGLANDULINA Cushman, 1929

PSEUDOGLANDULINA LAEVIGATA (d'Orbigny) (Pl. 17, fig. 4)

Very rare specimens similar to the one figured may be referred to d'Orbigny's species.

Family HETEROHELICIDAE

Genus NODOGENERINA Cushman, 1927

NODOGENERINA sp. (Pl. 17, fig. 12)

The specimen figured is from the Quinault material and seems to belong to this genus but specimens were too few and not well enough preserved to warrant a specific determination.

Family BULIMINIDAE

Genus BULIMINA d'Orbigny, 1826

BULIMINA FOSSA Cushman and Parker (Pl. 17, fig. 5)

Bulimina fossa Cushman and Parker, Contr. Cushman Lab. Foram. Res., vol. 14, 1938, p. 56, pl. 9, fig. 10; U. S. Geol. Survey Prof. Paper 210-D, 1947, p. 117, pl. 27, fig. 11.

This species has been previously recorded only from the Pliocene of California. The Quinault specimens are typical.

BULIMINA PAGODA Cushman, var. HEBESPINATA R. E. and K. C. Stewart (Pl. 17, fig. 11)

Bulimina pagoda Cushman, var. *hebespinata* R. E. and K. C. Stewart, Journ. Pal., vol. 4, 1930, p. 63, pl. 8, fig. 3.—Cushman and Parker, Contr. Cushman Lab. Foram. Res., vol. 14, 1938, p. 55, pl. 9, figs. 6, 7; U. S. Geol. Survey Prof. Paper 210-D, 1947, p. 117, pl. 27, figs. 9, 10.

This variety also has been previously recorded only from the Pliocene of California. The specimens from the Quinault formation have been compared with the types and seem identical.

BULIMINA (DESINOBULIMINA) AURICULATA (Bailey) (Pl. 17, fig. 6)

Bulimina auriculata Bailey, Smithsonian Contrib., vol. 2, Art. 3, 1851, p. 12, pl., figs. 25-27.

Bulimina (Desinobulimina) auriculata Cushman and Parker, Contr. Cushman Lab. Foram. Res., vol. 16, 1940, p. 20, pl. 3, figs. 19-21; l. c., Special Publ. 12, 1944, p. 28, pl. 3, fig. 48.—Cushman and Todd, l. c., Special Publ. 15, 1945, p. 40, pl. 6, fig. 14.—Cushman and Gray, l. c., Special Publ. 19, 1946, p. 29.—Cushman and Parker, U. S. Geol. Survey Prof. Paper 210-D, 1947, p. 129, pl. 29, figs. 22-24.

Bulimina pyrula Flint (not d'Orbigny), Ann. Rep. U. S. Nat. Mus., 1897 (1899), p. 290, pl. 36, figs. 4, 5.—Cushman, Bull. 104, U. S. Nat. Mus., pt. 3, 1922, p. 101, pl. 20, fig. 1.

Bulimina ovata Bagg (not d'Orbigny), Bull. 513, U. S. Geol. Survey, 1912, p. 38.—Cushman, Contr. Cushman Lab. Foram. Res., vol. 6, 1930, p. 56, pl. 7, fig. 22.

Numerous specimens in the Quinault material seem to belong to this species recorded from the Pliocene of Timms Point, Calif., and are also reported living off the west coast of America as well as in the western Atlantic.

Genus GLOBOBULIMINA Cushman, 1927

GLOBOBULIMINA PACIFICA Cushman (Pl. 17, fig. 7)

(For earlier references, see Cushman and Gray, Special Publ. 19, Cushman Lab. Foram. Res., 1946, p. 29.)—Cushman and Parker, U. S. Geol. Survey Prof. Paper 210-D, 1947, p. 134, pl. 29, fig. 37.

This species has been recorded from Eocene to Recent. It is common along the western coast of America and the specimens from our Quinault material seem typical.

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA SUBADVENA Cushman, var. ACUMINATA Natland (Pl. 17, fig. 10)

Bolivina subadvena Cushman, var. *serrata* Natland (not Chapman, 1892), Bull. Scripps Instit. Oceanography, Tech. Ser., vol. 4, No. 5, 1938, p. 145, pl. 5, figs. 8, 9.—Cushman and McCulloch, Allan Hancock Pacific Exped., vol. 6, No. 4, 1942, p. 213, pl. 26, fig. 14; pl. 27, figs. 1, 2.

Bolivina subadvena Cushman, var. *acuminata* Natland, Ms. in Cushman and Gray, Special Publ. 19, Cushman Lab. Foram. Res., 1946, p. 34, pl. 5, fig. 46.

This variety described from off the coast of California and recorded from the Pliocene of Timms Point, Calif., occurs in typical form in the Quinault material.

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA SUBPEREGRINA Cushman and Kleinpell (Pl. 17, fig. 8)

Uvigerina subperegrina Cushman and Kleinpell, Contr. Cushman Lab. Foram. Res., vol. 10, 1934, p. 12, pl. 2, figs. 9-11.—Woodring, Bramlette, and Kleinpell, Bull. Amer. Assoc. Petr. Geol., vol. 20, 1936, pp. 141, 145 (lists).—Kleinpell, Miocene Stratig. Calif., 1938, p. 298.—Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 17, 1941, p. 46, pl. 13, figs. 16, 17.—Cushman and Gray, l. c., Special Publ. 19, 1946, p. 36, pl. 6, fig. 14.

Most of the records for this species are from the Miocene but it has recently been recorded from the Pliocene of Timms Point, Calif., and our Quinault material seems typical.

UVIGERINA PEREGRINA Cushman, var. LATALATA R. E. and K. C. Stewart (Pl. 17, fig. 9)

Uvigerina peregrina Cushman, var. *latalata* R. E. and K. C. Stewart, Journ. Pal., vol. 4, 1930, p. 66, pl. 8, fig. 7.—Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 17, 1941, p. 76, pl. 20, figs. 1-3.—Hanna and Hertlein, Calif. Div. Mines, Bull. 118, pt. 2, 1941, p. 180, fig. 67 [plate], fig. 43.

The types of this variety are from the Pliocene, upper part of the Pico formation, of California. Specimens from the Quinault formation (Pliocene) are entirely typical.

UVIGERINA SENTICOSA Cushman (Pl. 17, fig. 13)

Uvigerina senticosa Cushman, Bull. Scripps Instit. Oceanography, Tech. Ser., vol. 1, No. 10, 1927, p. 159, pl. 3, fig. 14.—Cushman and Moyer, Contr. Cushman Lab. Foram. Res., vol. 6, 1930, p. 58.—Cushman and

R. E. and K. C. Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 68, pl. 5, fig. 9.

This species was described from Recent material from the eastern Pacific and recorded also from the Pliocene of California. There are other records in addition to those given above but they do not seem to refer to the same species. Our specimens from the Quinault formation (Pliocene) seem typical.

Family ROTALIIDAE

Genus VALVULINERIA Cushman, 1926

VALVULINERIA ARAUCANA (d'Orbigny) (Pl. 17, fig. 14)

Rosalina araucana d'Orbigny, Voy. Amer. Merid., vol. 5, pt. 5, "Foraminifères," 1839, p. 44, pl. 6, figs. 16-18.

Valvulineria araucana Cushman, Bull. Scripps Instit. Oceanography, Tech. Ser., vol. 1, No. 10, 1927, p. 160, pl. 4, figs. 7, 8.—Cushman and Moyer, Contr. Cushman Lab. Foram. Res., vol. 6, 1930, p. 60, pl. 8, fig. 10.—R. E. and K. C. Stewart, Bull. Amer. Assoc. Petr. Geol., vol. 14, 1930, p. 1448.—Cushman and R. E. and K. C. Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 71, pl. 6, fig. 4.

The types of this species are from off the coast of Chile; this species is also recorded from off the California coast and from the Pliocene of California. There are other records either without figures or not entirely typical. Rare specimens from the Quinault formation (Pliocene) apparently belong in this species.

Family CASSIDULINIDAE

Genus PSEUDOPARRELLA Cushman and ten Dam, 1948

PSEUDOPARRELLA SUBPERUVIANA (Cushman) (Pl. 18, fig. 1)

Pulvinulinella subperuviana Cushman, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 3, 1926, p. 63, pl. 9, fig. 9.—Cushman and R. E. and K. C. Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 73.—Cushman, Special Publ. 4, Cushman Lab. Foram. Res., 1933, pl. 26, fig. 2.—Woodring, Bramlette, and Kleinpell, Bull. Amer. Assoc. Petr. Geol., vol. 20, 1936, p. 133 (list).—Kleinpell, Miocene Stratig. Calif., 1938, p. 330.—Cushman, Foraminifera, 3rd ed., 1940, pl. 26, fig. 2.

Pseudoparrella subperuviana Cushman and Stevenson, Contr. Cushman Lab. Foram. Res., vol. 24, 1948, p. 65, pl. 10, figs. 24, 25.

This species is known from the Miocene and Pliocene of California. A very few specimens from the Quinault formation (Pliocene) apparently belong here.

Genus CASSIDULINA d'Orbigny, 1826

CASSIDULINA CALIFORNICA Cushman and Hughes (Pl. 18, fig. 3)

Cassidulina californica Cushman and Hughes, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, 1925, p. 12, pl. 2, fig. 1.—Cushman, l. c., vol. 1, pt. 2, 1925, p. 40; vol. 1, pt. 3, 1925, p. 54, pl. 9, figs. 5, 6.—Galloway and Wissler, Journ. Pal., vol. 1, 1927, p. 78, pl. 12, figs. 6, 7.—Cushman and R. E. and K. C. Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 75, pl. 6, fig. 8.—Cushman, Special Publ. 4, Cushman Lab. Foram. Res., 1933, pl. 26, fig. 3; Foraminifera, 3rd Ed., 1940, pl. 26, fig. 3.—Coryell and Mossman, Journ. Pal., vol. 16, 1942, p. 243, pl. 36, fig. 47.—Cushman and Gray, Special Publ. 19, Cushman Lab. Foram. Res., 1946, p. 39, pl. 7, fig. 10.—Cushman and Todd, Special Publ. 21, 1947, p. 22, pl. 4, fig. 2.

This species was described from the Pliocene of Timms Point, Calif. It is found also in the Pliocene of Panama, and Pleistocene of Lomita Quarry, Calif.; it lives in Queen Charlotte Sound, British Columbia, and off the coast of Washington. Very typical specimens occur in the Quinault formation (Pliocene).

CASSIDULINA QUADRATA Cushman and Hughes (Pl. 18, fig. 4)

Cassidulina subglobosa H. B. Brady, var. *quadrata* Cushman and Hughes, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, 1925, p. 15, pl. 2, fig. 7.—Cushman, l. c., vol. 1, pt. 3, 1925, p. 54, pl. 9, figs. 1, 2.—R. E. and K. C. Stewart, Bull. Amer. Assoc. Petr. Geol., vol. 14, 1930, p. 1448.—Coryell and Rivero, Journ. Pal., vol. 14, 1940, p. 342, pl. 44, figs. 16, 28.

Cassidulina quadrata Galloway and Wissler, Journ. Pal., vol. 1, 1927, p. 79, pl. 12, fig. 8.—Kleinpell, Miocene Stratig. Calif., 1938, p. 336.—Cushman and Gray, Special Publ. 19, Cushman Lab. Foram. Res., 1946, p. 42, pl. 7, figs. 11-13.

This species is known from the Pleistocene, Pliocene, and Miocene of California and recorded from the Miocene of Haiti. Specimens are fairly common in the Quinault formation (Pliocene) but are all rather small.

CASSIDULINA LIMBATA Cushman and Hughes (Pl. 18, fig. 2)

Cassidulina limbata Cushman and Hughes, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, 1925, p. 12, pl. 2, fig. 2.—Cushman, l. c., vol. 1, pt. 3, 1925, p. 55, pl. 9, figs. 7, 8; vol. 2, pt. 3, 1926, p. 56; Bull. Scripps Instit. Oceanography, Tech. Ser., vol. 1, No. 10, 1927, p. 166, pl. 6, fig. 4.—Galloway and Wissler, Jour. Pal., vol. 1, 1927, p. 78, pl. 12, fig. 12.—Cushman and Moyer, Contr. Cushman Lab. Foram. Res., vol. 6, 1930, p. 61.—Cushman and R. E. and K. C. Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 74, pl. 6, fig. 7.—Kleinpell, Miocene Stratig. Calif., 1938, p. 333, pl. 9, fig. 21.—Cushman and Gray, Special Publ. 19, Cushman Lab. Foram. Res., 1946, p. 42, pl. 7, figs. 14-16.—Cushman and Todd, Special Publ. 21, 1947, p. 22, pl. 4, fig. 4.

This species was described from the Pliocene of Timms

Point, Calif., and is recorded from the Miocene and Pleistocene of California; it lives off the coasts of California and Washington. It is rather rare in the Quinault formation (Pliocene) and the specimens are rather smaller than the average.

Family CHILOSTOMELLIDAE

Genus CHILOSTOMELLA Reuss, 1850

CHILOSTOMELLA cf. CZIZEKI Reuss (Pl. 18, fig. 5)

Specimens of this genus have been very rarely recorded from the Tertiary of the Pacific coast. The figured specimen from the Quinault formation (Pliocene) seems more nearly allied to this species of Reuss than to any other described form.

Genus PULLENIA Parker and Jones, 1862

PULLENIA cf. BULLOIDES (d'Orbigny) (Pl. 18, fig. 6)

(For earlier references, see Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 19, 1943, p. 13, pl. 2, figs. 15-18.)

Rare specimens in the Quinault formation (Pliocene) seem related to this species which has been recorded from the Miocene and Pliocene of California.

Genus SPHAEROIDINA d'Orbigny, 1826

SPHAEROIDINA BULLOIDES d'Orbigny (Pl. 18, fig. 7)

This widely distributed species has been recorded from the Pliocene and Miocene of California. Typical specimens occur in the Quinault formation.

Family ANOMALINIDAE

Genus PLANULINA d'Orbigny, 1826

PLANULINA ORNATA (d'Orbigny) (Pl. 18, fig. 9)

(For references, see Cushman and Gray, Special Publ. 19, Cushman Lab. Foram. Res., 1946, p. 44, pl. 8, figs. 9-12.)

This species was described from off the coast at Valparaiso, Chile, and has been recorded from off the coast of California, also from the Pleistocene, Pliocene, and Miocene of California and the Pliocene of Panama. The Quinault specimens are fairly typical.

Genus CIBICIDES Montfort, 1808

CIBICIDES CONCENTRICUS (Cushman), var. WASHINGTONENSIS Cushman and R. E. and K. C. Stewart, n. var. (Pl. 18, fig. 8)

Variety differing from the typical form in the more nearly circular test and the lobular projections near the umbilicus less definite. Diameter 1.00 mm.; thickness 0.35 mm.

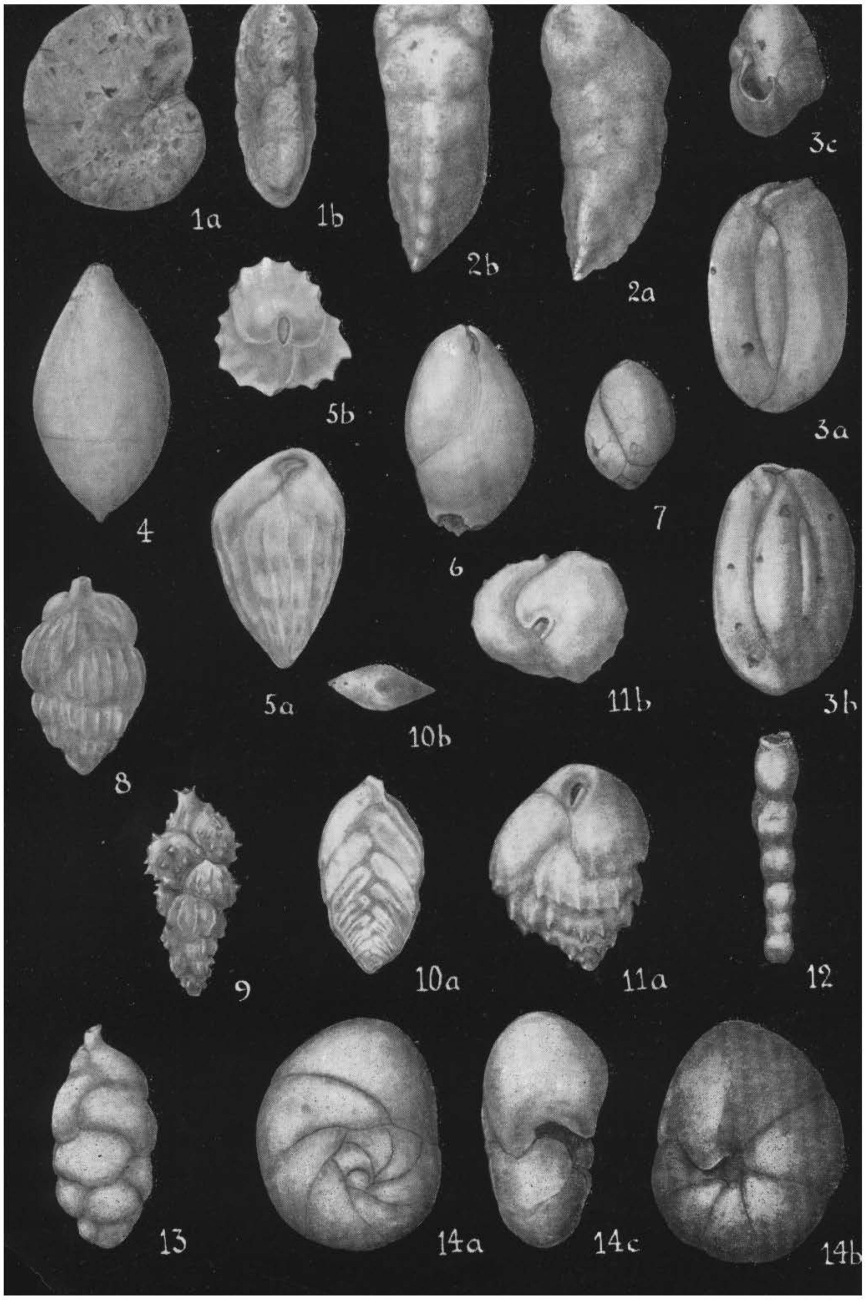
Holotype of variety (Cushman Coll. No. 56709) and paratypes (Oregon State Dept. Geology and Min. Industries Coll. No. 273 and Stewart Coll. No. 273) from the Pliocene, Quinault formation, near mouth of Quinault River, Quinault Indian Reservation, Grays Harbor County, Wash.

There are a number of specimens of this variety very much like the type species but differing as noted. The records for the typical form are all from the western Atlantic region ranging from Miocene to Recent.

Explanation of Plate 17

Fig.		Page
1.	*Cyclammina* cf. *constrictimargo* R. E. and K. C. Stewart. X 35. *a*, side view; *b*, peripheral view	150
2.	*Gaudryina pliocenica* Cushman and R. E. and K. C. Stewart, n. sp. X 35. Holotype. *a*, front view; *b*, side view	150
3.	*Quinqueloculina* cf. *seminuda* Reuss. X 35. *a*, *b*, opposite sides; *c*, apertural view	151
4.	*Pseudoglandulina laevigata* (d'Orbigny). X 70.	151
5.	*Bulimina fossa* Cushman and Parker. X 140. *a*, front view; *b*, apertural view	152
6.	*Bulimina (Desinobulimina) auriculata* (Bailey). X 35.	152
7.	*Globobulimina pacifica* Cushman. X 35.	152
8.	*Uvigerina subperegrina* Cushman and Kleinpell. X 70.	153
9.	*Uvigerina peregrina* Cushman, var. *latalata* R. E. and K. C. Stewart. X 70.	153
10.	*Bolivina subadvena* Cushman, var. *acuminata* Natland. X 70. *a*, front view; *b*, apertural view	153
11.	*Bulimina pagoda* Cushman, var. *hebespinata* R. E. and K. C. Stewart. X 70. *a*, front view; *b*, apertural view	152
12.	*Nodogenerina* sp. X 35.	151
13.	*Uvigerina senticosa* Cushman. X 70.	153
14.	*Valvulineria araucana* (d'Orbigny). X 140. *a*, dorsal view; *b*, ventral view; *c*, peripheral view	154

Figures drawn by Mrs. Vivian Clay.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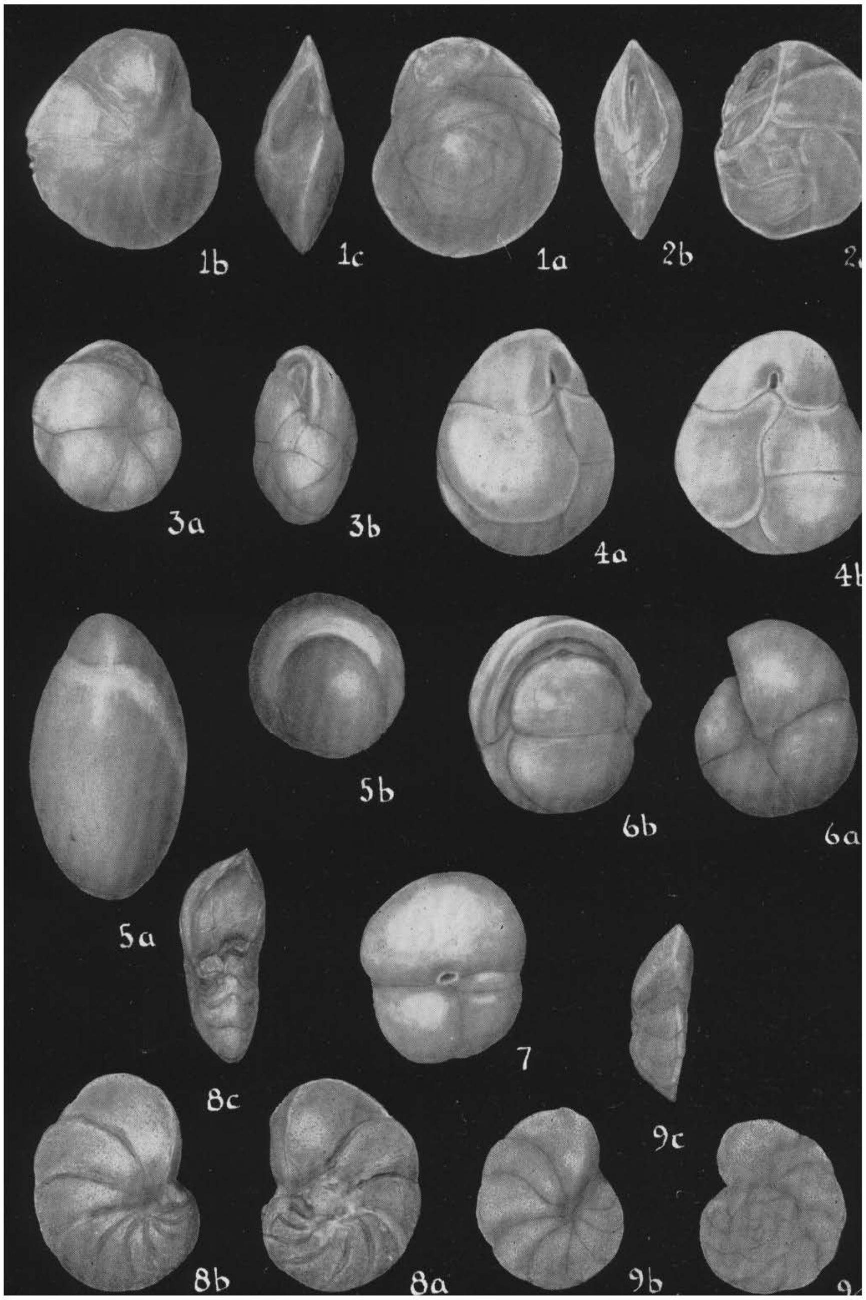
11a
11b
12
13
14a
14c
14b

Explanation of Plate 18

Fig.		Page
1.	*Pseudoparrella subperuviana* (Cushman). X 35. *a*, dorsal view; *b*, ventral view; *c*, peripheral view	154
2.	*Cassidulina limbata* Cushman and Hughes. X 70. *a*, side view; *b*, apertural view	155
3.	*Cassidulina californica* Cushman and Hughes. X 35. *a*, side view; *b*, apertural view	154
4.	*Cassidulina quadrata* Cushman and Hughes. X 140. *a*, side view; *b*, apertural view	155
5.	*Chilostomella* cf. *czizeki* Reuss. X 70. *a*, side view; *b*, end view	156
6.	*Pullenia* cf. *bulloides* (d'Orbigny). X 140. *a*, side view; *b*, apertural view	156
7.	*Sphaeroidina bulloides* d'Orbigny. X 140.	156
8.	*Cibicides concentricus* (Cushman), var. *washingtonensis* Cushman and R. E. and K. C. Stewart, n. var. X 35. Holotype. *a*, dorsal view; *b*, ventral view; *c*, peripheral view	157
9.	*Planulina ornata* (d'Orbigny). X 35. *a*, dorsal view; *b*, ventral view; *c*, peripheral view	156

Figures drawn by Mrs. Vivian Clay.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PART VIII

LOCAL RELATIONSHIPS
OF THE
MOLLUSCA OF THE WILDCAT COAST SECTION
HUMBOLDT COUNTY, CALIFORNIA
WITH
RELATED DATA
ON THE
FORAMINIFERA AND OSTRACODA

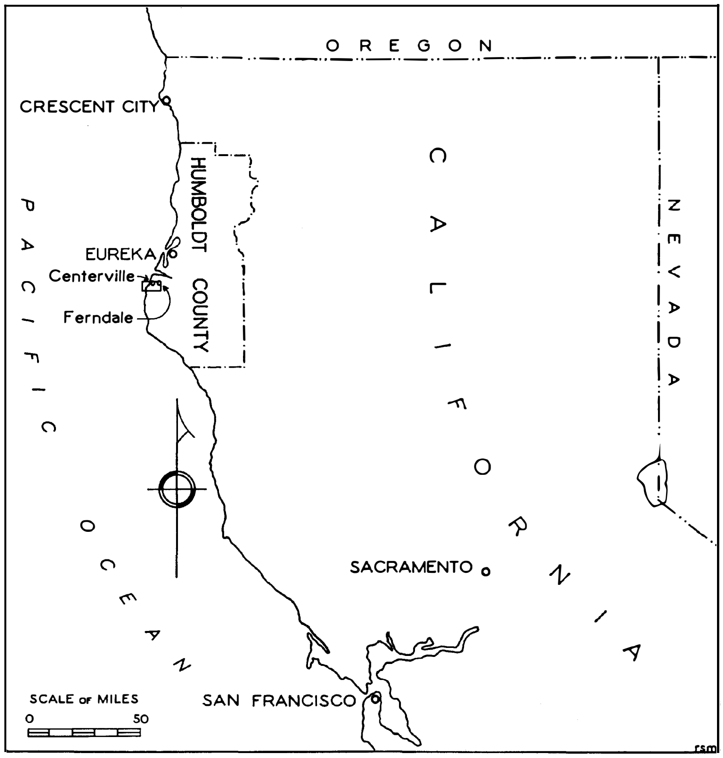

Figure 7. Map of northern California showing Humboldt County and, within it, the general area of the Wildcat coast section and Lawson's type section of the Wildcat series (See also Plate 19).

CONTENTS

ABSTRACT 169

INTRODUCTION 170

Preliminary field work 170

Purpose of the present study 171

Acknowledgments 172

THE WILDCAT SERIES 173

Distribution 173

Review of previous literature 174

THE WILDCAT COAST SECTION 186

General description 186

Description of the lithologic zones 186

The molluscan fauna 188

Related data on the Foraminifera and Ostracoda 196

BIBLIOGRAPHY 204

ILLUSTRATIONS

Figure 5 Map showing sample localities for Bulletin 36, Parts VI, VII, and VIII 116

Figure 7 Map of northern California showing Humboldt County and, within it, the general area of the Wildcat coast section and Lawson's type section of the Wildcat series (See also Plate 19) 166

Table 1 Table showing occurrences of molluscan species in the faunal zones and subzones 193

Plate 19 Map showing locations of the Wildcat coast section, Lawson's type section of the Wildcat series, and Hanna's Cretaceous fossil locality .... In pocket

Plate 20 Range chart, Wildcat coast section Mollusca and Cirripedia .... In pocket

Plate 21 Graphic representation of order of first and last appearance of species of Mollusca, Foraminifera, and Crustacea in the Wildcat coast section .... In pocket

Plate 22 Range chart, Wildcat coast section Foraminifera and Ostracoda .... In pocket

LOCAL RELATIONSHIPS OF THE MOLLUSCA OF THE WILDCAT COAST SECTION, HUMBOLDT COUNTY, CALIFORNIA

With Related Data on the Foraminifera and Ostracoda

by

Roscoe E. Stewart and Katherine C. Stewart

ABSTRACT

The Wildcat series of northern California and the Quinault formation of western Washington have a very important bearing upon the Pliocene paleontology and stratigraphy of Oregon, for they are the nearest Pliocene formations to the south and the north from which detailed records of both Foraminifera and Mollusca are available. Mollusca are common in the Pliocene of all three states, but the writers know of no occurrence of Foraminifera in the Pliocene of Oregon. Therefore, if Pliocene Foraminifera are found in Oregon, their correlation will probably be determined largely by comparison with those of the Quinault and the Wildcat.

The Wildcat series is represented by scattered Tertiary remnants which lie in troughs formed by folding and faulting of beds whose age is generally considered to be not younger than Cretaceous. The largest of these remnants covers an area of some 350 square miles in the vicinity of the lower courses of Eel and Van Duzen rivers, and it extends northward from the north flank of Bear River Ridge to the northern end of Humboldt Bay, forming a broad westward-plunging syncline whose axis passes approximately through the mouth of Eel River and the town of Fortuna.

The Wildcat coast section, comprising about 6,500 feet of soft, fossiliferous siltstones, claystones, shales, sandy shales, fine-grained sandstones, and, at the top of the section, unfossiliferous coarse sands and gravels, is exposed in sea-cliffs cut in the south flank of this syncline about 18 miles south of Eureka and 3 miles west of Lawson's type section of the "Wild-cat Series."

This section is divided into 16 zones for lithologic description.

On the basis of molluscan ranges (Plate 20) the Wildcat coast section is divided into lower, middle, and upper barren zones separated by lower and upper faunal zones. Four subzones, one within the lower faunal zone and three within the upper faunal zone, are distinguished by species, the upper, lower, or both limits of whose ranges are contained within them. Every predominantly sandy zone in the section is the scene of some marked change in the molluscan fauna, namely, the appearance, disappearance, or both the appearance and disappearance of several species (one of the subzones) or the disappearance of all species (one of the barren zones).

On the basis of rate of faunal change during the deposition of the Wildcat coast section (Plate 21), it is seen that with regard to both

appearance and disappearance of species the molluscan fauna and the microfauna undergo their greatest changes in the lower and upper portions of the section, with but little change in the middle division.

The Foraminifera of the upper 2,500 feet of the Wildcat coast section show close affinity with those of the Pleistocene Las Posas formation and the Pleistocene and Pliocene Santa Barbara formation of the Ventura-Santa Barbara area in southern California, and with those of the Pliocene type Merced near San Francisco. It is believed that these species indicate upper and perhaps some middle Pliocene deposition for the upper Wildcat and that they appeared later in uppermost Pliocene and Pleistocene time in the more southerly Ventura-Santa Barbara area. If any of the Wildcat coast section is Pleistocene in age, it is probably the uppermost 480 feet of coarse sand and gravel in which no fossils were found.

The Foraminifera from the lower 2,300 feet of the Wildcat coast section correlate with those of the lower Pliocene Repetto formation of southern California and are believed to represent approximately equivalent time of deposition.

The depositional history of the sediments exposed in the Wildcat coast section appears to have been one of generally decreasing depths from a beginning possibly in excess of 8,000 feet for the lowermost shales to very shallow, near-shore, or perhaps even non-marine conditions for some of the sands and gravels in the upper 480 feet of the section.

INTRODUCTION

Preliminary Field Work

In 1927 the writers spent six months in a geologic reconnaissance of that portion of Humboldt County, California, which lies in the vicinity of Mattole, Bear, Eel, Van Duzen, and Mad rivers and the streams which flow into Humboldt Bay. Much of the time was devoted to a study of the Wildcat series, which is exposed in various localities from Mad River near Eureka southward to Garberville and Briceland. A microfauna obtained from forty-eight scattered localities was made the basis of a paper published in 1930 (Cushman, Stewart, and Stewart, 1930).

In the summer of 1931 fifteen days were devoted to a more detailed study of the section exposed along the coast between Oil Creek and Centerville (Figure 7 and Plate 19). This section was measured, and both Mollusca and microfossils were collected wherever available throughout its entire extent. All fossil localities, lithologic divisions, and dip and strike stations were tied in to a traverse which was run along the coast with a 500-foot steel tape and a Brunton compass. The fauna collected at that time, together with a lesser amount of material collected in 1927, forms the basis of the present paper, which is a revision of a thesis presented in partial fulfillment of requirements for the degrees of Master of Science and Master of Arts at the University of Southern California in February 1935 (Stewart and Stewart, 1935).

Purpose of the Present Study

Gabb, Lawson, Merriam, Arnold, Martin, Smith, and others have recognized the Pliocene age of the Wildcat series and the very definite northern aspect of its molluscan fauna. Lawson, on the basis of his personal examination of the series and Merriam's interpretation of his fossils, believed the Wildcat to be correlative with the Merced series. Arnold, Martin, and Smith believed that Wildcat time might have included both Merced and Purisima time, and there was some idea that the Wildcat extended from uppermost Miocene to rather late Pliocene.

There is nothing in the material upon which this paper is based to contradict these opinions, and, except by way of reviewing the literature, it is not the purpose of the present paper to restate facts and evidence which previous authors have so ably presented.

To the best of the writers' knowledge, however, nothing in detail has ever been published on the ranges and the association or grouping (faunal assemblage) of the molluscan species within the Wildcat coast section, or on the relationship between the molluscan fauna and the microfauna of the Wildcat. The purpose of the present paper is to record such data.

The Wildcat and Quinault formations have a very important bearing upon the Pliocene paleontology and stratigraphy of Oregon, for they are the nearest Pliocene formations to the south and the north from which Foraminifera as well as megascopic fossils have been recorded (Cushman, Stewart, and Stewart, 1949). The writers know of no occurrence of Foraminifera in the Pliocene of Oregon, but if Pliocene Foraminifera are discovered here their correlation will be determined largely by comparison with the Foraminifera of the Quinault formation of Washington and the Wildcat formation of California.

Acknowledgments

The writers are indebted to a number of persons for courtesies and assistance in connection with the work here presented. Especially helpful have been the advice and suggestions of Dr. A. J. Tieje of the University of Southern California, under whose direction the paper has been prepared. Drs. Thomas Clements and Francis Marsh Baldwin have read the manuscript and offered valuable suggestions. Access to the fossil collection of Stanford University was arranged through the courtesy of the late Dr. J. P. Smith. Drs. R. W. Chaney and B. L. Clark kindly made available the collection of the University of California, and Dr. F. E. Turner assisted in its examination. Dr. W. P. Woodring assisted in the examination of specimens from the collection of the United State National Museum. Several rare publications were loaned by Dr. U. S. Grant IV of the University of California at Los Angeles. To all of these the writers wish to express their most sincere appreciation.

The above acknowledgments are taken without revision from the original thesis. With them should have been included the names of Mr. Frank E. Herrick and Mr. Fred Kay of Eureka, Mr. Norman Graham of Arcata, and Mr. L. J. Stone of Waddington, who gave invaluable assistance as guides in the field.

The manuscript of the present paper has been read and criticized by Dr. E. L. Packard of Oregon State College, Mr. H. J. Buddenhagen of the Shell Oil Company, and Mr. F. W. Libbey, Mr. H. M. Dole, and Mrs. Lillian F. Owen of the Oregon State Department of Geology and Mineral Industries. Mr. Ralph Mason of the State Department assisted with the revision of plates 20, 21, and 22, and with the making of figures 5 and 7 and plate 19. Several publications were loaned by Mr. Parke Snavely, Jr., of the United States Geological Survey. Their kind assistance and helpful suggestions are gratefully acknowledged by the writers.

THE WILDCAT SERIES

Distribution

The recorded Tertiary of Humboldt County is represented by scattered remnants which lie in troughs formed by the folding and faulting of beds whose age is generally considered to be not younger than Cretaceous.

Fossil evidence for the Cretaceous age of these beds is very meager. For the following record of an occurrence of such evidence near the base of the Wildcat coast section the writers are indebted to Dr. G. D. Hanna,[1] Curator of Paleontology at the California Academy of Sciences.

> In June 1928, Mr. Downs McCloskey and I made a brief excursion to the coast of Humboldt County in the vicinity of the mouth of Bear River. Passing north from the mouth of the river the first thousand feet (approximate distance) is a series of silty shales with numerous diatoms which we thought were Pliocene in age. This formation lies on a series of hard indurated and altered sandstones and shales which extends to the northward at least half a mile beyond False Cape; this is as far as we went. Careful search of the formation was made for fossils but in only one place did we succeed in finding any. Just to the south of False Cape, in a slight indentation of the shore line, a large piece of crystalline limestone had fallen from the adjacent cliff. This rock was at least six feet in greatest dimension and contained a considerable number of fossils. It was not possible with the tools available to secure good specimens for specific identification but we saw in section an ammonite fully six inches in diameter. Numerous shells had the shape and texture of the rudistid *Corraliochama* and some others resembled belemnites and may have been *Belemnitella.* Fragments of these were collected and it was hoped that better identification could be made but this has not been possible. From what was found it is believed that the age of the rocks in that vicinity may be called Cretaceous with safety.

[1] Personal communication. August 10. 1932.

The largest of the Tertiary remnants in Humboldt County covers an area of some 350 square miles in the vicinity of the lower courses of the Eel and Van Duzen rivers and the streams which flow into Humboldt Bay, and it extends northward from the north flank of Bear River Ridge to the northern end of Humboldt Bay. Structurally the beds in this area form a broad westward-plunging syncline whose axis passes approximately through the mouth of Eel River and the town of Fortuna, with some faulting and folding to the north in the vicinity of Salmon Creek, Elk River, and Freshwater Creek, and to the east in the vicinity of T. 1 N., R. 2 E. Lawson (1894, p. 255) applied the name "Wild-cat Series" to these beds because of their typical development in the Wildcat country between Ferndale and Bear River Ridge. His usage of the term "series" will be followed in the present paper, although strictly correct present usage restricts the meaning of this term to the beds of a major portion of a period, as, for example, the Eocene series.

Other Tertiary remnants in Humboldt County consist of small outliers in the vicinities of Bear River, Davis Creek, Domingos Creek, McNutt Gulch, Mattole River, Redwood Creek and Briceland, South Fork of Eel River near Garberville, Hoagland Creek south of Bridgeville, Mad River, Jacoby Creek, and at a few other places. More northerly exposures near Crescent City in Del Norte County have been reported (Diller, 1902, pp. 31-35), but were not visited by the writers.

Review of Previous Literature

The Wildcat series has quite generally been considered Pliocene in age, with perhaps some Miocene in the lower part. Some workers have suggested that it may be Pliocene throughout; others that it is chiefly or altogether Miocene. The occurrence of some Pleistocene at the top of the section has also been postulated.

Gabb, (1866 & 1869, pp. 45, 58, 71, 73, 96, 98, 99) recognized the Pliocene age of the Humboldt County Tertiary over twenty-five years before it was described and given a formational name.

In 1894 Lawson (1894, pp. 242, 255-261) proposed the name "Wild-cat Series," and gave an excellent description of a section exposed " . . . on the ridge followed by the stage road in descending from the Bear River Ridge to Ferndale, on the southern edge of the Eel River flood plain" (Plate 19). Its thickness was estimated at over a mile. On the evidence of fossils collected by himself and others and submitted to Dr. J. C. Merriam, Lawson stated that there was no doubt as to the Pliocene age of the Wildcat series, which he considered to be correlative with the Merced series.

In a brief summary of the general hypothesis arrived at in his paper regarding the geomorphogeny of the coast of northern California, Lawson attributed the present geomorphogeny to the following sequence of events:

1. The development in Pliocene time of a great coastal peneplain, with correlative accumulation of marine sediments.

2. The orogenic deformation of parts of this peneplain and the folding of the Pliocene strata, the general altitude of the peneplain, where not so disturbed, remaining about the same.

3. The reduction of the upturned soft Pliocene strata to base level, and the limited extension of the peneplain in between the uplifted blocks of the other disturbed areas.

4. The progressive uplift of this peneplain, with its residual monadnocks, to an elevation for the plain of from 1,600 to 2,100 feet above the sea level, the adjacent mountainous tracts participating in the same movement.

5. The advance in the new geomorphic cycle to a stage of late adolescence or early maturity.

6. A very recent local sag or depression of about 100 miles of the coast adjacent to the Golden Gate.

In a paper on the *Topographic Development of the Klamath Mountains,* Diller (1902, pp. 30–47) described briefly the Neocene deposits which occur along the coast of northern California and Oregon. Notes by W. H. Dall which were inserted with Diller's descriptions gave a Miocene age for most of the fossils from these localities which had been collected by Diller's party and submitted to him for study. A subsequent note written by Dall after he had visited the region in 1901 concluded with the following remarks:

> In a general way it looks as if the (Eel River) valley had been the scene of rather intense deposition of sand, clay, and gravel from the Upper Miocene to some period in the Pliocene without marked unconformity and with a continuous fauna which changed, if at all, chiefly by some species becoming more rare or disappearing entirely. . . . The uppermost sediments are, of course, younger than the lower ones, but I have seen nothing in the abundant fossil fauna or its distribution to alter my opinion first expressed after an examination of the fossils alone, that the characteristics of the fauna point to an Upper Miocene age and no distinctively Pliocene species of molluscs appear in it anywhere. . . .

Dall stated that at the time of his examination of Diller's fossils the only strictly defined California marine Pliocene fauna which had been recorded, and, therefore, the only one available for comparative purposes, was that of San Diego in the southern part of the state. He pointed out that doubtless there was a marked difference between the contemporaneous faunas of the San Diego region and of northern California and Oregon, each fauna probably comprising an almost totally distinct series of species from the other, and that therefore the Pliocene of northern California, if it exists, would be difficult to determine by paleontological comparison with that of San Diego.

On the basis of this fossil evidence Diller dated the age of the Klamath peneplain from Miocene time, but he apparently recognized the fact that Dall's age determinations might be open to question, for in concluding a discussion of the age of the Klamath peneplain he said,

> . . . . The tendency of the evidence throughout, as far as known, appears to indicate a late Miocene age for the Klamath peneplain, but if on further study the Wymer beds and those of the Hay Fork stage should turn out to be Pliocene or Pleistocene the age of the Klamath peneplain would be correspondingly reduced.

The Wymer beds are exposed near Crescent City in Del Norte County and those of the Hay Fork stage near Hay Fork in central Trinity County. In Diller's report both are considered approximately equivalent in age to the Wildcat series of Humboldt County.

Arnold (1906, pp. 25, 29), in a monograph on the *Tertiary and Quaternary Pectens of California,* stated that at least some of the beds on Eel River, Humboldt County, are doubtless the equivalent of the Purisima. The upper portion of the "Wildcat formation" of Eel River he considered questionably equivalent to the Merced.

Stalder (1914, p. 449), in referring to the "Wild Cat series" on the north flank of Bear River Ridge, gave a brief description of a section along the sea-cliffs to the north of Cape Fortunas, which is the Wildcat coast section of the present paper. He considered the thickness of this section to be in excess of 6,000 feet, but made no reference to its geologic age.

In the same publication, Harmon (1914, pp. 456, 457) briefly described an inland section of about 5,000 feet of "Wild Cat series" whose best exposure occurs just northwest of Scotia. He gave Pliocene as the age of these beds, and included a fossil list of twelve molluscan species.

Martin (1916, pp. 215–221, 234–241, 247, 249–259) published the results of a study of the Pliocene of middle and northern California, in which he reviewed the literature and summarized the stratigraphy and faunas of the various Pliocene occurrences within the region studied. In considering the Humboldt County Pliocene he was particularly impressed with the fact that one of the most noticeable characters of the fauna from the Wildcat series is the division which can be made between the upper and lower portions, which agrees very closely with the lithologic divisions. He found that some of the species from the lower portion occur also in the Empire formation[2] of Coos Bay and other Miocene formations along the coast of California and Oregon, and expressed the belief that probably the lower portion of the Wildcat series is not later than the uppermost Miocene in age. The upper portion of the Wildcat he found to contain a fauna quite similar to that of the Merced series,

[2] Now (1949) generally considered to be of Pliocene age.

and to be very conspicuously boreal in character. Similarity between the fauna of the upper portion of the beach section north of Guthrie Creek and those of the Pliocene of Santa Barbara and the Pleistocene of San Pedro was believed to indicate a rather late Pliocene age for the uppermost portion of the beach section. The beds at the mouth of Bear River were considered to be Miocene in age. Fossil lists given for the Bear River Miocene, the lower Wildcat and the upper Wildcat contained the following numbers of species and varieties:

Upper division of Wildcat	
Echinodermata	2 species
Pelecypoda	36 species and 1 variety
Gastropoda	26 species and 1 variety
Lower division of Wildcat	
Pelecypoda	9 species
Gastropoda	11 species
Upper portion of upper Miocene at mouth of Bear River	
Echinodermata	1 species
Pelecypoda	6 species
Gastropoda	6 species

In a monograph on the *Mesozoic and Cenozoic Mactrinae of the Pacific Coast of North America,* Packard (1916, pp. 283–285, 296, 297) included two species, *Spisula voyi* (Gabb) and *S. brevirostrata* Packard, from the "Wildcat group, Humboldt County, California," giving the age of the beds as Pliocene. The Recent occurrence of *S. voyi* was given as "Icy Cape, Alaska, to Neah Bay, Washington," citing Dall as authority. Only one occurrence was listed for *S. brevirostrata,* the type locality "Along the east bank of Eel River one mile north of Scotia, Humboldt County, California."

Smith (1919, pp. 139, 140, 143, 144, pl. 9), in an analysis of the climatic relations of the Tertiary and Quaternary faunas of the California region, gave a fossil list from the Wildcat fauna and stated that, although this fauna has been variously assigned to the Miocene and the Pliocene, its real age is that of the Purisima of middle California and the true Fernando of southern California, upper part of the lower Pliocene, although it is probable that in the thick section of the Wildcat formation the uppermost beds may overlap with the Merced, and the lowest beds may belong to the age of the lower Pliocene Etchegoin-Jacalitos fauna of middle California.

He found a cool-temperature fauna in the Wildcat beds, indicating a minimum temperature of about 50° F. (10° C.), and assigned it to the Puget Sound province, which in Wildcat time extended southward to Cape Mendocino, as it does now. All of the southern, warm-water types were said to be lacking in this fauna, which marks the southern limit of many of the northern forms. Regarding these conditions, Smith said,

> Cape Mendocino played the part, which now falls to Pt. Conception, as the dividing line between the warm-water and the cold-water faunas. This was the time of greatest differentiation of climatic zones on the California coast. The cold-water zone extended down to Cape Mendocino and the warm-temperate zone pressed northward nearly to the same place. There was thus some telescoping of the isotherms, with the middle Californian province obliterated. This fact has made difficult the correlation of the Pliocene of northern California with that of the southern part of the state, and has resulted in faunas of the same age having been assigned to very different parts of the geologic column.

The existing confusion in the correlation and nomenclature of the Pliocene formations on the West Coast Smith attributed to " . . . the disconnected occurrence of the beds, their varying lithology, and the great variety of rapidly changing climatic conditions under which they were laid down."

"There is much need of revision of the data concerning the Pliocene of California," he said, ". . . . , for this is, at present, the firing line in West Coast stratigraphy."

In a resumé of the petroleum resources of Humboldt County, California, Vander Leck (1921, p. 41) stated that the beds of tht Wildcat series are believed to be of Pliocene age, although it is possible that the lower beds may be of Miocene or even Eocene age.

Hoots (1928, U. S. Geol. Survey Press Bull., p. 6, geologic map and sections) stated that the rocks of the Wildcat series, chiefly of Pliocene age, consist of 7,000 to 11,000 feet of conformable beds of soft light-gray and brown shale and sandstone. Attention was called to a two-fold division of Lawson's type section into a lower unit of alternating beds of soft light bluish-gray and brown clay shale and fine-grained sandstone containing considerable glauconite and abundant fossils, and an upper unit of soft, well-sorted light-brown fossiliferous, massively bedded sandstone that becomes conglomeratic near the top.

Lower Pliocene was given as the age of clay shale along the lower part of Bear River west of Capetown, and probably Miocene for more steeply dipping beds of similar character farther east along Bear River.

Foraminifera strongly indicative of Miocene age were said to occur in light-gray diatomaceous shale associated with bluish-gray clay shale in the vicinity of Briceland.

A paper on *Tertiary Foraminifera from Humboldt County, California,* by Cushman, Stewart, and Stewart (1930, pp. 44–46, chart) gave Pliocene as the age of the Wildcat series in the vicinity of Eel River and Eureka, and both Miocene and Pliocene as the age of the beds along the lower course of Bear River.

An occurrence of "Lower Pliocene" in the eastern end of the Puente Hills, San Bernardino County, California, was recorded by Stewart and Stewart (1930, p. 1450), and its fauna was correlated with that of the "Lower Pliocene" of the Los Angeles and Ventura basins and with the lower part of the Wildcat series of Humboldt County, although the beds which contain this fauna in these widely separated basins were not said to have been exactly contemporaneous in time of deposition.

Since that paper was published some differences of opinion have developed regarding the age of the Puente Hills "Lower Pliocene" beds. Kleinpell (1938, pp. 28, 32, fig. 14) placed them questionably in the uppermost Miocene. Woodford, Shelton, and Moran (1945) said,

> . . . Near the Santa Ana River a smaller (Repetto) fauna was recognized first by R. E. Stewart and K. C. Stewart (1930) in a sandy siltstone which overlies Kreuger's Mahala

> conglomerate. New collections made by M. N. Bramlette confirm the correlation. In both areas the contact with the Puente formation (upper Miocene) is gradational, and near the Santa Ana River the Repetto formation is made up of interbedded sandy siltstone and conglomerate. . . .

H. L. Driver of the Standard Oil Company of California (personal communications) reports finding in or very near the Repetto beds in question an upper Miocene marker, *Rotalia garveyensis* Natland, in a foraminiferal fauna which is otherwise common to both lower Pliocene and upper Miocene. However, he states that he does not consider the fauna to be sufficiently distinctive to warrant definite age assignment to the beds in this vicinity, since they appear to be transitional between lowermost Pliocene and uppermost Miocene.

Since the lower Pliocene Repetto formation had not been named and described in 1930, it is not improbable that the term "Lower Pliocene" which was then in rather general use among micropaleontologists embraced those portions of both the upper Miocene Puente formation and the lower Pliocene Repetto formation which contain the very similar faunas to which Driver refers, and that beds containing both of these faunas occur in close association in the southeastern Puente Hills near the Santa Ana River.

In discussing the relationships of the "'Lower Pliocene' Stage" and the Repetto formation, Kleinpell (1938, p. 168), made the following observations:

> The youngest Formations involved in the Middle Tertiary sequence under discussion are typified . . . in their offshore facies by the Repetto Formation of Southern California. . . . If the essentially argillaceous shales and mudstones exposed in the Repetto Hills on either side of the pass traversed by Atlantic Boulevard be considered the typical Repetto, then beds of Delmontian as well as "Lower Pliocene" age could be included within this Formation. As the term Repetto is at present generally applied, however, the "*Bolivina seminuda* Zone" and the foraminiferal "Miocene-Pliocene Transition" beds are excluded, and the Repetto Formation is thus restricted to post-Delmontian

> beds of "Lower Pliocene" age. Also referable to the "Lower Pliocene" Stage of the present paper are the lower beds of the so-called Wildcat Series of Humboldt County, and probably also the major part of the Capistrano Formation of Southern California.

Regarding the history and status of the terms "Lower Pliocene" and Repetto formation see also Woodring (1938, pp. 3, 4).

Gale (Grant and Gale, 1931, pp. 55, 56, 60, 61, Table 1) considered the Wildcat beds and the "Bear River Miocene" as a single Pliocene unit, correlating the "Bear River Miocene" and the lower Wildcat with " . . . the Jacalitos, the Elsmere Canyon beds (+ the Santa Paula formation), the lower Purisima . . . , and, very hypothetically, the Empire and Montesano formations of Oregon and Washington." He correlated the upper Wildcat with " . . . the San Diego, the Pico, the middle or lower Etchegoin, the Merced, the upper Purisima . . . , perhaps the Coos conglomerate. . . . "

Gale suggested that the Klamath peneplain, instead of being in the process of formation up to and including the time of deposition of the Wildcat series, as Diller apparently thought, may have been warped and partially uplifted at the time when the coastal area about the mouth of Eel River was depressed to admit the invasion of the lower Pliocene (Wildcat) sea, and that in such a case the Miocene age which Diller postulated for the Klamath peneplain may stand, even though the Miocene age of the Wildcat series upon which he based his conclusions does not.

Reed (1933, pp. 234 (fig. 44), 243, 246, 251) assigned the Wildcat series to the Pliocene, and concluded that it accumulated in moderately deep water, in an embayment that was broadly open to the Pacific Ocean.

A close resemblance between the microfaunas of the upper Wildcat and the Merced was noted in two papers by Stewart and Stewart (1933, pp. 261, 262; 1934, pp. 2–4, species distribution chart). The second of these two papers also pointed out a marked resemblance between the upper Wildcat microfauna and the microfaunas of the upper Pliocene and Pleistocene of the Ventura Basin, and between the microfauna of the lower Wildcat and that of the southern California Repetto.

Hoots (1938, pp. 710, 716) briefly summarized data on the discovery and production of the new Tompkins Hill gas field 12 miles south of Eureka in Humboldt County, where gas is obtained from Pliocene (Wildcat) sands. This has been called the Eureka gas field by some authors.

Kleinpell (1938, pp. 2, 26, 119, 135, 136, 168, 180, fig. 14) included a map showing Humboldt Basin and the other major marine Neogene basins and barrier areas of California. "In California," he said, "deep narrow depositional troughs of tectonic origin in which abyssal Foraminifera were common developed in Los Angeles, Ventura, and Humboldt basins during the 'Lower Pliocene' (Repetto) Age at the same time that littoral and terrestrial deposits were being laid down in the Santa Maria, San Joaquin, Paso Robles, Santa Cruz, and Contra Costa basins; . . . " "Lower Pliocene," perhaps 3,000–4,000 feet or more in thickness, was said to lie directly on Mesozoic metamorphics over a wide area in Humboldt County.

Miocene faunules from the 1930 paper of Cushman, Stewart and Stewart were correlated as follows by Kleinpell: station No. 48, lower Luisian *Siphogenerina reedi* zone (?); stations Nos. 37, 38, 39, 40, and 48 (?), upper Relizian *Siphogenerina branneri* zone; station No. 36, lower Relizian *Siphogenerina hughesi* zone.

Woodring, Stewart, and Richards (1940, p. 109, correlation chart opposite p. 112) discussed the Wildcat series briefly on the basis of fossil lists given by Martin (1916, pp. 238–239). Martin's upper fauna they considered to be upper Pliocene, resembling the lower part of the Merced. His lower fauna they placed in the middle Pliocene, as they did also the Empire formation of Coos Bay, Oregon, and the upper part of the Repetto formation of the Ventura and Los Angeles basins in California. A cool-water (deep-water(?)) facies was suggested for both the upper and lower Wildcat faunas, although some contradictory evidence was found in the upper fauna.

Galliher's committee (1941, pp. 1462, 1463), in discussing possible future oil provinces in Pacific coast states, made brief reference to a gas field of minor importance (Tompkins Hill or Eureka gas field) producing from Pliocene beds in the Humboldt area.

Averill (1941, pp. 520–526) reproduced the text of Hoots' (1928) United States Geological Survey *Press Bulletin,* but did not include the geologic map and sections. Additional data were given on the gas production near Briceland and on the new gas field near Eureka.

In California Division of Mines *Bulletin 118* (Jenkins, 1943) there are references by several authors to the Tertiary of Humboldt County. Stalder (pages 75–80, fig. 35), in discussing the history of exploration and development of gas and oil in northern California, stated that a well drilled on the Davis Ranch in Humboldt County in 1861 appears to be the earliest well drilled for oil in California, and oil shipped to San Francisco in 1865 from a well located on the North Fork of the Mattole River in Humboldt County appears to be the first oil, from a drilled well in California, to be distilled and sold on the market. These wells were not drilled in Tertiary rocks.

Grant and Hertlein showed the upper and lower Wildcat of Humboldt County on a generalized correlation chart of the Pliocene of California on page 202 of Bulletin 118. On page 483, figure 203, P. J. Howard indicated Pliocene as the age of the producing sands of the Eureka gas field on a chart of the geologic horizons in the oil and gas fields of San Joaquin Valley and farther north. Tabulated data on 67 wells drilled in Humboldt County appear on page 640.

On pages 633–635 of the same bulletin H. D. MacGinitie discussed the structure, stratigraphy, basins of deposition, oil indications, and exploration for oil and gas in central and southern Humboldt County. Geologic sketch maps and diagrammatic sections were given for central Humboldt County and the Garberville and Briceland area. Regarding the Tertiary of Humboldt County, he said,

> There is a fairly complete sequence of Miocene and Pliocene marine sediments. These show a striking similarity to sediments of the same age in the southern Coast Ranges. The correspondence of the Pliocene formations of Humboldt County and of Ventura County is remarkable for its completeness . . . .
>
> . . . The Tertiary formations once covered all of southern

> Humboldt County with the exception of a narrow strip along the eastern boundary, and extended an unknown distance to the south . . . .

MacGinitie gave a thickness in excess of 12,000 feet for the Miocene-Pliocene Tertiary sequence. Cretaceous rather than Tertiary rocks were believed to be the most probable source of oil in Humboldt County, but this was not thought to exclude the Tertiary formations from the possibility of future oil discoveries.

Weaver (1945, pp. 1404, 1410) gave the following description of the general conditions which accompanied the deposition of the Wildcat series and other approximately equivalent marine formations in California, Oregon, and Washington:

> During the Pliocene these mountains (of western Washington and Oregon) were undergoing vigorous erosion and minor structural deformation. East of the ocean southward to California coastal plains were developed which locally were slightly down-warped. The oceanic waters transgressed eastward into these slowly and differentially subsiding sags and formed irregular-shaped bays and small gulfs. The seas did not all come in contemporaneously but by the close of the Pliocene several thousand feet of marine sandstones and shales had accumulated. These deposits are named the Quinault and Montesano formations in Washington, the Empire formation in southwest Oregon, and the Wildcat series in northwest California, and all were folded during the late Pliocene-early Pleistocene diastrophism.

Cushman, Stewart, and Stewart (1949), in a paper which immediately precedes this one under the present cover, find that a microfauna from the Quinault formation of western Washington points strongly to a correlation with the Repetto phase of the Wildcat coast section.

THE WILDCAT COAST SECTION

General Description

Lawson's type section for the Wildcat series lies along the road which runs southward from Ferndale to Bunker Hill Ranch and Bear River Ridge (Plate 19), but the beds are much better exposed in wave-cut cliffs along the coast about 3 miles to the west, and it is this latter section which is referred to in this paper as the Wildcat coast section. It represents the monoclinal south flank of the Eel River syncline. From Oil Creek on the south, where the lowest exposed Tertiary beds are in fault contact with partially metamorphosed Cretaceous sedimentaries, the strata are exposed in ascending sequence to Centerville, where they disappear beneath the marsh and meadowland of the Eel River valley. This section, as measured in the field, has a thickness of about 6,550 feet.

Lithologically the Wildcat coast section is characterized chiefly by soft fossiliferous siltstones, claystones, shales, sandy shales, and fine-grained sandstones, the predominant color of which is bluish gray. The upper 480 feet is made up of unfossiliferous coarse brown sands and gravels. As shown in the columnar section on Plate 20, the Wildcat coast section is composed of an 1800-foot shale member at the base, followed alternately in ascending order by four members which are predominantly sandy and three others which are predominantly argillaceous or silty. Additional details of lithology are given in the following lithologic description.

Description of Lithologic Zones

The term *shale* is here used to include rocks formed by the consolidation of such fine-textured sediments as clays, muds, and silts without regard for stratification, bedding, or fissility, it being realized that this does not conform to the strict academic definition of a shale.

Zone 1. (From the bottom of the section to 5,310 feet)—Massive gray and bluish-gray shale, weathering rusty brown. Much jointed and fractured. No bedding except in upper 50 feet, where rather indistinct bedding begins to appear. No good indication of dip and strike observed. Hard concretions in places. No sandstone was observed in the field.

Zone 2. (5,310–5,010 feet)—Massive blue-gray shale and sandy shale. Becomes more sandy toward top. Bedding fairly well defined in lower part by occurrence of thin beds of sandstone. In upper part shales become more sandy and bedding is better defined by brown sandy layers in rusty yellow sandstone. A 20-foot zone of bedded sandstone occurs near top.

Zone 3. (5,010–4,755 feet)—Massive bluish-gray shale.

Zone 4. (4,755–4,515 feet)—Predominantly fairly well-bedded rusty yellow sandstone with thin layers of sandy shale and bluish-gray clay shale. Three hard sandstone beds about 6 inches thick and 3 feet apart occur near center.

Zone 5. (4,515–3,970 feet)—Sandstone in lower part. Remainder mostly argillaceous sandstone with a little shale and some sandstone. Tends to be massive, but some bedding is shown. A hard sandstone bed 3 inches thick occurs near center. Sandstone becomes more argillaceous in upper 200 feet.

Zone 6. (3,970–3,700 feet)—Lower 100 feet is rusty yellow sandstone with beds of sandy shale. Bedding well shown. Remainder predominantly massive, sandy, bluish-gray shale with some sandstone. Some bedding shown, but hard to find good bedding planes suitable for taking accurate dip and strike readings except at very top, where a thin sandy zone occurs.

Zone 7. (3,700–3,260 feet)—Mostly blue-gray clay shale. Slightly sandy in lower 150 feet. Tends to be massive, but shows a little bedding, most of which is indistinct. Sandstone and sandy beds occur in upper 100 feet.

Zone 8. (3,260–2,625 feet)—Mostly blue-gray bedded sandstone, weathering to gray, yellow, and brown. A very little sandy shale. Bedding 6 inches to 2 feet thick. A 4-inch bed of hard sandstone near top.

Zone 9. (2,625–2,020 feet)—Practically all massive blue and blue-gray sandy shale and clay shale, much of which weathers to brown. Bedding shows occasionally.

Zone 10. (2,020–1,895 feet)—Mostly massive sandy shale and argillaceous sandstone. Fossil-bearing concretions near top.

Zone 11. (1,895–1,630 feet)—Mostly massive, fine-grained, blue-gray to brown sandstone with many reddish-brown, fossil-bearing concretions.

Zone 12. (1,630-1,355 feet)—Massive blue-gray clay shale. A 1½-foot ash bed near center.

Zone 13. (1,355–1,195 feet)—Massive blue-gray clay shale and sandy shale.

Zone 14. (1,195–870 feet)—Massive blue-gray shale. In upper part is slightly sandy and tends to be brownish in color.

Zone 15. (870–480 feet)—Massive blue-gray clay shale, sandy shale, and argillaceous sandstone. Contains brown, fossil-bearing concretions at base. Much of the upper portion is very fine-grained argillaceous sandstone. Some of the clay-shales appear to be lithologically similar to those exposed at Buhne Point on Humboldt Bay near Eureka. Lower 40 feet is bedded sandstone and shale. A shell bed occurs at or near top of Zone 15.

Zone 16. (480–0 feet)—Brown sands grading upward into coarse sands and gravels. The gravels become coarser as the top of the exposed section is approached. No coarse conglomerates were observed here, although they occur in the lower part of this sand and gravel zone farther to the east. Most of the upper 240 feet of this zone was masked by slumping. The most northerly exposure observed was in a roadcut in Centerville.

The locations in the columnar section on Plate 20 of the dip and strike stations shown along the coast in Plate 19 are as follows:

Plate 19 Coast Degrees of Dip	Plate 20 Columnar Section Feet Below Top
12	395
9	860
22	1,960
24	3,045
33	3,915
38	5,315

The Molluscan Fauna

The ranges of the molluscan species collected by the writers from the Wildcat coast section, together with their associations and groupings into faunal assemblages, are shown on Plate 20.

The section is seen to be divided into lower (6,550–6,200 feet), middle (3,115–2,525 feet) and upper (480–0 feet) barren zones separated by lower (6,200–3,115 feet) and upper (2,525–480 feet) faunal zones. The lower barren zone is composed entirely of shale. In the middle barren zone the upper 100 feet is shale and the exposed portion of the lower 500 feet is almost entirely sandstone. The upper barren zone is composed entirely of sand and gravel.

The beds of slightly less than one-half of the middle barren zone are cut away at the mouth of Guthrie Creek; so it is possible that some species of Mollusca would have been found if these beds had been present. However, since all of the beds exposed in both the upper and lower parts of this zone are barren, and since no fossil-bearing beds were seen in Guthrie Creek or in the canyon sides along the strike from the gap at the mouth of Guthrie Creek, it is tentatively assumed that the whole zone is devoid of Mollusca.

Foraminifera occur in the exposed beds of both the lower and middle barren zones, but they are very rare as to both species and individuals in the lower 550 feet of the section. None were found in the upper barren zone.

Plate 20 shows numerous gaps in the faunal sequence from which no Mollusca were collected. Some of these gaps represent strata which were well exposed and apparently contained no molluscan fauna. In the following, however, sliding and slumping had covered beds which were probably fossiliferous: 0–240, 515–585, 640–675, 775–845, 1,010–1,160, 1,605–1,715, 2,025–2,120, 3,485–3,610, 4,450–4,535, 4,910–5,060. Figures given represent distances in feet below the top of the section.

Besides the five barren and faunal zones, there are four smaller portions of the column, one within the lower faunal zone and three within the upper faunal zone, which may be designated as subzones on the basis of species, the upper, lower, or both limits of whose ranges are contained within them. The locations and extent of these subzones are indicated on Plate 20. Subzone 1 (4,750–4,125 feet) is predominantly sandstone, subzone 2 (2,020–1,715 feet) predominantly sandstone with sandy shale in the lower 60 feet, subzone 3 (1,605–1,255 feet) predominantly clay shale with sandy shale in the upper 50 feet, and subzone 4 (880–580 feet) sandstone and shale in the lower 50 feet and sandstone in the upper 100 feet with sandy shale between. Thus we see that every predominantly sandy zone in the section is the scene of some marked change in the molluscan fauna, namely, the appearance, disappearance, or both the appearance and disappearance of several species (one of the subzones) or the total disappearance of all species (one of the barren zones).

Subzone 3 and the lower barren zone do not fall within this category, as both are composed predominantly of claystone and siltstone. It is noteworthy, however, that very few fossils occur in the lower part of the section below 5,260 feet where we also find the lowest observed occurrence of sandstone. Except for very localized occurrences of a few indeterminate forms and two identified species, the lower barren zone would extend from 6,550 feet to 5,260 feet, where its upper limit, and, therefore, the lower limit of the lower faunal zone, would occur in association with a lithologic facies which is marked by the first appearance of sandstone beds in the lower argillaceous and silty member of the section.

Species, the upper, lower, or both limits of whose ranges are contained within the various subzones, are as follows:

Subzone 1

Species whose ranges are restricted to subzone 1
- Pelecypoda
  - *Nuculana* cf. *hamata* (Carpenter)
  - *Yoldia thraciaeformis* (Storer) Species "F"
  - Species "G"
- Gastropoda
  - *Priscofusus cammani* (Dall)
  - Species "E"
- Scaphopoda
  - *Dentalium neohexagonum* Sharp and Pilsbry

Species whose upper range limits only are in subzone 1
- None

Species whose lower range limits only are in subzone 1
- None

Subzone 2

Species whose ranges are restricted to subzone 2
Pelecypoda
Laevicardium (Cerastoderma) corbis (Martyn), var. *coosense* (Dall)
Panope (Panomya) ampla (Dall)
Schizothaerus nuttallii (Conrad), var. *pajaroanus* (Conrad)
Volsella (Brachidontes) stalderi (Martin)

Species whose upper range limits only are in subzone 2
Gastropoda
Acanthina spirata (Blainville)

Species whose lower range limits only are in subzone 2
Pelecypoda
Pandora grandis Dall
Pitar oregonensis (Conrad)
Psephidia lordi (Baird), var. *barbarensis* Arnold
Venus (Chione) succincta Valenciennes
Gastropoda
Taranis strongi (Arnold)

Subzone 3

Species whose ranges are restricted to subzone 3
Pelecypoda
Pecten (Pseudamussium) cf. *pedroanus* (Trask)
Thracia (Thracia) trapezoides Conrad
Yoldia scissurata Dall, var. *strigata* Dall
Gastropoda
Bittium (Lirobittium) asperum (Gabb)
Epitonium (Nitidiscala) indianorum (Carpenter)
Liomesus sulculatus Dall
Species "A"
Species "B"

Species whose upper range limits only are in subzone 3
Pelecypoda
Nuculana cf. *taphria* (Dall)
Venus (Chione) succincta Valenciennes
Gastropoda
Lora turricula (Montagu)
Taranis strongi (Arnold)

Species whose lower range limits only are in subzone 3
  Gastropoda
    Mitrella carinata (Hinds), var. *gausapata* (Gould)

Subzone 4

Species whose ranges are restricted to subzone 4
  Pelecypoda
    Lyonsia cf. *californica* Conrad
    Tellina buttoni Dall
  Gastropoda
    Exilioidea rectirostris (Carpenter)
    Pseudomelatoma fleenerensis (Martin)
Species whose upper range limits only are in subzone 4
  Pelecypoda
    Cardita cf. *ventricosa* Gould
    Macoma astori Dall
    M. calcarea (Gmelin)
    Pandora grandis Dall
  Gastropoda
    Lora sanctae-monicae (Arnold)
    Moniliopsis graciosana (Arnold), var. *mercedensis* (Martin)
    Natica (Tectonatica) clausa Broderip and Sowerby
    Neptunea (Colus) halibrecta (Dall)
    N. (Neptunea) lirata (Martyn), var. *altispira* Gabb
    Spirotropis (Antiplanes) perversa (Gabb)
    S. (Antiplanes) perversa (Gabb), var. *voyi* (Gabb)
    Trophon (Boreotrophon) fleenerensis (Martin)
  Cirripedia
    Balanus sp.
Species whose lower range limits only are in subzone 4
  None

Table I illustrates the occurrences of species of Mollusca and Cirripedia within the faunal zones and subzones. The unidentified forms listed are chiefly unidentifiable fragments, together with a few specimens whose features have been destroyed by crushing.

Table I

OCCURRENCE OF SPECIES IN THE FAUNAL ZONES AND SUBZONES

The nomenclature used here is that of Grant and Gale. Where this differs from the names which were previously in common use, the older, more common names are given under those of Grant and Gale.

* Indicates occurrence within the zones and subzones indicated. † Indicates occurrence restricted to the subzones indicated.	Upper Zone	Subzone 4	Subzone 3	Subzone 2	Lower Zone	Subzone 1
Pelecypoda						
Cardita cf. ventricosa Gould Venericardia castor Dall, V. subtenta Conrad, V. subtenta Conrad, var. quadrata Conrad of Martin, not of the original authors	*	*	*	*		
Laevicardium (Cerastoderma) corbis (Martyn), var. coosense (Dall) Cardium coosense Dall	*			†		
Lyonsia californica Conrad	*	†				
Macoma astori Dall	*	*		*		
M. calcarea (Gmelin)	*	*	*	*	*	*
Nuculana cf. hamata (Carpenter) Leda cf. hamata Carpenter					*	†
N. cf. taphria (Dall) Leda cf. taphria Dall	*		*	*	*	
Pandora grandis Dall	*	*	*	*		
Panope (Panomya) ampla (Dall) Panomya ampla Dall	*			†		
Pecten (Patinopecten) caurinus Gould	*	*	*	*		
Pecten (Pseudamussium) cf. pedroanus (Trask)	*		†			
Pitar oregonensis (Conrad) Marcia oregonensis Conrad, of some authors, probably not of Dall, 1909	*	*	*	*		
Psephidia lordi (Baird), var. barbarensis Arnold	*		*	*		
Schizothaerus nuttallii (Conrad), var. pajaroanus (Conrad) S. pajaroanus (Conrad)	*			†		
Solemya ventricosa Conrad						
Tellina cf. buttoni Dall	*	†				
Thracia (Thracia) trapezoides Conrad	*		†			
Venus (Chione) succincta Valenciennes Chione succincta (Valenciennes)	*		*	*		
Volsella (Brachidontes) stalderi (Martin) Modiolus stalderi Martin	*			†		
Yoldia scissurata Dall, var. strigata Dall Y. strigata Dall	*		†			
Yoldia thraciaeformis (Storer) Species F						†
Species G					*	†

* Indicates occurrence within the zones and subzones indicated. † Indicates occurrence restricted to the subzones indicated.	Upper Zone	Subzone 4	Subzone 3	Subzone 2	Lower Zone	Subzone 1
Gastropoda						
Acanthina spirata (Blainville) Probably Martin's Thais lamellosa (Gmelin)	*			†		
Bittium (Lirobittium) asperum (Gabb)	*		†			
Epitonium (Nitidiscala) indianorum (Carpenter)	*		†			
Exilioidea rectirostris (Carpenter) Chrysodomus rectirostris Carpenter	*	†				
Liomesus sulculatus Dall	*		†			
Lora sanctae-monicae (Arnold) Bela sanctae-monicae Arnold	*	*	*	*		
L. turricula (Montagu) Bela turricula (Montagu)	*		*			
L. turricula (Montagu), var. schneideri (Harmer)	*					
Mitrella carinata (Hinds), var. gausapata (Gould) Astyris richthofeni (Gabb)	*		*			
Moniliopsis graciosana (Arnold), var. mercedensis (Martin) Drillia mercedensis Martin	*	*				
Natica (Tectonatica) clausa Broderip and Sowerby	*	*	*	*	*	*
Neptunea (Colus) halibrecta (Dall) Chrysodomus halibrectus Dall	*	*	*	*		
N. (Neptunea) lirata (Martyn). var. altispira Gabb Neptunea altispira Gabb	*	*	*			
Polinices (Euspira) lewisii (Gould)	*	*	*			
Priscofusus cammani (Dall) Turris cammani Dall					*	†
Pseudomelatoma fleenerensis (Martin) Drillia fleenerensis Martin	*	†				
Spirotropis (Antiplanes) perversa (Gabb) Turris perversa (Gabb)	*	*	*	*		
S. (Antiplanes) perversa (Gabb), var. voyi (Gabb)	*	*	*			
Taranis strongi (Arnold)	*		*	*		
Trophon (Boreotrophon) fleenerensis (Martin) Boreotrophon fleenerensis Martin	*	*	*		*	
Species A	*		†			
Species B	*		†			
Species D	*					
Species E					*	†
Scaphopoda						
Dentalium neohexagonum Sharp & Pilsbry					*	†
D. cf. rectius Carpenter					*	
Cirripedia						
Balanus sp.	*	*		*		
Unidentified forms	*	*	*	*	*	*

Plate 21 illustrates graphically the order of first and last appearance of species in the Wildcat coast section; that is to say, their order of appearance in the section and disappearance from the section during the course of its deposition. It shows the rate of change of the fauna, with regard to incoming and outgoing species, during the period of deposition of the sediments of the Wildcat coast section.

One pair of lines, whose significance may be readily observed by comparison with Plate 20, illustrates the order of appearance and disappearance of the Mollusca and Cirripedia. The other pair, taken from an unpublished microfaunal range chart, gives similar data for the Foraminifera and Ostracoda. Each circle associated with a first-appearance line represents the first appearance of a species within the section; each circle associated with a last-appearance (disappearance) line represents the last appearance of a species within the section. Circles directly above and below each other do not necessarily represent the same species, since in each case the line of first appearance and that of last appearance are based upon different orders of arrangement of the species.

From Plate 21 it is seen that on a basis of faunal change the fossiliferous portion of the Wildcat coast section falls naturally into three major divisions: (1) a lower 2500-foot division in which about a dozen species of Mollusca and seventy-nine species of Foraminifera make their first appearances and seven species of Mollusca and twenty-nine of Foraminifera make their last appearances in the section; (2) a middle 1200-foot division in which only one molluscan species and three foraminiferal species make their first appearances and one molluscan species and eighteen foraminiferal species make their last appearances; (3) an upper 2300-foot division in which one barnacle, thirty-five species of Mollusca, and twenty-one species of Foraminifera and Ostracoda make their first appearances, and one barnacle, forty-three species of Mollusca, and fifty-six species of Foraminifera and Ostracoda make their last appearances in the section.

Thus it is seen that with regard to both appearance and disappearance of species the molluscan fauna and the microfauna both undergo their greatest changes in the lower and upper portions of the section, with but little change in the middle division. In the lower division this change is far less marked in the molluscan fauna than it is in the microfauna, due to the fact that there are only about a dozen species of Mollusca present while the foraminiferal fauna contains about eighty species. It may be that the waters in which the beds of the lower division were laid down were too deep to support a prolific molluscan fauna.

Related Data on the Foraminifera and Ostracoda[3]

The species shown on the accompanying range chart (Plate 22) represent only a portion of the foraminiferal fauna from the Wildcat coast section. In the eight columns on the left are given the ranges in this section of six species and one group of Foraminifera and of one pelecypod chosen by a committee on Pliocene nomenclature (Reed, 1933, pp. 229, 230; Woodring, 1938, p. 3) to designate different divisions of the Pliocene of southern California. The remaining columns give the ranges of forty-five species of Foraminifera and four species of Ostracoda with which these markers are associated in the Wildcat coast section.

Two of the southern California markers, *Cibicides lobatus* and *C. mckannai*, were not found in the material studied for this paper, but the remaining five occur in the same order here as in the south, with perhaps some differences in range. *Pecten caurinus* is shown on the chart because it was chosen by the committee as a companion marker with *Cibicides lobatus* in the south. The specimens of *Uvigerina peregrina* in the Wildcat series do not appear to be as large and well developed as those which mark the *U. peregrina* zone of the southern California Pliocene. *Bulimina subacuminata* appears to extend through a somewhat greater portion of the section here than in the southern part of the state.

The associated species shown in the remaining columns were chosen for the chart because of their limited ranges or because they serve to bridge between the very definite upper and lower faunal groups.

[3] Revised extract from Stewart and Stewart 1934.

The upper faunal group, which extends down into the section about 2,500 feet, contains a combination of species which are characteristically found in beds considered to be of both Pliocene and Pleistocene age in the Ventura region. In the Ventura quadrangle *Elphidium hannai, E. hughesi,* and *Buliminella elegantissima* are common in the Las Posas Pleistocene, and *Pecten caurinus, Uvigerina* aff. *tenuistriata, Gaudryina triangularis,* and *Polymorphina charlottensis* may be considered as markers for the Santa Barbara formation, locally called the "Mud-pit shale," whose foraminiferal fauna closely resembles that of the Santa Barbara beds of Bathhouse Beach and Packard's Hill. *Nonion scapha* and a few ostracods are found in both the Las Posas formation and the "Mud-pit shale."

Twenty years ago the Santa Barbara formation in the vicinity of Ventura was believed to be older than uppermost Pliocene.[4] Later, in the vicinities of both Ventura and Santa Barbara, it came to be considered as uppermost Pliocene,[5] and shortly afterwards as Pleistocene.[6] Still more recently Bailey and others have favored a two-fold division into a Pliocene *Pecten bellus* zone and a Pleistocene *Pecten caurinus* zone.[7] Woodring, Bramlette, and Kew,[7] referring to Bailey's[7] paper, said,

> . . . At both localities (Santa Barbara and Rincon Point) . . . the formation may be divided into a lower *Pecten bellus* zone and an upper *Patinopecten caurinus* zone. . . . The Santa Barbara formation is generally assigned to the upper Pliocene, or the lower part to the upper Pliocene and the upper part to the lower Pleistocene.

The type horizon of *Elphidium oregonense* is Pleistocene near the mouth of Elk River, 3 miles southeast of Cape Blanco,

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[4] Cartwright, 1928, pp. 239 (fig. 3), 246, 264 (fig. 12), "upper Pico."

[5] Gale, in Grant and Gale, 1931, pp. 35, 36, "Santa Barbara zone."
Grant, in Keen and Bentson, 1944, pp. 11, 12, "Packard's Hill beds, and possibly the Bathhouse Beach beds [Santa Barbara]."
Reed, 1933, p. 231, table XVI, "Restricted Pico" (at least in part); p. 236, table XIX, "Upper silts of Adams Canyon"; p. 249, table XXII, "Santa Barbara."
Stewart, in Jenkins (Ed.), 1943, p. 388, "Mud-pit shale."

[6] Reed, 1933, p. 254, footnote 1, "Santa Barbara beds."
Woodring, Stewart, and Richards, 1940, pp. 110, 111, 112, 112 (insert), 114, "Santa Barbara formation."

[7] Bailey, 1935, p. 494, "Santa Barbara formation."
Dibblee, in Keen and Bentson, 1944, pp. 12–15, "Santa Barbara formation."
Woodring, Bramlette, and Kew, 1946, pp. 104, 105, "Santa Barbara formation."
Redwine, 1947 a, b, pp. 60, 61, fig. 19, "Santa Barbara formation."

Curry County, Oregon (Cushman and Grant, 1927, p. 79). Specimens of *Elphidium hannai* occur in great abundance in a sample taken from the same horizon in the same general locality by Dr. Ewart M. Baldwin of the University of Oregon.

In a previous paper (Stewart and Stewart, 1933, pp. 261, 262) the writers have referred to a similarity between the faunas of the upper Wildcat and the type Merced. Of the species on Plate 22, only four occur in the type Merced, three Elphidiums and *Buliminella elegantissima.* It is not believed that this group alone constitutes sufficient evidence for correlating such widely separated formations as the Wildcat and the type Merced. When the complete foraminiferal fauna studied for the present paper is considered, however, ten more species are found to be common to both the type Merced and the Wildcat coast section, making fourteen in all. The foraminiferal fauna found in the material studied for the type Merced paper contained a total of only twenty-three species and varieties.

The foraminiferal assemblage from the lower part of the Wildcat coast section, which extends from about 4,300 feet on down through the lowest exposed beds, bears a marked resemblance to that of the lower Pliocene Repetto formation of southern California. The following list of species from the lower Wildcat faunal group might easily be mistaken for a list of Repetto Foraminifera from the southern part of the state.

Bolivina pisciformis Galloway and Morrey
Bolivinita angelina Church
Bulimina inflata Seguenza
B. rostrata H. B. Brady
B. subcalva Cushman and K. C. Stewart
Cassidulina cushmani R. E. and K. C. Stewart
Cyclammina cancellata H. B. Brady
Dentalina insecta (Schwager)
Ehrenbergina compressa Cushman
Globorotalia crassula Cushman and R. E. Stewart
Gyroidina soldanii d'Orbigny, var. *altiformis* R. E. and K. C. Stewart
Nodogenerina lepidula (Schwager)
Nodosaria parexilis Cushman and K. C. Stewart

N. tosta Schwager
Nonion barleeanum (Williamson)
N. umbilicatula (Montagu)
Planulina ornata (d'Orbigny)
Plectofrondicularia californica Cushman and R. E. Stewart
Pullenia sphaeroides (d'Orbigny)
Sphaeroidina bulloides d'Orbigny[8]
Uvigerina senticosa Cushman
U. proboscidea Schwager
Virgulina nodosa R. E. and K. C. Stewart

In another previous paper (Stewart and Stewart, 1930, p. 1450; present paper, p. 180) the writers have suggested a correlation between "Lower Pliocene" (Repetto) faunules from the Puente Hills and the fauna of the lower part of the Wildcat series. Among the species listed on Plate 22 of the present paper are ten which occur also in the Puente Hills material, and when all of the microfauna studied for the present paper is considered it is found that twenty-three of the twenty-nine identifiable species in the Puente Hills material occur also in the lower Wildcat series.

By comparison with a Recent fauna dredged between Long Beach and Catalina Island, California, by Natland (1933) and Clark, it is possible to arrive at some idea of the depth and temperature conditions under which the sediments of the Wildcat coast section were deposited.

On the basis of their bottom distribution Natland found the Recent Foraminifera of the Long Beach-Catalina Island section to be divided into the following five faunal-, or life-zones:

Zone I. Shallow, brackish-water lagoon
Depth at low tide, 1 foot; at high tide, 4 to 7 feet
Temperature, January 1933, 7:30 a. m., low tide
Water 24.44° C. Air 28.33° C.
Temperature, January 1933, 7:30 a. m., low tide
Water 6.54° C. Air 5.66° C.

Zone II. Bottom temperature range, 21.43° C.—13.20° C.
Depth range, 14 feet—125 feet (open ocean)

[8] Recently placed in synonymy under *S. chilostomata* Galloway and Morrey. See Cushman, J. A. and Todd, Ruth, The genus *Sphaeroidina* and its species: Cushman Lab. Foram. Research Contr., vol. 25, pt. 1, p. 18, March 1949.

Zone III. Bottom temperature range, 13.20° C.—8.50° C.
Depth range, 125 feet—900 feet

Zone IV. Bottom temperature range, 8.50° C.—± 4.° C.
Depth range, 900 feet—± 6,500 feet

Zone V. Bottom temperature range, ± 4.° C.—± 2.40° C.
Depth range, ± 6,500 feet—± 8,340 feet

Data for depths below 2,900 feet were obtained outside the Long Beach-Catalina Island area.

On the basis of species common to both Natland's chart and Plate 22 of the present paper, it appears that the Foraminifera of the upper Wildcat faunal group, 500 to 2,200 feet below the top of the Wildcat coast section, belong in the lower part of Natland's Zone II or the upper part of Zone III. Under depth and temperature conditions similar to those encountered by Natland off the coast of southern California this would indicate deposition of these upper Wildcat sediments at depths of about 75 to 150 feet with temperatures around 17.4° C. (64.3° F.)—12.7° C. (54.9° F.). Cooler waters during upper Wildcat time may have resulted in somewhat shallower environment for the upper Wildcat Foraminifera. Reed (1933, p. 253) has pointed out that temperatures, as indicated by the fossil mollusks, were higher in early Pliocene and in southern areas, cool-temperate or boreal farther north and later; and Natland (1933, p. 227) noted that temperature seems to have far greater influence than depth on some Foraminifera.

The lower (Repetto) Wildcat faunal group, 4,350 feet to bottom of the coast section, undoubtedly lived at depths considerably greater than any recorded by Natland between Long Beach and Catalina Island. The greatest depth and the lowest temperature recorded for his dredgings is 2,900 feet, 5° C. (41° F.). With the exception of *Cibicides pseudoungeriana* and *Cyclammina cancellata,* every lower Wildcat species plotted on Plate 22 which occurs in his Recent fauna ranges down to or below this depth on the chart which accompanies his paper. In the material recorded by Natland, some of these species were found only in samples from outside the Long Beach-Catalina Island area and from depths of 6,000 to 8,340 feet.

The depositional history of the sediments exposed in the Wildcat coast section appears to have been one of generally decreasing depths from a beginning possibly in excess of 8,000 feet for the lowermost shales to very shallow, near-shore, or perhaps even non-marine conditions for some of the sands and gravels in the upper 500 feet of the section.

This parallels rather closely the depositional history of the Pliocene and Pleistocene of the Los Angeles and Ventura basins as outlined by Woodring (1938, p. 17):

> In general terms the Repetto formation has a deep-water facies over a large part of the (Los Angeles) basin; the Pico formation has a moderately deep-water and intermediate-depth facies; and the Pleistocene has a shallow-water facies. This succession suggests that the deposition of sediments of decreasing-depth facies during Pliocene and Pleistocene time was a factor in the accumulation of the 6,000 to 10,000 feet of Pliocene and Pleistocene sediments in the Los Angeles Basin. But unless the Repetto sea was much deeper than now appears probable, subsidence also was a factor in the accumulation of these sediments.
>
> Stratigraphic data for the larger fossils may yield information to test the implication that, possible subsidence disregarded, the Repetto formation itself represents decreasing depth facies. . . .
>
> This interpretation of the history of the Los Angeles Basin is not new. It is implied in Natland's analysis of the succession of foraminiferal faunas in the Ventura Basin, where the succession is essentially the same as in the Los Angeles Basin. Reed, who used Natland's data and suggested that the water generally was too deep for bottom-dwelling mollusks, presented this interpretation. . . .

From megafossil evidence, however, Woodring assumed considerably shallower depths for Repetto deposition in the Los Angeles Basin than are indicated by the Foraminifera for considerable portions of the Los Angeles, Ventura, and Humboldt basins during most of Repetto time. His conclusions in this regard were:

> The fossils of deep-water facies suggest that during

> Repetto time the Los Angeles Basin sea had depths of 300 to 600 fathoms (roughly 2,000 to 4,000 feet) . . . .

When comparing faunas from such widely separated areas as these three basins, it is well to bear in mind the closing paragraph of Natland's (1933, p. 230) paper:

> The work here detailed has shown that on the present sea floor, which may some day be a fossil horizon in a sedimentary section, like that exposed in Hall Canyon, there are five distinct faunal assemblages in close proximity. Therefore dissimilar faunas may be contemporaneous and, conversely, the correlation of two widely separated outcrops based on similarity of their foraminiferal assemblages alone is apt to be erroneous. The resemblance of two assemblages indicates similar environments but not necessarily contemporaneity.

The close parallel between the microfaunal sequences of these three thick sedimentary sections (Los Angeles, Ventura, and Humboldt), however, strongly suggests that they were also rather closely related in time of deposition.

ERRATA

Plate 20

On right hand chart which shows "Species Arranged in Order of Last Appearance in Column":

Macoma astor should be *Macoma astori*

Tellina button should be *Tellina buttoni*

Exilioldea rectirostris should be *Exilioidea rectirostris*

Neptunea lirata, var. *altispira.* Second and third occurrences below top of section should be plotted with solid black spots instead of open circles.

On left hand chart which shows "Species Arranged in Order of First Appearance in Column":

Macoma calcarea. Occurrence 3,415 feet below top of section is not plotted. It should be plotted to conform with that shown in the right hand chart.

Neptunea halibrecta. Occurrence 1,730 feet below top of section should be plotted with a solid black spot instead of an open circle.

Mitrella carinata, var. *gausapata.* Uppermost occurrence is plotted about 15 feet higher in the left hand chart than in the chart at the right. From data available at the time of the present revision (1949) it is impossible to say which of these positions is correct.

Plate 22

Uvigerina perigrina should be *Uvigerina peregrina*

Bulimina subaccuminata should be *Bulimina subacuminata*

Goudryina triangularis should be *Gaudryina triangularis*

Clavulina communis (d'Orb.) should be *Clavulina communis* d'Orb.

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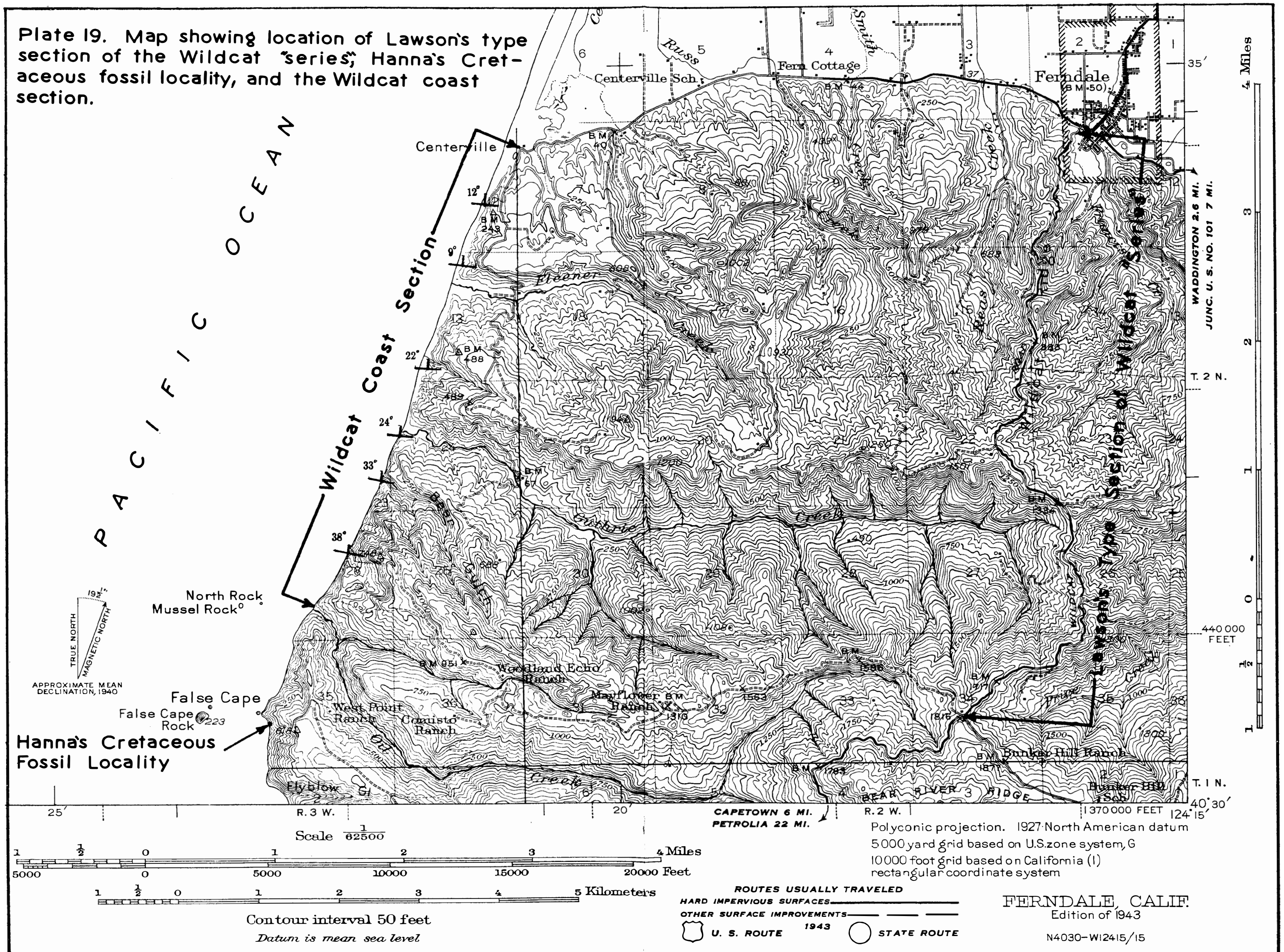
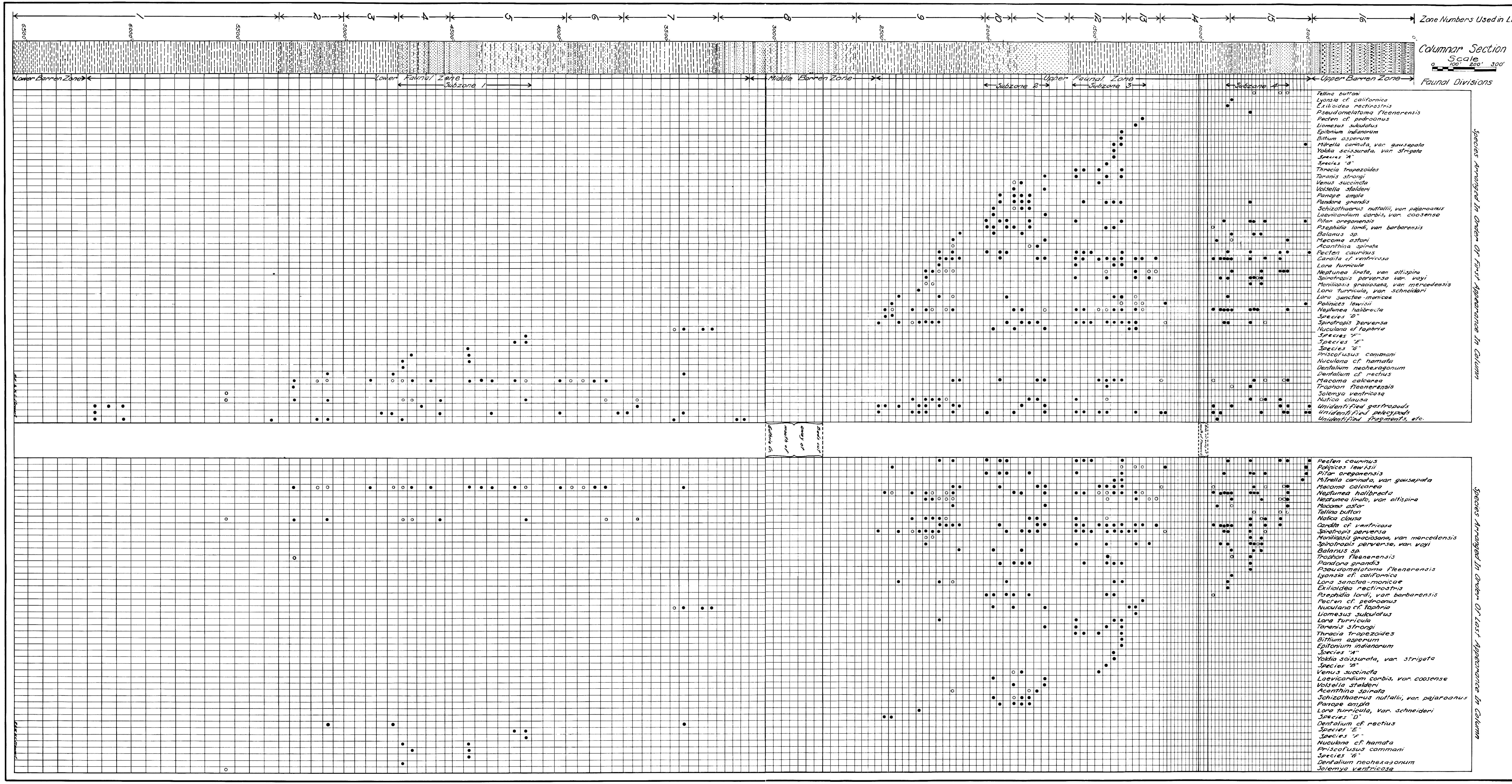


Plate 19. Map showing location of Lawson's type section of the Wildcat "series", Hanna's Cretaceous fossil locality, and the Wildcat coast section.



RANGE CHART

WILDCAT COAST SECTION MOLLUSCA AND CIRRIPEDIA

- ● Identifications based upon complete or nearly complete specimens.
- ○ Identifications based upon incomplete specimens but believed to be correct.

PLATE 20

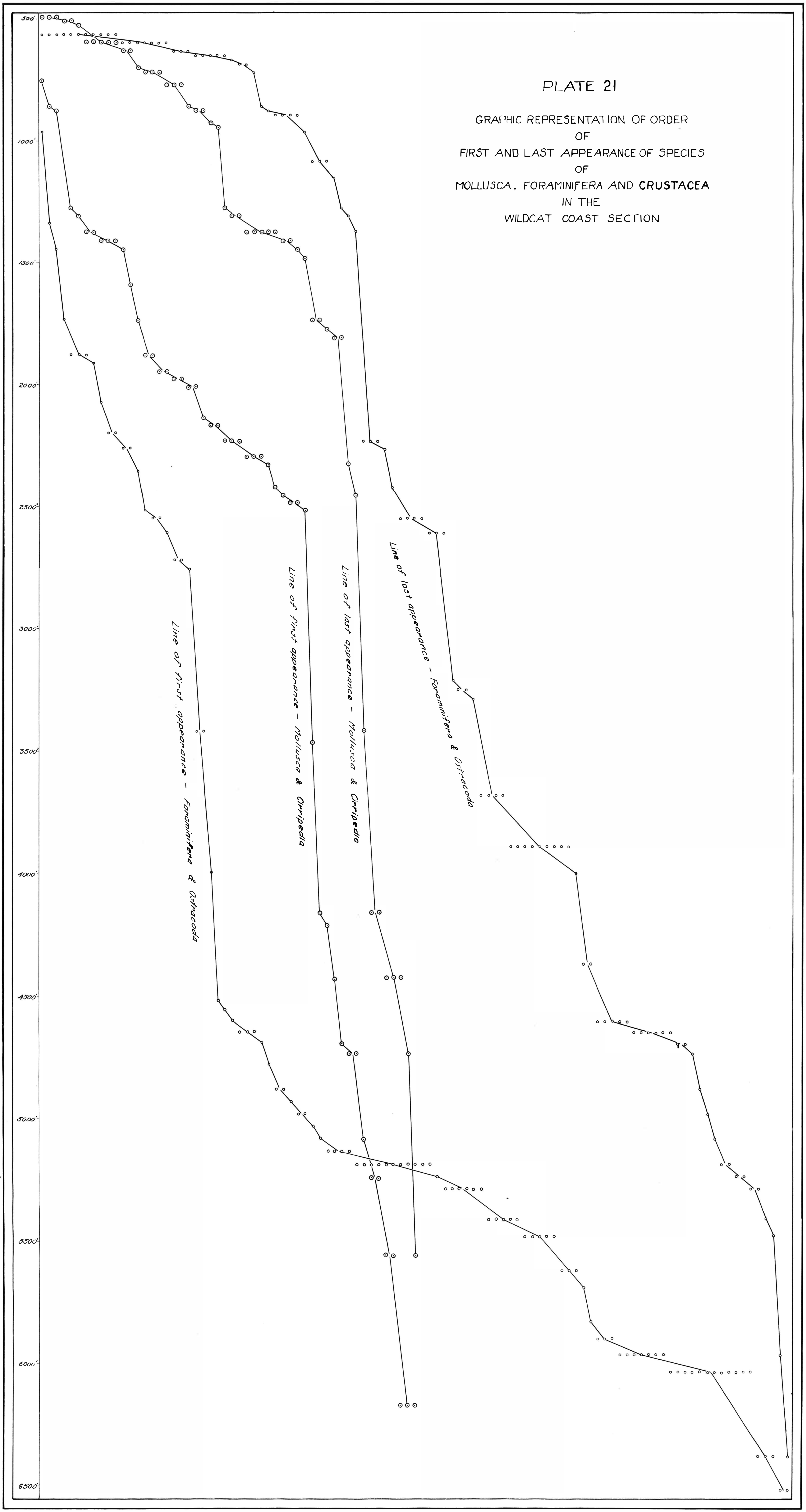


PLATE 21

GRAPHIC REPRESENTATION OF ORDER
OF
FIRST AND LAST APPEARANCE OF SPECIES
OF
MOLLUSCA, FORAMINIFERA AND CRUSTACEA
IN THE
WILDCAT COAST SECTION

RANGE CHART
FORAMINIFERA AND OSTRACODA FROM THE WILDCAT COAST SECTION HUMBOLDT COUNTY, CALIFORNIA
(Does not show complete fauna)

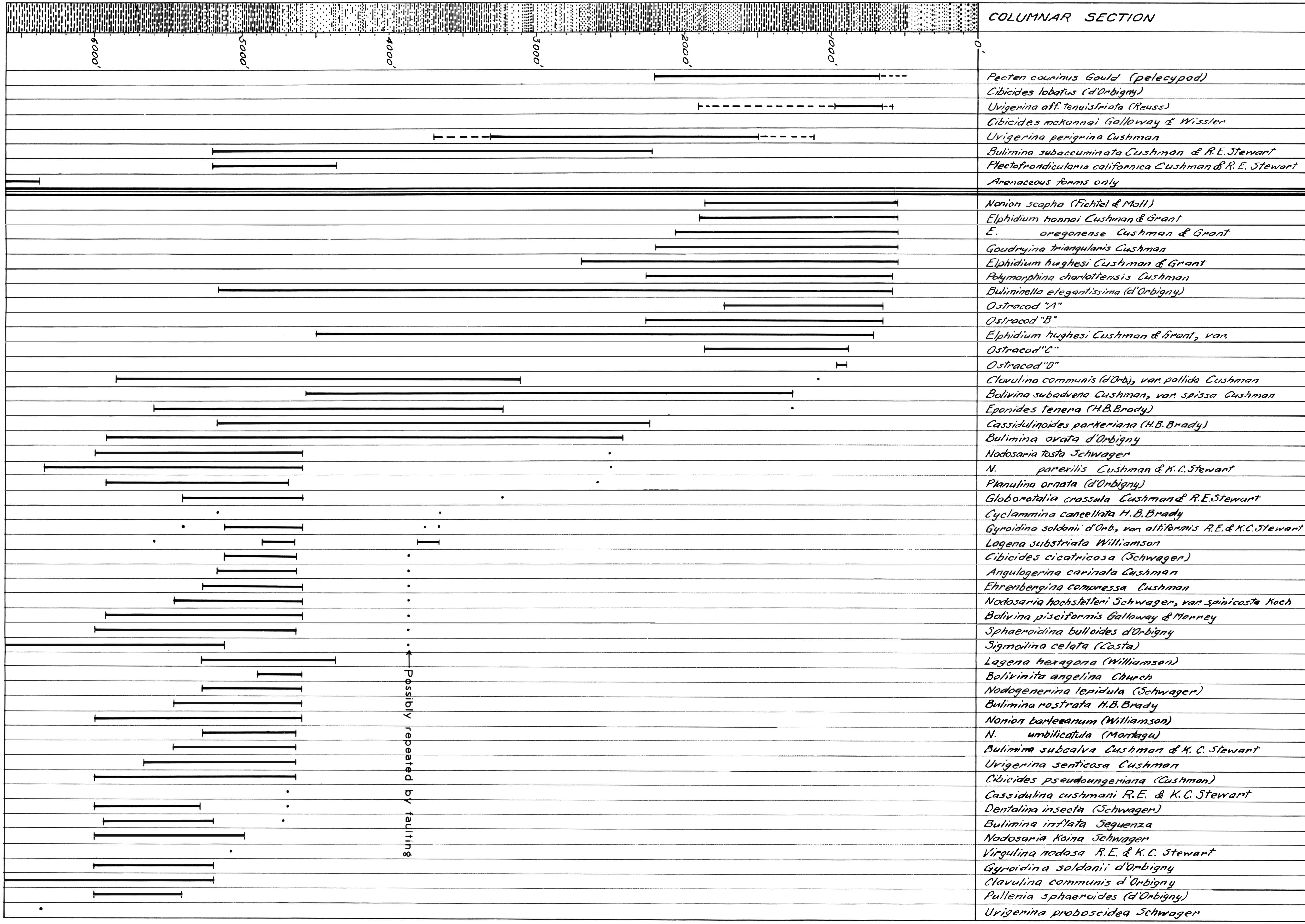


PLATE 22