STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

GEOLOGY OF
EEL RIVER VALLEY AREA
HUMBOLDT COUNTY, CALIFORNIA

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FERRY BUILDING, SAN FRANCISCO

STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
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GEOLOGY OF
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HUMBOLDT COUNTY, CALIFORNIA

By
BURDETTE A. OGLE

LETTER OF TRANSMITTAL

To His Excellency
THE HONORABLE EARL WARREN
Governor of the State of California

SIR: I have the honor to transmit herewith Bulletin 164, *Geology of Eel River Valley Area, Humboldt County, California,* prepared under the direction of Olaf P. Jenkins, Chief of the Division of Mines, Department of Natural Resources. The report is accompanied by a detailed geologic map covering the Ferndale and Fortuna quadrangles and the northern part of the Scotia quadrangle, scale 1 : 62,500. The author, Burdette Ogle, mapped the geology of the area and prepared the report in fulfillment of the requirements for the Doctorate at the University of California.

The area covers that part of the Eel River Basin in northwestern California where much interest is now being centered on the economic development of oil and gas resources. Other mineral materials of economic concern in the area are limestone, sand and gravel, crushed rock, volcanic ash, lignite, hematite, and water resources.

This report represents the results of basic geologic studies which should be of value to all manner of interests in natural resources.

Respectfully submitted,
WARREN T. HANNUM, Director
Department of Natural Resources

July 28, 1953

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GEOLOGY OF EEL RIVER VALLEY AREA HUMBOLDT COUNTY, CALIFORNIA

By Burdette A. Ogle *

ABSTRACT

The Eel River Valley area is in Humboldt County, in northwestern California. The oldest formational unit is the Franciscan formation (Upper Jurassic), which consists of graywacke and shale, and a minor amount of greenstone-basalt, chert, and glaucophane schist. The Franciscan is in fault contact with the Yager formation (Upper Jurassic-Cretaceous?) which unconformably overlies it. Well-indurated dark-gray mudstone, shale, and biotite-rich graywacke are the principal rock types of the Yager formation. A strong angular unconformity separates the Yager and Franciscan from the Wildcat group. Clastic sediments of the Wildcat are more than 12,000 feet thick in the Eel River-Van Duzen River area. In the Ferndale Hills, on the south side of the Cenozoic basin, the Wildcat group can be subdivided into five formational units: Pullen formation (Mohnian to lower Pliocene); Eel River formation (lower Pliocene), Rio Dell formation (middle to upper Pliocene), Scotia Bluffs sandstone (upper Pliocene), and Carlotta formation (upper Pliocene to lower Pleistocene). Northeast of Fortuna these formations cannot be differentiated. Thinning of formational units, facies variations, minor unconformities, and overlap result in rapid changes in thickness and character of the sediments. Sedimentary features and an abundant fauna (foraminifera and megafossils) indicate: (1) a transgression of the upper Miocene sea, (2) minor fluctuations during the Pliocene, and (3) regression during the upper Pliocene, followed by deposition of coarse nonmarine clastics during the lower Pleistocene. A major orogeny followed the deposition of the Wildcat group. The Hookton formation (middle to upper Pleistcene), was deposited on the eroded surface of the Wildcat formation. The Hookton and younger terrace sediments have been gently folded and uplifted.

In the southern part of the area, the False Cape shear zone has been mapped. It contains pulverized pelitic material, sandstone lenticles, and a few pods of basalt, limestone, and chert, which range in age from Jurassic to Pliocene.

Structures in the Yager sediments generally controlled the later structures in the Wildcat group, and these in turn controlled the post-Hookton-formation folds. The principal fold of the region is the east-striking Eel River syncline; smaller anticlines are present to the north and south, and the Yager-Little Salmon fault truncates these structures to the east. Pre-Wildcat-group faults to the northeast and south of the Eel River basin probably aided in the development of a depositional trough.

One small gas field (Tompkins Hill) has been discovered, and several structures remain to be tested for petroleum.

INTRODUCTION

The Eel River Valley area is in Humboldt County in the northwestern part of California. Mapping for this report was confined principally to the Ferndale and Fortuna quadrangles, and to part of the Scotia quadrangle; but considerable reconnaissance mapping, not included herein, has been done in adjacent parts of Humboldt County. The southern boundary of the Fortuna quadrangle is approximately 250 miles north of San Francisco by U. S. Highway 101, and the northern boundary is 4 miles south of Eureka.

The United States Geological Survey Fortuna and Ferndale topographic maps (edition of 1944 and 1943, scale, 1:62500) and a preliminary blue-line print of the Scotia quadrangle were used as base maps; aerial photographs were also used. The writer spent approximately 9 months mapping in the area during the summers of 1948, 1949, and 1950, and about a year in accumulating data, doing laboratory studies, and writing the report.

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* Consulting geologist, William Ross Cabeen and Associates, North Hollywood, California. Manuscript submitted for publication January 1953; condensation of a thesis prepared in partial fulfillment of the requirements for the Ph.D. degree, University of California, Berkeley.

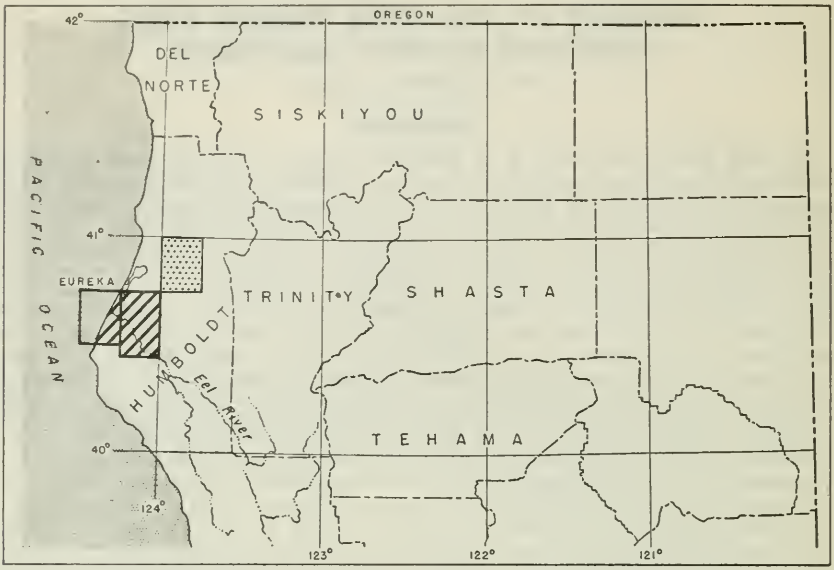


FIGURE 1. Index map of part of northern California showing location of the Eel River Valley area described in this report (heavy line pattern), and also of the Blue Lake quadrangle (stippled) recently published as a geologic map by the Division of Mines.

Purpose of the Investigation. One purpose of the study was to determine the possibility of petroleum production from the thick Tertiary sediments of the Eel River basin. The stratigraphy, sediments, and some of the structures bear a striking resemblance to the productive Ventura and Los Angeles basins, yet only a few oil showings and one gas field have been discovered. Another aim was the investigation of Tertiary sedimentation, paleontology, stratigraphy, and structure. Because of the lack of information about this part of California, considerable reconnaissance was done to obtain a regional background for the specific study, and to gain some general knowledge of the distribution of the formations.

Acknowledgments. The list of those who have contributed information, aid and helpful advice is long. Landowners in the area have always been agreeable and helpful. The lumber companies, especially Pacific Lumber Company, Hammond Lumber Company, Dolbeer-Carson Lumber Company, and Holmes-Eureka Lumber Company, have been of inestimable aid. Among those who have contributed well data and other information are Mrs. Margaret Moore Hughes, who, in her contribution, drew to some extent from material assembled by her late husband, Donald Hughes; The Texas Company; James Dougherty (water-well driller); Golden State Company; Hampton Smith; V. L. VanderHoof; Oscar Fowler; Harry MacGinitie; H. W. Horton; and Thomas W. Dibblee, Jr.; J. Wyatt Durham determined the invertebrate megafossils, and L. G. Hertlein checked the megafossil list; D. I. Axelrod identified some fossil leaves, and H. L. Mason identified some fossil seeds. Members of the Union Oil Company Paleontology Laboratory, Dominguez, California (principally Douglas Crawford and Brad Jones) determined the foraminifera, and C. C. Church checked the foraminifera list. Charles

Gilbert accompanied the writer in the field and offered helpful suggestions, as did Francis C. Turner and Colin Hutton. N. L. Taliaferro supervised the problem and supplied valuable information on several occasions. Robert Kleinpell and V. S. Mallory offered suggestions on stratigraphy and foraminiferal data. Miss Helen Bailey, librarian of the Geology Department, University of California, helped prepare the bibliography, and Mrs. Lorraine Ogle, who has been a constant source of encouragement, helped the writer measure some sections, and aided in the preparation of some plates.

GEOGRAPHY

Accessibility. All parts of the Ferndale quadrangle are readily accessible, except the Guthrie Creek basin. Of several good roads which cut across the general strike of the Tertiary formations, the best is Wildcat Road. U. S. Highway 101 crosses the Fortuna quadrangle from south to north, but it follows the low country, which offers few exposures. State Highway 36 extends from Alton eastward along the Van Duzen River and eventually reaches Red Bluff in the Sacramento Valley. The western and southern parts of the Eel River area have numerous county roads and many logging roads in various states of repair; but the eastern and northeastern parts are almost inaccessible. A few logging roads and logging railroads furnish access and some exposures, but most of the region is covered by a dense growth of virgin redwood or second-growth redwood forest.

Climate. Climate of the northern California coastal region is humid and cool. Rainfall is heavy and occurs mostly during the winter months. Many of the winter rains are torrential; as much as 4 inches in 24 hours has often been recorded. This causes occasional floods in the lower reaches of the Eel and Van Duzen Rivers, and leads to rapid erosion in the numerous small streams. Persistent and heavy fogs blanket the lowlands for at least part of the usual summer day, and overcast skies, drizzles, and mists are common.

Vegetation. Originally, most of the Eel River region was heavily wooded. Since the 1850s, however, the inhabitants have cleared most of the usable agricultural land in the lowland areas. Thus today the valleys of Eel River, Elk River, Salmon Creek, and Van Duzen River are principally open farm land. Many of the terrace surfaces are grassland used for grazing. But, aside from these open areas, the region mapped is covered by forests or brush, except for occasional natural-grass openings and man-made clearings. Redwood forests, either virgin or second growth, cover all of the upland area northeast of the Little Salmon Creek fault, as well as the area east of Price Creek and south of the Van Duzen River.

Two strikingly different floras occur, one consisting predominantly of fir and spruce, the other principally of the redwood *Sequoia sempervirens.* The redwood flora has its southwest limit along the ridge east of Price Creek in the southwest part of Fortuna quadrangle. From this area it extends south, north, and east, covering valleys and ridges alike throughout the northeastern part of the Fortuna quadrangle; but it extends only 3 miles east of the eastern boundary of the quadrangle, except along the Van Duzen River. Beneath the redwoods is a

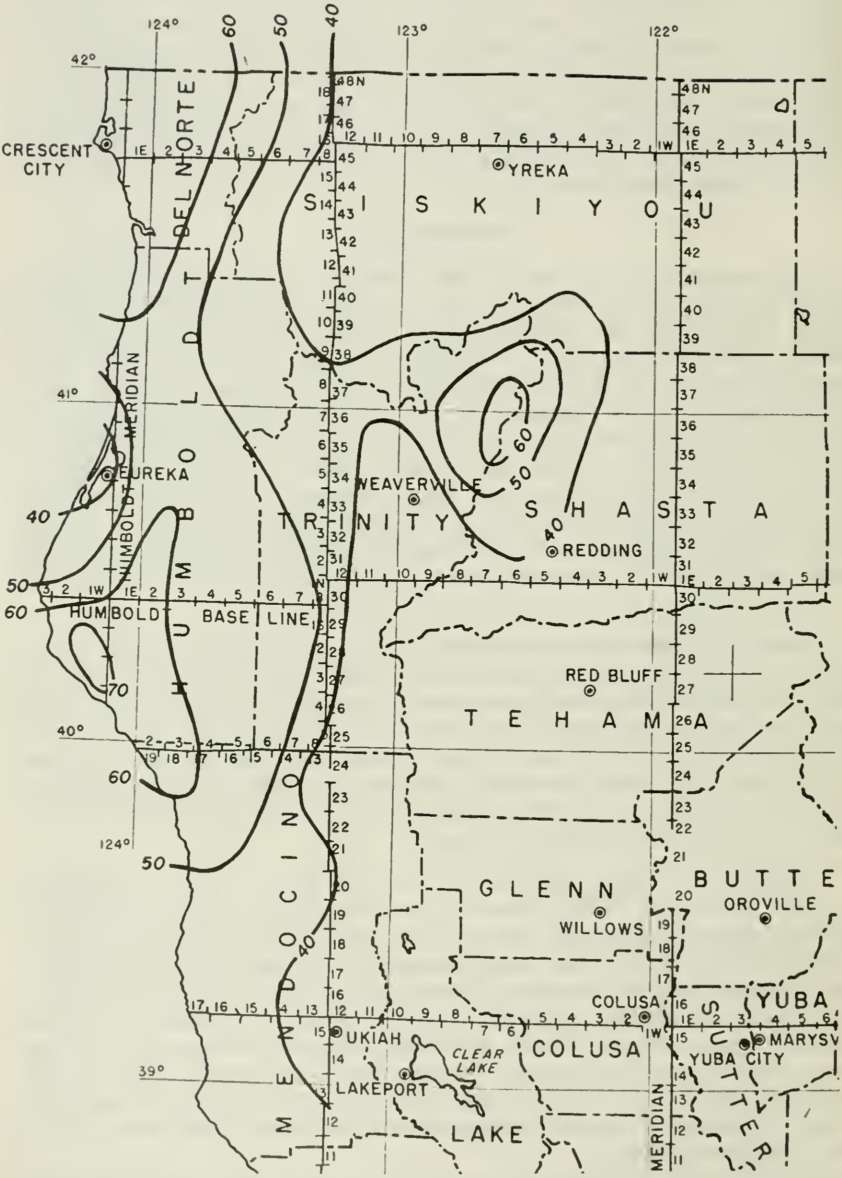


Figure 2. Map showing distribution of rainfall in 1944 in inches, northern California coastal region. From U. S. Weather Bureau Monthly Bulletin, Climatological Data.

constant dense shade, which keeps the ground moist. Scattered among the redwoods are madrones, tan oaks, and a varied low cover. The low vegetation is generally most dense and luxuriant on the southern slopes where more sunlight filters down to it. Sword ferns, salal, huckleberry, and young tan oak "brush" are common in most areas, and along streams alders, willows, thimbleberry, salmon berry, and nettles form an impenetrable thicket. The ground is commonly covered with a carpet of leaves, leaf mold, moss, and small shade-loving plants. By contrast, in the second-growth areas, the vegetation depends on the severity of the burning that follows logging operations, on the method of logging, and on the lapse of time since the last logging. Usually the redwood stumps begin to sprout young trees within the first year after burning. If seed trees are left, some redwood and firs begin to grow from seed the first several years. Often rapid-growing shrubs and trees such as *Ceanothus velutinus,* tan oak, manzanita, huckleberry, thimbleberry, and blackberry spring up and at first clog the landscape. They act as shade for the young evergreens and cause them to shoot skyward more rapidly. The struggle for occupancy of cut-over areas leads to a jungle of vegetation which is often more difficult to penetrate than the virgin forests.

The coastal flora covers the area west of Price Creek, and part of Table Bluff and Humboldt Hill. Many of the fir and spruce trees have been cut or burned in part of the area. On the coastal slopes dense brush covers some of the hillsides, and thimbleberry and salmonberry, normally confined to creeks, grow as thickets on the open hillside. Willows are common along the rivers, and California laurel and maple are numerous. Poison oak and nettles are abundant and annoying.

Vegetation generally grows with equal success on the various types of rocks in the area. Moisture is abundant and the regolith is deep so that, with a few exceptions the forests seem to grow as well on Franciscan schist as on Recent alluvium. However, some of the slumpy mudstone areas support only grass, probably because larger plants cannot become properly rooted. Although a few natural openings occur on the Yager shales in the eastern part of the Fortuna quadrangle, none exist on the Wildcat in that region. Some areas of the Hookton formation and later terrace deposits support little but annual grasses.

The abundant vegetation plays an important role in supplying organic acids which aid in the rapid chemical decomposition of the surface rocks. Podsolization in moist-temperate regions is most effectively carried out in conifer forests (Riecke, 1950). The myriad root systems also aid in the physical disintegration of the rocks and increase porosity, thus allowing deeper penetration of organic acids. Some fresh road cuts in the redwood forests have exposed sections 20 feet deep in foraminifera-bearing Pliocene siltstone in which all calcareous tests within 10 feet of the surface have been completely destroyed.

Topography. Approximately one-fifth of the mapped area is occupied by nearly flat alluviated valleys and tidal plains at or near sea level. The principal streams which have developed valley-plains near their mouths are the Eel River, the Van Duzen River, Salmon Creek, and Elk River. Most of the regions mapped as the Hookton formation and later terrace deposits are gently sloping plane surfaces 100 to 750 feet in elevation, The remainder of the area is mountainous. South of Eel River valley the Ferndale Hills rise in a succession of sharp ridges to the highest points along Bear River Ridge. The highest elevation shown on the map is 2,350 feet at the extreme southern edge of the Ferndale quadrangle. Many of the ridge crests are nearly level or gently sloping; but the slopes of the ridges are moderately steep, and some of them, like those cut in the Scotia Bluffs sandstone and Carlotta conglomerate, are precipitous.

The coastline south of Centerville Beach is a rugged combination of wave-cut cliffs, landslide scars, and small insequent streams. Waves are consistently undermining the relatively weak sediments, cutting near-vertical cliffs or causing slides; therefore exposures change considerably from year to year.

The mountains in the northern and eastern part of Fortuna quadrangle have no formal name, but may conveniently be called the Fortuna Hills. Their topography is generally similar to that of the Ferndale Hills.

STRATIGRAPHY

Formational units mapped include rocks ranging in age from Upper Jurassic to Quaternary. The oldest is the Franciscan formation (Upper Jurassic). In the southern part of the Ferndale quadrangle a group of sheared rocks, consisting predominantly of Franciscan rock types, has been mapped as the False Cape shear zone. In fault contact with the Franciscan and False Cape shear-zone rocks are sediments of the Yager formation (new name), which may range from Upper Jurassic to Cretaceous. Overlying all these units are the sediments of the Wildcat group, the members of which range in age from upper Miocene (Mohnian) to lower Pleistocene. The Wildcat group is divisible in the Eel River area into five formational units: the Pullen (new name), Eel River (new name), Rio Dell (new name), Scotia Bluffs, and Carlotta (new name).

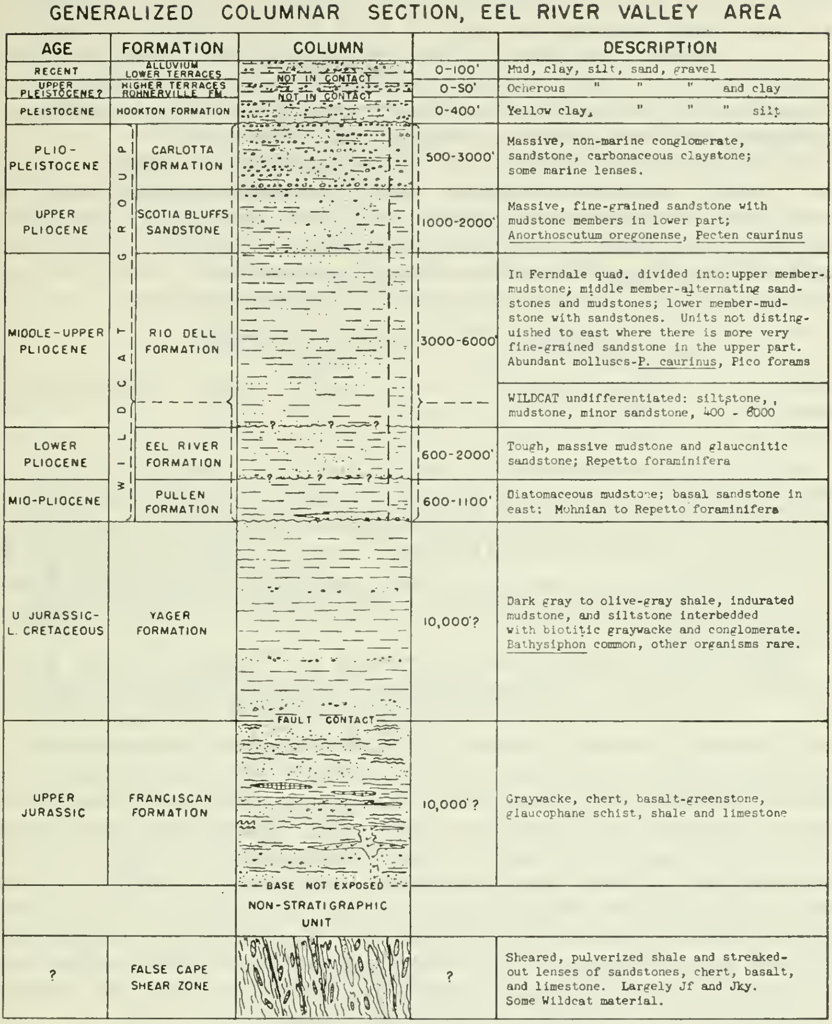
Continental sediments of Pleistocene age have been mapped as the Hookton formation (new name), the Rohnerville formation (new name), and terrace deposits. Recent stream-terrace deposits have been differentiated to indicate the number of stages; alluvium and younger stream gravels also have been mapped.

Franciscan Formation

Although an area of about 5 square miles in the northeastern part of the Fortuna quadrangle is the only Franciscan in the area mapped, Franciscan rocks form a large northwest-trending belt extending at least 20 miles in a northwesterly direction to the coast; over 100 miles in a southeasterly direction; and at least 15 miles in a northeasterly direction. A description of the contiguous part of this belt outcropping in the Blue Lake quadrangle has already been given by Manning and Ogle (1950).

The classic *Franciscan-Knoxville Problem* (Taliaferro. 1943b) is the most comprehensive, up-to-date account of Franciscan and Knoxville rocks in California, and contains an excellent bibliography. Earlier descriptions of the lithology of the Franciscan include the papers on chert by Davis (1918a) and Taliaferro (1933), and the one on sandstone by Davis (1918).

Lithology. In the Eel River area the Franciscan consists principally of massive graywacke, and a minor amount of platy, dark-gray shale,



GENERALIZED COLUMNAR SECTION, EEL RIVER VALLEY AREA

AGE	FORMATION	COLUMN		DESCRIPTION
RECENT	ALLUVIUM LOWER TERRACES	NOT IN CONTACT	0-100'	Mud, clay, silt, sand, gravel
UPPER PLEISTOCENE?	HIGHER TERRACES ROHNERVILLE FM.	NOT IN CONTACT	0-50'	Ocherous " " " and clay
PLEISTOCENE	HOOKTON FORMATION		0-400'	Yellow clay, " " " silt
PLIO-PLEISTOCENE	WILDCAT GROUP CARLOTTA FORMATION		500-3000'	Massive, non-marine conglomerate, sandstone, carbonaceous claystone; some marine lenses.
UPPER PLIOCENE	SCOTIA BLUFFS SANDSTONE		1000-2000'	Massive, fine-grained sandstone with mudstone members in lower part; Anorthoscutum oregonense, Pecten caurinus
MIDDLE-UPPER PLIOCENE	RIO DELL FORMATION		3000-6000'	In Ferndale quad. divided into:upper member-mudstone; middle member-alternating sandstones and mudstones; lower member-mudstone with sandstones. Units not distinguished to east where there is more very fine-grained sandstone in the upper part. Abundant molluscs-P. caurinus, Pico forams
				WILDCAT undifferentiated: siltstone, , mudstone, minor sandstone, 400 - 6000
LOWER PLIOCENE	EEL RIVER FORMATION		600-2000'	Tough, massive mudstone and glauconitic sandstone; Repetto foraminifera
MIO-PLIOCENE	PULLEN FORMATION		600-1100'	Diatomaceous mudstone; basal sandstone in east: Mohnian to Repetto foraminifera
U JURASSIC-L. CRETACEOUS	YAGER FORMATION	FAULT CONTACT	10,000'?	Dark gray to olive-gray shale, indurated mudstone, and siltstone interbedded with biotitic graywacke and conglomerate. Bathysiphon common, other organisms rare.
UPPER JURASSIC	FRANCISCAN FORMATION	BASE NOT EXPOSED	10,000'?	Graywacke, chert, basalt-greenstone, glaucophane schist, shale and limestone
		NON-STRATIGRAPHIC UNIT		
?	FALSE CAPE SHEAR ZONE		?	Sheared, pulverized shale and streaked-out lenses of sandstones, chert, basalt, and limestone. Largely Jf and Jky. Some Wildcat material.

FIGURE 3. Generalized columnar section, Eel River Valley area.

red, thin-bedded chert, dark-green greenstone-basalt, and glaucophane schist.

Graywacke, as defined by Pettijohn (1949), is the principal rock type and makes up perhaps 75 percent of the Franciscan outcrops in the mapped area. Most of it is massive, but some thin shales are interbedded with it. When fresh, as in some recently cut stream canyons, the graywacke is dark gray or gray green, hard, tough, and where waterworn characteristically forms smooth, rounded, massive boulders. On upland slopes it weathers locally to a dirty green-brown rock of varying hardness and resistance.

Hand specimens of Franciscan graywacke show angular to subangular poorly sorted grains of feldspar, quartz, biotite, and rock fragments (chert, volcanic rocks, quartzite, slate, mica schist) bounded by greenish-gray argillaceous material that is crystallizing to chlorite, epidote, sericite, and other silicates. Some distorted grains of pearly white muscovite (Crittenden, 1949) contribute to the overall igneous appearance of the graywacke. Some graywacke, in fact, is tuffaceous and may, in places, grade into altered tuff (Ogle, 1947).

Microscopic examination of the graywacke shows the feldspar grains to be chiefly oligoclase-andesine; heavy minerals separated from the rock were hornblende and epidote, and some zoisite and clinozoisite, sphene, zircon, apatite, tourmaline and brookite; the effects of rotation and shifting of angular grains under pressure are seen in thin sections as a dense packing of grains separated by thin cement films.

Composition of two samples of graywacke.

Sample	Fine rock fragments	Feldspar	Quartz	Shale chips	Minor	Carbonate	Matrix
80-S1	27	23	24	1	2	--	23
80-S2	52	21	11	--	--	8	8

Some fresh graywacke has been brecciated into fragments which range from a quarter of an inch to 6 inches in length, and then cemented by similar sandstone or limy or siliceous cement. Commonly, no extraneous fragments are mixed with the brecciated rock. A possible explanation of the origin of the rock may be that during deposition, consolidated Franciscan sandstone was fractured and rebonded by continued deposition of similar sand.

Although graywacke makes up most of the sediments of the Franciscan of this area, a few conglomerate beds were observed. Some outcrops of graywacke contained abundant shale chips. Shale and siltstone are apparently lacking, except for thin interbeds in the graywacke. In the few exposures studied, the fresh shale is dark gray-black, thin-bedded, slightly platy, hard, and brittle. Upon slight weathering, it becomes olive-gray to greenish or drab. Tiny disseminated mica flakes may give a slight sheen to the surface. The weathered shale closely resembles that of the Yager formation. Fractures and bedding planes are stained by iron and manganese. Only one exposure of chert was found, and that was in NE$\frac{1}{4}$ sec. 24, T. 4 N., R. 1 E., H. The outcrop consists of about 200 feet of thin-bedded maroon chert and clay shale and pale-green non-radiolarian interbedded chert. The beds are slightly contorted, but in general dip steeply to the east.

Few volcanic rocks were seen. One rather extensive outcrop was observed in the southeast part of the Franciscan exposed in the Fortuna quadrangle; another small mass has been quarried for road metal in the northeast corner of sec. 12, T. 4 N., R. 1 E., H.; and a large knob of metavolcanic rocks has been cut through by the logging railroad just east of the Yager-Franciscan contact in sec. 14, T. 4 N., R. 1 E., H. All of these are dark green rocks, much fractured and veined with calcite; they are mapped as Franciscan basalt. Contact relations between these and other rocks are not clear, but the first outcrop mentioned may be a flow, whereas the other two appear to be intrusions.

None of the diabase, diorite-gabbro, peridotite, or serpentine so common in Franciscan terranes has been found within the confines of the Fortuna quadrangle, but all occur in the Franciscan belt of which this is a part. Several are described from the Blue Lake quadrangle. On Chalk

Ridge are several dioritic intrusions, serpentine, and one white granitic intrusive known as "Chalk Rock." Bear Buttes, northwest of Garberville, is a large, intrusive complex of diorite-grabbro-diabase.

A few small exposures of schists in place were seen in the Fortuna quadrangle—a fact which has important bearing in consideration of the schist boulders at the base of the Pliocene, as well as those scattered widely over the surface of the Franciscan in this area. One small area of micaceous glaucophane-lawsonite schist was mapped in the NW¼ SW¼ sec. 12, T. 4 N., R. 1 E., H. This schist has schistosity and foliation, and locally is highly contorted, with numerous folds and crenulations.

A thin band of glaucophane-chlorite schist is exposed along a shear zone in a greenstone mass outcropping in sec. 12, T. 4 N., R. 1 E., H. Because of the crenulated nature of these rocks and evidences of paratectonic growth of the glaucophane, it is suggested that some structural forces may have been active during the formation of the metamorphic minerals. No intrusives are adjacent to the metamorphics. If the local pneumatolytic origin described by Taliaferro (1943b) is responsible, parent fluid sources must be inferred to be present at depth.* Briggs (1950, pp. 37-38) has recently called attention to the paratectonic development of glaucophane in Franciscan schists formed by dislocation metamorphism adjacent to the Ortigalita-Tesla thrust zone in the Diablo Range in central California.

Numerous accumulations of angular or rounded fragments of the more resistant types of Franciscan rocks (glaucophane schist, greenstone, chert, serpentine) occur on the upland surfaces and along rivers and creeks. Mass wastage, great ancient slides, and the relative resistance of these rocks must account for their erratic position.

Stratigraphic Relations. The Franciscan in the Fortuna quadrangle is in fault contact with the Yager formation and is overlain unconformably by the Wildcat group (undifferentiated). The Freshwater fault, which serves as the contact between Franciscan and Yager rocks, is an indefinite, partly inferred fault mapped in reconnaissance as a nearly straight line for at least 40 miles southeastward to a point near Phillipsville. Dibblee (oral communication, 1950) reports that west of Phillipsville, near Salmon Creek, the Yager formation, which he calls Knoxville, overlies the Franciscan on either a gradational depositional contact, or a locally unconformable contact. Weathered shale and sandstone of the Franciscan formation resemble those of the Yager formation. In gross percentages, there is usually more shale in the Yager and more sandstone in the Franciscan. The Franciscan rocks are normally more fractured, harder, more sheared and have more massive sandstone. In the large area mapped as Yager formation, none of the typical Franciscan rocks (glaucophane schist, red chert, greenstone basalt) have been found.

Fauna. No fossils were found in the Franciscan of this area, but in 1946 H. D. MacGinitie found some fossils in a lithologically similar belt of Franciscan near Trinidad, about 35 miles northwest of the Fortuna quadrangle. These were obtained by the writer (Ogle, 1947) and were later studied and described by Angel and Conrey (1948, p. 5, and plates),

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* A more complete discussion of the Franciscan metamorphics is given in the author's unpublished doctor's thesis (Ogle, 1951).

who identified two *Buchia (Aucella)* in a dark-gray massive limestone, and stated

> Both of these forms are bulbous and heavy-ribbed and seem to have more affinities to the Cretaceous *Buchia* than to those of the Jurassic. The smaller of the two forms has been tentatively identified as *Buchia occidentalis* (Anderson). F. M. Anderson (1945) states that [a specimen of] this form was found in Upper Jurassic beds. It is possible that these *Buchia* may be the forerunners of the later bulbous forms of the Cretaceous.

The larger *Buchia* was listed as *Buchia* sp. The writer knows of no other megafossils from the Franciscan of northwestern California which have been identified. This one *Buchia* then, is the most direct evidence of an Upper Jurassic age for the Franciscan in the Fortuna quadrangle.

Taliaferro (1943b) gives the age of the Franciscan-Knoxville group as late Upper Jurassic, Tithonian, based on meager fossil evidence. On the basis of lithologic similarity, the rocks mapped as Franciscan in this area may then be considered late Upper Jurassic in age. The base of the Franciscan has not yet been found; to the northeast the formation is in fault contact with older rocks, principally the Kerr Ranch schist (Manning and Ogle, 1950).

Thickness. No accurate figure can be given for the thickness of the Franciscan in the Fortuna quadrangle, or for the thickness of Franciscan exposed in the belt in Fortuna and Blue Lake quadrangles because (1) there may be unmapped folds, as attitudes are sparse; (2) unknown intra-Franciscan faults may duplicate the section; (3) neither the top nor the bottom is present in the area. The attitudes shown on the Blue Lake (Ogle, 1947) and Fortuna quadrangles indicate that the Franciscan comprises a homoclinal northeast-dipping series of beds whose aggregate thickness may total nearly 50,000 feet. However, this figure is probably far greater than the correct one. Although continuous northeast-dipping strata can be traced for several thousand feet along the Kneeland-Mad River road in the Blue Lake quadrangle, unknown faults may reduce this thickness to possibly half that given, or 20,000 feet plus. The width of outcrop of known Franciscan, measured perpendicular to general strike by D. McNaughton and the writer between the Yager-Franciscan contact west of Bridgeville and the Franciscan-Kerr Ranch schist contact on South Fork Mountain, is more than 20 miles. Much of this area does not appear to be tightly folded or badly contorted, but major faults may be numerous. Estimates of thickness of the Franciscan farther south have been given as 10,000 to 25,000 feet by Taliaferro (1943b) and others.

Yager Formation

The name Yager formation is proposed for the series of dark-gray indurated mudstone, shale, graywacke, and conglomerate exposed in Yager Creek in Fortuna quadrangle, north of the fault contact with the Wildcat group. It is suggested that this name be used until suitable faunal evidence establishes the age of the unit and allows more adequate correlation with established formations, or until a well-exposed type section with clear stratigraphic relations above and below can be set up. It is possible that the rocks included in the Yager formation range from Upper Jurassic to Upper Cretaceous in age. Most evidence points to a Cretaceous age.

The Yager formation exposed in the eastern Fortuna quadrangle is in contact with the Franciscan along the Freshwater fault, and is overlain by Wildcat sediments with strong angular unconformity. The Wildcat formation in this area is thin and low-dipping, and streams have cut through it and exposed the Yager formation in the valley bottoms. In the southern part of the mapped area the Yager is a narrow belt of sediments in fault contact on the south with rocks of the False Cape shear zone, and overlain unconformably on the north by the Pullen formation (upper Miocene to lower Pliocene). It is fairly well exposed on the east bank of the Eel River at Scotia. That the Yager underlies the Tertiary sediments of the Eel River Valley area is known from well data.

The eastern boundary of the Yager formation has been fairly well established by reconnaissance beyond the Eel River Valley area. The Yager and Franciscan are probably in fault contact along the Freshwater fault from upper Elk River southeast to Chalk Mountain. The fault has been traced southward from Chalk Mountain to Phillipsville, where it apparently passes into the Franciscan. West of Phillipsville the Yager-Franciscan contact has been mapped as depositional (Dibblee, T. W. Jr., oral communication, 1950).

The Yager shale and sandstone can be seen at many localities along U. S. Highway 101 and along the Eel River between Phillipsville and Larabee. Good sections are exposed on Salmon Creek (Eel River tributary near Miranda); along the North Fork of the Elk River (Fortuna quadrangle), both in logging-railroad cuts and in the stream bed; on Yager Creek near the Pacific Lumber Company Camp; along parts of Salmon Creek (Fortuna quadrangle); and along the Van Duzen River and State Highway 36 west of Bridgeville. Near Swain's Flat (*Melania* locality) is an excellent road cut in spheroidal-weathering mudstone from which megafossils have been obtained. On Larabee Creek, east of Larabee Lodge, are numerous conglomerates associated with the sandstone and shale.

Only a few outcrops of sandstone and conglomerate are found in the upland areas. Typically the surface is covered with forest duff and soil sprinkled with a few shale and sandstone chips. Most road cuts, 4 to 5 feet deep, show nothing but a rubble of sandstone and shale fragments, the result of slumps and surface creep.

Petrography. The Yager formation is principally mudstone, shale, graywacke, siltstone, and conglomerate, with some interbedded limy siltstone. The pelitic sediments weather to soft clayey materials, and so are poorly exposed, in contrast to the harder sandstones which are found along the streams as boulders. From exposures along railroad cuts in the Yager Creek and Elk River areas it appears that the mudstone, siltstone, and shale make up perhaps 70 percent of the total, while the sandstone makes up 25 percent, and the conglomerate less than 5 percent.

The predominant fine-grained sediment is platy shale, much of which is interbedded with thin sandstone or siltstone. It is hard, irregularly fissile, and breaks into small platy chips when subjected to mechanical weathering. The mudstone and siltstone are thick bedded, and weather to hard ovoid or curved chips. When fresh, these sediments all are dark gray in color, but when slightly weathered they change to olive gray. A purplish-brown stain, probably a ferruginous-manganiferous coating, is common on fracture surfaces. A fresh-broken surface has a slight sheen which is produced by abundant finely divided plates of mica. Some carbonaceous material is present in the shale. Near the Yager fault on Yager

Creek there are numerous small black carbonized-wood fragments, which resemble bituminous coal in luster and texture; there are also numerous crustacean * borings, 4 to 6 inches in length and averaging half an inch in diameter. Some of the borings are horn-shaped, and some resemble long tubes.

The graywacke of the Yager formation is dark gray in color when fresh, but in most exposures is olive gray, and when deeply weathered becomes olive brown. It is not as hard as the typical Franciscan graywacke; it usually breaks around the grains, forming an irregular surface, in contrast to the many Franciscan graywackes, which break across the grains. The Yager graywacke is resistant when compared with the pelitic sediments, and forms large pillar rocks above the surrounding landscape. Some of the beds are massive and several hundred feet in thickness, whereas others are but thin interbeds in the shale.

In hand specimen the typical Yager graywacke is seen to be medium grained, greenish gray, and well indurated; large flakes of muscovite showing a rude orientation suggestive of bedding occur in some specimens. Platy chips of shale-slate are common; they range from one-eighth of an inch to as much as an inch in length. Under the hand lens abundant sharply angular to sub-angular feldspar, quartz, and tiny rock fragments can be seen. Many of the grain boundaries are not clear because of greenish-gray intergranular clayey material which surrounds the grains. Some chlorite can be identified and epidote is common. The rock generally has a dull color except for the flash of the micas. Weathered specimens are difficult to distinguish from some Franciscan graywacke, but as a rule biotite is more abundant in the Yager.

The quartz is clear and sharply angular, and much of it is sliver-shaped. Feldspar is somewhat less angular; some of it is fresh, but much of it is cloudy and altered. Much of the biotite is being altered to chlorite and magnetite. Some of the bright green patches of chlorite may be authigenic.

Rock fragments in the Yager graywacke include colorless and red chert and greenstone, and some quartzite and mica schist. The presence of red chert and glaucophane suggests that the Yager graywacke may have been derived from Franciscan rocks, at least in part. The Yager sandstone has more feldspar, more rock fragments and less chert, about the same amount of quartz, more biotite, and less paste than the Franciscan graywacke. Because of the lesser amount of paste the Yager graywacke might be considered better sorted than its Franciscan counterpart.

Conglomerate is not common in the Yager formation; in general it forms small lenses interbedded with graywacke. Nevertheless, some of the conglomeratic members are among the most resistant of the Yager rocks, and they form bold outcrops.

Two types of conglomerate can be distinguished: one made up principally of small chips of shale-slate, and another composed of a variety of pebbles including red (Franciscan?) chert, greenstone-basalt, graywacke, well-rounded porphyry, quartzite, and black chert. In the second type, most of the pebbles range from half an inch to 2 inches in size and are Franciscan rock types; also present are the well-rounded resistant pebbles found in Franciscan and all younger conglomerates of the Coast Ranges. These pebbles are set in a matrix of argillaceous sandstone.

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* Identified by J. Wyatt Durham.

*Composition of five typical graywackes from the Yager formation.**

Sample	Feld-spar[1]	Rock fragments		Quartz	"Paste"[2]	Biotite	Chlorite	Other minor minerals[3]
		Chert	Others					
80-S3	42	8	17	23	5	3	1	1
80-S4	49	8	5	14	9	5	5	5
80-S5	23	4	15	37	7	6	4	4
80-S6	38	10	11	27	5	6	2	1
80-S7	39	10	10	27	4	6	3	1

* Percentages computed with Wentworth stage. Localities from which specimens were taken are listed in the appendix.

[1] Feldspar is predominantly plagioclase, generally in the range oligoclase-andesine, but there are minor amounts of orthoclase.

[2] "Paste" is the term suggested by Pettijohn (1949) for the fine, more or less indistinguishable, intergranular material in graywacke. In these rocks little other than finely divided chlorite can be identified. It appears that the paste has not progressed as far toward recrystallization as that of the Franciscan graywacke. Some of the fine chloritic material appears to grow into the quartz and feldspar and produce a ragged edge on such grains.

[3] "Other minor minerals" include, in order of abundance, muscovite, epidote, opaque minerals, zircon, sphene, glaucophane, hornblende, garnet, apatite, rutile, augite, and zoisite. Some calcite is present as veinlets or as a secondary mineral replacing plagioclase.

Stratigraphy. The Yager formation is in fault contact with Franciscan in the northeastern part of the Fortuna quadrangle, and with the rocks of the False Cape shear zone along the Russ fault in the southern part of the quadrangle. It is overlain unconformably in the southern area by the Pullen formation, and farther north by rocks mapped as undifferentiated Wildcat. Along the Yager fault, the Yager formation is faulted against mudstones of the Rio Dell formation and Eel River formation.

The relationship of the Yager formation to the Franciscan formation suggests that the Yager is younger. Rock types of the Yager are generally less indurated and sheared than similar rocks of the Franciscan; some Yager conglomerates contain numerous red chert, greenstone-basalt, and Franciscan-like sandstone. Furthermore, rocks of the Yager formation resemble those of the Knoxville formation or Cretaceous formations cropping out in other parts of California.

The Geologic Map of California (Jenkins, 1938) shows belts of Cretaceous, Knoxville, and Franciscan on the Van Duzen River between the Pliocene contact and Bridgeville. The Franciscan-Knoxville contact is shown at the approximate location of the writer's Franciscan-Yager contact (Freshwater fault), but no Cretaceous-Knoxville differentiation can be made on the basis of lithology. Faunal data are woefully meager. A few of the Yager shales or mudstones contain numerous slender objects shaped like pine needles, rarely as much as 3 inches in length, which have been identified as the arenaceous foraminifer *Bathysiphon sp.* Stanley Beck has identified two additional arenaceous foraminifera, *Cribrostomoides sp.* and *Clavulina sp.* from Yager mudstone collected at the Forest of Arden Resort north of Garberville (Douglas Wilson, oral communication 1950). B. C. Jones of the Union Oil Company Paleontology Laboratory has identified *Bathysiphon sp.* and *Silicosigmoilina sp.* in one Yager sample. Not enough is known about the earliest occurrence of the genus *Silicosigmoilina* to give a positive statement about the indicated correlation; but its common occurrence in California sediments of the Cretaceous and early Tertiary suggests that the Yager is at least as young as Cretaceous. The writer and others have seen *Bathysiphon* in some sheared shales mapped as part of the Franciscan, but no mention of them has been found in the literature on Knoxville and Franciscan rocks. Dr. N. L. Taliaferro informed the writer (oral communication, November 1950), upon seeing some of the *Bathysiphon,* that he had found similar foraminifera in Knoxville shale on the Pacheco Pass road. Although no accurate age-determination can be made on the basis of the above foraminifera, it is possible that careful study of Cretaceous and Upper Jurassic rocks in other parts of California may reveal a similar abundance of these forms in some part of the section.

Megafossils are extremely rare. Diller (1902, p. 65) reported that he found an *Aucella* above Hydesville, along the Van Duzen River, which was identified by Stanton as a Cretaceous form. Diller, however, merely stated

> It is certain that some of the sandstones and shales are younger than the rocks which form the mass of the Klamath Mountains.

This is the only fossil previously reported from rocks herein mapped as Yager, excluding the ''Cretaceous ammonite'' found by Hanna, which is discussed with the False Cape shear zone rocks. Near Swain's Flat, along State Highway 36, about 6 miles west of Bridgeville, the writer found a small gastropod in spheroidal-weathering, gray-green Yager mudstone. Several *Bathysiphon,* some borings, and a second broken gastropod cast were seen. The tiny gastropod was identified by J. Wyatt Durham as *Melania* n. sp. Investigation of the literature showed that species of this genus had been described from the Eocene of France and from the Eocene Markely formation of California. The genus has not been described from pre-Cretaceous strata. Durham (oral communication, 1950) stated that this specimen is probably an Eocene form, and that there is little chance of its being pre-Cretaceous.

A few crustacean borings in shales along Yager Creek in the center of sec. 10, T. 2 N., 1 E., H., indicate shallow-water environment. At the same locality numerous small fragments of carbonized wood suggest a nearby wooded terrane.

The inadequacy of the above stratigraphic data, together with the uncertainty of lithologic correlations, is the reason for use of the local name Yager formation, until such time as better stratigraphic correlation and definition are possible. The weight of the limited faunal evidence points to a Cretaceous or even an Eocene age. However, certain facts seem to rule against an Eocene age: MacGinitie (1936) noted the presence in the Hyampom area (about 25 miles to the east of the area mapped) of continental beds, assigned to the Oligocene on the basis of paleobotanical data; these beds overlie Cretaceous sediments with strong angular unconformity. The Cretaceous beds are generally similar in lithology, structure, and induration to the Yager; the Tertiary sediments, on the other hand, are poorly consolidated and for the most part only slightly tilted. Many factors relating to the Tertiary climate and geomorphology suggest that the Oligocene beds in the Hyampom area were deposited on an eroded surface which also was cut on folded Yager rocks. It seems probable that the Yager is Cretaceous; but because of the lack of a truly diagnostic, adequate fauna there is the possibility that at least part of the formation may be equivalent to Knoxville.

Therefore it has been assigned to the Upper Jurassic-Cretaceous. If the Yager is Cretaceous, it must have been deposited in a geosyncline west of the Sacramento Valley, and separated from it by the South Fork Mountain mass. MacGinitie (1936) in referring to the Cretaceous at Big Bar, 30 miles to the northeast of the present Yager exposures, stated:

> These localities [200′ of Cretaceous] mark the western strand line of the Lower Cretaceous overlap in this region.

He also mentioned the presence of 1,100 feet of Paskenta farther east, southeast of Weaverville.

The graywacke of the Yager closely resembles Franciscan graywacke, but is found to be distinctly different when carefuly studied. Here, as in many other localities, the Franciscan rocks as mapped by the writer are sheared, contain metamorphic rocks, and are penetrated by igneous intrusions; Yager rocks show none of these characteristics.

Thickness. The thickness of the Yager cannot be measured accurately. The base of the formation is not visible in the Eel River area, and the top is overlain by Tertiary sediments with strong angular unconformity. Near Phillipsville, the Yager formation may be more than 10,000 feet thick. In the Fortuna quadrangle along the North Fork of Elk River, at least 2,500 feet of Yager are exposed dipping north into a syncline; on Freshwater Creek there appears to be perhaps 2,500 feet of the formation, also dipping north. Poor exposures are commonplace, and the possibility that tight folds may have been missed must be kept in mind when estimating thicknesses. Some of the cross-sections show an aggregate thickness of 15,000 to 20,000 feet, but it must be remembered that these are diagrammatic and based on inadequate evidence. Because of lack of intraformational stratigraphic detail it has not been possible to estimate what part of the total section is exposed at any particular locality.

Conditions of Deposition. Conditions under which Yager sediments accumulated were probably similar to those which existed during the deposition of the Franciscan. At the source, the land mass was probably rugged, so that active downcutting streams of steep gradient carried large loads of mechanically weathered debris. Some vegetation was present on the slopes and the climate was probably cool-temperate and humid. Source rocks were in part Franciscan red chert, greenstone-basalt, and glaucophane; but in addition there may have been some plutonic rocks—granodiorite or quartz diorite—which contributed the high percentage of feldspar. It is significant that there is a higher percentage of feldspar and a lesser percentage of rock fragments in the Yager graywacke than in the Franciscan of this area. Perhaps a granitic batholith intruding an area of geosynclinal sediments had been exposed by erosion by the time the Yager was being deposited, and provided this different source material. Part of the source area must have been to the east, but it is probable that an old land mass to the west also made some contribution. Recent evidence of the active tectonic nature of the region west of this part of the Pacific Coast has been presented by Scripps Institution and Office of Naval Research investigators (see especially Menard and Dietz, 1951). Taliaferro (1943b) has suggested that a land mass existed west of the present coast line during Franciscan time. Such a mass could also have been present during deposition of the Yager formation.

The Yager was probably deposited in the bathyal and neritic zones of the sea; crustacean borings are present, indicating a relatively shallow site. The washed or cleaned character of the graywacke may indicate a somewhat shallower depth than that at which the Franciscan was deposited. Wave action could effect some winnowing of the rapidly depositing sediment. Turbidity currents (Kuenen and Migliorini, 1950) explain some of the alternating graywacke and shale. The material must have been deposited in a rapidly subsiding geosyncline which may have been partly restricted.

False Cape Shear Zone

Along the coast from the mouth of Oil Creek south to the edge of the Ferndale quadrangle there are nearly continuous exposures of lenticular masses of sandstone, pulverized pelitic material, and a few lenses of greenstone, chert, and limestone. The exposures continue along the coastal cliffs south of the mapped area to the contact with the Bear River Tertiary rocks. The total distance of these exposures is approximately 3 miles. South of the Bear River Tertiary rocks the same zone or a similar one continues for several more miles to the south. Because rocks of several formations are involved in this shear zone and because much of the material is unidentifiable stratigraphically, the name False Cape shear zone has been applied. It is a structural unit which has a gross lithologic identity but no stratigraphic restriction. The coastal cliffs offer the only opportunity for a careful study of these rocks. To the east only a few exposures are afforded, in road cuts and actively eroding streams. Most of the upland terrane is characterized by smooth rounded hills dotted with a few random outcrops of the harder included sandstone lenses. Although most of the zone is made up of highly sheared and contorted rocks, there are some areas, such as near the head of Howe Creek, where considerable thicknesses of unsheared rocks of Franciscan type are included.

The usual sea-cliff exposure shows an assortment of gray, lenticular, subangular or rounded fragments of sandstone set in a dark gray-black matrix of pulverized pelitic material. Some of the sand bodies form lens-shaped masses several feet in length, while other fragments may be small, rounded masses the size of a walnut. In places, a series of the phacoids are aligned, indicating that the individual fragments were originally part of a continuous sandstone bed. Some of the phacoids can be traced through tight folds. Where not contorted, the lenticular beds or random lenses dip at angles near vertical, and most planes of shearing dip at similar angles. The phacoids usually have highly polished slickensided surfaces which are the result of differential movement of the harder fragments in the finely divided pelitic matrix; some of them show minute grooving and striations. Although the lens shape is typical, some small masses have been rolled and show a high degree of rounding.

From the relative amounts of sandstone lenses and pelitic material, it is concluded that the original sediments must have been interbedded sandstone and shale. In addition, there are some random small discontinuous lenses of dark greenstone-basalt, gray limestone, red and green radiolarian chert, and at least one small polished lens of greenish, glauconitic, foraminiferal Wildcat limestone.

While the above describes the appearance of most of the exposed False Cape shear zone, there are numerous exposures of more massive, continuous masses of sandstone, such as those which form the small stacks known as Mussel Rock and False Cape Rock. The larger bodies may be as much as 100 to 200 feet in thickness, and most of them in the upland areas form prominent knobs which stand out above the surrounding soft, easily weathered, sheared pelitic material. Most of the sandstone is greenish-gray, massive, fine-grained to medium-grained graywacke which is cut by numerous calcite veins. At the mouth of Oil Creek there is a large iron-oxide-coated mass some 50 feet across of altered greenstone-basalt. No similar rocks are adjacent and this mass cannot be traced farther. At a small indentation in the coast line, just south of False Cape (NW¼SW¼ sec. 35, T. 2 N., R. 3 W, H.), there is a 10-foot-thick outcrop of red radiolarian chert that is composed of thin contorted beds and is bounded by the usual pulverized pelitic material which has aided in developing a polished surface on the chert. This body can be traced a few hundred feet to the east but it does not crop out beyond that point. Stewart and Stewart (1949) note that Cretaceous fossils found by Hanna were from approximately this same point on the coast. In the area near the head of Howe Creek (Scotia quadrangle) a considerable thickness of sandstone and Hackett limestone, and one small mass of an altered olivine basalt, are virtually unsheared. They have been included within the zone because the material surrounding this area is similar to that described above. Several steeply dipping fault planes can be seen in the sea-cliff exposures; but because of the nature of the adjacent material, it is not possible to estimate the amount or direction of displacement.

With the hand lens, the sandstone of both the pods and the more massive outcrops is seen to be fine to medium grained, a lighter gray than the usual Franciscan or Yager rocks, sheared in places, locally veined, and composed of abundant feldspar, quartz, and dark rock fragments. Under the microscope little evidence of deformation can be seen except for local granulation of grains and the presence of some strained quartz grains.

The pelitic material is normally a loose, unconsolidated material made up of minute, glistening, slickensided fragments, or powder. When moistened it becomes a paste or clayey substance that most resembles fault gouge. The pulverized material is too finely divided and soft to show structure and appears as a formless matrix surrounding the more resistant pods.

One specimen of glauconitic foraminiferal Wildcat limestone was found included in the zone in a small gulch tributary to the ocean approximately a mile from the nearest outcrop of Tertiary rocks.

The False Cape shear zone represents crushing and shearing on a grand scale, similar to that described by Lamplugh (1895) on the Isle of Man, where the original materials involved in the cataclastic deformation were interbedded sandstones and shales.

It is probable that the original rocks in the Fortuna quadrangle were highly folded sediments of both the Franciscan and Yager formations which were subjected to repeated strong deformation. As the folds became tighter, the sandstone fragments were stretched, faulted and pinched off by the squeezing of the plastic pelitic material. The resistant beds were disrupted principally by fracturing rather than by any internal movement or reconstitution of the component parts. The oblique slip-planes breaking repeatedly across the beds aided in the development of the typical lens shape. Numerous faults developed which displaced some of the involved rocks considerable distances. The complexities of the varied types of differential movement were such that fragments were moved far from their original position. As repeated movements took place, the soft pulverized pelitic gouge acted like jeweler's rouge in polishing the pods. Following deposition of the lower part of the Wildcat, some of the Wildcat sediments became involved in the repeated deformation.

The age of the rocks involved is open to some question. One fragment of Wildcat limestone is included in the False Cape shear zone, and it is probable that some of the pulverized pelitic material is Wildcat mudstone. In the Independent Exploration Company well ''Roscoe'' 1, drilled in 1950 in the NW¼ sec. 33, T. 2 S., R. 1 W., H., about 20 miles to the southeast, all the cores were composed of highly sheared, pulverized shale and sandstone lenticles similar in all respects to the surface exposures of the False Cape shear zone. Otto Hackel (oral communication, 1950) informed the writer that some Pliocene foraminifera were identified in samples of these cores. Thus, while the sandstone lenticles in the cores were apparently Yager or Franciscan, some of the indistinguishable pelitic material proved to be Pliocene mudstone. A similar condition may prevail in the False Cape shear zone.

Dr. G. D. Hanna in 1928 found an ammonite 6 inches in diameter, a *Corraliochama* (?), and a *Belemnitella* (?), in a 6-foot piece of crystalline limestone along the shore line in the NW¼ SW¼ sec. 35, T. 2 N., R. 3 W., H. (Stewart and Stewart, 1949; oral communication from G. D. Hanna, 1951). These Cretaceous fossils may be from some part of the Yager formation, or other Cretaceous beds not previously described, which have become involved in the shear zone and are isolated, as lenticles, from other similar beds. It has been noted previously that some of the more resistant fragments bear close similarity to typical Yager and Franciscan rocks. It is therefore evident that rocks of several ages are in juxtaposition, and it follows that fossils found in the zone are indicative of the age of only that particular fragment in which the fossils are imbedded.

Wildcat Group

Deposition in the Eel River Basin continued with only minor stratigraphic breaks from upper Miocene to mid-Pleistocene. Distinctive features occur in some parts of the 12,000-foot section, such as glauconitic sand in the lower part and massive sand and conglomerate in the upper part; but the weathered mudstones from all parts of the group are similar in appearance. Where a nearly continuous section is exposed, as along the Eel River, units can be differentiated on the basis of lithology; some parts of the section contain an abundant, diagnostic microfauna. Several formations have been mapped in the southern part of the Ferndale-Fortuna-Glynn area, but the Tertiary-lower Quaternary sediments have not been differentiated into cartographic units in the northeastern part of the Fortuna quadrangle. The Wildcat group includes all of these sediments; where differentiation has been possible, however, formations and members of formations have been mapped.

The name Wildcat series was first proposed by Lawson (1894) for those sediments exposed in the Wildcat country—the mountainous region south of Ferndale—but has since become established in the literature * as a loose term for Tertiary sediments in Humboldt County of suspected Pliocene age. The writer uses the term Wildcat group for sediments ranging from upper Miocene to lower Pleistocene, the great bulk of which has a foraminiferal fauna correlative with the complete lower to upper Pliocene sequence of the Los Angeles and Ventura basins.

The most complete section of the Wildcat is exposed along the Eel River from west of Scotia north to the Van Duzen River; thence along unnamed streams to the Cuddeback Creek area. This is taken as the type section of the Wildcat group as defined in this paper, and also serves as the type section of all the formations defined (see Appendix).

Distribution

All of the Wildcat sediments mapped in the Ferndale-Fortuna-Glynn area are part of the Eel River embayment. To the south there are smaller patches of Tertiary rocks whose stratigraphic position and distribution are imperfectly known. Some of the patches can be shown to have been a part of the sediments deposited in the Eel River embayment; these include the small synclinal area of Miocene sediments west of Scotia; the small isolated areas of upper Pliocene sediments south of Bridgeville, part of which are fault slivers along the Yager-Little Salmon fault; and the Miocene and lower Pliocene sediments in the Bear River area which form a faulted synclinal structure separated from the main part of the deposits of the Eel River embayment by a faulted anticline composed of rocks of the False Cape shear zone.

To the south, a small area of lower Pliocene sediments in the Domingues Creek-McNutt Gulch region is bounded by faults; another area of sediments with uncertain contact relationships is between Petrolia and the mouth of the Mattole River. These could have been separated from the Bear River Tertiary deposits by a faulted anticline(?) in the Branstetter Ridge area, or they could be part of a separate embayment whose trend has since been followed by the Mattole River. The Briceland Miocene deposits, the Garberville Airport Pliocene outcrops, and the Garberville Pliocene rocks may well be a part of the deposits laid down in such a Mattole embayment. The possibility remains, however, that the Pliocene beds could conceivably have been a part of the sediments of the Eel River embayment, if suitable uplifting of the intervening pre-Tertiary rocks by faulting and upwarping has taken place. In either case it seems likely that the Rainbow Ridge-Mt. Pierce-Grasshopper Peak area remained as a positive area, either as an island or as a peninsular ridge during most of Tertiary time. Some Pliocene sediments may be seen along U. S. Highway 101 south of Piercy, a few miles south of the Humboldt County-Mendocino County line. To the northeast and east of the Eel River embayment are Pliocene sediments of the Mad

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* See Gabb, 1866, 1869; Diller, 1902; Dall, 1902; Matthes, 1908; Stalder, 1914; Harmon, 1914; Martin, 1916; Smith, 1919; Hoots, 1928; Cushman, Stewart, and Stewart, 1930; Jenkins, 1938; Hughes, 1942; MacGinitie, 1943, p. 632; Trask and Patnode, 1942; Stewart and Stewart, 1949. In addition to these published sources of information, several petroleum geologists, including Bradford Adams, Albert Gregerson, the late Donald Hughes, Harold Horton, Thomas W. Dibblee, Jr., and Hampton Smith have mapped in the area, and have contributed to the general knowledge of the structure and stratigraphy of the Wildcat.

River embayment. The writer believes that this narrow faulted belt was separated from the Eel River embayment (except near Arcata) by the Fickle Ridge-Kneeland Ridge mass during Tertiary time. Manning and Ogle (1950) have mapped this belt in the Blue Lake quadrangle, and the writer has traced its apparent southern extent in the Danger Creek-Van Duzen area. To the northwest of Blue Lake the extent of this belt is not clear, since much of the terrane is covered by terrace deposits and low-dipping Pleistocene beds (possibly equivalent to the Hookton formation), and exposures are generally poor. Durham (oral communication, 1950) collected some upper Pliocene megafossils from an outcrop near Clam Beach which may be a part of the sediments of the Mad River embayment. North of Clam Beach there are patches of Plio-Pleistocene sediments in the Patrick's Point Big Lagoon area. At Patrick's Point State Park there is an excellent exposure of these beds unconformably overlying sheared Franciscan graywacke. North of Orick are other Plio-Pleistocene beds (Jenkins, 1938). In Del Norte County there are limited outcrops of Plio-Pleistocene sediments, and a very limited upland exposure of Miocene deposits (Diller, 1902; Maxson, 1933).

Units

The Wildcat group is composed principally of slightly indurated mudstone, siltstone, claystone, sandstone, and conglomerate. There are minor amounts of limestone, tuff, and lignite. Mudstone is the most common rock type.

Pullen Formation

The Pullen formation is the lowermost mappable lithologic unit of the Wildcat group in the southern part of the Ferndale and Fortuna quadrangles. It cannot be mapped in the area northeast of the Little Salmon-Yager fault and has not been identified in the Table Bluff and Tompkins Hill wells. However, there is some evidence that the lowest Tertiary deposits in the Salmon Creek area contain foraminifera which may correlate with those from part of this unit as observed in the Price Creek area (Dibblee, oral communication, 1950). The lowest Tertiary sediments cored in The Texas Company well "Eureka" 1 might conceivably be part of the Pullen formation, from the descriptions given by Hughes (unpublished notes, 1935), and from observations of the cores by the writer. The Pullen formation thins from its southern outcrop northward and is overlapped by younger Tertiary beds in the northern part of the Fortuna quadrangle. To the east and southeast it thins and is overlapped by the Eel River formation in the vicinity of Elinor. It overlies the Yager formation with profound angular unconformity, as shown by the difference in attitude and by the material at the base of the Pullen formation in the Eel River section, although the actual base was not observed. The thickest and most complete section of the Pullen formation is well exposed along Eel River near Scotia. The name "Pullen" is used because of the excellent exposures and fauna at Pullen Ranch on Price Creek. Measured sections indicate that the formation is thickest in the Eel River and Price Creek areas, where the other units of the Wildcat group are also thickest. It thins to the west and also to the east of the Eel River section.

The lithology shows some variations from west to east. In the coastal area, especially near the Mayflower Ranch, the mudstone and siltstone are diatomaceous except for some dark blue-gray mudstone near the base. The diatomaceous sediments are brittle, hard, and break with a blocky fracture into small subrectangular chips, quite different from the nodular-weathering mudstone higher in the section. They weather to a creamy buff or nearly white color, like the diatomaceous shales of the Monterey group. Associated with these diatomaceous mudstones are some yellow-orange-weathering ferruginous limestone nodules, a few thin greenish-brown glauconitic sandstone beds, and some thin ash beds. Where glauconite is present the sediments are streaked rusty brown on fracture surfaces as a result of the oxidation of the glauconite to limonite. The lower, less diatomaceous, dark blue-gray mudstone has a peculiar bluish coating when newly weathered, but becomes rusty brown on fracture surfaces exposed to longer weathering. No basal sandstone was observed in the western exposures but there are a few thin sandstone beds, most of which are slightly glauconitic. To the east, in the Price Creek-Eel River area, the mudstone is less diatomaceous, although still brittle and hard, and is more similar to the lower dark mudstone of the coastal area. At Eel River there is a basal sandstone member, 242 feet thick, which thins to the west, as a result of the lensing of the lower part in the Price Creek area. This sand is difficult to trace west of Price Creek because of the numerous slides, but it probably disappears as a result of lensing about one mile west of the exposures at Pullen Ranch on Price Creek. The characteristics of this basal sandstone are different from the typical sandstone of the rest of the Wildcat group. It is high in feldspar and quartz and very low in detrital ferromagnesian minerals. Where the sandstone is free of glauconite, it weathers to a light buff or creamy white tinged with tan streaks. The sandstone is rarely seen fresh, but presumably is light gray to off-white. The rock is compact, fine grained, fairly well sorted, and moderately porous. Near the base in the Eel River section the abundance and size of fragments of Yager and Franciscan material are impressive. Angular fragments of Yager sandstone up to 8 inches long are common, and there is one lens of pulverized Yager shale and sandstone fragments 6 feet thick. The nature of the material and the sequence of sedimentation are indicative of the unconformable contact at the base of the Pullen. The rapid lateral variation of the basal conglomerate and pebbly sandstone beds implies shallow-water deposition. A possible explanation of the large lens of shale and sandstone fragments exposed on the east bank of the Eel River several feet above the base is that an adjacent land mass of considerable relief slumped occasionally, contributing debris from the Yager formation.

Fossils are lacking in much of the formation. In the coastal area, most of the diatomaceous mudstone is barren of foraminifera and mollusks. The few foraminifera identified from this unit in the coast section are principally lower Pliocene or Delmontian (Kleinpell, 1938) forms, but these all are from the upper part of the formation. In the Price Creek section the writer found abundant foraminifera in the middle and lower part of the formation which have been identified as species characteristic of the Mohnian stage (Kleinpell, 1938), upper Miocene. In the Eel River section some samples from the upper part of the Pullen formation were found to contain foraminiferal species characteristic of the lower Pliocene (Kleinpell, 1938). No diagnostic microfauna was obtained below these samples in the Eel River section, but in the basal sandstone there are some poorly preserved pelecypods. Of those collected *Spondylus* n. sp. and *Andara* cf. *osmonti* (Dall) have been identified. While not diagnostic, those forms suggest a Miocene age. In addition, there are abundant diatoms, radiolaria, and silicious sponge spicules in the diatomaceous mudstone.

The above data indicate that the lower part of the Pullen formation is as old as upper Miocene (Mohnian), and the upper part may be as young as lower Pliocene. While the contact with the overlying Eel River formation is apparently disconformable, the evidence does not make clear whether there was actually elevation of the Pullen above sea level and subaerial erosion, or whether the overlying conglomerate simply indicates the development of shallow-water conditions, and erosion by wave action. The fauna above and below the lithologic break indicate only a limited time gap for this event.

Eel River Formation

Overlying the Pullen formation in the southern part of the area is a series of dark gray-black mudstone, siltstone, and sandstone. Most of the sandstone is glauconitic, as are some of the finer-grained sediments. The lithological top of the unit approximates the upper limit of a foraminiferal assemblage characteristic of the Repetto. The type section is that section exposed on the west bank of the Eel River near Scotia; the name Eel River is proposed because of the excellent exposures at this locality. The base of the unit can be mapped between the coast section and Eel River because of a distinctive glauconitic sandstone and conglomerate occurring near the base. The conglomerate may mark a minor disconformity between the Pullen formation and the Eel River formation; although no angular discordance is evident, some evidence of a cut surface on the Pullen can be detected. Foraminifera of the upper part of the Pullen indicate that deposition was in deeper water than is indicated by the conglomerate and sandstone, which were probably deposited under shallow marine conditions. It is possible that no subaerial erosion took place but only an elevation of the depositional basin and local submarine wave cutting. The conglomerate is erratic in thickness and extent, and occurs as lenses in the glauconitic medium-grained sandstone. It is well exposed at Eel River, Price Creek, and in the coast section. Of the three, the Eel River occurrence is the most spectacular. In most places the conglomerate, or pebbly sandstone, includes large angular to subrounded yellow-weathering ferruginous limestone cobbles or boulders, containing borings, small pea-sized, polished, rounded chert or quartzite pebbles, and very abundant glauconite pellets. Limestone nodules and lenses of material similar to the material making up the cobbles are common in the Pullen formation, and it is probable that the Pullen is the source of the fragments. The weathered appearance, slight rounding, borings, and glauconitic coating all point to erosion, possibly submarine, and a period of nondeposition. The sudden appearance of the small reworked Franciscan pebbles in this part of the section must be the result of some tectonic activity which caused erosion, and changed the environment, and possibly the source, of the overlying sediments. Several feet above the basal conglomerate in the coast section is a 6-foot glauconitic sandstone which contains large fragments of carbonized wood and has numerous casts of large borings (worms?), both indicative of shallow-water deposition. Glauconitic sandstones are common throughout the formation but vary greatly in abundance in different parts of the basin. In the coast section the sandstones in the lower part of the unit only are glauconitic, while at Price Creek there are at least nine important glauconitic sandstone members distributed throughout the section. Some of the glauconitic sandstone beds are at least 40 percent glauconite and are dark green-black in color where freshly exposed. Typically they are poorly sorted, argillaceous, fine to medium grained, and have low porosity and permeability. The members usually form resistant beds which may be locally lime-cemented. In addition to glauconite, the important constituents are feldspar, quartz, rock fragments, and the clayey bonding material. When weathered, the sandstone becomes streaked with a rusty brown stain and ranges from dirty tan to brown in color. In places along ridge tops where chemical alteration may be severe, the rocks become streaked and veined with a rusty red-brown limonite gossan developed by the alteration of the glauconite. All variations of glauconite percentage and grain size may be found. Where little glauconite is present in the sandstone only a slight greenish cast is observed in the fresh exposure. In hand specimen, the grains can usually be detected with a hand lens. It is common to find that the grains are round, smooth, have a lack of cleavage or other crystalline characteristics, and are generally larger in size than the associated clastic particles. Some glauconitic mudstone beds have coarse, sand-size pellets set in a uniformly fine mud; one such glauconitic mudstone in Howe Creek contains about 25 percent glauconite pellets and 25 percent foraminifera.

In addition to the glauconitic standstone units there are several argillaceous, feldspathic sandstone beds in the upper part of the section. They are fine-grained, range from a few inches to a few feet in thickness, are friable or locally calcareous, and are gray when fresh and weather to buff. The common constituents are feldspar, quartz, rock fragments, and an argillaceous matrix. Ferromagnesian minerals are not abundant. These sandstone units have a fair porosity and permeability and could serve as reservoir rocks for petroleum.

An important member in the section west of the Wildcat Ridge Road is a white rhyolitic ash bed, which ranges in thickness from a few inches to as much as 6 feet in the Woodland Echo Ranch area. The ash is well sorted, containing principally silt-size grains, and is white, grading to off-white as clastic impurities increase. Some beds contain over 99 percent glass shards. The variation in thickness may be partly due to the relative admixture of clastic detritus. Where abundant nonvolcanic material was deposited contemporaneously, the glass shards become few in number and are masked. The high purity of as much as 4 feet of this ash in local areas is remarkable in view of the lack of volcanism in the area and the probable rapidity of deposition of the clastic material. East of the Mayflower Ranch the bed cannot be traced although a few ashy streaks may be seen in the same part of the section and some of the siltstone beds reveal abundant glass shards when they are wet-sieved for foraminifera. To the northeast of Fortuna in the undifferentiated Wildcat there are exposures of a thin ash of similar appearance and composition about 350 feet above the base in Allen Creek, and on both main forks of Elk River. The presence of other ash beds of similar composition in other parts of the established section rule against accurate correlation, but the similarity of appearance, the similar fauna in associated mudstone, and the associated glauconitic sediments lead the writer to believe that the ash beds on the two sides of the basin may be contemporaneous.

Probably over 70 percent of the formation is mudstone and siltstone. These fine-grained sediments are noticeably harder and tougher when struck with a hammer than those of the Rio Dell formation. Characteristically, they weather to a brownish-gray color and may have a rusty ferruginous coating on the weathered fracture surfaces. This coating probably is a result of a small amount of glauconite in most of the mudstone, which upon weathering forms iron oxide that leaches out and precipitates upon the weathered surface. The mudstone and siltstone are massive, show onion-skin contraction fracturing, or form ovoid or nodular masses when exposed on the surface for a short time. When very fresh the siltstone is dark gray and the mudstone is dark gray to black. Foraminifera are common in many parts of the section and diatoms are locally abundant in the lower part of the Eel River formation in the coastal area. Wet-sieved samples contain numerous glass shards, pyrite aggregates, and a few radiolaria and silicious sponge spicules, as well as foraminifera, diatoms, and glauconite pellets which are not apparent in the hand specimen. Associated with the fine clastics are a few creamy yellow limestone nodules and lenticular beds. Near the top of the formation are a few fragments of carbonized wood.

The Eel River formation was mapped chiefly on the basis of the presence of glauconite. In well-exposed sections the top has been determined as the beds immediately underlying an unconformity (as in the coast section), or as the beds underlying the highest thin glauconite bed which in most places appears to be deposited on an irregular surface. On the coastal cliffs, the basal Rio Dell overlies the Eel River formation on an irregular, cut surface with a discordance of about 5 degrees. Glauconite is present at the base of the Rio Dell formation at this point. The differences in strike of the Eel River beds and the Rio Dell beds in the Ferndale quadrangle also give evidence of discordance. Although the Eel River formation can be distinguished as a unit in some places, over much of the area there is only deeply weathered mudstone or soil derived from mudstone. However, a distinctive foraminiferal fauna similar to that of the Repetto formation of the Los Angeles and Ventura basins is found in the Eel River mudstone; therefore, on the basis of its fossil content, rather than on the basis of distinctive clastic material, some of the nondescript mudstone in the Wildcat group can be assigned to the Eel River formation. In the northeastern part of the Fortuna quadrangle, where exposures are very poor and there is less glauconite in sediments of the undifferentiated Wildcat which are faunally equivalent to the Eel River formation, it has not been possible to map any contact as the lithologic top of the Eel River formation; but the fauna and lithology of the beds near the base indicate that correlation is valid.

As mapped in the southern part of the area the Eel River unit forms a northward-dipping belt of varying thickness which extends from the coast southeastward to the Eel River and beyond. Detailed mapping east of the Eel River was not attempted but reconnaissance indicates that the unit may be mapped across an anticlinal fold in the vicinity of Elinor. Owing to an unconformity the upper several hundred feet of the unit are not present in the coast section. North from the outcrop the formation also displays variations in thickness in the subsurface records. In The Texas Company well "Eureka" 1 at Table Bluff there are 900 to 1,000 feet of Eel River sediments, while 4 miles to the southeast at The Texas Company well "Eureka" 2 there are 1,500 to 1,700 feet (Hughes, Donald, unpublished notes). In the northeastern part of the quadrangle equivalent sediments thin and are overlapped by upper Pliocene sediments in the Freshwater Creek area. Evidence indicates that there is a rapid thickening from this "wedge edge" westward. To the north of the Freshwater area, however, the unit does not exist. A well drilled by Mr. Spier at Brainard Cut (5 miles north of the Freshwater Creek area in the Eureka quadrangle) in 1949 showed only upper Pliocene foraminifera to within at least 200 feet of the top of the Franciscan, which was found at a depth of 800 feet.

Rio Dell Formation

The Rio Dell formation is the thickest unit of the Wildcat group, and has the greatest areal extent. Massive mudstone, alternating thin sandstone and mudstone, phantom-banded mudstone, and very fine-grained sandstone are the principal lithologic units. In the coastal area three members can be mapped for a short distance to the east and the contact between the upper member and middle member may be traced east of Wildcat Ridge.

The upper member of the Rio Dell formation consists principally of massive mudstone or phantom-banded mudstone, siltstone, and a few thin sandstone beds and thin limy beds. *Pecten (Patinopecten) caurinus* Gould is common throughout, and foraminifera characteristic of the upper Pico are locally abundant. A 10-inch impure ash bed is exposed in the sea cliff 1,050 feet above the base of this upper member; at the base in the coast section is a massive, dark gray siltstone containing abundant white tubelike or elliptical forms which may be worm tubes or some form of *Bathysiphon*. The siltstone overlies a slightly irregular surface cut into the upper beds of the middle member. No discordance can be noted. The contact mapped between the top of the upper member and the base of the Scotia Bluffs sandstone is arbitrary; the writer has followed the practice of mapping the top of the Rio Dell as the rocks below the lowest massive, buff-weathering sandstone of the Scotia Bluffs sandstone, but, because of the lenticular nature of the massive sandstone units, this contact may be relatively higher or lower in the section in various parts of the area. East of Williams Creek the upper part of the Rio Dell becomes somewhat more silty, and at Price Creek there are numerous very fine-grained silty sandstones interbedded. Near Weymouth Inn, on Price Creek, these uppermost beds dip steeply to the north or are overturned. Between the exposures on the Eel River near the mouth of Price Creek and the next exposures to the east of Scotia Bluffs—a distance of 4 miles—the lithology changes; the general trend is an increase of very fine-grained silty sandstone and siltstone, and an important increase of mollusks. The upper Rio Dell in the Scotia Bluffs area is famous for the abundance of Pelecypods, which occur in great concentrations in certain layers. Many of the fossiliferous beds are several inches thick and are resistant because they have been cemented by lime. Typical fossils are *Pecten (Patinopecten) caurinus* Gould, *Securella stalcyi* (Gabb), *Cardium (Cerastoderma) meekianum* Gabb, and *Psephidia lordi* var. *barbarensis* Arnold.

The middle member in the coast section is a striking lithologic unit composed of rhythmically alternating thin fine-grained sandstone and mudstone or siltstone. Near the upper part of this unit in the coast section and at Wildcat Ridge are 50 to 100 feet of diatomaceous mudstone and siltstone. Locally the diatoms are concentrated and form thin white laminations. East of the coast section the lower part of the middle member becomes less distinct because of the increase in amount of the finer-grained sediments, and at the Wildcat Ridge road differentiation of the lower and middle members is not possible. In the area between Wildcat Ridge and Scotia rapid changes in lithology are common. Alternating lenticular sandstone beds become less numerous and massive mudstone beds are more abundant in the Rio Dell-Scotia area. Fossils are generally less common in the middle member than in the upper part of the Rio Dell.

The lowest member in the coast section is made up of siltstone units and a few thin sandstone beds in the upper part and more numerous alternating sandstone beds in the lower part. Pelecypods are rare, but the common foraminifera may be correlated closely with those of the lower Pico. In the lower part of the Rio Dell east of Wildcat Ridge there are a few friable, fine-grained sandstone beds several feet thick, but much of the section is mudstone or siltstone with only a few thin sandstone zones. The base chosen is a thin glauconitic mudstone or fine-grained sandstone overlying a cut surface of upper Eel River formation mudstone. Foraminiferal samples indicate that the upper limit of most of the Eel River foraminifera is approximately the base of the Rio Dell lithologic unit. Some samples, however, contain species whose range is greater than indicated in the coast section. It can be shown that the Rio Dell formation thins to the north and contains more sandstone in the outcrops in the Ferndale Hills than in the Tompkins Hill gas field, where alternating sandstone beds from the middle part of the formation are important reservoir rocks.

Rocks equivalent to the Rio Dell form an appreciable part of the outcrop area mapped as undifferentiated Wildcat in the northeastern part of the Fortuna quadrangle. Siltstone predominates over sandstone in this area. Faunal evidence indicates that sediments equivalent to the upper part of the Rio Dell overlap and mask older units of the Wildcat group.

The Rio Dell mudstone is typically dark gray when fresh, but weathers to various shades of buff and light gray. Onion-skin weathering, or an intricate system of cross fracturing is usual. The rocks are generally softer than mudstones of the Eel River and Pullen formations. Mechanical analyses show that silt-sized particles form an appreciable percentage of the total volume. Some of the mudstone in the upper part of the formation locally contains carbonized wood fragments. The mudstone may form considerable thicknesses of massive outcrop with little or no visible bedding, or may be interbedded with thin fine-grained sandstone or siltstone beds. The term "phantom-banded mudstone" has been used by the writer for these mudstone and thin siltstone units which show very slight rhythmic alternations of grain size.

Siltstone beds are light gray, slightly porous and moderately compact; some are micaceous. Locally the siltstone is well cemented with calcium carbonate and more resistant lenses or nodules weather out on exposed surfaces. Many of the limy areas are closely associated with molluscan fossils.

The sandstone beds of the Rio Dell formation are poorly sorted, fine grained to very fine grained, light gray, friable to slightly compact, argillaceous and feldspathic. Weathered exposures may be light gray to pale buff. The basal few inches of the Rio Dell may be glauconitic mudstone or sandstone and a few pebbles, but the lack of glauconite elsewhere is one of the characteristics of the sandstones of this unit.

The one conglomerate in the formation is exposed along the west bank of the Eel River north of the mouth of Howe Creek, NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 34, T. 2 N., R. 1 W. It is present in the scar cut by a large slide into Eel River, and large boulders of the conglomerate form a riffle across Eel River at this point. Where seen in place, there is a lenticular bed of silty to sandy conglomerate which ranges from 6 to 10 feet in thickness. The pebbles, which average 1 inch in diameter, are Franciscan types common in the Carlotta formation several thousand feet higher in the section. Some of the conglomerate is abundantly fossiliferous, and much of it is hard. Carbonized wood fragments several inches long are locally abundant. The conglomerate is deposited on an irregular surface of massive dark gray mudstone and grades upward into fine siltstone. It cannot be traced along the strike to the east because of the alluvial covering, and to the west it is masked by terrace deposits. Conglomerate has not been observed at a similar stratigraphic position anywhere else in the area, and it is assumed that this one large lens may represent a local shallow water condition, or may be the result of turbidity currents. The cut surface is probably a result of submarine erosional processes. The formation in general thins to the north, east, and southeast from the maximum thickness exposed in the Price Creek and Eel River areas.

Scotia Bluffs Sandstone

The upper part of the Wildcat group is predominantly coarse clastics. The lower sandy phase has been mapped as the Scotia Bluffs sandstone and the upper conglomeratic part as the Carlotta formation. The contact between the two is gradational, but for the most part the sediments of the two units are distinct in the southern part of the area. Much of the Scotia Bluffs sandstone was deposited under shallow marine conditions while practically all of the Carlotta is nonmarine or brackish-water sediment. The best exposures of the two units are in the Eel River-Van Duzen River area. To the west, in the Wildcat Ridge section, the upper part of the Carlotta formation is not exposed, and the lower part is noticeably more sandy than the lower Carlotta of the Eel River area. For this reason geologists working for The Texas Company used the term ''Ferndale sandstone'' for the sandstone and conglomerate in the section along Wildcat Ridge, and the term has entered the literature (MacGinitie, 1943; Trask and Patnode, 1942). However, the two are mappable as units, and the name ''Scotia Bluffs sandstone'' is proposed for the lithologic unit exposed in the Eel River section immediately overlying the Rio Dell formation and underlying the Carlotta formation. The name is well suited because of the easily accessible, impressive exposures of this unit in the cliffs at Scotia Bluffs east of Rio Dell.

The base of the Scotia Bluffs formation is the lowest massive, buff-weathering, fine-grained sandstone, and the top is the sandstone immediately below the lowest massive pebble-to-cobble conglomerate.

The most characteristic feature of the formation is the massive fine-grained sandstone. When fresh, the rock is gray, moderately well sorted, and shows little indication of any bedding. Although friable, the sandstone has a certain compactness, which, coupled with the relative resistance to chemical decomposition of many of the grains, enables it to form bold cliffs and ledges which stand out in strong contrast to the sediments of the lower units of the Wildcat group. Feldspar, quartz, and rock fragments are the principal constituents. Locally biotite is common, and argillaceous material and a small percentage of heavy minerals are present. The grains are angular to subangular and the beds have a high porosity and permeability. Although too high in the section to be useful as an oil-reservoir rock in most structures, the sandstone may be an important aquifer in the Eel River Valley. When weathered, the rock is buff to light brown and may be coated with a brown moss.

From Price Creek westward the Scotia Bluffs contains two siltstone-mudstone members. These are rarely well exposed. Some fine-grained, softer, silty sandstone beds are included. The siltstone and mudstone are similar to those in the Rio Dell formation, except that they are somewhat more carbonaceous. They contain some foraminifera characteristic of shallow-water environment. It has been postulated by Stewart and Stewart (1949) and by Hughes (unpublished notes, 1946) that this microfauna suggests correlation with uppermost Pico, Santa Barbara, or lower Pleistocene. In the Eel River section pelecypods are numerous in the lower part of the formation. The most common are *Cardium (Cerastoderma) meekianum* Gabb, and *Psephidia lordi* var. *barbarensis* Arnold. Limy beds are associated with the fossils and often serve to emphasize the bedding. The most important fossil is the echinoid *Anorthoscutum oregonense* Howe, which forms a few thin layers in the sandstone about 600 feet above the base in the Eel River section, and has been found in the same stratigraphic position elsewhere. A few thin pebble lenses and trains appear in the sandstone at approximately the *Anorthoscutum* horizon, and locally sandy, pebbly conglomerate beds form lenses a few feet in thickness. Associated with these in the Eel River section are a few feet of blue-gray carbonaceous claystone containing several carbonized tree stumps. Similar claystone is not present to the west. The echinoids are the marine fossils seen highest in the section, and the carbonaceous claystone may mark the beginning of the essentially nonmarine deposition. Above this are more massive sandstone beds and an increasing number of clay beds and pebble conglomerate. The top is chosen as the sandstone underlying a 20-foot-thick, massive, unsorted, strongly outcropping cobble conglomerate exposed at the Circle R Ranch near Metropolitan. At Wildcat Ridge road a 50-foot cobble conglomerate immediately overlies this formation.

The Scotia Bluffs sandstone generally crops out south of Fortuna only. It has been cored in the wells drilled by The Texas Company in the Tompkins Hill-Table Bluff area, and north of Hydesville. Very little if any sandstone of similar nature is mapped with the undifferentiated Wildcat because of its relatively high stratigraphic position and because of structural conditions. It is not possible to differentiate the Carlotta and Scotia Bluffs accurately in well cores. In the Tomkins Hill, Humboldt Hill, and Pine Hill areas the sandstone, claystone, and conglomerate beds underlying the Hookton formation have been mapped as Carlotta, although they may be at least partly equivalent to the upper part of the Scotia Bluffs sandstone.

In the Eel River section approximately 2,100 feet of Scotia Bluffs sandstone are exposed, while at Wildcat Ridge only 1,800 feet are exposed. The unit thins to the north, but maintains a nearly equivalent thickness to the south and east. Near Centerville Beach the formation is unconformably overlain and overlapped by the tilted terrace deposits of the Hookton formation for approximately a mile along strike, and the massive sandstone beds are not seen in the coast section. Stewart and Stewart (1949) included the orange-colored alternating thin sandstones and pebble conglomerates of the Hookton formation in their measured coast section of the Wildcat.

Carlotta Formation

The Carlotta formation, composed predominantly of nonmarine conglomerate, sandstone, and claystone, is the uppermost unit of the Wildcat group. The contact between the Carlotta and Scotia Bluffs is gradational and may transgress time lines in any direction. The principal distribution of the Carlotta is in the trough of the major Eel River syncline, and in the western part of the Fortuna quadrangle, where some of the sediments may be seen beneath the capping of Hookton. East of the Fortuna quadrangle the formation crops out for a distance of about 3 miles. The westward plunge of the Cenozoic structures and the Little Salmon Creek fault limit the eastern extent. Similar continental beds, which may be the same age, are found elsewhere in Humboldt County in the troughs of synclines near Korbel, and southeast of Garberville. The formation is largely obscured in the Eel River Valley area by the alluvium of the valley, various terrace deposits, and the Hookton formation. There are a few isolated exposures of beds believed to be equivalent to the Carlotta formation, as mapped in the southern outcrops, which may be seen at the base of the cliff at Buhne Point at low tide, near Swain Slough, north of Beatrice, and north of Fields Landing. Data from both water wells and oil wells indicate that the Carlotta-Scotia Bluffs units extend as far north as Humboldt Hill, but the two formations cannot be differentiated on the basis of well logs. All available data indicate that the Carlotta has more shallow marine clay and less conglomerate in the northern part of the area. The thickness of the unit is not well established because the upper part is obscured or eroded in most of the area. In the most complete section, the Eel River section, the writer has measured and calculated a thickness in excess of 3,300 feet, although it is probable that the unit thins considerably north and west of this section. The areas where the typical conglomerates may be best observed and where the section is thickest are the forested areas north and south of Van Duzen River in the vicinity of Carlotta.

As the most important outcrops of the Carlotta formation are near the small town of Carlotta, this has been chosen as the type section. No complete, well-exposed section exists, but by piecing together available exposures along the logging roads, small stream cuts, and cliffs formed by

Size analyses by the Bouyoucus hydrometer method (Bouyoucus, 1936)

Formation	Number	Sand size (percent)	Silt size (percent)	Clay size (percent)
Hookton	1)80-S50 sdst.	82.5	7.2	10.3
	2)80-S51 sdst.	79	12	9
	3)80-S52 slst.	21	54	25
	4)80-S55 slst.	26	47	27
Carlotta	5)80-S60 clst.	0	44	56
	6)80-S61 slst.	1	65	34
	7)S35-3* sdst.	69.4	8.2	12.4
	8)S35-4* ash.	14.3	38.5	47.2
	9)80-S62 ash.	13	80	7
	10)80-S63 sdst.	63	23	14
Scotia Bluffs	11)80-S20 sd.	46	33	21
	12)S35-3* sdst.	80.5	3.6	15.9
Rio Dell	13)80-S80 sdst.	68	22	10
	14)80-S81 ash.	3	65	32
	15)BAO20 cl.	11	46	43
Eel River	16)80-S90 ash.	6	74	20
	17)BAO23 mdst.	19	43	38
Pullen	18)80-S95 sdst.	69	19	12
	19)80-S96 sdst.	59	26	15
	20)80-S97 sdst.	72	18	10
	21)80-S99 sdst.	64	22	14
Wildcat (undifferentiated)	22)BAO62 mdst.	17	54	29
	23)BAO65 mdst.	10	55	35
	24)BAO73 mdst.	9	62	29
	25)BAO71 mdst.	8	62	30
	26)80-S98 ash.	0	66	34
	27)S35-1* slst.	11	31	59

Composition of sandstones of Wildcat group

Sample	Feldspar	Rock fragments	Quartz	Hbde	Glaucon-ite	Other minor minerals and clay*
S35-3 (Carlotta)	21	45	19	6		9
S35-2 (Scotia Bluffs)	21	55	16	2		6
S35-5 (Scotia Bluffs)	20	41	23	8		8
80-3100 (Eel River)	15	23	35		12 biot.-chlor.-clay	15 other minor
80-396 (Pullen)	26	23	28	15		7

* Other minor minerals average about 3 to 5 percent, the remainder being clayey material.

the resistant conglomerates, a satisfactory estimate of the lithologic features and stratigraphic relationships can be obtained.

The conglomerate beds stand out in places as strong outcrops, not because of their cementation, but because of the contained rock fragments. Most of the claystone beds weather rapidly and form slides. Interbedding of the two often results in undercutting of the claystone followed by the dropping down of masses of the loosely compacted conglomerate; this finally results in sheer, vertical cliffs 100 feet or more high. Sorting of the conglomerate is poor. Fragments may range in size from boulders of sandstone 8 inches in diameter to fine interstitial sand, silt, and clay. Many outcrops show a ferruginous, brown coating on some pebbles—a result of secondary alteration and precipitation of iron oxides, or of iron oxide precipitation at the time of deposition. The ferruginous substance is abundant enough in places to bind the grains together to form a hard, resistant rock. The grains range from large subangular Franciscan and Yager sandstone, Franciscan chert, basalt, serpentine, and schist fragments, to well-rounded small pebbles formed from porphyry, black chert, quartzite, and schist. The source of the rounded material is probably the conglomerate beds of the Franciscan and Yager formations. Red radiolarian chert pebbles are especially common. In numerous pebble counts the Franciscan and Yager sandstone cobbles were found to be most abundant; next in abundance were red and green chert, glaucophane and related schist, basalt, and serpentine. The conglomerate beds in places are massive for thicknesses of 30 feet or more. An indication of bedding is given by small thin lenses of sandstone or a very slight gradation of grain size of cobbles. Channeling, rapid gradation, and lensing are also typical of some beds. In the lower part of the formation the conglomerate is interbedded with medium-grained, massive, friable, brown-weathering sandstone. The contact between the members appears to be gradational. In the middle and upper part of the unit the conglomerate is interbedded with blue-gray claystone. Typically the conglomerate lies on an irregularly cut surface of claystone. Troughs cut 2 feet or more into the claystone are common. These probably represent a change from quiet water, marshy or mudflat depositional conditions to erosion by stream channeling with concurrent deposition of coarse clastics by aggrading streams.

Most of the massive conglomerate beds grade up into a few feet of coarse to fine sand, which grades to fine gray silt and claystone. The claystone is blue-gray, compact, tough and normally somewhat carbonaceous. The grain size is exceedingly fine. Some silt beds show fine-scale cross-bedding. There are a few thin lignite beds interbedded with the claystone, and some large limbs, trunks, and stumps of carbonized wood. Some stumps with partial root systems are inverted to the bedding or lie on their sides. It is probable that the stumps and other debris were transported to the site of deposition, became water-logged, and sank into the soft material. A few thin leaf-bearing siltstone beds were found along a logging road cut in the SE¼SW¼ sec. 36, T. 2, R. 1 W., H. D. I. Axelrod identified the plant remains as species of willow, and suggested that the trees might have lived on the margins of a lake or back swamp. Numerous localities yield thin beds of reeds which substantiate the swampy environment.

The massive sandstone beds are generally dirtier than the typical sandstone of the Scotia Bluffs formation, coarser in grain size, and weather to a brown color. While less abundant than the conglomerate beds in the Eel River—Van Duzen area, the sandstone beds make up the greater part of the exposed section in the Wildcat Ridge area. Some irregular pebbles and clots of Tertiary siltstone are present in part of this sandstone.

White volcanic ash beds occur at two localities within the Carlotta formation. One is in the Wildcat Ridge section, about 170 feet above the base as exposed along the Wildcat Ridge road; it consists of about 6 feet of light gray to off-white impure ash. The ash is interbedded with massive sandstone and siltstone and appears to have been water-laid. It cannot be traced beyond this exposure in the road cut and has not been seen in other parts of the area. The second ash bed was exposed in 1949 along U. S. Highway 101 near the center of sec. 29, T. 4 N., R. 2 W., H., by a local slump but was obscured in 1950 by further slippage. About a foot of friable, coarse, silt-size, white, rather pure ash is interbedded with mudstone, friable coarse-grained sandstone, and a 6-inch lignite bed. Because terrace deposits and the Hookton formation cap surrounding areas, the tuff cannot be traced. An ash bed 2 feet in thickness interbedded with similar material is described by Laizure (1925) ''on the property of the Hanify Lumber Company, 4 miles south of Elk River.'' The writer was not able to find this locality, but it may be the same bed or another bed in the same part of the section.

At a few scattered localities there are thin lenses containing marine pelecypods. All of the forms could have lived in bays or waters of low salinity. One whale jaw fragment was found (SW¼ SW¼ sec. 9, T. 2 N., R. 1 E., H.) in a conglomerate bed in a logging road cut. The fossils identified are not diagnostic of age but they give some information as to environment. Most of the species are living today; many are species which range from at least Pliocene to Recent, and some are typical of Pleistocene deposits of other areas in California. The fauna and flora noted in beds believed to be Carlotta are typical of that unit and different from the assemblages found in the Scotia Bluffs and Rio Dell. The writer interprets the very thin lenses of marine or brackish water pelecypods as being a result of minor encroachment of saline waters onto a broad flood plain bordering a bay or estuary. The great bulk of the sedimentation, however, was nonmarine. The age is open to question but stratigraphic position and meager faunal evidence suggest that at least part of the unit may be as young as lower Pleistocene.

In many parts of the area the formation is overlain by alluvium or terrace deposits. In the Hydesville, Tompkins Hill, Humboldt Hill, and Pine Hill areas the Hookton formation overlies the unit with angular unconformity. However, because the post-Hookton fold axes coincide generally with the post-Carlotta fold axes, there is only slight discordance in these particular areas. One of the greatest problems of field mapping in this area centers around differentiation of some weathered Carlotta sediments from the Hookton sediments.

The writer is uncertain as to the precise contact in some timbered areas in the Pine Hill region. Usually the Hookton clay and conglomerate can be recognized by a characteristic yellow color which is quite different from the brown, ferruginous stain seen in Wildcat sediments.

Part of the difficulty in the northern area is that both the Carlotta and Hookton appear to have become finer-grained and both show marine interfingering, while to the south they are respectively coarser in grain and are nonmarine. Typically, the Carlotta claystone is more compact, blue-gray and carbonaceous, whereas the Hookton clay is plastic when moistened, yellow, bluish-gray or greenish-gray, and contains numerous root tubes. The Carlotta conglomerate is generally massive, coarser, and has fragments bonded by clay and ferruginous cement; the Hookton lenses are thinner, and show little bonding of grains.

At Buhne Point there is exposed the only outcrop of Carlotta along the margins of Humboldt Bay. Lower beds of mudstone, interbedded sandstone, and pebbly sandstone which strike generally north and dip 14° E. are overlain unconformably by yellow and greenish-gray silt, clay, sand, limonite-cemented pebbles, and a lignite bed, which strike northwest and dip about 8° N. The lower beds contain *Ostrea lurida* (Conrad), which is also found in the Carlotta in Deering Gulch, and near Swain Slough. This species is not found at any other part of the section. From the stratigraphic relations, structural position, and included fossils the writer concludes that the lower beds at Buhne Point and the isolated exposure at Swain Slough are equivalent to the Carlotta.

Undifferentiated Wildcat

Most of the Wildcat group northeast of the Yager-Little Salmon Creek faults has been mapped as undifferentiated Wildcat, because of the dense vegetation, poor exposures, inaccessibility of much of the area, and general lack of distinctive lithology. The eastern part of the region has only a thin veneer of Wildcat sediments, which dip regionally to the west at a gentle angle. Because of the structural features only a few hundred feet of section are actually exposed over a large area of surface outcrop in the area northeast of Salmon Creek. Foraminiferal samples indicate that there is a very thin sequence of lower Pliocene sediments in the upper Elk River area which is overlapped by upper Pliocene beds on the upper North Fork of Elk River (at the east edge of the Fortuna quadrangle) and in the Freshwater Creek area. Either none of the middle Pliocene sediments are present in this area, or they are very thin. In the northeastern area the beds equivalent to the Eel River formation are probably less than 80 to 100 feet thick, and the maximum thickness of the upper Pliocene beds is less than 700 feet—in most places less than 400 feet as exposed. West of the Little South Fork of Elk River the prism of sediments thickens rapidly to the west and foraminiferal evidence indicates that a more complete section is present. In the Newburg syncline south of Salmon Creek, faunal evidence suggests that part of the middle part of the Wildcat group has thinned considerably or is not present.

The lithology of the undifferentiated Wildcat is somewhat similar to that of the formations previously described except that there is generally less sandstone and more siltstone. In the Salmon Creek and Elk River area glauconitic beds with associated Repetto foraminifera may be seen near the base of the Wildcat. A thin ash bed, present about 350 feet above the base in several exposures, may be continuous. A prominent basal conglomerate or pebbly sandstone is present in many of the exposures on Elk River and near the forks of Freshwater Creek. In sec. 36, on a small branch of the North Fork of Elk River, locally called Doe

Creek, there are boulders of Franciscan schist up to 35 feet in greatest dimension, and many smaller boulders of Franciscan schist and sandstone 5 feet in diameter. Some small cobbles and pebbles are poorly rounded, but most of the large fragments show only slight rounding and many have some polish on their surfaces. The boulders are approximately a mile from present Franciscan exposures. Many of the schist boulders contain pholas borings, and there are some pholas borings in the underlying Yager sediments. At some places there are several feet of Yager and Franciscan rubble (pulverized shale and small angular sandstone fragments) overlying the steep-dipping Yager shales which are in place. The rubble is mixed with Wildcat sand, pebbles, cobbles, and huge boulders, and grades up into siltstone or thin sandstone. The Wildcat was deposited in this part of the basin on an irregular surface containing numerous troughs and small knobs. Mappable buried ridges are shown near Salmon Creek (sec. 18, T. 3 N., R. 1 E., H.) and near the North Fork of Elk River (sec. 36, T. 4 N., R. 1 E., H.). Other larger isolated exposures of Yager may be buried ridges rather than highs resulting from folding. The Wildcat formation in sec. 21, T. 4 N., R. 2 E., H., forms the north gently dipping flank of a small syncline whose south flank dips as much as 55° N. Glauconitic pebbly sandstone exposed near the base on the south flank is not present on the north flank. The siltstone and fine sandstone exposed in gulleys on the north flank dip 10° to 15° S. yet the contact with the Franciscan is a nearly straight line. Exposures show that the contact is not faulted but depositional, and that here the Wildcat beds were deposited against a cliff of Franciscan rocks. Some exposures indicate that part of the dip value of the Wildcat beds near the base is initial, especially where the beds are adjacent to irregular highs of the older rocks.

Petrography

Petrographic studies of Wildcat sediments have been made in an effort to aid in the differentiation of the various units where megascopic and paleontologic methods have not been successful. The results are summarized below *:

Using the Bouyoucus hydrometer method (Bouyoucus, 1936) 19 samples from the Wildcat group were studied. In summary: (1) Most mudstones have a predominance of silt rather than clay. (2) Most ashes show excellent sorting. (3) The range of sizes in a particular sandstone (such as the Pullen sandstone) is as great or greater than the size variation between sands of various units. (4) The pelitic sediments of the nonmarine Carlotta formation are unusually well sorted in comparison with other pelitic sediments of the Wildcat group. (5) There is typically more silt than clay in the sediments, whether the samples are sandstone or mudstone (on a triangular diagram most samples fall near a line from the sand apex to a 35 percent clay-65 percent silt point on the clay-silt join). Rubey (1930) suggested that such a sorting might result from flocculation by salt water of mud particles of many different sizes into aggregates.

Mineral grains were examined with petrographic and stereoscopic binocular microscopes. The results may be summarized as follows: (1) The feldspar is chiefly plagioclase in the range oligoclase-andesine, although

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* More complete information on the methods and discussion of the data are given in an unpublished Ph.D. thesis (Ogle, 1951).

some samples have a few percent of orthoclase. (2) Rock fragments, especially chert, are abundant in most sandstone samples and may form as much as 50 percent of the total volume. Some of the chert is colorless and some is red, containing radiolaria. Other common rock fragments are basic volcanics and shale-slate. (3) Hornblende is the most abundant minor constituent, being most common in sands of the Rio Dell, Scotia Bluffs, and Carlotta formations, less common in the Eel River formation, and rare in the Pullen formation. It is followed in order of abundance by epidote, biotite-chlorite, opaque minerals, and glaucophane. (4) Biotite-chlorite is especially abundant in the Rio Dell sandstones. Most of the flakes show some alteration of the brown biotite to greenish chlorite. (5) Glauconite is an abundant mineral in sediments of the Eel River formation, is common in some Pullen sandstone, and is rare to absent in other units of the group. (6) In samples of mudstone collected for foraminifera study, fish teeth, fish bones, and bird bones are often found. Pyrite in the form of aggregates or foraminiferal, diatom, and radiolaria casts is common. Glauconite may be present as fillings in foraminifera, as molds of organic forms, or more often as irregular, botryoidal, ovoid, apple-green to dark green masses. Colorless, curved volcanic glass shards are locally abundant. Frosting and pitting of quartz and feldspar grains and foraminifera tests are common in mudstone of the Pullen formation, but not in other sediments.

The mineralogy of the Wildcat sandstone indicates that the Franciscan and Yager formations are the probable chief source materials. Most of the sandstone may be termed argillaceous feldspathic sandstone. It might be considered to be graywacke or sub-graywacke (Pettijohn, 1949; Tallman, 1949), although the writer prefers to restrict that term to rocks, such as the Yager and Franciscan sandstones, which contain a partly recrystallized paste.

Glauconite is common in various sediments of the Eel River formation, in some sandstone of the Pullen formation, at the unconformity between the Eel River formation and Rio Dell formation, and in the lower part of the undifferentiated Wildcat in the northeastern part of the Fortuna quadrangle. While often associated with organic tests, it is also widely distributed in mudstone and sandstone. Much of the glauconite is associated with sediments containing foraminifera which are believed to be characteristic of bathyal or abyssal depths. Takahashi (1939) pointed out that glauconite forms under anaerobic or reducing conditions, usually associated with iron sulfides. This association is common in Wildcat sediments and since glauconite sometimes fills the tests of benthonic foraminifera which must have had some aeration on the ocean bottom, it is probable that the glauconite formed slightly below the surface of sedimentation. Because glauconite is thought to be a product of submarine weathering it may be implied that the mineral would tend to form at times when there were lags in sedimentation. These conditions may have existed at the stratigraphic breaks and at various times during the deposition of the deeper water Eel River sediments.

Several thin beds of white volcanic ash occur in the Wildcat group. Four samples of ash from different localities are included in the size analyses. In addition to the identifiable ash beds, there is considerable ash disseminated in the sediments of the lower part of the Wildcat group.

In examining samples of ash from 10 different localities it was determined that in addition to the predominant clear volcanic glass, there

COMPOSITION OF WILDCAT SEDIMENTS ● abundant ○ common X rare SAMPLE	80-S63 Carlotta sd.	80-S64 Carlotta sd.	S35-4* Carlotta ash	S35-3* Carlotta sd.	80-S65 Carlotta silt	80-S70 Scotia Bluffs sd.	80-S71 Scotia Bluffs sd.	S35-2* Scotia Bluffs sd.	80-S80 Rio Dell sd.	BAO-48 Rio Dell slt.	80-S91 Eel River sd.	80-S101 Eel River sd.	80-S96 Pullen sd.	80-S95 Pullen sd.	80-S99 Pullen sd.	80-S102 Wildcat undiff. sd.	S35-1* Wildcat undiff. sd.
Major constituents																	
feldspar	●	●	●	●	●	●	●	●	●	●	○	○	●	●	●	●	●
quartz	○	●	●	●	●		●	●	●	●	●	○	●	●	●	●	●
rock fragments																	
chert	●	●	○	●	●	●	●	○	●		○	○	●	●	●	●	○
other	●	●				●			●		○				○		
Minor constituents																	
actinolite																	○
augite							○		X	○							X
biotite	○		○			●	○	X	●		○		●	X	X	○	
calcite				●				○									
carbonaceous frags.						●			●								
chlorite			○			○		X	○	●				X	X		
epidote	X	X	○	●	○	○		●	●	○			X		X	●	●
garnet			X	X			X	X		○		○				○	
glauconite											●	●					
glaucophane		X	○	○	○		○	○		○		●					X
hornblende	X	●	○	●	●	●	●	○	●	●	○	●	X			●	●
hypersthene			○	X			○	○								○	X
muscovite								X									
opaques	●	●		○	●	●	X	X	●	○	●	○				●	○
picotite			X														X
rutile		X	X		X									○	○		X
sphene		X		X	X		○									X	X
spinel	X	X		X													
staurolite								X									
topaz			○					○									
tourmaline			X	X				X									
volcanic glass		X	●														
zircon	X	○	●	X	X			X		○				X	X	X	

FIGURE 4a. Table showing composition of Wildcat sediments

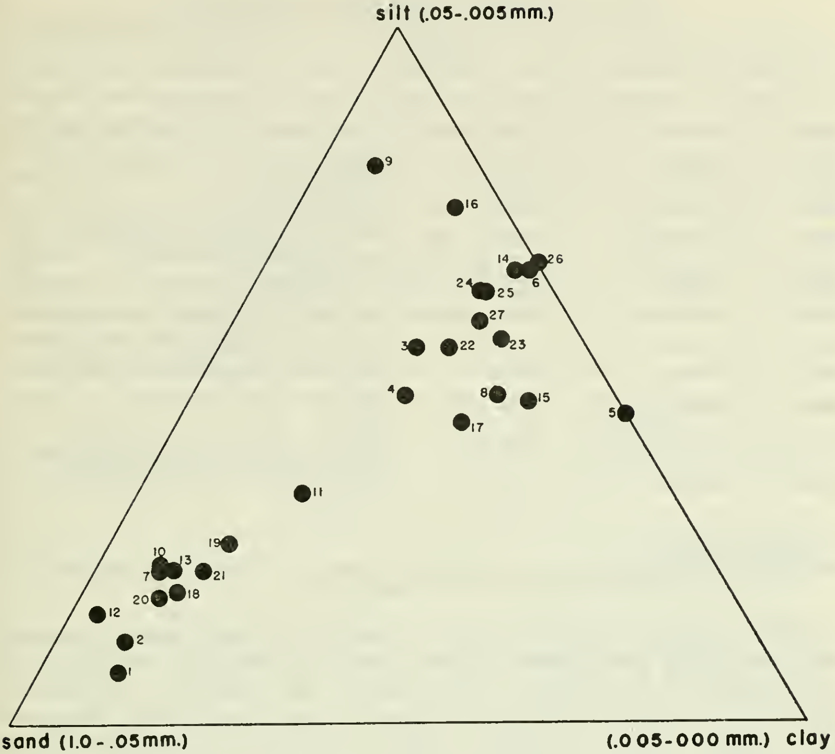

FIGURE 4b. Size distribution chart, Wildcat sediments

were a few grains of feldspar and quartz and rare ferromagnesian minerals. It is not possible to determine whether some of the minor constituents had a volcanic source or whether they are all epiclastic grains. Under the binocular microscope the glass is seen to be colorless, clear, and unaltered. Most of the shards are curved, thin, sharp fragments—the remains of shattered bubbles—although one sample showed some elongate, grooved pieces containing minute bubbles. The glass has a silica content of 70 percent as determined by the refractive index method (George, 1924; Matthews, 1951). This silica content is typical of rocks in the rhyolite-dacite range. Because most glass is more acid than related crystalline rocks, the ash may have come from a volcano erupting dacitic or andesitic lava. There are no known volcanic rocks of Pliocene age west of the Klamath Mountains. East of the Klamath Mountains, active Pliocene volcanic centers which produced andesite or more acid lavas, include the Lassen area, and the Medicine Lake Highlands region. It is about 130 miles from the Eel River area to Lassen and about 160 miles to Medicine Lake Highlands. There were Pliocene centers of volcanism in the Clear Lake area (C. A. Anderson, 1936) approximately 120 miles south of the Eel River area, and in Sonoma County, 200 miles south, where the Tolay and Sonoma volcanic rocks accumulated. Travis (1951) noted that in the Sebastopol quadrangle glass in tuff-breccia of the Merced formation (upper Pliocene) had refractive indices ranging from 1.499 to 1.502.

Refractive indices of glasses of the Wildcat group

Sample	Formation	R.I.	Percent glass	Remarks
80-362*	Carlotta	1.508	99 plus	1′ bed, unconsol., more coarse than other ash beds
S35-4*	Carlotta	1.50	?	impure ash, 6′ total, of which less than 1′ is relatively pure
80-381*	Rio Dell	1.506	99 plus	10″ ash bed exposed on coast, contains enough fine clay to give a gray-white color
80-393	Eel River	1.508	99 plus	2″ pure white ash, 2′ impure off-white ash, compact, 50′ above 80-390
80-390°	Eel River	1.504	99 plus	2″ pure white ash, impure ashy silt above and below, coast section
80-394	Eel River	1.508	99 plus	a total of 6′ of ashy beds of which approx. 2′ is pure; approx. same horizon as two samples above, but near Woodland Echo Ranch
BAC 34	Pullen	1.505	25	ashy mudst., included to show disseminated ash
80-S98*	Wildcat (undiff.)	1.503	99	white, 2″ irregular ash bed, Elk River (north fork)
SC-S104	Wildcat (undiff.)	1.504	99	white, 3″ irregular ash bed, Elk River (south fork), approx. same horizon as 80-398
80-3103	Wildcat (undiff.)	1.508	99	white, irregular 1″ ash bed, Yager-Allen Creek area

* Included in size analyses.
NOTE: Percent glass indicates the percent in that part of the sample coarser than .053 mm. Some samples have some very small sizes of glass and a few have some fines other than glass.

During transport by wind, ash is sorted by size and specific gravity, acid ash being transported farther than basic ash. The constancy of composition of the Wildcat ashes probably was effected by the source and wind currents remaining the same during deposition, so that only those ashes of acid composition reached the area of deposition. More basic ashes, if they were occasionally erupted, would have fallen closer to the source. Since clastic sedimentation must have been continuing at a relatively rapid rate, concentration of the ash probably took place by the ash at first floating on the quiet water surface because of the surface tension and contained bubbles (Mellin, 1948; McKelvey, 1941; Menard, 1950), and then suddenly sinking during turbulence of the sea (Menard, 1950).

Paleontology and Correlation

Megafossils and microfossils are abundant in most of the marine part of the Wildcat group. Lenses of marine or brackish-water sediments in the upper nonmarine part of the group contain a few megafossils. A few well-preserved leaves have been found in the Carlotta formation.

Megafossils. A check list of megafossils collected in the Wildcat sediments is included herein. Identifications were made by J. Wyatt Durham and the writer. Locality numbers are those of the University of California, Department of Paleontology, where the collections are on file.

Pecten (Patinopecten) caurinus Gould appears to be a marker fossil restricted to the middle and upper Rio Dell formation and lower Scotia Bluffs sandstone. It is present locally in great abundance, forming thin beds composed largely of pectens. *Pecten dilleri* Dall was not found by the writer but the type locality is given by Diller (1908, p. 30) as "bluffs opposite Rio Dell," and "slide below Rio Dell", which suggests that the type must have been found in the lower part of the Rio Dell formation. This pecten would appear to be restricted to a lower part of the section than *Pecten caurinus* Gould (see Martin, 1916). The fact that it is apparently not abundant detracts from its value as a marker. *Anorthoscutum oregonense* Howe appears to be restricted to the lower and middle part of the Scotia Bluffs sandstone and has been found at several localities in the same part of the stratigraphic section. *Psephidia lordi* var. *barbarensis* Arnold, *Cardita* cf. *substanta* (Conrad), *Cardium (Cerastoderma) meekianum* Gabb and *Securella staleyi* (Gabb) are typical of the middle and upper Rio Dell and lower Scotia Bluffs. *Solemya ventricosa* (Conrad), *Thyasira disjuncta* (Gabb), *Lucina acutilineata* Conrad, and *Argobuccinum arnoldi* (Martin) are typical in the lower Rio Dell and upper Eel River formations (and equivalent parts of the undifferentiated Wildcat). Two species of importance were found in the basal Pullen sandstone along Eel River: *Spondylus* n. sp. and *Anadara* cf. *osmonti* (Dall). Durham (oral communication, 1951) summarized the evidence furnished by these two species by stating that all indications point to an older age than that of the typical Wildcat faunas. This concurs with the evidence furnished by the foraminiferal fauna (Mohnian) from the Pullen formation at Price Creek. Species found in the marine lenses in the Carlotta are generally non-diagnostic but many of the forms are not found in the previously mentioned Wildcat faunas. Fossils found are *Ostrea lurida* Howard, which is common in the upper Etchegoin, upper Merced, and exceedingly common in many Pleistocene beds, according to Grant and Gale (1931) ; *Mytilus californianus* Conrad, which has been recorded from formations of Pleistocene to Recent age by Grant and Gale (1931), but which ranges into the upper Rio Dell formation in this area; *Macoma nasuta* (Conrad) ; *Protothaca staminea* (Conrad) ; *Saxodomus nuttalli* (Conrad) ; *Schizothaerus nuttalli* Conrad ; *Cardium* sp. (*corbis?*) ; and *Thais lamellesa* Gmelin. In recent dredgings of the upper 5 feet of recently deposited muds in Humboldt Bay, at Buhne Point boat landing, there are abundant fresh-appearing shells of all the above species except the first two and last one. Durham (oral communication, 1951) stated that all of these species can stand less salinity than is found in the open ocean. The close comparison of the Recent and Carlotta faunas suggest similar conditions of deposition and, with the other correlations noted above, a possible Pleistocene age for the Carlotta beds. The evidence is far from conclusive, however, and it is possible that the difference between the Carlotta fauna and older Wildcat faunas is only a difference of facies.

Martin (1916) divided the Wildcat megafossils into an upper and lower fauna. It appears, however, that the upper fauna is from the middle and upper Rio Dell; and the lower fauna is largely from the lower Rio Dell; thus they are not representative of the lower 2,000 feet of lower Pliocene and upper Miocene beds. Stewart and Stewart (1949) listed the first and last appearances of megafossils in the coast section. It is not certain that such a scheme holds true in other sections of the Wildcat group. The present writer has not attempted to zone the Wildcat on the basis of the megafossils because of the random nature of the collection and lack of abundant diagnostic forms. The species listed above have, however, been of aid in the field mapping.

Microfossils. Approximately 100 samples, collected by the writer, have been examined for microfossils by paleontologists of the Union Oil Company in Dominguez, California. The data on the foraminifera are presented in an accompanying check list of foraminifera. A complete check list of samples BA01 to BA060 collected in 1948 was furnished by Douglas Crawford. Stewart and Stewart (1949) published a range chart for foraminifera collected by them in the coast section. Samples other than those listed above have been compared to Stewart and Stewart's lower unit (approximately the writers' upper Pullen, Eel River, and lower Rio Dell formations), and their middle unit and upper unit (the writer's middle and upper Rio Dell). Hughes (unpublished paper, 1942) sampled the coast section which includes Pullen, Eel River, and part of the Rio Dell formations, and listed typical assemblages for several formational units. Because this material is not readily available, the characteristic assemblages of Hughes are given below:

Wildcat group (top to bottom)

Ferndale sandstone 2000′ [included the writer's Scotia Bluff sandstone and part of the Carlotta], contains only species of *Elphidium* in the lower part.

Price Creek formation [Rio Dell formation of the writer].

Upper member, 2000′, foraminifera are characteristic of the upper Pico of the Los Angeles basin. The most characteristic species are *Bolivina subadvena* Cushman var., *Cassidulina* Cushman and Hughes, *Cassidulina limbata*, *Cassidulina translucens* Cushman and Hughes, *Gaudryina triangularis*, *Globigerina bulloides* d'Orbigny, *Globigerina dubia* Egger, *Nodosaria* cf. *calomorpha* Reuss, *Nonion scapha* (Fichtel and Moll), *Elphidium lensiformis* n. sp., *Elphidium simplex* n. sp. *Elphidium striatopunctata?*, *Epistomina?*, *Rotalia* aff. *beccarii* (Linne), *Uvigerina tenuistriata.*

Middle member, 900′, *Bolivina robusta*, *Bolivina spissa*, *Uvigerina peregrina* are characteristic.

Lower member, 1000′ *Bulimina subacuminata*, *Cibicides mckannai*, *Nodosaria sulcata*, *Chilostomella*, *Uvigerina peregrina*, *Uvigerina latalata* are characteristic.

Eel River formation [generally the same as that of the author], 750′ in the coast section, 2000′ at Price Creek, characteristic foraminifera (of the 100 species present) are *Bolivinita quadrata*, *Bulimina inflata*, *Bulimina buchiana*, *Cibicides spiralis*, *Epistomina elegans*, *Clavulina communis*, *Nonion pompilioides*, *Gyroidina soldanii*, *Nodogenerina antillea*, *Planulina muellerstorfi*, *Plectofrondicularia californica*, and *Pullenia sphaeroides.*

Fortunas formation [equivalent to much of the Pullen], 1000′?, the foraminifera are mostly arenaceous species; characteristic are *Ammodiscus* sp., *Bolivina obliqua*, *Clavulina* sp., *Cyclammina* sp., *Haplophragmoides* sp., *Nodosaria uvasemi?*, and *Uvigerina hispida.*

There is some discrepancy in species identified by Stewart and Stewart (1949), Hughes, and Crawford. Some ranges of species listed in the present check list do not coincide with ranges found by Stewart and Stewart (1949) in the coast section.

The Mohnian foraminifera have not been described previously. Gester (1951, p. 205) has noted the presence of rocks of Miocene age at the base of the Wildcat group but gave no reason for assigning this age; Hughes (unpublished notes, 1946) mentioned that the Fortunas formation was upper Miocene in age. The excellent assemblage of Mohnian foraminifera collected on Price Creek from the Pullen indicate that the basal Wildcat at this locality is upper Miocene in age. The lower samples contain species characteristic of Kleinpell's (1938, p. 139) *Bolivina modeloensis* zone of the Mohnian stage and some of the higher samples contain species characteristic of the *Bolivina hughesi* zone. The writer did not find any samples containing foraminifera characteristic of the Delmontian stage, but *Bolivina obliqua* (reported by Hughes) probably represents that part of the section (Kleinpell, 1938, p. 132). Foraminifera in the upper part of the Pullen are characteristic lower Pliocene forms. To the south, in the Bear River area, Relizian, Luisian (Kleinpell, 1938), and Mohnian foraminifera have been identified from a continuous section. Sedimentation in this region probably continued without major breaks (only changes in margins of basins) from the Relizian into lower Pliocene.

Fossil Leaves. Fossil leaves found in the Carlotta near the Van Duzen River were identified by D. I. Axelrod, who stated:

> All of the material identifiable seems to represent willow. Three different species appear to be represented: *Salix lasiolepis* (white willow), *S. laevigata* (smooth willow) and *S. hookeriana* (Hooker willow). All of them occur in the region of the fossil locality today, and range north and south for some distance. The absence of any forest trees (redwood, Douglas fir, lowland white fir, hemlock) and their regular associates is probably to be interpreted as indicating that the deposit is somewhat on the order of a backswamp, possibly a small lake, which was bordered by a wide zone of willows. Such communities are common today in the coastal region.

Vertebrate Remains. In 1949 the writer found a vertebrate bone in a Carlotta conglomerate bed (SW¼ sec. 9, T. 2 N., R. 1 E., H.). V. L. VanderHoof helped to excavate it, and identified it as the jawbone of a whale, of no value in correlation. The fragment was trough shaped, 40 inches long and 6 inches across the trough; it was left in place.

Correlation. The abundance of fossils, especially foraminifera, makes it possible to establish correlation with other formations in California. Most of the Pullen formation may be equivalent to most of the Puente and Modelo formations of the Los Angeles basin, the lower part of the Purissima formation of the Santa Cruz basin, and the Tice shale (Monterey group) of the San Francisco Bay area. It is partly equivalent to the Wymer beds (Del Norte County). The upper part of the Pullen beds and the whole Eel River formation are probably equivalent to the Repetto formation of the Los Angeles and Ventura basins, the Jacalitos formation of the San Joaquin Valley, and part of the Purissima formation of the Santa Cruz basin. The Rio Dell formation is essentially equivalent to the Pico formation of the Los Angeles and Ventura basins, and the upper part of the Purissima beds (Santa Cruz basin). The upper part of the Rio Dell formation is equivalent to the lower part of the Merced formation of the Santa Rosa area and the lower part of the Empire formation at Coos Bay, Oregon. The lower part of the Scotia Bluffs sandstone may be equivalent to part of the Santa Barbara formation (Ventura basin), part of the Merced formation, and most of the Empire formation, Coos Bay, Oregon. The upper Scotia Bluffs and the Carlotta formation are tentatively correlated with the San Pedro beds of southern California, the upper Santa Barbara formation (Ventura basin), the upper part of the Merced formation (near Santa Rosa), possibly with the beds at Battery Point, Crescent City, and part of the Pleistocene beds at the mouth of Elk River in southern Oregon.

Conditions of Deposition

Before the deposition of the Wildcat (as mapped herein) there was deposition to the south in the Bear River and Briceland areas during middle Miocene (Relizian-Luisian) time. The basin, or basins, were limited and deep. Faulting probably aided in the development of these narrow, restricted troughs. Bear River deposition continued without a break into the Mohnian stage and the margins of the basin were extended to the north and east. Thus the Pullen-Bear River Mohnian sediments overlapped the older deposits and became the basal beds of the Wildcat in the Price Creek-Eel River area. This deposition probably did not extend northeast of Fortuna or southeast of Stafford.

The basal Pullen beds are probably not correlative in age at all localities, and basal sediments differ widely in character. Some surface irregularities probably persisted, although much of the region must have been essentially a peneplain. Depth conditions varied widely. In the small syncline of Pullen west of Scotia there are *Saxacava* and *Lithophaga* which occupied borings in limestone of the Pullen formation. These forms must have lived in depths less than 50 feet. The formation, hardening, and boring of the limestone must have required a relatively slow rate of deposition. The presence of *Spondylus* in the basal sands at Eel River also suggests a shallow-water environment and warm waters (at least 15° C. and possibly as warm as 20° C.). The presence of great quantities of Yager formation debris at this same general locality suggests the proximity of a positive rugged land mass. Deeper-water conditions prevailed to the west during this same general time, as indicated by the massive mudstone and diatomaceous mudstone of the Pullen formation west of Price Creek, and the presence of bathyal foraminifera. Following the basal sand deposition rapid subsidence continued and bathyal foraminifera were partially replaced by abyssal forms. During the deposition of the upper Pullen beds, depths may have been as great as 4,000 to 6,000 feet in various parts of the basin. The Pullen deposition was brought to a close by uplift to wave base, or the sediments may have been exposed to subaerial erosion. Basal conglomerate and abundant glauconite were formed in shallow water at the beginning of the deposition of the Eel River beds. Rapid subsidence to abyssal depths followed. It is probable that recurrent movement along major fault systems aided in this rapid fluctuation. The fine-grained sediments of the Eel River formation and the bathyal and abyssal foraminifera suggest deep-water deposition. The western part of the basin was deeper than the eastern part; the northern margin was in the vicinity of the northern edge of the Fortuna quadrangle and the eastern margin was near the North Fork of Elk River. Open-sea conditions prevailed. Eel River deposition was brought to a close by uplift, and erosion by waves or subaerial agents or both; some warping occurred in parts of the basin. Subsidence again followed erosion. The lower Rio Dell fauna indicates that depths of 1,000 to 4,000 feet were characteristic in most of the basin. From this maximum, the depth became progressively more shallow from this time on, although minor fluctuations undoubtedly occurred. Deposition of upper Rio Dell beds was in more shallow water and considerable variation existed in the basin; depths of 500 to 900 feet prevailed in the coast section while depths in the vicinity of the Eel River section were not greater than 100 feet (forms such as *Cardium* and *Securella* are typical of the shallower conditions). These shallower seas extended over greater areas than the earlier seas and sediments overlapped the older rocks in all directions. At the base of the undifferentiated Wildcat

FIGURE 5. False Cape shear zone. Sandstone lenticles in pulverized shale (crush-conglomerate), in NW¼ sec. 35, T. 2 N., R. 2 W., H., in the coast section.

FIGURE 6. Eel River formation. Spheroidal or onion-skin weathering of massive dark-gray mudstone, west bank Eel River, NE¼ sec. 7, T. 1 N., R. 1 E., H.

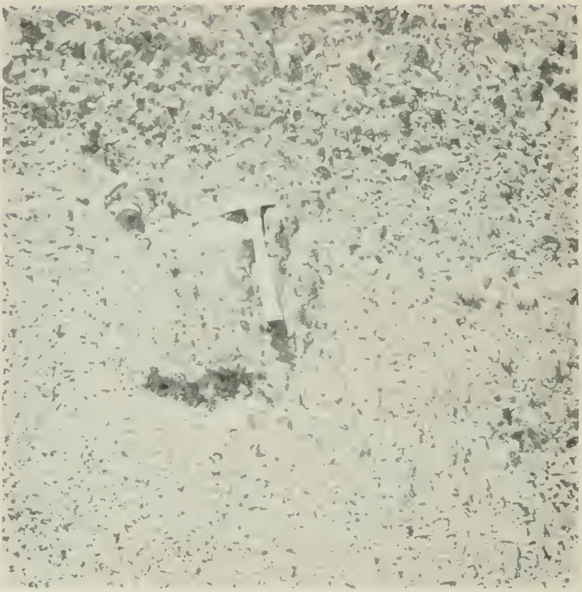

FIGURE 7. Carlotta formation. Massive pebble-cobble conglomerate, with some indications of rude bedding. Wildcat Ridge road, SW¼ sec. 11, T. 2 N., R. 2 W., H.

FIGURE 8. Old alluvium. Stream gravels and sands which have been recut near the mouth of the Van Duzen River. This type of bedding is similar to that in the Hookton formation in the eastern part of the area.

FIGURE 9. Carlotta formation. Inverted tree stump to right of pick, in massive blue-gray claystone, south bank Van Duzen River, SW¼ sec. 26, T. 2 N., R. 1 E., H.

FIGURE 10. Hookton formation. Boulder-gravel at the base near center sec. 17, T. 2 N., R. 1 E., H.

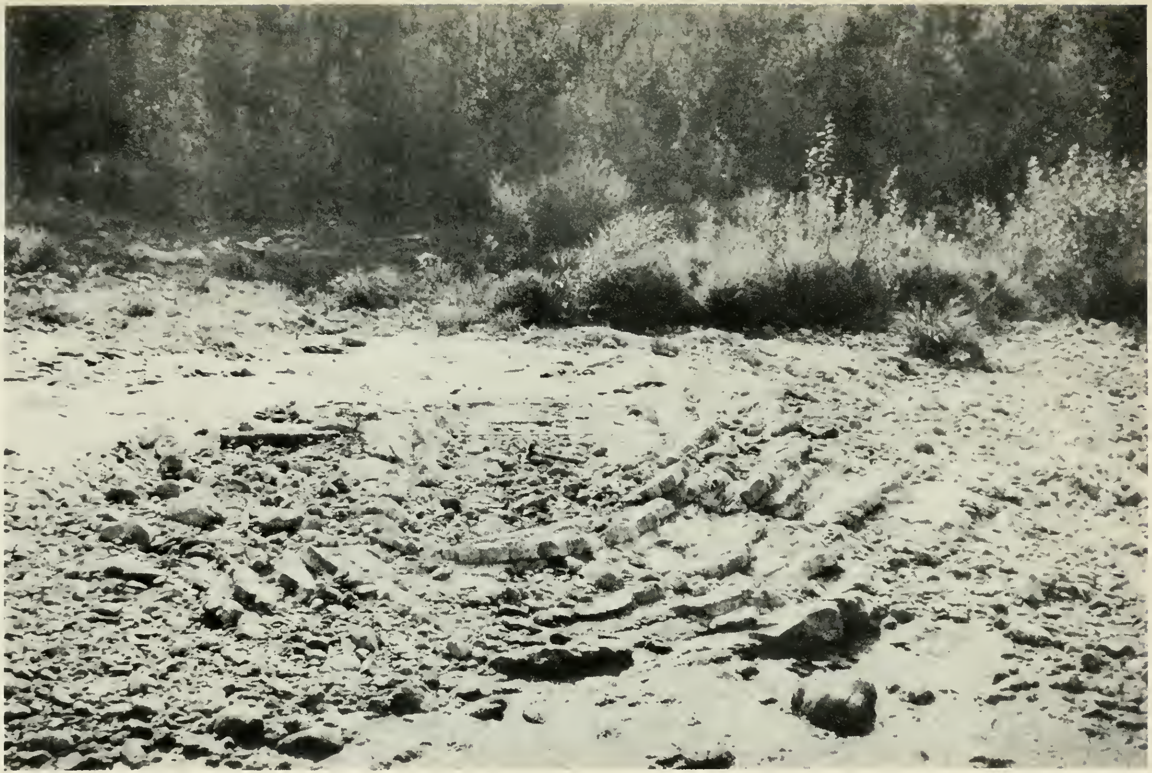

FIGURE 11. Yager sandstone and shale. The beds are tightly folded. The rod in center of picture is touching the same bed on the two flanks of a syncline; the same beds swing around to the right to form a small anticline plunging away from the observer. Near Scotia on east bank Eel River immediately below base of Pullen (exposed at low water), SE$\frac{1}{4}$ sec. 7, T. 1 N., R. 1 E., H.

FIGURE 12. Rock-debris slide on dip plane surface of interbedded Rio Dell sandstone and mudstone. This is an important method of erosion on the coastal cliffs. Rhythmic alternation of bedding is typical of middle member of Rio Dell. Coast section, NW¼ sec. 24, T. 2 N., R. 3 W., H.

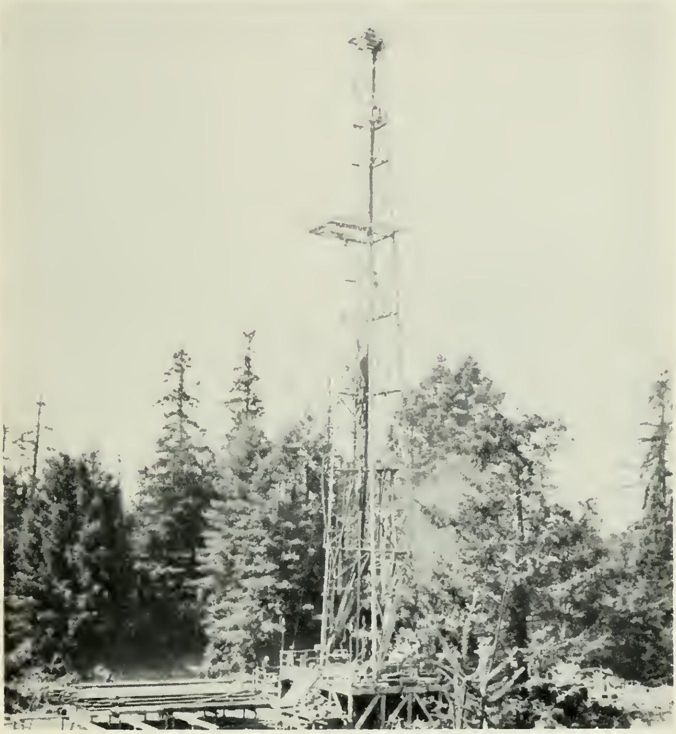

FIGURE 13. Salmon Creek Oil & Gas Co. "Fowler" 1, drilled in 1948 in sec. 15, T. 3 N., R. 1 W., H. Some oil and gas reported, but the well was abandoned.

FIGURE 14. O'Rourke 1950 slump. House was damaged by movement of differential blocks of the slump.

in the northeastern part of the Fortuna quadrangle, these seas lapped against cliffs of Franciscan. Great boulders of schist were contributed by landslides and, as they accumulated along the coast, their surfaces were pierced by pholas borers. The land surface was somewhat irregular, and many local sands buttressed against prominent masses. As the basin continued to become more shallow deposition of the Scotia Bluffs sandstone began in different parts of the basin at different times. The basin became more restricted and some marginal uplift and warping may have started. The massive character of the sands indicate a lack of current and wave action. Offshore bars may have aided in protecting the basin from open-sea conditions. Abundant pelecypods in the lower part indicate a depth of less than 100 feet. A few *Elphidium* in mudstone members suggest littoral conditions. During deposition of the Scotia Bluffs sediments, the basin continued to become more shallow, and marine conditions were gradually replaced by brackish water to nonmarine conditions during deposition of the upper Scotia Bluffs formation. Some fragments of Pliocene mudstone in the upper Scotia Bluffs indicate marginal uplifts. Trains of pebbles in the upper part of the Scotia Bluffs formation are the forerunners of the coarser clastics of the Carlotta formation. By the time of the deposition of the Carlotta there was a great variation of depositional environment from east to west. Many types of flood plain, swamp, lake, lagoonal, and bay deposits were accumulating. In the eastern area the coarse cobble conglomerate predominates, while to the west there is more sand, silt, and clay. Fluctuations of the sea formed restricted marine lenses at various times. Uplift of the margins of the basin continued and streams with steep gradients were actively eroding the surrounding area. Vegetation was locally abundant and the climate may have been similar to that of the present. The depositional history was brought to a close by a strong orogeny whose beginning effects strongly influenced deposition of the Carlotta formation.

Hookton Formation

Sediments mapped as the Hookton formation include gravel, sand, silt, and clay which characteristically have a yellow-orange color. In the Eel River Valley area they are extensively exposed and cap the gently dipping terrace surfaces at Centerville Beach, east of Rohnerville, and east of Elk River school. They also form the surface beds whose dip slopes result in the topographic form of Table Bluff, Tompkins Hill, and part of Humboldt Hill. Youthful streams and gulleys have cut through this thin formation in the Tompkins Hill area and exposed the underlying sediments of the Wildcat group. Mapping has shown that an unconformity exists between the two, that the Wildcat group was folded before the Hookton was deposited, and that the more gentle post-Hookton folds usually follow the general axes of the earlier post-Wildcat folds. Thus the Hookton is exposed on the south side of the Eel River syncline at Centerville Beach, dips under Recent alluvium, and appears again to the north at Table Bluff on the north limb of the syncline. To the east of Rohnerville and Fortuna it can be followed through the Eel River syncline as it forms a low dissected plane surface and passes over the Tompkins Hill anticline where folding has been more intense.

Lithology, Distribution, and Thickness. Accurate mapping of the Hookton formation is difficult because of its close spatial relationship to the Carlotta continental beds in surface exposures. This has been brought about by the stratigraphic position of the two units, the structural conditions and the fact that the Carlotta conglomerate beds are resistant and generally aid in the preservation of the capping formations and terrace deposits.

The lithology of the Hookton is extremely variable, both locally and between the larger areas of exposures. Where exposures are poor the weathered gravel, sand, and clay may easily be confused with weathered sediments of the Carlotta and Scotia Bluffs formations. One of the principal differences is the common yellow-orange of iron oxides of Hookton sediments as opposed to the reddish-brown color of the iron oxides coating the conglomerate and sandstone of the Carlotta.

No adequate type section can be given because of the extreme variability of these beds. The name Hookton is used because there are numerous, more or less typical, random exposures of the sediments in the Hookton-Table Bluff area. Most of the formation is nonmarine but some sediments included in it in the western part of the area are shallow marine or marginal deposits. Broadly speaking, the coarser gravels are most common in the southeastern area (east of Rohnerville and Fortuna) whereas to the west there is more sand, silt and clay which suggests that the sources of the material were the parental Eel and Van Duzen Rivers.

The most completely exposed section of the Hookton may be seen near Centerville Beach, where the unconformable contact with the underlying Wildcat is visible. Stewart and Stewart (1949) included the sand and gravel of the Hookton here exposed in their section of the Wildcat. The Hookton sediments dip from 4° to 11° N. At the base is an eroded surface of Wildcat mudstone upon which has been deposited ocherous loose sand and gravel. The uppermost exposures at Centerville Beach, are friable orange-tan sand with gravel lenses; from that point the formation dips to the north under the alluvium. The writer measured approximately 420 feet of section here (Stewart and Stewart, 1949, noted 480 feet) but exposures are not continuous, as there are several large slumps, and variations in dip are common in the exposed beds. Alternating thin, pebble-gravel beds and thin medium- to coarse-grained loose sand beds make up the greater part of the formation in this section, but there are several thicker sands in the lower and upper part. The pebbles are mostly rounded to sub-rounded Franciscan rock types and they range from a quarter of an inch to an inch in size. There are also a few small cobbles. The interbedded sands are usually rather clean, friable to loose, and vary from medium to coarse in grain size. Feldspar, quartz, and rock fragments are the most abundant constituents, and ferromagnesians appear to be minor. The minerals are difficult to identify in the hand specimen because the mineral grains are generally coated with a yellow-orange, ferruginous (limonite?) coating, as are the pebbles. Cementation is locally accomplished by precipitation of limonitic material around the grains. At many localities the alternating sand and gravel beds result in a banded outcrop in the sea cliff, as a result of differential weathering, which removes the sands more easily than the gravels.

In the Fortuna-Hydesville area the conglomerate is composed of coarse cobbles and boulders, while in the Tompkins Hill-Table Bluff area the sediments become finer-grained, and sand, clay and silt predominate. Near the Table Bluff lighthouse alternating sand and gravel beds unconformably overlie Wildcat beds with strong angularity. Wells on Table Bluff penetrate as much as 200 feet of the Hooker formation, although the contact with the underlying Carlotta is difficult to identify in well logs. It is significant that logs mention ''yellow clays'' at depths greater than 100 feet; such evidence suggests that the coloration was largely original at the time of deposition.

In the Humboldt Hill area the formation is 200 to 400 feet thick and is composed of loose orange-brown sand including pebble lenses and blue-gray clay, some of which contains wood fragments. At the base in Shaw Gulch, the unconformity with underlying Wildcat mudstone can be clearly seen; large cobbles of Wildcat mudstone are present at the base of the Hookton.

In the northwestern part of the quadrangle, beds believed to be Hookton formation are exposed in Henderson Gulch and in several gulches to the west. Here loose brown sand, brownish gray clay, and silt contains some slightly carbonized woody material and a few poor casts of marine pelecypods such as *Cardium* and *Macoma*.

The yellow sand and clay forming the terraces between Eureka and Arcata are also probably correlative with the Hookton. Of interest in this area is a fault on the old highway south of Washington Gulch, near the center of sec. 9, T. 5 N., R. 1 E., H., which offsets the soft creamy yellow sand against serpentine. This fault and fault zone are along a line which is the projection of the Freshwater fault.

It may be that some of the high terrace deposits in the coastal area north of Mad River can also be correlated with the Hookton. The high terraces composed of similar material along the highway between Trinidad and Patricks Point are also possible equivalents. These slightly tilted yellow terrace sand, gravel, and clay are well-exposed on the beach cliffs at Patricks Point State Park, where they unconformably overlie Plio-Pleistocene beds dipping 10° to 15°, and sheared Franciscan rocks.

Sample	feld	rock frag	qu	bi	cl	gl	glauc	hb	hyp	zir	ru	op	ep
80-S50 (sd)	A	C	A	C	C		C	C	R			A	C
80-S51 (sd)	A	C	A	C			R			R		C	R
80-S52 (slt)	A	A2	A			C	R	R		R		C	C
80-S53 (slt)	A	A	A				C	A		R	R		C

Feld—feldspar chiefly plagioclase, usually badly altered and milky. Plagioclase is in the range oligo-and.; forms at least a third to half of most samples. Some orthoclase present.
rock fragments—chiefly chert but minor amounts of volcanics.
qu—quartz grains are clear and fresh, often sharply angular.
bl—biotite is brown to pale and bleached; some is altering to chlorite.
cl—chlorite is various shades of green, often seen to be altering from biotite.
gl—volcanic glass, colorless, sharp shards with an R.I. of 1.50.
glauc—glaucophane, pleochroic, blue to violet.
hb—hornblende, blue-green variety and green-brown type.
hyp—hypersthene, rare, colorless.
zir—zircon, small euhedral and rounded grains.
ru—rutile, rounded grains, yellow-brown.
op—opaque, iron ores, principally magnetite ?
ep—epidote, colorless, high biref., some zoisite included.
A—abundant; C—common; R—rare; (A2—very abundant).
Feldspar, quartz and rock fragments are the major constituents in all cases and form approximately 90 percent of the total. Minor constituents, about 10 percent of the total.
The location of all samples is given in Appendix C.

Petrography. Little petrographic work was done on sediments of the Hookton. The four samples selected for size analysis have been grouped with specimens of the Wildcat group, for convenience and for comparison. From these analyses it appears that typical sand of the Hookton is as well-sorted as sand of the Wildcat group, and better sorted than most sands other than the Pullen sandstone. About 50 percent of the grains in the siltstone are silt size, about 25 percent are sand size, and 25 percent are clay size.

Not many of the Hookton sediments contain as many ferromagnesian minerals as the sandstone in the upper part of the Wildcat. Most of the feldspar is more altered, probably to kaolinite, and quartz and rock fragments are always important constituents. The most common accessory minerals are epidote, opaque minerals (magnetite?), glaucophane, and hornblende. Part of the deep weathering of the feldspar may be a result of leaching and alteration in place, as that part of the Hookton formation available for sampling is usually near a surface long exposed to weathering.

Structure. Because of the unconformity between the Hookton and all older formations, the correlation between structures mapped in the Hookton and those mapped in the older units is important. The Wildcat has proved to be capable of producing petroleum substances and thus the Hookton-Wildcat structural relationship is most significant for economic reasons. Dips in the Hookton are generally lower than those in the Wildcat, but strike directions are essentially the same—that is, strikes of the Hookton are generally easterly. The writer has been able to show that structures mapped in the Hookton have axes nearly coincident with axes of structures in the Wildcat. Excellent examples are the Eel River syncline, and the Tompkins Hill, Table Bluff, and Humboldt anticlines. Thus it would seem that the post-Hookton gentle folding had its axes controlled by the earlier established structural trends, even as the earlier post-Wildcat folding was probably controlled by structures in the Yager.

The topography in the area of Hookton outcrops is a more or less subdued expression of the structure. This can be shown by topographic correlation of the Hookton as it passes through the Eel River syncline, the Tompkins Hill anticline and the Table Bluff anticline. That the topography expresses any close relationship to the Hookton structure is evidence of the youth of the post-Hookton folding. The warped Rohnerville formation and other later terrace deposits indicate that gentle folding has continued to very recent times and probably is continuing at present. It is probable that the post-Hookton folding began some time in the middle or upper part of the Pleistocene, in view of the evidence, however meager, dating the Hookton as middle to upper Pleistocene.

Some movement on the Little Salmon fault has been post-Hookton. The author believes that this movement has followed a pattern set up by the earlier movement on the Yager fault. Numerous small faults with a few feet displacement can be seen in the Hookton in the Fields Landing exposures.

Age. No positive age can be established for the Hookton formation from information presently available to the author. However, several inferences suggest that it is probably middle to upper Pleistocene in age.

A few very poorly preserved pelecypod casts were seen by the writer in various parts of sec. 2, T. 4 N., R. 1 W., H., in the Eureka quadrangle.

These could be identified only as *Cardium* sp. and *Macoma* sp.; both genera are common in Pliocene to Recent sediments in this area. Both forms could live in marine waters of low salinity such as might exist in upper San Pablo Bay (Durham, oral communication, 1950) or in Humboldt Bay today. These marine fossils were seen only in the northern part of the area and are restricted to certain clayey beds. They probably indicate that the Hookton formation in the Pine Hill area was deposited in a marginal environment in which very shallow marine mud, probably deposited in an estuary or bay similar to the present Humboldt Bay, alternated with coarser flood-plain material. To the southeast simultaneous flood-plain deposition was taking place.

In the Humboldt Hill and Pine Hill areas and at Buhne Point are numerous occurrences of carbonaceous material. Some partially carbonized tree remains are present in the clay and silt, and a few thin lignitic beds are interbedded with clay. At Buhne Point the low-dipping clay, sand, and gravel beds overlying the more steeply dipping Wildcat sediments contain a 3-foot bed of very low-grade lignite. The material is brown to black in color, soft when wet, but hardens and becomes brittle when dried; although it may be classed as a lignite, it has not advanced far beyond the peat stage. Some limbs and roots of trees can be identified, but most of the material is composed of fragments of reeds and finely divided plant debris. Part of the wood has been slightly carbonized, but much has a brown or light yellow color when broken open. In contrast to the carbonized wood of the Carlotta, these wood fragments, when wet, are fibrous and pliable instead of being hard and brittle. Underlying the lignite is a greenish-blue clay which has a few fragments of plant remains. None of the plant remains are diagnostic, but they do give evidence that swampy conditions existed during the deposition of this part of the Hookton. The character of the material indicates that the sediments are youthful and have had little overburden.

At a sharp bend of the south branch of Rohner Creek, in the NW¼SE¼ sec. 25, T. 3 N., R. 1 W., H., is a 6-inch lignite bed similar to the one described above. It is interbedded with some soft green-blue-gray silt and ocherous sand and gravel. The silt above and below the lignitic bed is carbonaceous. Samples of both the lignite and lignitic silt were collected by the writer for lithologic study. Upon wet seiving the material on 60 and 100 mesh screens, numerous small carbonaceous fragments and some microscopic objects were recovered. R. L. Mason identified some of these small objects as seeds. The following types were recognized:

(1) *Carex* sp.—marsh plant.

(2) *Eleocharis* sp.—marsh plant which lives in fresh water or brackish water marshes but not in salt water marshes; this type is most abundant, is thin-skinned, amber in color, chitinous-like in appearance, and somewhat flattened. The average size of this seed is about ¼-mm.

(3) *Spergularia* sp. (?)—often found today on sea bluffs along the California coast.

(4) *Rubus spectabilis*—thimbleberry which is common today in moist areas in the coastal Humboldt area.

Some additional carbonized ovoid and spherical seeds were present which were not immediately determinable. Some shiny, black, hollowed-out fragments were identified as insect parts, and other larger black fragments were found to be tiny bird bones.

According to Mason (oral communication, 1950), all the plants are herbaceous types which enjoy marshy conditions. The concentration of types and the preservation indicate that the material was not transported. All these plants, or very similar species, are living today. Some of the material is similar to that found in the Tomales Bay Pleistocene (Mason, 1932).

Though no age determination is possible, it is significant that the material is fresh, not strongly crushed, and is similar to other Pleistocene floral remains.

The topographic evidence of youth has already been noted; the meager organic remains are all forms that are living today, mostly in the same region, but they are not diagnostic, except that they are probably Pleistocene; the sediments are youthful in character, compared to the underlying Wildcat sediments; from the stratigraphic position it has been shown that the Hookton is later than folding which affected the uppermost Wildcat beds, and also that considerable erosion must have taken place between the post-Wildcat folding and the deposition of the Hookton. As discussed elsewhere in this report, certain evidence indicates that deposition of the Carlotta extended into Pleistocene time. Thus, the Hookton was probably deposited during the middle or upper Pleistocene, depending upon the time of the post-Carlotta orogeny.

Beds similar to the Hookton both lithologically and stratigraphically have been described from the Los Angeles basin by Wissler (1943, p. 211-212), from the Ventura basin by Bailey (1943), from Tomales Bay by Dickerson (1922), and from Irvington (Savage, 1951).

Conditions of Deposition. Considerable variation in environmental conditions in various parts of the basin existed during the deposition of the Hookton, similar to the conditions in the Eel River Valley today.

Following the folding of the Wildcat, rapid erosion began. A broad valley plain bordering the Pacific was developed, to which sediments were contributed by the ancestral Eel, Van Duzen, and other rivers. The inland mountains were rugged, the climate was generally humid-temperate, and rainfall was probably heavier than that at present (Deevey, 1950), so that great quantities of clastic debris were made available. The plain extended inland somewhat farther than at present, and also extended beyond the present coast line. Continued subsidence of the basin must have taken place, for flood plain and marginal sediments more than 400 feet thick were deposited. Slopes were wooded and the lowlands were covered with grass and brush. Swamps were common and there were probably some lagoons, estuaries, and barred bays. From the facies changes of the Hookton it can be assumed that deposition occurred at or near sea level. During subsidence, a very neat balance with deposition must have been maintained, in order that dominantly nonmarine sedimentation might continue. It is possible that some Pleistocene subsidence of sea level could have taken place during this time. The tectonic activity in this area makes any positive statement regarding eustatic changes in sea level unwarranted (see Higgins, 1950, regarding effects along the coast to the south in the Russian River area; also Kuenen, 1950). Deposition was brought to a close by the reactivation of structural forces along earlier established trends.

Rohnerville Formation

The Rohnerville formation is limited in extent, but is widespread enough to warrant separating it from other more limited terrace deposits. It is restricted to the sloping surface upon which Rohnerville and Fortuna are built, and to the isolated surface known as Grizzly Bluff. The formation ranges from 10 to 25 feet in thickness; it can best be seen along road cuts west of Rohnerville and south of Hydesville.

The materials making up this warped terrace deposit are of flood-plain origin and are predominantly gravel with lesser amounts of sand, silt, and clay. All of the sediments have a typical orange-brown or yellow-brown color resulting from the coating of the grains with ferruginous material. No regularity of bedding can be noted; cross-bedding is common and lenticularity is the rule. Most of the sediments are poorly consolidated, but in some places iron oxide cements the material together to form a relatively hard rock. The upper few feet are made up of silt and clay in most parts of the area, and this usually grades into 6 inches to 1 foot of dark soil.

The Rohnerville sediments overlie the Carlotta conglomerate and claystone with angular unconformity. The contact is exposed in the road cut where a branch road to Rohnerville meets U. S. Highway 101 in sec. 11, T. 2 N., R. 1 W., H. The present upper surface of the Rohnerville forms a gently warped surface controlled largely by the dip of these beds. This surface dips approximately 5° N. near Alton, flattens out near Strongs Creek and dips 1° to 2° S. at Fortuna. It can be seen that this surface has been warped along the axis of the Eel River syncline. Dips in the Rohnerville are only slightly less than those in the Hookton in the same area. One may observe (from a point west of Fortuna) that the two surfaces, Rohnerville and Hookton, are essentially subparallel as they pass through the Eel River syncline. The terrace gravels capping Grizzly Bluff dip about 2° S. By projecting the Rohnerville surface from Alton south and the Grizzly Bluff surface north it may be seen that the two would meet along the axis of the Alton anticline. It is believed that the two separate areas of terrace gravel represent the same valley-plain deposition and they have been mapped as one unit. Thus, the Rohnerville formation has been involved in a very late gentle folding along the old structural axes of the Eel River syncline and the Alton anticline.

It is probable that the Rohnerville formation formerly covered an extensive area but has since been removed by later meandering of Eel River, except in the rock-defended areas where it is now exposed.

No positive statement regarding the age of the formation can be made since no fossils have been found in it. It is post-Hookton and thus probably upper Pleistocene.

Terrace Deposits

Undifferentiated Terrace Deposits. Numerous elevated terrace levels are capped with a thin deposit (5 to 25 feet) of gravel, sand, silt, and clay. Several levels are present in the vicinity of Eel River. All of these are valley plain terrace deposits in which gravels predominate. Boulders up to 1 foot in diameter are common. These deposits have the yellow-orange color typical of the Rohnerville and Hookton sediments. Some of the higher terraces may be equivalent in age to the Rohnerville or Hookton, but because of the warping and distance apart they have not been differentiated.

Some of the higher terrace deposits in the coastal area are stream terraces, but several in secs. 25 and 26, T. 2 N., R. 3 W., H., at an elevation of approximately 900 feet are marine terraces which show more regular stratification and are deposited on a wave-cut platform. These terraces may be approximately equivalent in age to the Hookton; by projecting the uniform dip of the Hookton south from Centerville it can be seen that that plane would meet the level occupied by these terraces.

Young Stream Terrace Deposits. Adjacent to many of the streams are youthful terrace deposits from 2 to 10 feet thick. Gravels predominate but sand and silt are locally more common.

Alluvium

Old Alluvium. The term old alluvium is used for the most recent floodplain deposits, which are now being recut by the present streams. They differ from alluvium in that they are not now being deposited. The material consists of gravel, sand, and silt, but the upper few inches are usually silt.

Alluvium. Stream channel deposits, sand bars, sand spits, mud flats, and delta areas have been included under alluvium. It is apparent that any contact with old alluvium is largely hypothetical and may vary from year to year.

Landslides

Materials making up landslides are generally poorly consolidated and fragmented. Large areas of Wildcat mudstone have slumped in the Ferndale Hills, giving rise to rumpled, disordered rubble spread over many acres. In the creeks southeast of Carlotta, old landslides of Yager material have accumulated more than a mile from their source. Fielder Creek has cut into the old landslide material as much as 50 feet, exposing only Yager rubble; but outcrops on the ridges indicate that Carlotta conglomerates are actually the materials in place.

STRUCTURE

The dominant structural feature of the Eel River area is the general eastward trend of the Tertiary sediments. A major structure in the area is the large Eel River syncline, whose axis strikes about N. 80° W. To the north and south of this major fold are minor anticlines having an overall westerly plunge. The structures in the older rocks are less clear, but the Yager formation forms the trough of a large northwest-trending folded syncline which is bounded by faults on the northeast and southwest.

Pre-Tertiary Structures. Movement along the False Cape shear zone and similar zones to the south may have aided in the development of the Tertiary basins, and caused the rapid elevation and subsidence that accompanied their filling. Offshore from this and other zones to the south, prominent submarine structural features, such as the Mendocino escarpment (Shepard and Emery, 1941), which may extend offshore for at least 1,000 miles, although the direction of the escarpment is reversed 70 miles from shore (Menard and Dietz, 1951). Byerly (1937) has noted that earthquake epicenters are aligned with the eastward trend of this zone. The False Cape and related shear zones may be old major zones of weakness which continue to be active.

The Russ fault serves as the northern limit of the False Cape zone of shearing; but because parts of the zone appear to be relatively unsheared Franciscan rocks, it is also the contact between Franciscan and Yager formations. Movement along the Russ fault is probably as great as that along the Freshwater fault, though the trace cannot be located. From the compressional history it is believed that the fault is a high-angle reverse fault or thrust.

The Freshwater fault may have helped to define the Tertiary basin on the northeast, as the False Cape shear zone did on the south. Its major movement was probably post-Yager and pre-Wildcat, and was at least several thousand feet. The fault plane was not observed. It bounds the southwestern side of the upthrust Kneeland block of Franciscan rocks.

Although the Franciscan was somewhat deformed before deposition of the Yager beds, the first definable structural movements took place during the interval following deposition of the Yager and before deposition of the Wildcat group. The second period of movement followed the deposition of the Wildcat rocks.

Cenozoic Structures. The Yager and Little Salmon faults form a northwest-trending fault system that cuts the east-striking folds northeast of Fortuna. Movement, which has taken place at different times, has been partly along former traces. Along the Yager fault at Yager Creek the Yager formation is thrust from the north against the Rio Dell formation or Eel River formation. Vertical displacement along the fault plane may be as much as 10,000 feet. However, some left lateral horizontal component also may be involved; if so, the vertical displacement may be less.

In the southeastern part of the area movement along the Little Salmon fault may have been as great as 1,000 feet but to the northwest the amount of movement decreased; it was probably negligible in the Humboldt Hill area.

Major movements along the False Cape shear zone and its northern bounding fault, the Russ fault, took place prior to deposition of the Wildcat group, although some of the faults within the False Cape shear zone have been active in post-Wildcat time. Some late movement along the Russ fault in the western part of the area appears to have offset the Pullen against False Cape shear zone rocks, although little stratigraphic displacement is involved. Any rocks in contact with the False Cape shear zone rocks show minor faulting effects along the contact because of the nature of the shear zone material and the ease of movement along the numerous planes of weakness.

Numerous minor faults, with displacements of a few feet, may be observed in road cuts. Some are normal faults, a few are thrusts. In the eastern part of sec. 34, T. 2 N., R. 1 W., H. along the Wildcat Ridge road, several small faults with displacements of 2 to 15 feet have been observed. At the eastern edge of the town of Field's Landing several small faults which displace terrace gravel are well exposed in a large quarry.

Folding, at least partially governed by older folded structures, took place after deposition of the Carlotta formation (mid-Pleistocene?). Still later folding, which followed deposition of the Hookton, was also controlled by previous folds. Warping along the mid-Pleistocene-post-Hookton axes has continued to recent times.

The south flank of the major structure of the area, the large Eel River syncline, is steeper than the north flank. It may plunge to the west in the western part of the Eel River Valley. Late folding or warping along the axis of this fold may be responsible for the greater thickness of late deposits in the alluviated trough than is exposed in other parts of the region. The axis of the post-Hookton and post-Rohnerville folding follows closely the axis of the mid-Pleistocene folding. The westward-plunging Newburg syncline, east of the Yager-Little Salmon fault, is probably the eastward continuation of the Eel River syncline. In the area near Carlotta the smaller Wolverton syncline is locally overturned adjacent to the Little Salmon fault, and is truncated by the fault near Fielder Creek. West of Scotia a small syncline has Pullen sediment exposed along the axis. Numerous minor synclines have been mapped in the northern part of the area.

Several small anticlines have been mapped in the area north of the Eel River syncline, but there are few on the south flank of this structure. Because of the potential economic importance of some of these features they have been mapped in as much detail as possible. The most northerly structure, the Pine Hill anticline, plunges to the west with no surface closure evident, although it is possible that cross-warping might effect a closure in the alluviated region west of Elk River. The Humboldt anticline, next to the south, plunges to the west along its eastern extent but shows closure in the Humboldt Hill area. South of this structure, east of the Little Salmon fault, are two minor anticlines; one along Salmon Creek has been drilled by the British-American Oil Producing Company, and the other, Fowler anticline, has had a well drilled near the axis by the Salmon Creek Oil and Gas Company. Both of these structures plunge to the west and closure is not effected. West of the fault there are three en echelon anticlines, the Tompkins Hill anticline, Table Bluff anticline, and an unnamed structure, only partly defined, north of Table Bluff. The structure of these folds is shown by the surface topography and can be mapped in the Hookton sediments which are exposed at the surface. The structure as mapped in the Hookton compares closely with the structure in the underlying Wildcat beds. Data collected by The Texas Company show that the Tompkins Hill anticline plunges to the east beneath the Little Salmon fault as well as to the west. There are minor flexures on the south flank of this fold. The north flank of the Table Bluff anticline is cut by a pre-Hookton fault. The evidence for this is obtained partly from subsurface data from wells 1 and 4. Only the south flank of the unnamed anticline north of Table Bluff is exposed. Data from a core-hole well on the South Spit indicate that the structure may have a ''high'' offshore.

The Alton anticline is the only major fold on the south flank of the Eel River syncline. It may be traced at the surface in the Cummings Creek and Cuddeback School area, where it plunges to the west, but is covered by alluvium west of that point. Geophysical data, stratigraphic features, and geomorphic implications indicate a probable arching north of the Grizzly Bluff anticline, a minor flexure south of the Alton anticline. North of the Russ fault is a vague anticlinal trend, that has a small mass of Yager along its axis at the Woodland Echo Ranch. Evidence for the south flank of this fold in the Woodland Echo area is poor, because of mass slumping. Southeast of Scotia, a broad anticline extends beyond the mapped area. Scotia Bluffs sandstone is exposed on the south flank of this fold near Pepperwood.

Regional Structure. The Klamath Mountain mass of crystalline and older sedimentary rocks has internal structures—schistosity and strike of sedimentary beds—which strike westward near Forest Glen, then northwestward near Willow Creek, north in Del Norte County, and northeast in southwestern Oregon. The mass resembles a blunt V-shaped wedge pointing to the west. Numerous faults paralleling the margins of this mass have thrust the older rocks outward against the younger rocks, which have been crushed against the rigid mass by compressional forces acting normal to it. Thus the younger structures in northern California and southern Oregon are wrapped around the Klamath Mountains. Fold axes trend west, northwest, north, then northeast.

The strong west-striking zone of weakness in the False Cape-Cape Mendocino region is a major structural feature of California which has acted independently of the San Andreas fault. Movement along this zone probably precedes and also postdates movements along the San Andreas. There is some evidence (Shepard and Emery, 1941) that the San Andreas fault may continue to the northwest, north of this major zone.

Compressional forces acting in northeast-southwest and later north-south direction have acted on sediments in the Eel River Valley area causing folding and some thrusting over a long period of time. Movements have been intensified over certain periods but minor folding has continued between the strong orogenies. Zones of weakness developed during these repeated orogenies have localized later shearing and faulting.

GEOLOGIC AND GEOMORPHIC HISTORY

The mapped area herein discussed is a part of the northern Coast Ranges of California (Lawson, 1894; Diller, 1902; Fenneman, 1931).

Lawson (1894) in his classic paper, *The geomorphogeny of the northern coast of California*, noted that the present physiography of the coast range from San Francisco to Humboldt County is the result of the following sequence of events:

> (1) The development in Pliocene time of a great coastal peneplain and correlative accumulation of marine sediments.
>
> (2) The orogenic deformation of parts of this peneplain and the folding of 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 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, and the consequent flooding of the stream valleys by the ocean; Lawson (1944) suggested that sea level had changed eustatically.

Diller (1902), in an early paper on the Klamath Mountains of southwest Oregon and northwest California, discussed the topographic development of this part of the Coast Ranges. He postulated several stages of post-Eocene peneplanation and uplift. Two principal peneplains were described:

> (a) The Klamath peneplain whose remnants throughout the higher Klamath Mountains are even-crested ridges [i.e., South Fork Mountain, east of Redwood Creek and the southern Mad River (Manning and Ogle, 1950)].
>
> (b) The Bellspring peneplain, which he described as a later, lower peneplain, whose remnants form the higher even-crested ridges of the northern coast ranges.

Diller thought that the Klamath peneplain had formed by Miocene time. In conjunction with this peneplanation Miocene sediments were being deposited to the west. Toward the end of the Miocene, orogenic activity caused faulting of the Miocene sediments. Slight uplift then elevated the entire region

> "allowing the low hills of soft Miocene beds along the coast to be reduced nearly to sea level, thus developing by subaerial processes a peneplain over the region of the northern end of the Coast Range. This peneplain is practically continuous with the peneplain of the adjacent Klamath Mountain district."

Diller's dating of these events as Miocene was the result of Dall's identification of megafossils from the Empire formation of the Coos Bay area and the Wildcat formation of Humboldt County as Miocene forms. It has since been shown conclusively that the greater part of the sediments mapped as Wildcat (Martin, 1916; Stewart and Stewart, 1949), and the Empire formation (Weaver, 1945) are Pliocene.

Diller's Klamath peneplain, therefore, corresponds broadly to Lawson's step (1) and his Bellspring peneplain compares with Lawson's step (3).

The record of events from Cretaceous (?) to middle Miocene is obscure, as no sedimentary record for that time is left in this area. It is possible that the Humboldt region was positive during this entire time. Erosion of both the Klamath Mountain crystalline rocks to the east and the Franciscan and Yager sediments in the Coast Ranges continued throughout the time. Sediments accumulated in the Coos Bay area to the north. and in the Covelo basin to the south during the Eocene. Some small local embayments may have existed in the Humboldt region which were uplifted and their sediments later eroded. MacGinitie (1936) has shown that the Klamath Mountain area near Weaverville and Hyampom was a broad plain which supported a flora indicating that no high mountains separated that area from the ocean to the west.

In the middle Miocene some small embayments developed and as the old, moderately low land mass continued to be eroded, fine clastic sediments were deposited in them. The only remnants of these sediments in the Humboldt area are diatomaceous mudstone, sandstone, and siltstone in the southern part of the Bear River syncline and in the Briceland area.

Later, in upper Miocene and lower Pliocene time, the basins of deposition became more extensive. Fine clastic sediments continued to be deposited in them throughout the Pliocene, and in the upper Pliocene shallow seas encroached farther to the north and east and deposited a thin layer over the gently westward sloping, slightly irregular surface. Evidence of this fossil land surface (Cotton, 1948, p. 300) can be seen in the upper Elk River-Freshwater Creek areas where streams have cut through the thin upper Pliocene veneer. Sea cliffs existed at Doe Creek near the upper North Fork of Elk River (sec. 31, T. 4 N., R. 2 E., H.) as shown by the great boulders of Franciscan schist, filled with pholas borings, and by the nearby vertical depositional contact of the low-dipping Pliocene sediments with the resistant Franciscan rocks. This was the northeastern margin of Pliocene sedimentation in the Eel River basin. Separating this basin from the Pliocene embayment in the present Mad River area (Manning and Ogle, 1950) was a prominent ridge of rather resistant Franciscan sandstone and schist, now the Kneeland-Fickle Ridge.

Toward the end of Pliocene time the basin became shallow and finally nonmarine. The surrounding land was gradually uplifted and more rapid downcutting allowed sand and later gravel to pour into the Eel River basin. Some downwarping of the synclinal Eel River trough also may have begun. Although continental deposition probably continued through early Pleistocene time, it was interrupted many times, as indicated by the numerous diastems between coarse conglomerates and marshland claystones. Throughout this time of deposition, the relatively stable land mass to the east continued to be eroded and the conglomerate beds deposited indicate streams with considerable velocity and gradient.

During the mid-Pleistocene orogeny, the relatively weak Tertiary sedimentary rocks were folded and faulted. Where the rocks were thick in the southern and central part of the Fortuna quadrangle, folding was intense, but in the northeastern part of the quadrangle the sediments were thin and broad warping was characteristic. As orogenic activity decreased, an epeirogenic uplift re-elevated the whole of northwestern California and southwestern Oregon, and a new erosion cycle began.

Where the Franciscan and Yager formations remained as positive areas during the Cenozoic sedimentation, the peneplain which had been forming was re-elevated and renewed downcutting began. The accordant ridge crests of Franciscan and Yager rocks are somewhat lower in elevation than the ridges in the Klamath Mountains. The variation in lithology of the Franciscan gives rise to many surface irregularities, but the elements of the peneplain seem clear. Some local depressions are caused by downfaulted blocks of Pliocene sediments such as in the Mad River area (Manning and Ogle, 1950).

In the region where Cenozoic sediments accumulated on the old pre-Tertiary eroded surface, rapid erosion of the youthful sediments was begun by vigorous streams as folding continued. In areas of large folds, as along Bear River Ridge, the underlying older rocks were rapidly laid bare.

In the Oil Creek area, near the coast, the Tertiary sediments were removed and stream gravels and littoral sediments were deposited on the newly planed surface. This involved removing a tremendous amount of material between mid-Pleistocene and the time of deposition of the terrace gravels which are now 700 to 900 feet above the sea. Some evidence indicates that warping and possible uplift of parts of the Humboldt basin may have started in early and middle Pliocene. This would give a longer period for the removal of lower Wildcat sediments from the Bear River Ridge area. Fault movements in the False Cape shear zone also may have aided in the uplift and removal of Pliocene sediments.

The above-mentioned high coastal terrace deposits are probably contemporaneous, or nearly so, with the deposition of the Hookton formation in the area extending from Centerville Beach to north of Eureka.

A great valley plain was fashioned by the ancestral Eel River, Van Duzen River, Salmon Creek, Elk River, and subsidiary streams, with its western limits west of the present coast; on this the Hookton formation was laid down. Inland, a broad valley-plain extended up the ancestral Van Duzen River past Hydesville, and numerous small, high river terrace deposits adjacent to the Van Duzen may correlate with the Hookton deposition. The plain probably did not extend much to the east of the present Little Salmon fault in the area east of Fortuna, but to the north in the Ryan Creek area, the Hookton sediments may have lapped over the low gentle surface for 2 or 3 miles farther to the east than their present limit. Thus, the flat-topped accordant ridges underlain by Pliocene rocks in this area are part of a resurrected fossil land surface. Along the southern limits of this middle to upper Pleistocene coastal plain the ancestral Eel River had cut a rather steep southern bank in the resistant Carlotta conglomerate. When the Hookton was being deposited the Van Duzen River flowed northwest into the Humboldt Bay region, probably slightly east of the present site of Fortuna, as shown by the coarse boulders and cobbles in the Hookton formation. The deposits were chiefly fluviatile channel deposits, flood plain material, marshland deposits and, in the north, some marginal mud flat deposits containing marine organisms. Slow subsidence of this coastal plain accompanied the deposition of 200 feet or more of these sediments. It is possible that some marine interfingers may have occurred in the area near the mouth of Eel River. While deposition of the Hookton was taking place, the surrounding country was being eroded by streams, many of which have not yet changed their courses greatly. Variations in lithology probably resulted in an irregular topography. For example, the Scotia Bluff Ridge underlain by resistant sandstone and conglomerate, extended above the neighboring flood plain, whereas the soft siltstone in the Ryan Creek-Freshwater Creek area was eroded to form a gentle, west-sloping surface upon which the Hookton formation lapped.

In the late Pleistocene, the Hookton formation was warped into broad gentle folds which followed closely the axes of the mid-Pleistocene structures. Where mid-Pleistocene folds, such as the Eel River syncline, were broad and gentle, the Hookton beds were warped into gently tilted plane surfaces. From Tompkins Hill north to Humboldt Hill, the small folds were more numerous and tighter.

The Hookton was apparently somewhat uplifted, but it is difficult to separate the continued warping of these structures from purely vertical regional uplift or eustatic changes of sea level. The net result is a differential elevation of various areas of Hookton, or correlated deposits. Thus, if the terrace deposits south of Bear Gulch (800 feet present elevation) and south of Fleener Creek (present elevation 650 feet) are the same age as the Hookton formation, an elevation of the south flank of the Eel River syncline is indicated. This warping probably involved a tighter compressing of the mid-Pleistocene folds. As the deposition of 100 to 400 feet of the Hookton formation must have occurred in a sinking basin, at or near sea level, some epeirogenic change is indicated. Along the western part of the Eel River syncline there may be Hookton sediments which are now covered by later alluvial deposits.

As the smooth Hookton plain was being slowly warped and elevated, the whole region was rejuvenated and downcutting was intensified. The present courses of streams emptying into the lowland areas began to evolve.

The best record of post-Hookton events is in the vicinity of the Yager Creek-Van Duzen River confluence. During the late Hookton deposition the Van Duzen River followed a course north of the Scotia Bluffs Ridge, thence northwest near Hydesville and Rohnerville. Evidence that Yager Creek flowed into the Van Duzen just south of Rohnerville is given by the channel of ancestral Yager Creek in the elevated Hookton surface near Wolverton Gulch. As the warping progressed, the Van Duzen River and Yager Creek cut new valley plains in the Hookton deposits, leaving as a remnant of these early plains the intermediate terrace near the Rohnerville airport. The Van Duzen River then carved a fairly sharp bank in the Hookton terrace along its course from the present mouth of Wolverton Gulch northwest through Rohnerville and Fortuna and thence west from Fortuna to its former confluence with the Eel River. In maintaining its gradient with the controlling Van Duzen River, Yager Creek swung farther southeast, forming the Rohnerville deposits in the vicinity of Hydesville. The deposits formed on this valley plain were extensive although only 12 to 25 feet thick. Continued activity along the old axes warped this very late, poorly consolidated terrace deposit. From south to north this folded plane now dips 2° to 3° S. at Grizzly Bluff on the south limb of the Alton-Grizzly Bluff anticlines, then can be projected over the anticlinal axes and then dips 5° N., forming the surface of the terrace north of Alton. The plane continues dipping gently north to the axis of the Eel River syncline where it is almost flat. From there it begins to rise gently to the north (in the city of Fortuna) with a slope of 1° to 2°. West of Fortuna the Rohnerville formation has been eroded by the modern Eel River. Some of the undifferentiated terrace deposits, for example at Spruce Point, may be correlative with the Rohnerville formation. Following the deposition of the Rohnerville a series of at least eight terrace levels was developed by Yager Creek. It is probable that these are noncyclic terraces (Cotton, 1948, p. 193) formed by the meandering of a graded stream. As the Van Duzen was downcutting, Yager Creek was attempting to maintain grade and as the meanders of Yager Creek shifted a thin gravelly surface was left behind. When the channel again swung back it had lowered a few feet, and the former stream level had become a terrace. It should be noted that these, as well as most other older terrace deposits, were rock-defended, as a result of being deposited on resistant, cliff-forming Carlotta conglomerate.

The present elevation of some of the terraces may result from local warping or minor uplift.

After the time of deposition of the Hookton formation, Eel River also contributed to deposits which now stand as terrace cappings several hundred feet above the present river. Some of the higher levels west of Rio Dell probably correlate with the Rohnerville terrace, and the terrace gravels capping Grizzly Bluff are a part of the arched Rohnerville terrace. The multiple terraces west of Rio Dell, south of Metropolitan, southwest of the mouth of Oil Creek, and at Grizzly Bluff, which show a lower flat plain flanked by side terrace surfaces 25 to 50 feet higher, are old channels and flood plains preserved as the river swung out of its course farther upstream. The late history of Eel River involves a progressive moving of the channel from the northern edge of its valley, north of

Metropolitan, to its present course between Metropolitan and the mouth of Van Duzen River. A series of low terraces made up of pebbles, sand, and capped with silt, were formed. Numerous irregular old channels have been preserved. Perhaps the swinging of the Eel River to the south and west here resulted from the difficulty of cutting north through the hard sandstones and conglomerates, compared to the cutting of the mudstone and siltstone south of the barrier. Then, as the grade relationship with the Van Duzen changed, successive lower terraces were left. Coupled with this lithologic barrier may have been the continuous slight arching of the Alton and Grizzly Bluff anticlinal areas.

From the confluence of the ancient Eel and Van Duzen Rivers, the combined rivers' course was westward along the line formed by the present abrupt slope bordering the south edge of the Eel River Valley. This sharp line was cut since deposition of the Rohnerville terrace. Evidence east of this area indicates that the Mad River has captured part of the Van Duzen drainage to the northeast and a branch of the North Fork of the Eel River has captured part of the drainage from the south. From its previous course along this south margin of the valley plain, the Eel River has, by progressive meanders and braiding, swung north and east to Fernbridge. From there it shows considerable meandering and some braiding in its lower course. The record of the meandering, northeastward progression is shown by successive, low noncyclic terrace levels, and the preservation of old channels. At some moderately recent time the Eel swung northeast out of its channel cutting off the Salt River's most important water source. At the present time flood waters from the Eel occasionally may flow through the channel, but the rest of its water source is from such streams as Williams Creek and Francis Creek. Near its mouth, Salt River receives tidal water and is brackish. In its lower course, the channel of the Eel shifts annually in sweeping meanders causing considerable property redistribution. The sloughs, drowned channels, tidal incursion, and spits indicate a local subsidence of the coast. The Eel drainage is drowned at the mouth. Man-made dikes and levees now protect much of the land and affect the course of the river and its normal sedimentation. U. S. Coast and Geodetic Survey Chart 5602 (1940) shows no evidence of delta formation offshore; instead, the strong, along-shore currents build spits across the mouth of the Eel Bays and Humboldt Bay.

The lower Eel River follows generally the trough of the Eel River syncline. If warping is continuing, the area near the mouth of the river would be submerged due to structural forces. Data from shallow wells indicate lenticular channel flood plain and mud flat deposits to depths of 100 feet, but the age of these may be from the time of Hookton deposition to Recent. At the Connick well (sec. 32, T. 3 N., R. 2 W., H.) oyster shells were found at a depth of 20 feet in poorly compacted clay, perhaps indicating downwarping exceeded sedimentation at some recent time, or perhaps a bay may have been at an earlier mouth of the Eel River.

As gentle warping began, the Ferndale Hills and coastal area were raised and tilted northward. Rotational elevation has continued to the present, raising the wave-cut terrace (sec. 25, T. 2 W., R. 4 W., H.) to an elevation of 950 feet while the Hookton formation at Centerville Beach passes below sea level. Subsequent streams such as Fleener, Guthrie, and Oil Creek were rejuvenated and cut deep canyons. Oil Creek has a peculiar course which may have resulted from its being a superposed stream, but which may also have been affected by landslide effects near the mouth. A similar but larger slump has caused past ponding and alluviation at the east edge of sec. 24, T. 2 N., R. 3 W., H.

Along the coast, a steep wave-cut cliff has developed. As the large waves sweep in from offshore, they undercut the soft sediments which temporarily maintain nearly vertical cliff faces. Undercutting produces numerous slumps whose development is aided by bedding-plane slip in the interbedded sandstones and mudstones. As the slumps develop, small rivulets are formed which grow by further headward stream erosion and by slumping.

Warping, which took place after deposition of the Hookton, arched the Table Bluff, Tompkins Hill, Humboldt Hill, and Pine Hill areas. The physiographic form of some of these ridges outlines the underlying structure. Consequent streams began flowing down dip, and continued headward erosion has since cut many sharp V-canyons in this warped plain. Many smooth interstream surfaces remain because these areas are still in a youthful cycle of erosion.

As these consequent streams were eroding the upwarped areas, the antecedent and essentially subsequent Salmon Creek and Elk River were attempting to maintain grade. New valley-plains were developed, the remnants of which remain as valley-plain terraces near Beatrice, Fields Landing, and lower Elk River. During this time Salmon Creek must have flowed in the alluvial valley now occupied by Little Salmon Creek.

The North Fork of Elk River has numerous recently incised meanders and a well-developed low terrace level, developed by warping transverse to the flow direction, aggradation, and later uplift.

Ryan Creek is a minor stream flowing north into Freshwater Slough and Humboldt Bay. Its ancestral history differs from that of other streams in that it originally flowed on the Hookton plain-surface throughout its course. At the present time, it is eroding Wildcat siltstone and mudstone, having recently cut through the Hookton capping. It may owe its origin to some old north-trending channel or other irregularity on the Hookton plain. If this is true, Ryan Creek was antecedent and began renewed downcutting as the Hookton was uplifted. As gentle folding of the Pine Hill anticline progressed, the upper part of the creek began aggrading and wide alluvial areas were developed. In the axial area of transverse warp vertical corrasion was more rapid as the antecedent stream was attempting to maintain grade in an area of local uplift.

At present Humboldt Bay consists of a long, narrow, shallow body of water with an enlargement at the south, called South Bay, and a larger one at the north, Arcata Bay. The bay is separated from the Pacific Ocean for most of its extent by the South Spit and North Spit; its only inlet is less than half a mile wide and is kept this large only by man-made jetties and constant dredging.

From the distribution pattern, lithologic character, and limited fossil evidence it is probable that the ancestral Van Duzen-Eel River system may have flowed northward during Hookton deposition. This drainage may have emptied into a large ancestral bay extending far north and south of the present one. As warping of the Hookton began, the great southern streams were blocked off by the development of Table Bluff and the new bay area was delimited. To the north, Mad River flowed into this ancestral bay-coastal plain during Hookton deposition and its course was not greatly affected by the very slight warping which followed. Mad River until fairly recent times flowed into Arcata Bay by way of Mad River Slough; thus Arcata Bay is principally the drowned mouth of the old Mad River, across which has been developed the North Spit. To a lesser extent it also formed by being the drowned mouths of Freshwater and Jacoby Creeks. South Bay may have had some partially controlling factor such as downwarping, but it appears to be the drowned mouths of Salmon Creek and Elk River which have been sheltered from the ocean by the building of the South Spit. The narrow connecting channel between Arcata Bay and South Bay is maintained by the protecting spits which are positioned by headlands to the north and south, and by currents sweeping through the bay entrance. The peculiar coral reef feature seen on the topographic map at the mouth of Hookton Slough is the result of the breaking of a dike, and flooding of the enclosed land, leaving only the dike emerged.

Summary of Events. Long gaps in the record exist between Yager deposition and the start of mid-Miocene deposition. The region at the start of this deposition must have been generally peneplained.

Marine deposition began in the mid-Miocene and continued into upper Pliocene time. Marginal warping and uplift contributed to the start of nonmarine deposition in uppermost Pliocene, which continued into the early Pleistocene. Erosion by streams with steep gradients was rapid.

In mid-Pleistocene (?) a strong orogeny intensely folded and faulted the thick Cenozoic sedimentary rocks, but only broadly warped the thin Tertiary sediments and older rocks. Some old fault systems and fault zones were reactivated.

The folded and faulted rocks were being eroded during and after the orogeny. Although the whole region was not yet peneplained, broad valley-plains were developed in which Hookton sediments were deposited. Contemporaneous with this was the deposition of some marine wave-cut and isolated stream terraces.

Hookton deposition was brought to a close by warping and regional uplift. New valley-plains were cut in the lowlands. Deposition was interspersed with periodic uplifts forming several levels of valley plain terraces. The modern rivers began to develop their present patterns. The surrounding older rocks were continually being elevated and recut by streams with steep gradients.

Numerous low terraces were formed along the larger rivers after Hookton time; these are partly noncyclic effects of a downcutting stream but some late warping and uplift may be involved. Surrounding mountainous regions have continued to be uplifted and many streams show a recent sharp V-canyon cut into an older broader valley. The present topography of the upland regions is that of late adolescence or early maturity, while the area of post-Wildcat sediments is in a youthful cycle of erosion.

Landslides. Landsliding and slumping have important effects on present landforms. Landslides are much more numerous than the features mapped, which do not begin to represent the amount of material that is actually slumping or has slumped. Where heavy forests cover the surface it is impossible to show the outline of slumps, and even in open areas minor slippages cannot be shown on the scale of the map. Following the classification of Sharpe (1938) most of the major features are slumps, but some rockslides or debris slides and mud flows may be recognized.

Slumps. Most slumps have taken place on surfaces where Wildcat mudstones are exposed. Particularly vulnerable are areas of Rio Dell and Pullen. Much of the landscape of the Ferndale Hills is carved by this process. A cirque-like head marks the start of most slump scars, the soft mudstones move as a series of irregular blocks which may rotate forward or backward, depending on the steepness of slope and position on the slumps. Successive major slumps may be identified.

Some slumps having important movement within recent years are the 1906 slump, the Crosby slump, and the O'Rourke slump.

In 1906, at the time of the great earthquake, a large mass slumped into the ocean in sec. 26, T. 2 N., R. 3 W., H. (Matthes, 1908). The mass moved as a rotating block; the lower part of the block slumped into the ocean and was removed by wave action, while the upper surface of the mass tilted toward the scar but dropped about 300 feet from its original position. Some terrace gravels still cap the surface of this backward-tilted slump-block. A small lake has been formed in the scar cavity and the slopes of the scar are covered with spruce trees all of the same age. The slump took place in an area of numerous older slumps and it is probable that the material was poised for slipping and the earthquake acted as a trigger for the actual break. There is no evidence that the slumping is directly connected with movement along a fault.

A recent large movement on an old slumped area took place in 1935 on the Crosby ranch in sec. 17, T. 2 N., R. 1 W., H. This slump is composed of numerous small rotating blocks. The present topographic form is rumpled, and numerous small ponds have developed as a result of the slumping.

The best documented of the slumps took place in 1950 during the heavy winter rains in the vicinity of the O'Rourke barns (sec. 34, T. 2 N., R. 2 W., H.) on an area of old slumping. Curved blocks, sub-parallel to the outline of the cirque scar rotated forward in a manner similar to a tipped deck of cards. O'Rourke's barn was damaged, the road was destroyed, and some smaller buildings were ruined. Movement on some of the rotating blocks took place over several days. Actual movement of the individual blocks was only a few inches a day. Slow creep continued after apparent movement had ceased, resulting in the snapping of a replaced phone line several weeks later. George Waldner, editor of the Ferndale Enterprise, and Joseph Bognuda of the University of California Seismograph Station, Ferndale, observed the slumping. Mr. Waldner kindly furnished the writer an account of the slump and contributed photographs. Some minor faulting near the head of the slump probably had no direct effect on the movement. This is another example of becoming ''re-greased'' during heavy rains, and slipping; some undercutting by the headwaters of Price Creek was involved in the ancestral history of this slumped region.

Slumps are important in this region because of the damage produced occasionally, but more because they furnish somewhat flatter areas which are often tilled, and also provide numerous springs. The effectiveness of slumping as an erosional agent is great. The rapid erosion which must have taken place during later Cenozoic time was probably accomplished by mass wastage such as slumps and mud flows.

Rock Slides or Debris Slides. On the coast there are numerous slides of material along the dip planes of the interbedded sandstones and mudstones of the Rio Dell formation. Moisture works along the permeable sandstone and causes plasticity of the interbedded mudstone. As undercutting by wave action takes place, a great block, perhaps including vegetation in place, will slip on a bedding surface. Some of the low dips of beds along the coast may be the result of an analogous slipping of large masses along such bedding planes.

Similar rock slides or debris slides are common in the heavily wooded area in sec. 35, T. 2 N., R. 1 E., H., where the claystone beds of the Carlotta formation become lubricated.

Mud Flows. Some slides in Yager sediments are combinations of various types of sliding and slumping. For example, in the large Blanton slide in the eastern part of the Fortuna quadrangle some slumping has taken place at the cirque-head of this feature but much of the lower part has been lubricated with water, resulting in the resistant chips of Yager sandstone and shale being moved along in a sea of mud. The slide is a jumble of debris. Part of the Blanton slide is an old one upon which are growing redwood trees 1,000 to 2,000 years in age. Considerable of the forested area must be underlain by old slumps.

The material clogging Wilson Creek, Cuddeback Creek, and Fielder Creek, in the southeastern part of the Fortuna quadrangle, is largely mud-flow debris. An even larger flow is present in Cummings Creek immediately to the east of this area. Some of these mud flows are over 100 feet thick as exposed by recent stream cutting. This entire thickness is made up of rubble of Yager debris mixed with a few Carlotta pebbles. In some places the Yager debris has moved more than 2 miles from the nearest outcrop. Most of these accumulations are relatively old; one has a stream terrace deposit of the Van Duzen River deposited across the lower end of it. Late movements on the Yager or Little Salmon faults or both may have caused these great mud flows. On Cummings Creek (eastern part of sec. 30, T. 2 N., R. 2. E., H.) a more recent flow or slide wiped out the large old redwoods and the slide is now occupied by a more youthful stand of Douglas fir.

ECONOMIC GEOLOGY

Oil and Gas

A. H. Weber (1887) has an authentic account of the early development of the petroleum industry in Humboldt County. Most of the development was in the Mattole-Bear River area south of the region covered in this report, but he mentions the wells drilled in the Oil Creek area. Of the Fortuna quadrangle, he says: "When cutting the tunnel (1940 feet long) on the Eel River and Eureka Railroad, in secs. 8 and 17, T. 3 N., R. 1 W., great difficulty was experienced on account of the inflammable gas flowing from the strata pierced." The tunnel was driven through the anticlinal fold later drilled by The Texas Company in 1937.

F. M. Anderson (1900), Walter Stalder (1914, 1941), A. K. P. Harmon, Jr., (1914), L. Vander Leck (1921), H. W. Hoots (1928), W. Stalder (1941), and C. V. Averill (1941) all discuss petroleum in northwestern California.

Surface Indications of Petroleum. At the mouth of Oil Creek, sec. 26, T. 2 N., R. 3 W., H., the writer observed an active oil seep in 1948. Bubbles of light green oil which rose to the surface of a pool in Oil Creek, were quickly carried away by the fast moving stream. When revisited in 1950, the seep could not be found, possibly because of the shifting of the stream gravels and clays. Hoots (1928) also noted a seep in this same area. Taliaferro (oral communication, 1949) recalled a large active seep between Oil Creek and False Cape, but this could not be found by the writer. Between Oil Creek and Bear River most of the shear zone rocks emit a strong gasoline or kerosene odor when broken. On some of the freshly wave-cut cliffs the odor is very strong. The odor is probably a result of rapidly volatilizing, high-gravity petroleum similar to that found in wells to the south. In the same general area there is an active gas seep in a large slide area containing both Pullen sediments and False Cape shear rocks. At this point inflammable gas is presently rising from a water-filled pot hole. A gas seep in sec. 36, T. 2 N., R. 2 W., H., in upper Price Creek was described by Stalder (1914). He stated, ''The gas burned with a luminous flame and smelled of gasoline.'' The area is presently covered by Tertiary slide debris.

Gas seeps are present in the northern part of the area near Little Salmon Creek in the vicinity of the projection of the Yager fault.

Local residents report numerous other gas seeps which become visible in the winter when the ground is wet or when there are forest fires. Most of these could not be located in the summer months.

A near-surface indication of gas was reported during the drilling of a water well (1948) in sec. 12, T. 2 N., R. 1 W., H.

South of the mapped area in the Bear River-Mattole-Briceland area, over 50 wells have been drilled in the past 85 years. Some have been small temporary producers of high-gravity oil, and some gas. Most of these have been drilled near seeps without consideration of structure. Many have been in steep dipping shear-rocks.

Exploration for Petroleum. The surface indications of petroleum show that both natural gas and oil are present in the area. The most impressive seeps are from the pre-Tertiary rocks, indicating that the Yager and possibly Franciscan(?) sediments must be source beds for some seeps. The gas in the Tompkins Hill gas field may have its source in sediments of the Wildcat group. Although the organic content of any particular part of the Wildcat is not particularly high, the total amount is relatively large because of the great thickness of marine rocks.

The sandstone beds of the Rio Dell and part of the Eel River and Pullen formations are all possible reservoir rocks; in fact, sandstone of the Rio Dell formation is productive in the Tompkins Hill gas field. Lenticularity is characteristic of all these sandstone members, indicating that stratigraphic traps may exist. The productive sands in the Tompkins Hill gas field vary considerably in productivity and stratigraphic position in the relatively short distance between wells. Rocks of the Yager and Franciscan do not appear to be suitable reservoir rocks, although some sheared areas may be permeable. McNaughton (1951) has recently pointed out the dynamic role of dilatancy in brittle basement rocks and has indicated that late fracturing might effectively suck in the petroleum. False Cape shear zone rocks might be suitable reservoir rocks for

Exploratory wells drilled in the Eel River Valley area.

T.	R.	Sec.	Name of company and well	Date	Elevation (feet)	Total depth (feet)	Remarks
4N	1W	17	Dinwiddie "Buhne" 1	1934-36	250	2632	Oil shows; oil sands at 1982′, 2019′ (42.1° B). Twisted off 2000′ pipe at 2632′; bankrupt, abandoned. Started in Hookton, bottomed in "Pico."
4N	1W	16, 21	Walter Eich Fee 1	1935		779	Oil shows and sands. Could not get water shut off; 37°-53.5° gravity.
4N	1W		2	1935			Water.
4N	1W		3	1935			Pipe stuck at 400′.
4N	1W		4	1935		1600	Started in Hookton, abandoned in "Pico". Off structure.
4N	1W	21	Eureka Oil Co. "Duff" 1	1928 (?)	600	(?) 3100	Cable tools lost. Started in Hookton; sands at 1900-1956′, 2000′, 2490′, 3000′; several showings of oil and gas; tar sand at 1900′; abandoned in "Pico".
3N	1W	6	Corehole, The Texas Co., "Table Bluff Corehole" 1	Aug. 1935		400	Started in Hookton, yellow clays noted at 153′, passed into Carlotta-Scotia Bluffs at 300-400′. **Elphidium** noted at 435′, bottomed at 1133′ still in Scotia Bluffs sand.
3N	2W	1	The Texas Co. "Eureka" 1	1934-35	350	6133	Numerous gas shows and sands; strong gas shows at 5657′-5677′ and 5743′-5768′; production test 13,000 mcf gas/day with some salt water; water flooded out well, abandoned. Top "Repetto" at 4793′; Yager at 5948′.
3N	1W	10	The British-American Oil Prod. Co. "Mitchell-Dorr" 1	1944	287	2843	Predominantly mudstone and siltstone section, some gas shows and flash on core; abandoned; started low in "Pico", top Yager at 2740′.
3N	1W	15	Salmon Creek Oil and Gas Co. "Fowler" 1	1948	525	5557	Numerous sands, gas show reported at 4876′; oil shows reported 1570′, 3225′, 3300′; not satisfactory coring program or testing; abandoned. Started in "Pico", passed through fault into Scotia Bluffs sandstone (?); bottomed in lower "Pico" (?).
3N	1W	23	Corehole, The Texas Co., "Tompkins Hill Corehole" 2	Nov. 1935		1001	0-395′ mudstone with upper Pico foraminifera, Little Salmon fault at 395′, 395-1001′ in carbonaceous clay and gravels, Hookton (?) and Carlotta.
2N	1E	8	The Texas Co. "Anderson" 1	1946	445	9082	Strong gas shows in sands near 7800′, attemped to produce, pressure dropped, abandoned. Yager at 8800′; bottomed in Yager.
4N	2W	26	Corehole, The Texas Co. "Sandspit Corehole" 1	Nov. 1935		1485	Some pebbles in upper 100′, then into lower "Pico" mudstone; top "Repetto" at 200-300′; bottomed in glauconitic mudstone and sandstone at 1485.
			Old wells	About 1865		Minus 200	Some oil and gas shows reported.

limited production, but the writer knows of no suitable cap rock in this area.

Mudstone beds of the Wildcat group form suitable cap rocks for the interbedded sandstones. Some claystones in the upper part of the nonmarine section might act as cap rocks for the very permeable Scotia Bluffs and Carlotta sediments, although these excellent potential reservoirs have been eroded from most structures.

Some structural traps may exist where east-trending structures are cut by the Yager-Little Salmon fault. Judging by the stratigraphy, structures in the southern and western part of the area would have the best possibility as traps. The Tompkins Hill gas field has shown that trapping is possible in anticlinal structures in this area.

The writer believes that future exploration and drilling will prove the existence of other commercial accumulations of gas and possibly oil.

Tompkins Hill Gas Field (Eureka Gas Field). The Texas Company "Eureka" 2, drilled in 1937, was the discovery well of this field. A total of 10 wells has been drilled to January 1, 1953; all except the Texas Company "Eureka" 3 have been commercial producers of dry gas. The gas is purchased by the Pacific Gas and Electric Company, who distribute it as fuel to neighboring communities. Population growth in Humboldt County in the years 1940-50 is an important factor in the drilling and expansion of the field in 1951-52.

Trapping of the gas is due largely to anticlinal closure but also may be partly controlled by the Little Salmon fault and lenticularity of sand bodies. The producing sands are in the middle part of the Rio Dell formation; some gas also has been observed in the lower part of the Wildcat group.

Hematite

Laizure (1925) gave an account of the Centerville hematite deposit 4 miles south of Centerville. The material has been described as a vein of hematite 8 feet wide, containing numerous veins of calcite; it has a brownish-red color and "tends to scale off like micaceous iron." Some of the ore was ground and used locally as a mineral paint. The only material seen by the author which resembles such a description is the highly altered basalt-greenstone present in the False Cape shear zone at the mouth of Oil Creek. This large mass is an isolated fragment, 10 feet in diameter, which is highly veined with laumontite, chlorite, and calcite. The surface of the altered volcanic is brick-red, and most fracture surfaces are similarly coated. It is probable that the iron oxide coating is limonite and not hematite. The material is impure and of very low grade.

Lignite

All of the lignite deposits are in either the upper part of the Wildcat group or the Hookton formation. To the east in Trinity County there are several lignite deposits in lacustrine Eocene-Oligocene beds. Most of the lignite beds in Humboldt County are thin and lenticular. Those of the Wildcat are harder, more dense, compact, higher in carbon content, and of better grade than those of the Hookton.

Weber (1887, p. 186) described lignite beds found at 12th and L Streets in Eureka; one bed was 22 inches thick and the other 12 inches thick. "The lignite is a very poor, soft material, soaked with water, in

Tomkins Hill gas field (Eureka field)

Well	Date spud	Total depth (feet)	Producing interval (feet)	Initial rate	Notes
The Texas Co. "Eureka" 2	7/37	7708	4010-5350	1400 MCF/day	Discovery well; top Eel River ("Repetto") 6029'; near Yager (K) at bottom.
"Eureka" 3	7/39	5067	3384-5031	256 MCF/17 hrs. presume 1640# shut in	Abandoned after small production.
"Holmes-Eureka" 1	12/39	4850	3780-4845	5200 MCF 30/64'' B-after 1 month 2885 MCF/day, 16/64'' B. 1740# CHP	
"Holmes-Eureka" 2	1942	5200	3740-5101	2730 MCF/day 1''8., 1747/2020#	
"Holmes-Eureka" 3	6/46	7850	3940-50 3970-90 4060-75 4200-05 4435-55 selective gun perf.	5000 MCF/day 3/8'' B.	Formation tests: 7732-7745' gas with petrol. odor 4582-4602 gas w/mist 3000 MCF/day est., cemented off.
"Holmes-Eureka" 4	1/49	4429	3881-4420	2785 MCF/day 1/4'' B 2030/2015#	
"Holmes-Eureka" 5	4/51	5100	4365-5035	2450 MCF/day 2250/2275# 74 gallons condensate	
"Holmes-Eureka" 6	9/51	7205	5575-5850	2500 MCF/day rate estimated	5500' step-out **(wildcat)** test 5870-6571' est. 700 MCF/day, pressure dropped. May be separate structural closure.
"Holmes-Eureka" NCT-1, No. 7	10/27/52	5302	4465-4495 4530-4580 4620-4640 4693-4718 4770-4800 4880-4940 4983-5008 5045-5075 5095-5105 5125-5160 5175-5185	Estimated 3290 MCF rate	

"Little" A-1	8/ 9/52	6000	5400-20 5460-5523 5580-5655 5785-5745	Estimated 4,000 MCF/day 3/8" B., shut in pressure 2100/ 2250#	6000' step-out (**wildcat**)

NOTES:

The wells usually produce approximately 1000 MCF of gas per day. Sands are lenticular and individual wells probably produce from several different sands.

Cumulative production to January 1, 1951	7,708,626 MCF (4 wells)
Gas sold in 1950	1,264,740 MCF (4 wells)
Estimated reserves as of July 1, 1951 (California Division of Oil & Gas)	25,253,643 MCF (4 wells)

(The four wells drilled since the above estimation of reserves has probably tripled the size of the field.)

reality being only a somewhat consolidated peat. It must be dried like peat before it can be used. The only use that has been made of it has been to help burn the bricks made of the clay and sand found above and below the lignite. The clay below it is an excellent material for brick making, particularly when mixed with some sand.'' This deposit was probably in the Hookton formation.

Another thin lignite bed, averaging 6 inches in thickness is in the Hookton formation at a sharp bend of the south branch of Rohner Creek NW¼SE¼ sec. 25, T. 3 N., R. 1 W., H. It is similar to those mentioned above and is also of little economic value.

Numerous other occurrences of lignite are in the Humboldt Hill area, but all are thin and of similar low grade.

There is an 8 inch lignite bed interbedded with clay, ash, and sandstone in the NE¼SE¼ sec. 19, T. 3 N., R. 1 W., H. The lignite is part of the Carlotta formation. It is dark in color, has a woody texture, is brittle, and will burn with a sooty flame. Upon standing it has a tendency to slake. No economic use has been made of this material and it is doubtful whether it is extensive enough or of high enough quality to warrant its recovery.

Several similar beds of lignite are present in the SW¼ sec. 36, T. 2 N., R. 1 E., H. They are interbedded with the blue-gray claystones of the Carlotta formation.

Another such bed crops out of the steep cliff in the SE¼ sec. 22, T. 2 N., R. 1 W., H. This bed is part of the Scotia Bluffs sandstone and is the most compact of all the lignites described.

Limestone

Rickter Deposit. Averill (1941) located the Rickter deposit in the SE¼SE¼ sec. 11, T. 1 N., R. 1 W., H., but on a more recent map its location appears to be in NE¼SE¼ sec. 11. He noted a quarry 75 feet long with a maximum depth of 25 feet reached in quarrying. He stated that the deposit might have a total length of 1,000 feet but that stripping of the overburden would be required to prove this. The material has been quarried for agricultural use. When the writer visited the deposit in 1950, only a few small outcrops of the limestone could be seen. Much of the area was covered with a dense growth of poison oak. From the limited exposures the writer concluded that the bed was possibly 10 feet thick with a moderate south dip and a general east strike. The limestone is impure, silty, hard, and weathers with a yellow-tan color. The limestone bed is a member of the Pullen formation. There is a road to the deposit, and it is probable that a limited quantity of limestone might be obtained for agricultural use.

Hackett Deposit. The Hackett deposit is located in sec. 16, T. 1 N., R 1 W., H., on the west fork of Howe Creek, about 4 miles southwest of Rio Dell, about a quarter of a mile from a passable logging road. It crops out strongly along the banks of Howe Creek and forms a continuous bed that can be traced for perhaps half a mile to the northwest. The bed is approximately 75 feet thick, strikes N. 60° W. and dips 45° N. Great quantities of limestone float may be found along the creek for some distance downstream. The limestone ranges from purplish red to gray or pure white. When etched with formic acid, the white and gray limestones were found to be nearly pure calcite, whereas the red limestone showed as much as 40 percent ferruginous material. The limestone is hard, is usually aphanitic, but has many small veinlets of crystalline calcite. It is a part of the False Cape shear zone rocks, but an essentially unsheared part. The size of this body, its relative purity and its availability indicate that it is one of the more important limestone deposits in Humboldt County. It should prove usable in agriculture, but the high percentage of iron oxide would probably be detrimental for cement manufacture or construction purposes.

McClellan Deposit. Averill (1941) located this deposit on the McClellan ranch in sec. 5, T. 1 N., R. 1 W., H. He states: "It is a deposit of calcareous tufa covering an area of an acre to a depth of three feet." Mr. McClellan has used some of this limestone on his land and states that an analysis showed it contained over 99 percent calcium carbonate. The "tufa" deposit may be genetically related to the Russ fault which cuts the Hackett limestone, and may have been formed by solutions moving along the fault.

Volcanic Ash

Laizure (1925) mentioned a bed of fine, creamy white volcanic ash, 2 feet in thickness, on the property of the Hanify Lumber Company. The area in 1925 was under lease to Clarence Weatherby, and was located 4 miles south of Elk River. The ash was reported to be interbedded with clay and lignite and would thus closely resemble the ash bed in the SE¼ sec. 19, T. 3 N., R. 1 W., H. The composition of the ash given by W. R. Gallagher, chemist, of Eureka, is as follows:

	Percent
SiO_2	70.0
Al_2O_3	18.5
Fe_2O_3	0.6
CaO	3.4
MgO	0.5
K_2O	2.4
Undetermined	1.2
	100.0

There are several ash beds in the Wildcat group; none can be traced for any distance, owing to the lack of exposures and the general lenticular nature of the waterlaid deposits. Many of these ash beds are very pure and are evenly sized. Only the thicker, purer ash deposits are listed here:

(1) Ash (SE¼NW¼ sec. 25, T. 2 N., R. 3 W., H.) on the Herb Russ property occurs in the basal Eel River formation. Locally, it is 6 feet in thickness but becomes impure and silty along the strike and only about 2 feet is pure. The same bed is exposed on the coast in the NE¼ sec. 26, T. 2 N., R. 3 W., H. The ash is composed of more than 99 percent glass shards having a refractive index of 1.505, indicating an approximate silica content of 70 percent.

(2) Ash (SW corner sec. 11, T. 2 N., R. 2 W., H.) along Wildcat Ridge road. Six feet of light gray to off-white, impure ash, coarser than that mentioned above, has a similar silica content. The bed could not be mapped beyond this exposure and the extent and quantity are unknown. The dip is 18° N.

(3) Ash (near center sec. 29, T. 4 N., R. 2 W., H.) along U. S. Highway 101. This bed has been described with the Carlotta formation. It is approximately 1 foot in thickness and there is little overburden; the dip is about 5° N. The refractive index of the glass indicates a silica content of about 69 percent; 99 percent of the ash is glass shards; 80 percent of the material falls within the siltsize fraction.

The ash beds may be of use as pozzolans in local concrete construction (Meilenz et al., 1949).

Clay

W. P. Dietrich (1928) has listed several clays in Humboldt County, and described their firing properties and characteristics as determined by the methods of that time. None of these clays described are from the area under discussion, but are from the same formations and are similar. Most of the clay samples he described are from the Hookton formation.

Laizure (1925) has given the most complete data on one of the clay deposits. He stated that the Loofbourrow clay is on the property of Dr. T. L. Loofbourrow, 4 miles south of Eureka, a quarter of a mile east of the highway. The clay is a dark blue, smooth plastic clay said to average 22 feet in thickness over 10 acres. It is overlain by 4 to 6 feet of yellow clay. The composition of the clay as determined by Harry A. Duffy, chemist of Eureka, is:

Loss on ignition ---------- 22.30% of total sample

	Percent
SiO_2	42.80
Al_2O_3	38.24
Fe_2O_3	2.60
Na_2O	2.40
K_2O	4.41
CaO	3.34
MgO	3.01
Organic content	3.20
	100.00

The locality and description indicate that this material is part of the Hookton formation. Dietrich (1928) noted that this clay vitrifies completely at cone 1 (1125°C-1160°C) and that the fired structure is sound. It would be suitable for brick making.

Averill (1941) mentioned the clays which crop out along the road between Beatrice and Loleta "in or near" sec. 5, T. 3 N., R. 1 W., H., which have been used by R. H. Jenkins of Humboldt State College for pottery making.

Most of the clays of the Hookton formation are plastic to some extent and many are rather pure. It is probable that numerous beds would be suitable for brick making since they are generally low dipping and usually have interbedded sand.

Probably one of the most important uses for the abundant mudstones of the Wildcat group is the production of lightweight aggregate by expanding the mudstone. Due to certain "impurities" in some clay or shale, such clay will "bloat" upon heating; that is, the clay will actually become a fused, vesicular mass several times the size of the original mass (Conley et al., 1948). Not all clays and shales are expansible and the materials responsible for expansion are not completely known. The material produced is used for lightweight aggregate in building blocks and other concrete work. Evidence that the mudstone beds of the Wildcat are expansible has been found by the writer in several natural occurrences of mudstones expanded by forest fires.

Sand and Gravel

The broad expanses of stream gravels along the Eel River and Van Duzen River are an almost unlimited source of sand and gravel for road building and construction work. Most of the material is not processed in any plant and only crudely sized by mounting large wire grates on the dump trucks which haul the gravel. Because of its ready access, one principal loading area is located at the mouth of the Van Duzen River. A study of the pebbles indicated that few if any reactive materials are present which would be detrimental for concrete work. Franciscan chert pebbles are common but it has been shown (Mielenz, White, and Glantz, 1949) that this chert is chalcedonic and not reactive.

One gravel company, has equipment for sizing, cleaning, and loading. The plant is located in sec. 34, T. 3 N., R. 1 W., H., along the Northwestern Pacific Railroad. They utilize the Recent gravels of the Eel River.

Some of the Hookton gravel has been used for roads and fill. Several quarries have been used in the Table Bluff area; one rather large one was at Southport Landing. The gravel is rusty to yellow-brown in color because of a coating of iron oxide on the pebbles.

The logging companies use whatever road-surfacing materials are available close to their operations. For this reason numerous temporary gravel pits may be found on any of the streams near logging operations. In areas where all-year logging is planned, at least 2 feet of gravel or crushed rock is laid as a base for logging roads.

In Bulletin 142, California Division of Mines (1949) the quantity of sand and gravel actually marketed in Humboldt County in 1947 is given as 261,063 short tons, which had a value of $221,278.

Crushed Rock

In areas distant from stream gravels Franciscan basalt, chert, sandstone, and Yager sandstone are sometimes use for road-surfacing material. Of these, the basalt is undoubtedly the best material because it usually breaks readily into small, angular fragments which are resistant to further granulation. In former years, when logging railroads were used for transportation, deep beds were laid over many backwood areas. These beds are now overgrown and it is usual to find a considerable range of varied rock types scattered over the terrane as float from these old road beds.

Water Resources

Springs. In the mountainous areas springs are numerous but generally small. Many of them are intermittent. Most inhabitants of the upland areas obtain their water from springs and in most cases the location of suitable springs governs the site of ranch headquarters. Water from the Wildcat and younger formations is generally moderately hard and contains soluble salts. Iron oxides which are sometimes present are detrimental for household water. Water from the Franciscan and Yager is normally purer and more palatable.

Streams. The streams of Humboldt County are one of the great potentials of the area for power, irrigation, and the development of industry. At the present time no dams control the flooding of the lowlands, nor are there any reservoirs in the immediate area. Eureka has dammed Mad River to the northeast and obtained a suitable water supply, besides helping to control the river.

Paulsen (1950) gives the total runoff of the Eel River at Scotia for the year 1947-48 as 4,608,000 acre-feet; the Van Duzen River at Bridgeville runoff for the year 1947-48 was 532,100 acre-feet.

If future dams are built, it would be best to build them on Yager or Franciscan foundations. Much of the Wildcat sediment is incompetent or highly permeable.

Ground Water. Because of the lack of any central water system most of the farms in the valley and several of the towns obtain their water from wells. The valley plain of the Eel River is underlain by considerable thicknesses of Recent gravel and clay which in turn are underlain by the Hookton formation and the Carlotta and Scotia Bluffs sandstone. The essentially synclinal valley forms an artesian basin, especially for the older sediments. The younger sediments are extremely lenticular in distribution and the lack of continuity of permeable beds restricts the building up of artesian pressures. Near the ocean the upper 80 feet is contaminated by salt water while the lower beds contain fresh water. In the Loleta area some of the water which has been encountered in wells of the Golden State Company is decidedly saline. Part of this may be connate water.

In some parts of the region where only a rather thin terrace deposit covers the mudstone of the Wildcat, water must be obtained at shallow depths or not at all. In the low hills formed by Hookton sediments or underlain by Carlotta conglomerate, water can usually be obtained from one of these two units. Sometimes this water is unfit for use because of the high iron-oxide and manganese-oxide content.

In view of the occasional presence of saline waters in certain strata, it is extremely important to properly case wells drilled through such strata. If care is not taken, valuable aquifers of the area will become dangerously contaminated.

Mineral Water. Felts Springs (sec. 31, T. 3 N., R. 1 E., H.) was a thriving resort in the 1870's but burned completely in 1878, was rebuilt and burned again in 1894. Waring (1915, p. 300) noted the presence of three springs—two saline and one sulphuretted. One well six feet in diameter and 24 feet deep was saline, and emitted non-inflammable gas. One spring that emitted H_2S, and a well giving off a gas assumed to be CO_2 were found during the present mapping. The springs are in an open grassy meadow surrounded by tall second-growth redwood trees.

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APPENDIX

LIST OF FORAMINIFERA LOCALITIES FROM THE WILDCAT GROUP */

LOCALITY NUMBER	LOCATION (H.B.& M.) SECTION	T.	R.	REMARKS
BA01	NE$\frac{1}{4}$NE$\frac{1}{4}$ 26	1N	3W	Dark gray sandy siltstone with foraminifera on coast south of Bear River (CM).
BA02	NW$\frac{1}{4}$SE$\frac{1}{4}$ 15	1N	3W	Dark gray siltstone, small gastropods, foraminifera (CM).
BA03	NE$\frac{1}{4}$SW$\frac{1}{4}$ 14	1N	3W	Along Bear River, 1600' upstream from mouth; conchoidal fracture, buff-gray, slightly siliceous shale (CM).
BA04	SE$\frac{1}{4}$SE$\frac{1}{4}$ 2	4S	3E	Dean Creek and South Fork of Eel River. Massive, micaceous, brown siltstone with limy nodules, forams in limy nodular material (BD).
BA05	SE$\frac{1}{4}$SE$\frac{1}{4}$ 2	4S	3E	South Eel River and Dean Creek; dark gray mudstone, conchoidal fracture, some forams.
BA06	SE$\frac{1}{4}$SE$\frac{1}{4}$ 27	4S	4E	Squaw Creek, 6000' north of mouth; dark gray mudstone. Forams.
BA07	NE$\frac{1}{4}$SW$\frac{1}{4}$ 9	4S	3E	Massive brown-gray sandy siltstone; fish scales. Forams.
BA08	SW$\frac{1}{4}$NE$\frac{1}{4}$ 18	4S	2E	Laminated buff to white diatomaceous, foraminiferal siliceous shale.
BA09	NW$\frac{1}{4}$SW$\frac{1}{4}$ 4	4S	3E	Dark gray, silty mudstone, "onion" weathering. Forams.
BA010	Center 28	3S	3E	Massive, silty dark gray mudstone. Forams.
BA011	NE$\frac{1}{4}$SE$\frac{1}{4}$ 2	1N	2E	Massive silty dark gray mudstone; abundant forams (Bemis Creek near the Van Duzen).
BA012	NW$\frac{1}{4}$SE$\frac{1}{4}$ 2	1N	2E	Massive mudstone with forams stratigraphically above 13.
BA013	NW$\frac{1}{4}$NW$\frac{1}{4}$ 15	1N	2E	Massive, silty, gray mudstone with forams.
BA014	NE$\frac{1}{4}$NW$\frac{1}{4}$ 17	1N	3E	Sample of black JKy, brittle shale, no organic material noted.
BA015	NW$\frac{1}{4}$NW$\frac{1}{4}$ 1	1N	2E	Dark gray silty massive mudstone.
BA016	NE$\frac{1}{4}$NE$\frac{1}{4}$ 13	2N	3W	Massive gray sandy siltstone with forams, north of Fleener Creek.
BA017	SW$\frac{1}{4}$SW$\frac{1}{4}$ 16	1N	2W	Soft sandy siltstone, abundant forams.
BA018	SW$\frac{1}{4}$NE$\frac{1}{4}$ 34	2N	2W	Massive buff-gray siltstone with forams.
BA019	NW$\frac{1}{4}$NW$\frac{1}{4}$ 35	2N	2W	Dark gray silty mudstone with forams.
BA020	NW$\frac{1}{4}$NW$\frac{1}{4}$ 34	2N	1W	Micaceous siltstone, blue-gray, few forams.
BA021	SW$\frac{1}{4}$SW$\frac{1}{4}$ 28	2N	1W	Dark gray mudstone, few forams.
Ba022	NE$\frac{1}{4}$SE$\frac{1}{4}$ 32	2N	1W	Along Price Creek, dark gray mudstone, abundant forams.
BA023	SE$\frac{1}{4}$SE$\frac{1}{4}$ 32	2N	1W	On Price Creek, dark gray silty mudstone, with forams.

BA024	NE¼SW¼ 28	2N	1W	On Price Creek, tough, dark gray mudstone, with forams.
BA024A	NW¼SW¼ 14	2N	2W	Gray mudstone with forams; Wildcat Ridge.
BA025	SW¼SW¼ 23	2N	2W	Gray siltstone with forams; Wildcat Ridge.
BA026	SE¼NW¼ 26	2N	2W	Dark gray silty mudstone; Wildcat Ridge.
BA027	NW¼NW¼ 5	1N	2W	Light gray siltstone, questionable forams; may not be in place.
BA028	SW¼SW¼ 32	2N	2W	Light gray siltstone, siliceous, harder than most Tw. Near fault with forams and glauconite.
BA029	NE¼SE¼ 31	2N	2W	Blocky gray hard siltstone; weathers buff; chalky feel, has forams.
BA030				Missed this number.
BA031				Cannot find FE-23, sample poor, 2N. 2E., use NW¼SE¼ sec. 31.
BA032	SE¼SW¼ 25	2N	3W	Light gray, creamy siltstone, abundant forams, moderately hard.
BA033				Missing.
BA034	NW¼SE¼ 26	2N	3W	Punky siltstone full of forams, medium gray, weathers creamy gray; some limestone nodules.
BA035	NW¼SE¼ 34	2N	2W	Weathered sandy siltstone with forams.
BA036	NW¼NW¼ 36	2N	2W	Upper Price Creek; had gray siltstone with mud pectens and forams.
BA037	NE¼NE¼ 15	1N	3W	Mouth of Bear River; light gray foraminiferal silty somewhat diatomaceous mudstone.
BA038	NW¼SE¼ 11	1N	3W	Gray siltstone.
BA039	NW¼NW¼ 11	1N	3W	Dark gray shale with mud pectens and forams, near fault with JKy.
BA040	NW¼SE¼ 24	2N	2W	Williams Creek; mudstone, Tw, badly weathered, has forams.
BA041	SW¼NE¼ 30	2N	1W	Gray siltstone, with few forams (FA).
BA042	SW¼SE¼ 34	2N	1W	Howe Creek; gray siltstone, abundant forams, Tw (FA).
BA043	SE¼NW¼ 13	2N	3W	Massive, dark gray siltstone with forams (FE).
BA044	NW¼SE¼ 32	2N	2W	Gray, hard siltstone with forams (FE).
BA045	SE¼NW¼ 33	2N	2W	Dark gray mudstone (FE).
BA046	NW¼SW¼ 26	2N	2W	Dark gray mudstone with forams (FE).
BA047	NW¼NE¼ 34	2N	2W	Gray mudstone with forams, Wildcat Ridge (FE).
BA048	SW¼NW¼ 24	2N	3W	Siltstone and sandstone with forams (FE).
BA049	NE¼SE¼ 23	2N	3W	Dark gray silty mudstone with forams; mouth of Bear Gulch (FE).
BA050	NW¼NE¼ 26	2N	3W	Bedded gray siltstone with forams (FE).
BA051	SW¼SE¼ 26	2N	3W	Massive hard gray siltstone with abundant forams (FE).
BA052	NE¼SW¼ 32	1N	2E	Micaceous, gray siltstone and fine sandstone, rusty fracture with forams (DE).
BA053	SW¼NE¼ 13	3N	1W	Dark gray mudstone with forams, weathered, massive; Salmon Creek area (FA).
BA054	NE¼SE¼ 27	4N	2W	Table Bluff lighthouse; Tw gray siltstone and thin sandstone with forams (FE).

LIST OF FORAMINIFERA LOCALITIES FROM THE WILDCAT GROUP */ (CONT'D)

LOCALITY NUMBER	LOCATION (H.B.& M.)			REMARKS
	SECTION	T.	R.	
BA055	SW$\frac{1}{4}$NE$\frac{1}{4}$ 26	4N	1W	Elk River, gray, sandy siltstone with forams (FA).
BA056	SW$\frac{1}{4}$SW$\frac{1}{4}$ 24	1N	1E	Silty mudstone with forams (GN).
BA057	SE$\frac{1}{4}$NE$\frac{1}{4}$ 18	4S	3E	Massive gray hard rusty mudstone with forams (BD).
BA058	NW$\frac{1}{4}$SW$\frac{1}{4}$ 15	3N	1W	Gray, sandy siltstone, with forams, near Salmon Creek Oil and Gas Company, Fowler No. 1 (FA).
BA059	SE$\frac{1}{4}$SW$\frac{1}{4}$ 5	1N	1E	Limy bed in mudstone, with forams, Scotia Bluffs, 2B.
BA060	SW$\frac{1}{4}$SW$\frac{1}{4}$ 5	1N	1E	Silty mudstone and siltstone with forams, Scotia Bluffs, 2B.
BA061	NW corner 10	2N	1E	Massive, tough, gray mudstone, with abundant forams (FA).
BA062	SW$\frac{1}{4}$SW$\frac{1}{4}$ 3	2N	1E	In medium-dark gray siltstone with good forams (FA).
BA063	SE$\frac{1}{4}$SW$\frac{1}{4}$ 3	2N	1E	Massive, dark gray mudstone with big forams (FA).
BA064	NE$\frac{1}{4}$NW$\frac{1}{4}$ 35	3N	1E	Massive weathered gray siltstone, with forams in poor condition (FA).
BA065	NE$\frac{1}{4}$SE$\frac{1}{4}$ 31	3N	1E	Abundant forams, blue-gray, sandy, fine siltstone, (FA).
BA066	NE$\frac{1}{4}$SE$\frac{1}{4}$ 9	2N	1E	Forams in siltstone on Indian Creek (FA).
BA067	SE$\frac{1}{4}$NE$\frac{1}{4}$ 24	3N	1W	Massive mudstone, abundant forams, especially a globular hyaline type (FA).
BA068	NE$\frac{1}{4}$SW$\frac{1}{4}$ 13	3N	1W	Massive fractured sandstone with forams, very abundant (FA).
BA069	SE$\frac{1}{4}$NW$\frac{1}{4}$ 18	3N	1E	Abundant forams associated with echinoids in sandstone, lower Tw, Salmon Creek (FA).
BA070	NE$\frac{1}{4}$SE$\frac{1}{4}$ 27	2N	1W	Few forams, small varieties, in sandy siltstone (FA)
BA071	NW$\frac{1}{4}$SE$\frac{1}{4}$ 25	4N	1E	Silty, gray mudstone, with few forams (FA).
BA072	SW$\frac{1}{4}$SW$\frac{1}{4}$ 31	4N	1E	Mudstone with forams (FA)
BA073	NE$\frac{1}{4}$NE$\frac{1}{4}$ 5	3N	1E	Lowest Tw glauconitic siltstone, good forams (FA).
BA074	SE$\frac{1}{4}$NE$\frac{1}{4}$ 36	4N	1E	Glauconitic, silty sand with some good forams (FA).
BA075	NE$\frac{1}{4}$SE$\frac{1}{4}$ 34	4N	1E	Glauconitic, silty sand with some large forams (FA).
BA076	SW$\frac{1}{4}$SE$\frac{1}{4}$ 29	4N	1E	Massive mudstone with abundant forams (FA).
BA077	SE$\frac{1}{4}$SW$\frac{1}{4}$ 29	4N	1E	Slight glauconitic sandstone with good forams (FA).
BA078	NW$\frac{1}{4}$SE$\frac{1}{4}$ 32	4N	1E	Silty gray mudstone with tiny forams (FA).
BA079	NE$\frac{1}{4}$SE$\frac{1}{4}$ 22	4N	1E	Forams in weathered buff siltstone (FA).
BA080	SE$\frac{1}{4}$SE$\frac{1}{4}$ 10	4N	1E	Massive Tw siltstone, very fresh, few forams (FA).

BA081	Center 6	3N	2E	Upper mid-fork of North Fork of Elk River (FA).
BA082	SW$\frac{1}{4}$SW$\frac{1}{4}$ 12	4N	1W	Henderson Gulch, window of Pliocene (FA).
BA083	SW$\frac{1}{4}$NE$\frac{1}{4}$ 26	2N	3W	Coast section, (FE).
BA084	Center 36	4N	1W	South Fork of the Elk River (FA).
BA085	NE$\frac{1}{4}$NW$\frac{1}{4}$ 4	3N	1W	Northeast of Beatrice (FA).
BA086	NW corner 21	4N	1E	(FA).
BA087	SE$\frac{1}{4}$SE$\frac{1}{4}$ 26	4N	2W	Near Southport Landing (FE).
BA088	SW$\frac{1}{4}$SW$\frac{1}{4}$ 2	4N	1E	Graham Gulch (EA)
BA089	SE$\frac{1}{4}$SW$\frac{1}{4}$ 7	1N	1E	"Bathysiophon shale" (GN).
BA090	NE$\frac{1}{4}$SE$\frac{1}{4}$ 32	2N	1W	On Price Creek, (FA).
BA091	NW$\frac{1}{4}$NW$\frac{1}{4}$ 36	4N	1E	"Bathysiophon shale".
BA092	SE$\frac{1}{4}$NE$\frac{1}{4}$ 30	2N	1W	Crosby Road (FA).
BA093	SE corner SW$\frac{1}{4}$SW$\frac{1}{4}$ 3	1N	1W	Basal Tertiary, Sound Lumber Company road (GN).
BA094	SE$\frac{1}{4}$NE$\frac{1}{4}$ 34	2N	1W	On Howe Creek (FA).
BA095	NW$\frac{1}{4}$NE$\frac{1}{4}$ 5	1N	1W	Upper Price Creek (FA).
BA096	NW$\frac{1}{4}$NE$\frac{1}{4}$ 5	1N	1W	Upper Price Creek 500 feet stratigraphically above BA095 (FA).
BA097	NW$\frac{1}{4}$NE$\frac{1}{4}$ 5	1N	1W	Upper Price Creek 300 feet, stratigraphically above BA095.(FA).
BA098	NW corner SW$\frac{1}{4}$NW$\frac{1}{4}$ 11	1N	3W	Coast section north of Bear River, lowest Pliocene seen (CM).
BA099	NW$\frac{1}{4}$NE$\frac{1}{4}$ 5	1N	1W	Upper Price Creek 100 feet stratigraphically above BA095 (FA).
BA0100	SE corner SW$\frac{1}{4}$NW$\frac{1}{4}$ 26	2N	2W	Wildcat Ridge road below disconformity (FE).
ERS No. 1	SW$\frac{1}{4}$NE$\frac{1}{4}$ 7	1N	1E	507 feet above base of Tertiary on west bank of Eel River (GN).
ERS No. 2	NE$\frac{1}{4}$NE$\frac{1}{4}$ 7	1N	1E	Eel River just below highest glauconite; on west bank (GN).
ERS No. 3	NE$\frac{1}{4}$NE$\frac{1}{4}$ 7	1N	1E	120 feet stratigraphically above west bank ERS No. 2 (GN).
ERS No. 4	SW$\frac{1}{4}$SW$\frac{1}{4}$ 5	1N	1E	West bank of Eel River, below Scotia-Rio Dell bridge, approximately 200 feet stratigraphically below ERS No. 5 (GN).
ERS No. 5	SE$\frac{1}{4}$SW$\frac{1}{4}$ 5	1N	1E	East bank of the Eel River (GN).
ERS No. 6	NW$\frac{1}{4}$SW$\frac{1}{4}$ 32	2N	1E	243 feet stratigraphically below a conglomerate at 33-58-4 in Scotia Bluff sandstone (FA).

*/Samples are on file in Union Oil Company of California Paleontology Laboratory, Dominguez oil field, California. CM-Cape Mendocino quad., BD-Briceland quad.. H-Harris quad., FA-Fortuna quad., FE-Ferndale quad., GN-Scotia (formerly Glynn) quad., DE-Dyerville quad.

LIST OF MEGAFOSSIL LOCALITIES FROM THE WILDCAT GROUP

LOCALITY	LOCATION (H.B.& M.)			REMARKS
NUMBER *	SECTION	T.	R.	
A4551	W edge 30	1N	4E	Along Bridgeville-Blockburg road (Dyerville quad., DE-27).
A4552	NW¼NW¼ 1	1N	2E	On logging road cut (Dyerville quad., DE-30).
A4553	SW¼SE¼ 12	2N	3W	3/8-mi. north of mouth of Fleener Creek (Ferndale quad., FE-7).
A4554	NW¼SW¼ 34	2N	1W	On logging road near Oil Creek (Fortuna quad., FA-4).
A4555	NE¼SW¼ 11	1N	1W	Along a small stream 400 yds. north of Bear River (Cape Mendocino quad., CM-29).
A4556	NW¼NW¼ 24	2N	3W	1500' north of Guthrie Creek along the coastal cliffs (Ferndale quad., FE-46).
A4557	SW¼SW¼ 13	2N	3W	2500' north of the mouth of Guthrie Creek, coast section (Ferndale quad., FE-47).
A4558	NW¼SW¼ 8	4N	1W	From the lower beds at Buhne Point (Fortuna quad., FA-39).
A4559	SW¼NW¼ 11	1N	3W	3500' north of mouth of Bear River, near the base of the Pliocene exposed at this point (Cape Mendocino quad., CM-22, BAO 39).
A4560	SW¼NE¼ 5	1N	1E	At the RR trestle over Nanning Creek, Scotia Bluffs area (Fortuna quad., 2B-93-5).
A4561	NW¼NE¼ 5	1N	1E	1000' NW along the RR tracks from the mouth of Nanning Creek, Scotia Bluffs area (Fortuna quad., 2B-93-3).
A4562	NW¼NE¼ 6	1N	1E	900' NW along the RR tracks from the mouth of Nanning Creek, Scotia Bluffs area (Fortuna quad., 28-93-4).
A6848	NE¼SW¼ 32	2N	1E	Along NWP RR tracks, 2000' NW of mouth of French Gulch (Fortuna quad., B.A. Ogle's F-4).
A6849	SE¼SW¼ 19	2N	2E	In heavily wooded country on mountainside (Kneeland quad., F-5).
A6850	SE¼NE¼ 5	1N	1E	At Yoder Station along NWP RR tracks (Mouth of Nanning Creek) (Fortuna quad., F-3).
A6851	SW¼NE¼ 6	2N	1E	At head of north branch of Jameson Creek, 100' above creek bed (Fortuna quad., F-2).
A6852	SW¼NW¼ 31	3N	1E	Along bank of the north fork of Strongs Creek (at a big slide, 1500' NE of the forks of Strongs Creek (Fortuna quad., F-1).

A6853	SW$\frac{1}{4}$SW$\frac{1}{4}$ 9	2N	1E	Along a logging road cut on a ridge north of Anderson ranch, 1000' E and 900' N of SW corner of sec. 9 (Fortuna quad., F-6).
A6854	NE$\frac{1}{4}$NE$\frac{1}{4}$ 5	3N	1E	Along South Fork of Elk River, 3000' NE of branch called Little South Fork of Elk River (Fortuna quad., F-7).
A6855	SW$\frac{1}{4}$NE$\frac{1}{4}$ 6	2N	1E	Along South Fork of Elk River, 3500' west of branching of Little South Fork of Elk River (Fortuna quad., F-8).
A6856	NE$\frac{1}{4}$NW$\frac{1}{4}$ 30	2N	2E	Along logging road in cut-over timber, at east edge of Fortuna Quad., 1000' south of the north boundary of sec. 30 (Fortuna quad., F-12).
A6857	Center NE$\frac{1}{4}$ 30	3N	1W	Along bank of Salmon Creek, 2500' west of a small logging road crossing the creek in sec. 11 (Fortuna quad., F-13).
A6858	NE$\frac{1}{4}$NE$\frac{1}{4}$ 36	4N	1E	On a logging road cut near a small stream canyon which is tributary to the North Fork of Elk River, 1500' south and 300' west of the northeast corner of sec. 36 (Fortuna quad., F-14).
A6859	SE$\frac{1}{4}$NW$\frac{1}{4}$ 18			Salmon Creek area, along a logging road cut 2300' east and 1000' south of the NW corner sec. 18 (Fortuna quad., F-16).
A6860	NE$\frac{1}{4}$SW$\frac{1}{4}$ 10	2N	1E	Along bank of Yager Creek, 1500' north of mouth of Cooper Mill Creek (Fortuna quad., F-18).
A6861	NE$\frac{1}{4}$NE$\frac{1}{4}$ 17	3N	1W	Along old highway in Deering Gulch (Fortuna quad., F-20).
A6862	NW$\frac{1}{4}$NW$\frac{1}{4}$ 24	2N	3W	1000' north of north bank of Guthrie Creek (Ferndale quad., F-21).
A6863	SE$\frac{1}{4}$SW$\frac{1}{4}$ 2	4N	1W	At south edge of Eureka Quad., along a small dirt road 1 mile south of Cutten (Eureka quad., F-22).
A6864	SW$\frac{1}{4}$SW$\frac{1}{4}$ 19	2N	2W	500' SE of road crossing Guthrie Creek in sec. 24, 2N. 3W., (Ferndale quad., F-23).
A6865	NE$\frac{1}{4}$NE$\frac{1}{4}$ 34	2N	1W	Along the west bank of Eel River at a big slide 1500' NW of mouth of Howe Creek (Fortuna quad., F-24).
A6866	SW$\frac{1}{4}$NE$\frac{1}{4}$ 5	1N	1E	Along RR, 500' south of mouth of Nanning Creek on east side of Eel River (Fortuna quad., 2B-93-647).
A6867	SE$\frac{1}{2}$SW$\frac{1}{4}$ 5	1N	1E	Along NWP RR cut, 1600' north of highway bridge west of Scotia (Glynn quad., F-25).
A6868	SE corner 12	2N	3E	Near the Red Hill Road (Danger Creek Pliocene) (Kneeland quad., F-26).
A6869	SW$\frac{1}{4}$NW$\frac{1}{4}$ 10	4N	1W	Small dirt road cut from ranch house by Swain's Slough to terrace level above (Fortuna quad., F-27).
A6870	North edge 10	4N	1E	Along Freshwater Creek (Eureka quad., F-28).
A6871	SW$\frac{1}{4}$SW$\frac{1}{4}$ 17	4N	1W	In excavation at NE edge of town of Field's Landing (from Wildcat exposed here) (Fortuna quad., F-29).

LIST OF MEGAFOSSIL LOCALITIES FROM THE WILDCAT GROUP (CONT'D)

LOCALITY	LOCATION (H.B.& M.)			REMARKS
NUMBER *	SECTION	T.	R.	
A6872	NW¼NE¼ 5	1N	1E	At base of Scotia Bluffs sandstone, along east bank of Eel River (Fortuna quad., F-30).
A6873				At a depth of 373' in a water well drilled in 1950 in the yard of the Golden State Company, Loleta.
A6874	NW¼NW¼ 13	2N	3W	Coast section 1100' south of the mouth of Fleener Creek.
A6875	NE¼SE¼ 11	1N	1W	At the Richter limestone deposit on the Richter ranch (Glynn quad., F-33).
A6876	Center of 7	1N	1E	Along the east bank of the Eel River, at the base of the Pullen formation (Glynn quad., ERS No. 1).
A6877	NW¼NE¼ 5	1N	1E	Along cliffs on the east bank of the Eel River, north of Nanning Creek (Fortuna quad., ERS No. 4).
A6878	SW¼NE¼ 7	1N	1E	On west bank of the Eel River (Fortuna quad., ERS No. 3).
A6879	NE¼NW¼ 13	1N	3W	On coast section, north bank of mouth of Fleener Creek (Ferndale quad., 14-03-7).
A6896	SW¼SW¼ 7	4N	1W	Dredgings at Buhne Landing.

*/The numbers used are those of the University of California Museum of Paleontology, invertebrate file.

TYPE SECTION OF THE WILDCAT GROUP

EEL RIVER SECTION

(Measurement begun at exposure of lowest observable Tertiary sediments on west bank of Eel River, by Scotia. Contact between the Tertiary basal sandstone and Yager sandstone and shale obscured by alluvium and landslide; lowest Tertiary exposure described is probably within 10 feet of base, as Yager folded sandstone and shale, and overlying basal Tertiary sandstone are exposed at low water on east bank 400 feet across river.)

WILDCAT GROUP

Pullen formation
(Measured along west bank of Eel River near Scotia)

Basal sandstone member

37 Fine-grained, silty, compact, moderately hard, gray sandstone; weathers rusty yellow-brown 4

36 Irregular zone of pebbly sandstone similar to above with psephitic debris including the following: angular cobbles and small boulders to 8" of hard, platy, micaceous Yager sandstone; cobbles of tough yellow-weathered limestone; a few small, rounded black chert pebbles, and numerous sub-angular flat pebbles of Yager shale... 2

35 Compact, gray, silty, feldspathic, rusty-streaked sandstone with a one-inch irregular streak of Yager shale pebbles averaging 1/2 inch in diameter.................................. 3

34 Fine silty sandstone as above with occasional small poorly preserved pelecypods including *Spondylus* sp. and *Anadara* sp. The upper five feet contain irregular, limy concretionary bodies enclosing pelecypods, angular cobbles of Yager sandstone and some small Yager shale fragments.. 25

33 Fine silty, gray sand as above with rusty colored streaks where weathered. The lower 1/2 inch contains two 2 inch streaks of Yager shale pebbles and fine sandstone pebbles......................... 30

32 Massive sandstone as above with occasional poorly-preserved pelecypods. The lower 1/2 inch contains numerous, nodular, limy concretions and abundant small worm tubes to 4 inch in length. This zone has a bluish gray color in contrast to the usual rusty, streaked sandstone.......................... 10

31 Fine-grained, tough, massive silty sandstone as above with a 1 inch zone of Yager shale pebbles,

	sandstone pebbles, and a few rounded, black chert pebbles. Immediately above this pebble zone the sandstone is hard and lime-cemented	26
30	Sandstone (as above) with irregular lenses of lime-cemented sandstone containing angular to sub-angular Yager shale pebbles, sandstone cobbles, Franciscan or Yager limestone cobbles and a few rounded, black chert pebbles	2
29	Very silty, fine-grained, tough, slightly glauconitic, rusty-streaked, brownish-gray when fresh, sandstone	42
28	Silty sandstone as above with numerous worm tubes and a few vertebrate bone fragments	3
27	Silty sandstone as above but more limy and glauconitic	18
26	Very fine, silty, sandstone (as above) containing many pebbly sandstone streaks. The pebbles are mostly 1/8 inch to 1/4 inch diameter, rounded, black cherts. At the base is a fragment of vertebrate bone 4 inches in diameter in a limy concretion	14
25	Fine-grained, very silty sandstone as above	12
24	Sandstone with several lenses to 4 inches thick of fine rounded pebbles 1/4 inch to 1/8 inch diameter and numerous glauconite pellets of similar size	3
	(A few small faults, striking NW and dipping SW, have duplicated a few feet (1' to 3') of section by dropping the NE side relatively down)	
23	Fine-grained, slightly glauconitic, very silty, rusty-streaked, brownish-gray sandstone	32
22	Hard, sandy, yellow-orange when weathered, gray-brown when fresh, limestone	1
21	Sandy, tough, brownish-gray massive siltstone with a rusty fracture; becomes silty toward top; two 1 inch thick zones of limy nodules near the top. (This is the top of the strong outcropping basal sandstone member).	15
	Basal sandstone member	242
	Upper mudstone member	
20	Sandy, massive, dark gray when fresh, weathers brownish-gray with a rusty colored fracture; some yellow sulfurous coating	39
19	Sandy, yellow-weathering limestone	2
18	Dark gray, tough siltstone which has some occasional thin, platy, laminations to 1/4 inch in thickness. This weathers with a	

	rusty fracture; the thin-bedded material breaks into small brittle chips (probably diatomaceous and siliceous)	18
17	Impure yellow limestone	1
16	Very silty fine-grained sandstone with some small glauconite pellets	5
15	Very silty sandstone as above with numerous elliptical yellow-orange weathering limestone nodules to 8 inches in diameter	2
14	Somewhat platy, laminated, brittle, dark gray, silty shale which becomes brownish-gray when weathered. When very fresh the laminations are seen to be 1/16 inch thick concretions of white diatomaceous material alternating with thicker layers of clastic material	5
13	Dark gray, tough, sandy siltstone; the lower 5 inches is diatomaceous and ashy(?), and the upper 1 inch has numerous limy nodules to 8 inches in diameter	19
12	Massive dark gray, hard, brittle mudstone which is somewhat diatomaceous. The upper 6 inches has glauconite pellets to medium sand size	13
11	Laminated diatomaceous shale	2
10	Glauconitic silty mudstone	8
9	Massive, tough, gray-black when fresh, rusty fractured when weathered, mudstone with limy lenses in the upper 1 inch	26
8	Tough, brownish-gray, massive siltstone with a 6-inch yellow-weathering limestone bed 16 feet from the base and limy lenses to 1 foot in thickness in the upper 1 foot	26
7	Massive, tough, dark brownish-gray mudstone which is somewhat diatomaceous. Small foraminifera are common (ERS Foram 1 at 45' from base). This mudstone (where freshly weathered) has a light blue-gray "bloom"; where deeply-weathered it becomes stained rusty-brown and breaks up into small hard angular fragments. Near the base are large, "biscuit"-shaped limestone lenses to 3 feet thick and in the upper part yellow-orange weathering limestone nodules and lenses are common	240
6	Dark-gray, impure limestone bed which weathers yellow-orange; appears fairly continuous	2
5	Tough, dark gray mudstone which weathers rusty-brown. Forams are common, and occasional molluscs are present A few limestone nodules are present	57
4	Massive mudstone except for a 4 inch fine-grained silty sandstone at the base, 2 feet	

	from the base, and 26 feet from the base	30
3	Massive dark gray mudstone which is often very silty. Weathers rusty brown; sometimes nodular-weathering. There are occasional small yellow limestone nodules in the lower part and more numerous, larger, spherical to lenticular limestone masses in the upper part. There is one continuous limestone bed 8 inches thick, 255 feet from the base. Forams are occasionally present	358
2	Silty, light gray limestone which weathers yellow-orange. It is locally brecciated into 1/2 inch fragments and recemented with calcite	2
1	Massive dark gray siltstone (top Pullen)	10
	Upper mudstone member	865
	Pullen formation, total	1107

Eel River formation

(The type section of the Eel River formation; measured on the west bank of Eel River near Scotia)

22	Dark gray siltstone with lenses of silty, coarse-grained, feldspathic sandstone with polished, rounded black chert pebbles 1/8 inch in diameter, and numerous large glauconite pellets to 1/4 inch in diameter	1
21	Massive, dark gray siltstone	15
20	Massive sandy, somewhat glauconitic, siltstone makes up the "matrix" of this member. Set in this are numerous irregular streaky, lenticular masses of pebbly, limy sandstone, pebbly limestone, and large angular to sub-rounded masses of yellow-orange limestone. The pebbly limestone and sandstone have pebbles of hard, rounded black cherts, white quartzites, red cherts, and other resistant rock types which are polished and average 1/4 inches to 1/8 inches but with a few to 1 inch diameter; and occasional cobble-size, angular to sub-rounded, yellow-orange limestone fragments. Some of these limestone fragments are rather platy and resemble those older limestones occasionally seen in the False Cape Shear Zone rocks. Some of the large limestone masses show rounding due to erosion, and one large mass has numerous borings on its surface. A green coating which appears to be glauconite lines some of the cavities on this mass. (Many of the large blocks have tumbled out of place	

	along the river bank. The number of lenticular masses varies greatly within a few feet along strike.)	20
19	Massive sandy, slightly glauconitic, dark gray siltstone	17
18	Muddy, green, tough glauconitic sandstone in which the glauconite pellets appear to make up at least 50 percent of the rock. The glauconite is dark greenish-black when fresh, becomes apple-green when slightly weathered, and rusty-brown when deeply weathered. An occasional small pebble is present in the lower few feet. The lower 5 feet contain many large boring, or coprolite casts, which average 1/2 inch to 1 inch in diameter and are 6 inches long. These weather out as rusty-brown resistant masses on the surface of the sandstone. The upper part of this member becomes silty	14
17	Massive, dark gray siltstone which weathers with numerous cross-fractures, or shows nodular or onion-skin (spheroidal) weathering. The weathered fragments are not as hard and resistant as the pelitic sediments of the Pullen. A rusty stain on the fragments is common where the siltstone is occasionally slightly glauconitic. Forams are present but rare. There is a sandy, gray 4-inch limestone bed 111 feet from the base; occasional cream-colored limestone nodules are present in the upper 70 feet; and an 8-inch cream-colored limestone bed occurs 170 feet above the base	182
16	Very silty, fine-grained, brownish-gray, slightly glauconitic, poorly-sorted sandstone with occasional 1/8 inch polished pebbles. This bed stands out as a more resistant bed than the siltstone above and below	18
15	Dark gray siltstone grades up from sandstone of 7 massive, weathers brownish-gray; shows onion-skin weathering, and has rusty stains on fracture surfaces	135
14	Silty, gray-brown glauconitic, fine-grained sandstone with glauconite pellets to medium sand-size making up 30 to 50 percent of the sediment. There are a few orange, limy concretions and some large borings similar to those in 18)	10
13	Massive sandy gray siltstone, rusty-fractured, with onion-skin weathering; occasional cream-colored spherical to lenticular nodules of limestone are common in the upper part	107
12	Silty, massive, dark gray mudstone which weathers with a rusty fracture	30
11	Very fine-grained brown sandstone which contains abundant glauconite. The glauconite is dark	

	green when fresh and generally of fine sand size; it makes up 40 percent of the rock in the lower part and perhaps 20 percent in the upper part	10
10	Very fine, slightly glauconitic sandstone becoming more silty upward	18
9	Massive, gray-brown, moderately soft, siltstone which weathers with a rusty stain along onion-skin joints. Occasional forams present..	94
8	Yellow-orange limestone bed	1
7	Siltstone as above	10
6	Dark gray-black mudstone with occasional glauconitic pellets to fine sand size and a few forams	5
5	Gray-brown soft siltstone	16
4	Tough, dark gray to black mudstone which weathers to a light gray or buff. Nodular-weathering is common but rusty staining is absent. There are a few flauconite pellets of fine sand size and a few forams; the glauconite becomes less common in the upper part of the member	223
3	Mudstone as above which contains numerous fragments of carbonized wood. The fragments are 1 to 6 inches long by 1 or 2 inches wide and some contain _Teredo_ borings; a yellow sulfurous coating is present around some wood fragments	1
2	Mudstone as above with occasional wood fragments	10
1	Tough, gray-black mudstone with the lower 4 inches composed of a black, carbonaceous mudstone (nearly a lignite); forams are present but rare (ERS Foram 2). (This is picked as the top although a change in facies occurs as low as 3).	3
	Eel River formation, total	940

Rio Dell formation

(This section is given as the type section of this formation. Members 1-33 were measured on the east bank of Eel River north of Scotia; members 34-45 were measured along the west bank of Eel River west of Scotia.)

45	Fine-grained, friable, well-sorted, feldspathic sandstone with abundant dark green glauconite in the lower inch (20 percent glauconite). Thin layers of glauconitic concentrations are present throughout this sand. This sand is deposited on a slightly irregular cut surface of carbonaceous dark mudstone (Eel River formation).....	0.4
44	Massive, dark gray, tough mudstone which weathers buff-gray and shows nodular weathering. Few forams are present; at 4 and 8 feet above the	

	base are 1-inch lignitic mudstone beds	124.6
43	A series of alternating, thin sandstones and mudstones in which mudstones predominate. There is a 1-foot sandstone at the base and a total of 32 sands in this unit; the sandstones range from 3 inches to 2-1/2 feet in thickness with the average about 6 inches. These alternate with mudstones which range from 4 inches to 11 feet in thickness; the average in most of the series is about 1-1/2 feet, but in the upper 30 feet mudstones become thicker with several from 4 to 11 feet in thickness. The sandstones are fine-grained, friable, feldspathic and gray when fresh but weather to buff. Many of the sands in the lower part contain abundant biotite, often in dark laminations. The mudstones are dark gray and massive; forams are common (*ERS Foram* 3 collected 4 feet from the base). The sandstones and mudstones do not grade through siltstones but show a sharp demarcation. Several small faults striking NW show offsets of 1 to 5 feet.	93
42	Massive dark gray mudstone with a 1-foot sandstone 24 feet from the base and a 6-inch sandstone 33 feet from the base; material similar to that previously described	73
41	Alternating series of thin sandstones and massive mudstone. A total of 9 sands average 4 inches in thickness; the mudstones average more than 4 feet, and one is 22 feet thick near the base.... (Numerous small faults in this part of the section.)	47
40	Massive dark gray massive mudstone which weathers light gray to buff. A few thin lenticular sands near the top	97
39	Alternating series of sandstones and mudstones. A total of 5 sands average 4 inches in thickness; one mudstone is 5 feet thick.	7
38	Massive mudstone with a 4-inch sandstone 18 feet above the base, and others 32, 48, and 106 feet above the base. There is a 4-inch thick series of orange limy nodules 193 feet above the base. In the upper 250 feet of this member there are a few poorly preserved molluscs and occasional small orange limy nodules. Forams are common to rare...	384
37	Massive mudstone with an 8-inch sandy limestone bed containing pelecypod fragments at the base and a 4-inch limestone at the top	6
36	Massive, nodular-weathering, dark gray mudstone with rare forams (*ERS Foram* 4 collected 14 feet above base). There is a 6-inch sand 94 feet above base, another 96 feet above base, and a 1-foot sand 300 feet above the base. There are	

	occasional limy nodules, and a series of 4-inch orange limy nodules 113 feet above the base. In the middle of the section are several large limestone masses; one is 3 feet in diameter.............	340
35	Alternating series of sandstones and mudstones. There are a total of 15 sands ranging from 4 inches in thickness in the lower part to several 1 foot thick in the upper part. The mudstones vary in thickness from 6 inches to a few 4 to 8 feet in the upper part............................	34
34	Hard yellow-orange limestone bed with numerous *Pectens* and other pelecypods. (This limestone bed is the highest exposure, stratigraphically, on the west bank of the river and is believed to be equivalent to a sandy limestone at the base of (33); the beds above are here covered with alluvial gravels).	3
33	Massive gray siltstone with a few thin fine-grained feldspathic gray sandstones and a hard, sandy limestone at the base. A few forams are present (*ERS Foram* 5 collected). *Pecten caurinus* is common and a few other molluscs are rare. (Below the limy sandstone mentioned above are numerous thin sandstones believed to be approximately equivalent to (35) measured on the west side of the river)..	14
32	Approximately all this measured member is massive mudstone or siltstone. Much of it is poorly exposed due to slumping along the railroad cuts. Where seen in place the mudstone or siltstone is dark gray when fresh, weathering to light gray or buff-gray. Forams are common (*BAO* 60 collected at the base, and *BAO* 59 collected at the top).......	600
31	Massive, very fine-grained silty sandstone; contains numerous limy concretionary areas, usually around common pelecypods or gastropods.............	15
30	Very fine-grained silty sandstone with numerous streaks of pelecypods and limy concretionary layers. Five feet from base is a 2-inch bed of *Securella staleyi*, and again 6 feet from the base. ...	15
29	Coarse, sandy, gray siltstone with occasional pelecypods..	6
28	Very fine-grained silty sandstone, friable.........	6
27	Massive, compact, tough, sandy, gray siltstone; contains occasional streaks of pelecypods.........	93
26	Massive, gray, very silty, very fine-grained sandstone which stands out as a stronger bed; contains numerous pelecypods (*Cerastoderma meekianum* and *Securella staleyi*). This grades imperceptibly into the siltstone of (25). (From) (31) to (25) most of the sediments are on the "borderline" between sandstone and siltstone, and it is difficult to differentiate between	

	them in some cases	83
25	Sandy, massive, gray siltstone with a 1-foot limy bed 50 feet from the base; a few limy nodules are present. Numerous pelecypods in the upper part and one echinoid (*Anorthoscutum interlineata*)	93
24	This "member" is slumped siltstone and mudstone with an approximate stratigraphic thickness of ...	250
23	Massive, dark gray mudstone (in place)	30
22	Interbedded thin, fine-grained gray sandstones, and dark dray mudstones; beds average 8 inches in thickness	4
21	Silty fine-grained, sandstone with several thin layers of fine carbonaceous fragments and a few pelecypods	7
20	Massive mudstone, partly slumped, approx	180
19	Fine-grained, gray, massive sandstone	10
18	Rhythmically alternating fine-grained sandstones and siltstones averaging 4 inches each	40
17	Massive sandstone	4
16	Alternating sandstone and mudstone	32
15	Alternating thin, very silty, very fine-grained sandstones and silty mudstones averaging 4 inches each. (This type of alternation only shows up well on a cutbank which has been exposed for a considerable time. Under certain light it is rather difficult to make out. The writer has used the term "phantom banding" for this rhythmic size variation.)	100
14	Silty, fine-grained, gray sandstone with occasional 6-inch beds of sandy siltstone. In the upper 20 feet are numerous limy lenses and abundant streaks of pelecypods. 77 feet from the base is a 6-inch bed of pelecypods (predominantly *S. staleyi* and *C. meekianum*).	87
13	Slumped "phantom banded" silty sandstone and mudstone, approx.	80
12	"Phantom banded" sandstones and mudstones; numerous pelecypods	120
11	Silty, very fine-grained, gray, feldspathic, compact, sandstone which is principally massive but has occasional indications of bedding due to gradations in the amount of silt in the composition. Limy nodules are common, and pelecypod streaks are numerous (*S. staleyi* and *C. meekianum*) and 110 feet from the base is a 4-inch bed made up of thousands of the tiny pelecypod, *Psephidia lordi* (lowest seen).	200
10	Bluish-gray, sandy siltstone with abundant large *P. caurinus* up to 8 inches in height	56
9	Silty, gray sandstone	10
8	Slumped area of gray siltstone containing abundant *P. caurinus*	120

7 Silty, gray, fine-grained sandstone with abundant pelecypods, especially *P. caurinus*.................. 120

(Check point: north bank Nanning Creek; Yoder Station)

6 "Phanton banded" sandy, gray siltstone, and dark gray mudstone with abundant molluscs............... 180

5 Silty, very fine-grained, gray sandstone with abundant pelecypods usually concentrated in limy lenses and beds (*S. staleyi*, *C. meekianum*, and *P. caurinus*, principally). 67 feet from the base is 6-inch hard, limy, pelecypod bed overlain by a 6-inch mudstone. This member becomes silty toward the top and contains several fragments of carbonized wood 6 inches long and some sandstones banded with carbonaceous fragments....................... 140

4 Tough, sandy, dark gray siltstone with a few carbonized wood fragments and occasional pelecypods.. 120

3 "Phantom banded" siltstone and mudstone with occasional pelecypods and many rusty, limonitic streaks...................................... 90

2 Sandy, gray siltstone with occasional thin mudstone members.................................. 85

1 Silty, very fine-grained, gray sandstone with a few 3-inch mudstone beds.......................... 60

Rio Dell formation, total 4259

Scotia Bluffs sandstone

(The section whose description follows is the type section of this unit. It was measured along the Scotia Bluffs on the east side of Eel River).

22 Massive, fine-grained, buff-tan weathering, friable sandstone. When fresh the sandstone is gray, but due to the permeable nature of this, and other typical sandstones of this unit, most outcrops have been weathered due to oxidation and permeating solutions. It is noticeably cleaner and less silty than sands of the Rio Dell. Although friable, it makes strong outcrops and cliffs. Occasional limy mollusc-bearing lenses are present............. 55

21 Fine sand, as in 22, with numerous 2-inch silty members 4

20 Very fine-grained, silty, gray sandstone; bedding stands out due to occasional thin silty members. 62 feet from the base is a limy bed composed of *Psephidia lordi*; a similar one is present at 63 feet.................. 65

19 Very fine-grained sandstone with several 1-inch mudstone beds near the base and numerous limy concentrations of pelecypods (especially *P.*

	lordi. These lenses occur approximately every 4 to 10 feet and give a bedded appearance. At 110 feet above the base is strong outcropping, limy bed of *C. meekianum* with pebbles. There are a few 1/2 inch mudstone streaks in the upper 10 feet	140
18	Massive, fine-grained, buff-brown weathering, friable, relatively clean sandstone. This is the base of the strong outcropping, thick, massive, cliff-making sandstone of Scotia Bluffs. It often has a moss-like crust, brown in summer, which gives it a brown color when viewed from the distance. This is characteristic of this porous sandstone and is undoubtedly due to its water-bearing capacity as opposed to the silty sands below. There are occasional limy pelecypod lenses. 100 feet from the base is a 5-foot silty sandstone, and 120 feet from the base is a 6-inch lens of *C. meekianum* and *P. lordi*. 135 feet above base is a strong outcropping lens of *C. meekianum*	165
17	Massive fine-grained sandstone; pelecypods are rare, limy lenses are few, and the sandstone has a massive appearance	50
16	Sandstone with a series of thin,cemented pebble lenses averaging 1/2 inch to 6 inches in thickness. The pebbles are rounded, hard black cherts principally, which average 1/2 inch in diameter. There are rare pelecypods	15
15	Massive pebble conglomerate; pebbles average less than 1/2 inch diameter, with a few to 1 inch	15
14	Sandstone with pebble lenses	15
13	Blue-gray, tough, claystone alternating with fine to medium-grained brown sandstone (ERS Foram 6 taken of the claystone.)	10
12	Coarse brown sandstone with lenticular pebble beds	2
11	Blue-gray, tough siltstone alternating with fine-grained brown sandstone	10
10	Massive, sandy, pebble conglomerate overlying a cut surface of the siltstone below	20
9	Blue-gray, clayey siltstone	25
8	Sandy, pebble conglomerate with a few small pelecypods and some echinoids (*Anorthoscutum oregonense*). This is the lowest occurrence in the section for *A. oregonense*.	1
7	Friable, buff, massive, fine-grained sandstone with a 2-inch bed of *A. oregonense* 3 feet from the base, and a pebble lense 4 feet from the base. 27 feet above the base is a 2-inch limy bed of pelecypods (*Macoma nasuta*, and other thin-shelled forms), and *A. oregonense*. 22 feet above the base is a 2-inch limy bed of *A. oregonense*. At 29 feet are a few pelecypods (the highest	

	seen in the section). at 67 feet, 77 feet and 87 feet are thin lenses of *Anorthoscutum* (highest marine fossil seen.	107
6	Massive, buff-weathering, fine-grained sandstone with lenticular pebble streaks to 4 inches thick in the lower part which increase in number and size to 1 foot thick every other foot in the upper part. The pebbles average 1/2 inch in diameter.	65
5	Sandy, pebble conglomerate.	8
4	Buff sandstone with pebble lenses.	30
3	Claystone with considerable carbonaceous material. A large carbonized stump, 2 feet in diameter is inverted near the top.	10
2	Pebble conglomerate and fine-grained sandstone. (Member (2) is the highest measurable unit in the continuously exposed section on the east bank of the Eel River.)	5
1	Predominantly massive, buff-brown weathering sandstone which is moderately clean, friable and fine-grained. Thin pebble lenses and pebble conglomerate members are occasionally interbedded, and a few thin claystones are present. No marine fossils are observed. This sandstone forms the sheer cliffs of Scotia Bluffs which can best be seen from Rio Dell along U.S. Highway 101. The thickness given here was figured along section C-C' on the cliff in sec. 32, 2N. 1E; the slope of the cliff is between 50° and 60° from horizontal, and the dip of the beds average 33°, thus the thickness of the beds approximates the thickness as measured along the cliff slope; approximately. ... (Due to sheer cliffs thickness manned by calculation).	1300
	Scotia Bluffs sandstone, total	2117

Carlotta formation

(Due to structural features, heavy vegetation, and lack of continuous exposures at any one place, no completely adequate type section can be given. For this reason estimates of total thickness are only approximate. That which follows must serve as the best and most complete section possible under the circumstances. While not strictly along Eel River, it is measured on a continuation of the general bearing of the Eel River Section and is measured normal to the strike of the beds at approximately the same part of the basin. Reference to Section C-C' will aid in the interpretation of the structural conditions which must be considered, although part of the section is measured to the west of this at the Circle R Ranch, and part to the east in the Hammond Tree farm area and Cuddeback Creek area.)

Circle R Ranch area, sect. 25, T. 2 N. R. 1 W., (near Metropolitan)

10 Massive, hard, strong outcropping, brown, cobble conglomerate. Psephitic material is 2 to 4 inches in diameter, rounded to sub-angular cobbles of Franciscan rock types, which are bonded together with clayey and ferruginous material. Sorting as to size is poor. This is the lowest massive cobble conglomerate in the Wildcat group and is picked as the base of the Carlotta on that basis. It may be seen at the base of the cliff at the east end of the Circle R Ranch where it overlies a massive buff sandstone picked as the top of the Scotia Bluffs formation at this point. (The contact is gradational and lateral variation is such that no time-stratigraphic boundary is concerned in mapping these two units.) 20

9 Poorly-exposed, alternating, pebbly sandstones and massive pebble-cobble conglomerate, each unit averaging 20 to 30 feet........................100

8 Massive, brown, medium-grained, compact sandstone... 20

7 Massive, unsorted, pebble to boulder conglomerate. This conglomerate is bonded together with argillaceous, sandy material and some ferruginous cement giving it a reddish-brown color. The hardness of the rock varies with the degree of cementation; the upper 20 feet is very resistant and forms a strong outcropping ledge. While the debris varies from clay to boulders 8 inches in diameter, the average size is in the cobble range. These fragments are rounded to sub-angular Franciscan cherts, sandstones, basalts, serpentine, and schists in the larger sizes, and mainly rounded to sub-rounded black cherts, quartzites and reworked pre-Franciscan types in the smaller sizes...100

6 Massive brown, medium-grained, compact sandstone.... 20

5 Poorly-exposed and inaccessible in part, but principally alternating, massive sandstones and cobble conglomerates averaging 20 to 50 feet in thickness. Variation of cementation causes an alternation of strong and weak outcropping ledges. The aggregate thickness approximates................300

4 Massive, strong outcropping, cobble conglomerate which forms the backbone of the main ridge 50

Hammond Lumber Company Tree Farm area (sec. 26, T. 27, R. 34, and 35, T. 2 N. R. 1 E)

3 Poorly-exposed and inaccessible in part, but mostly composed of alternating sandstones and conglomerates as in member 5..........................200

2 Pebble-cobble conglomerates and pebbly sandstones alternating with blue-gray claystones. There is typically a gradation as follows: 20 to 100 feet of coarse cobble conglomerate grading up into finer conglomerate and sandstone and finally into 10 to 30 feet of claystone, than a strongly-cut, erosional surface on the claystone and a repetition of the cycle. The claystones have abundant carbonized wood fragments ranging in size from 1mm. to stumps 1 foot in diameter; lignite beds are present and some leaf beds were found. The conglomerates are unsorted with material ranging from clay to occasional boulders up to 8 inches. Pebbles and cobbles form the greatest percentage of fragments; interstitially there is often a sandy and clayey matrix with occasional ferruginous cementation. Much of the conglomerate is loose-to-poorly-compacted, but it forms steep, nearly vertical cliffs as the interbedded claystones are eroded and undercut. The ferruginous coating of some of the fragments is reddish-brown, quite different from the yellow-brown of the later gravels. The sandstones are medium-to-coarse grained, poorly-sorted, and argillaceous. Most of the discernible grains of the sandstones and conglomerates have a Franciscan aspect; red cherts, basalt and sandstones are typical. This debris varies from angular to rounded. The approximate thickness..................................1500

Cuddeback Creek area (sec. 23, T. 2 N. 1 E.)

1 Massive dirty, unsorted, cobble conglomerate alternating with massive, brown, fine to coarse-grained sandstone. The beds show channeling, rapid gradations, and lensing but average between 10 and 50 feet in thickness. No claystone beds are seen, but the only area where this part of the section is exposed is in nearly impenetrable brush and exposures are poor. The thickness is only approximate and is subject to correction because of the difficulties in deciphering the structure near the Little Salmon Creek Fault........ 1000

3310

Approximate thickness, Carlotta formation......... 3300'

(This figure seems too high in comparison with thickness estimates to the west, but with the writer's present structural data this would not be a maximum in the area where this section was measured.)

Wildcat group, total thickness........................... 11733
or, in line with the lack of accuracy in the upper part of the section, an approximated total of .... 12000'

Additional notes on the section measured at the base of the Pullen formation on the east bank of the Eel River by Scotia.
(This section is equivalent to the basal 100 feet of the Pullen measured on the west bank but shows no direct correlation of component parts. A 9-foot gap of exposures between Yager sediments and the lowest Pullen sandstone is covered with alluvial gravels.)

1	Fine-grained, light gray to buff, compact sandstone with clots of black to dark-gray-green Yager shale. The fragments of shale are angular, range in size from 1/8 to 2 inches, and make up 70 percent of the bed..............................	2
2	Sandy breccia made up of angular fragments of Yager sandstone up to 8 inches across with sand similar to that in (1).......................................	0.8
3	Sandstone as (1) with sub-rounded, greenish-black pebbles of Yager shale......................	3
4	Gray, compact sandstone similar to (1) with a few shale pebbles................................	1
5	Breccia of Yager sandstone angular fragments up to 9 inches in diameter set in a matrix of pulverized Yager shale debris (similar to landslide material seen on present slopes)....................	6
6	Hard, well-cemented fine-grained, gray to buff, feldspathic Pullen sandstone with occasional chunks of Yager sandstone.........................	7
7	Breccia-rubble as (5) but with numerous polished black, rounded, chert pebbles........................	3.5
8	Sandstone as in (1) with 6 feet long, 1 inch thick lenses of Yager rubble in the upper few feet.	10
9	Sandstone as (6) with the upper foot slightly glauconitic...	66
10	Sub-angular fragments of Yager sandstone to 4 inches with shale fragments and rounded pebbles ..	0.5
11	Very fine-grained, silty sandstone to end of exposure	14
		110.8

COAST SECTION

(Measured along coast from southern exposures of Pullen formation in the 1906 slide area (sec. 26,T. 2 N. 3 W.) north to contact with unconformably overlying Hookton formation. Base of Wildcat group poorly exposed because of large slide; upper part not present because of overlapping by the Hookton.)

Hookton formation (top to bottom)

> Approximately 420 feet of ocherous, orange-brown, poorly consolidated, medium to coarse-grained sandstones and pebble conglomerates. The beds are a few inches thick to over 20 feet thick, locally strongly cross-bedded, and somewhat lenticular. The grains are individually coated with iron oxides. This unit overlies the Wildcat group with an angular unconformity.

WILDCAT GROUP

Rio Dell formation (4720')

Upper member 2620'

570'	mainly massive mudstone with some interbedded, gray siltstone; occasional thin limy layers and a few 2-inch friable fine-grained sandstones indicate bedding. *Pecten caurinus* is common and a few forams are present.
250'	phantom-banded, thin, alternating siltstones and mudstones except for the upper 15 feet of section which contains several 4-inch to 2-foot fine grained sandstones. Numerous molluscs are present, especially *P. caurinus*. (Hughes noted some brackish water forams and carbonized wood fragments in this upper sand and picked it as the base of his Ferndale sandstone.)
600'	massive mudstone without megafossils except for a bed of large mud pectens (*Pseudoamusium* n. sp.), 200' above the base. Forams characteristic of the "upper Pico," (*Gaudryina triangularis*, *Cassidulina californica*) are common.
1200'	phantom-banded, alternating mudstones and siltstones; the average thickness of each is 5 to 10 inches. 150 feet below the top is a 10-inch off-white, impure, rhyolite ash bed. Pelecypods are common; 220 feet below the top is a 4-inch limy bed of *P. Caurinus*, and another 750 feet below the top. Some "upper Pico" forams are present. 330 feet above the base is a 1-foot siltstone containing clots of glauconite to 1/4 inch (the only glauconite above the Eel River for-

mation)' associated are some limy concretions and carbonized wood fragments. There are a few thin sandstones near the base. At the base is a 6-foot tough siltstone containing abundant white-gray worm tubes (Bathysiphon?), 1/4 inches in diameter by 3 inches long; this overlies a massive, brittle, diatomaceous, light gray mudstone on an irregular cut surface (diastem or minor disconformity?). There are a few thin sands in the troughs of the cut surface.

Middle member 900'

100' hard, brittle, diatomaceous mudstone with a few thin sandstones. At the base of this member is 1 foot of laminated diatomaceous shale with white laminae of diatom concentrations.

800' alternating, rhythmically bedded, fine-grained, friable, gray sandstones averaging 2 to 4 inches and siltstones averaging 4 inches to 3 feet thick. The sands average 20 percent of the section in the upper part, 50 percent in the middle part, and 20 percent in the lower part. The siltstone beds are more resistant than the sands in the beach cliff. The base is picked at the lowest of the 6-inch alternating sands; the contact with the lower member is gradational. A few "middle Pico" forams are present (Bolivina spisea, Bolivina robusta, and Uvigerina peregrina).

Lower member 1200'

400' siltstone with thin 2-inch sandstones every 6 feet to 10 feet of siltstone; part of this is poorly exposed due to slumping.

400' alternating fine-grained, friable, gray sandstones and siltstones. The upper 50 feet has several sandstones to 8 inches and some limy nodules; the middle 300 feet has 2 inch sands alternating with 6 to 8 inches of siltstone; the lower 50 feet has numerous sandstones from 8 inches to 2 feet in thickness and forms a resistant outcrop. "Lower Pico" forams are common (Bulimina subacuminata, U. peregrina).

300' alternating 2-inch sandstones and 2-foot siltstones.

100' siltstone with rare sandstones; the lower 2 feet of siltstone is glauconitic and contains carbonized wood fragments. The basal 2 inches is dark green, glauconitic sand which overlies and truncates an irregular cut surface the interbedded sandstones, limestones, and siltstones of the Eel River formation. The angle of discordance is small, being about 5°; this contact is an important unconformity on the basis of lithologic and faunal evidence.

Eel River formation (820')

370' gray to brownish-gray siltstone-mudstones with numerous thin, 2 to 4 inches, friable, gray sandstones. There is one glauconitic sand, 4 inches thick 3 feet below the unconformity and numerous orange-weathering limy sandstones are present. Part of this member is poorly exposed due to slumping.

80' several sandstones 4 to 20 feet thick interbedded with siltstone. The sands are fine-grained, feldspathic, and locally calcareous.

300' siltstone, tough mudstone and a few thin friable sandstones. The mudstone weathers with a brown-gray fracture surface and may be somewhat glauconitic. "Repetto" forams are common (*Plectofrondicularia californica*, *Bulimina subcalva*).

70' tough to brittle, ashy, diatomaceous, gray siltstone, ash beds, and basal glauconite sandstone beds. At the top is a 2-inch pure, white, rhyolite ash bed grading up into 2 feet of impure sandy ash; 35 feet above the base is a 2-inch white, pure ash bed; 20 feet above the base is a 6-foot dark green, hard, glauconite sandstone with numerous large borings and carbonized wood fragments; 6 feet below this is a 2-foot glauconite sand; and the base is picked at a 1- to 3-foot glauconitic, conglomeratic sandstone which contains clots of angular to slightly rounded orange limestone cobbles to 8 inches and small rounded pebbles. The lower surface is somewhat irregular; it is believed to be a disconformable contact.

Pullen formation (800')

200' the upper 50 feet contain several 2-inch glauconitic sandstones; the rest of this exposed member is massive, tough to brittle, ashy, diatomaceous, light gray to buff siltstone and mudstone.

600' the formation below this upper 200 feet is all part of the great slump of 1906 in the coast section. None of it is in place although some of the stratigraphic relations are apparent due to the slump rotating as a mass; approximately the lower 200 feet are obscured including the basal contact. The upper 400 feet(?) is buff-white when weathered, brittle, hard and diatomaceous. The lower part is dark gray mudstone with a rusty fracture coating. There are a few thin glauconitic sandstones and some thin ash beds. Numerous orange limestone nodules are present. Forams are rare; many of the ones identified have both Pliocene and upper Miocene affinities. The contact with the rocks of the False Cape shear zone is not exposed but it is presumed to be a fault which has had little effect on the thickness of the Pullen formation.

False Cape shear zone

fault contact with the Pullen formation. The rocks of the shear zone include sheared sandstones, basalts, cherts, pulverized shales and a few fragments of Pliocene limestone.

WILDCAT RIDGE SECTION

(Measurement started at the Pullen-Yager contact at intersection of Wildcat Ridge road and Bear River Ridge road in sec. 34, T. 2 N. R. 2 W. and continued along Wildcat Ridge road to intersection of this road with the Centerville Beach road near Ferndale (sec. 11, T. 2 N. R. 2 W.). Exposures poor along many parts of road and much of soft Pliocene material is deeply weathered. Upper part of Carlotta formation not exposed.)

WILDCAT GROUP

Carlotta formation (1620')

Top not exposed.

300' massive, friable, poorly consolidated, tan-brown, fine grained to medium-grained, feldspathic sandstone with occasional slight indications of bedding due to vertical size and porosity variations. There are occasional streaks of mudstone pebbles (reworked Wildcat mudstone). 150 feet below the top is a 2-foot lenticular bed of silty, sandy, cobble conglomerate.

200' exposures poor, but mainly soft, fine-grained, silty sandstone beds alternating with 5- to 10-foot beds of loose, pebble and cobble conglomerate; there is a strong outcropping conglomerate, 15 feet thick at the base.

100' approx. thickness of poorly exposed, soft gray siltstone and claystone with a soft sand at the base.

50' loose, pebble to cobble conglomerate and pebbly sandstone. A few fragments are small boulders; all of the fragments are Franciscan cherts, graywackes, basalts, and because of the resistance to weathering of these components this bed makes a strong ridge.

300' slumped material, principally soft siltstone, claystone, and friable sandstone.

50' massive tan, friable, fine-grained sandstone except for the upper 10 feet of thin-bedded sandstones, averaging 1 inch alternating with 1/2 inch dark gray shales.

There are a few 1/4 inch layers of rounded, carbonized wood fragments in the alternating sandstones.

350' massive, strong outcropping, unsorted, sandy, brown, poorly consolidated, cobble conglomerate containing a few lenses of dirty tan sandstone, and a 50-foot pebbly sandstone 75 feet above the base. The conglomerate shows all grain sizes from clay to small boulders; is mostly Franciscan debris (identifiable sizes); and has rounded to angular pebbles and cobbles which are bonded together to a slight extent by clay and ferruginous cement.

100' upper part is buff-tan, friable, fine-grained, feldspathic sandstone with a streak of siltstone pebbles near the top; the lower part is poorly exposed fine silty sand.

7' light-gray to off-white, impure ash with silt-size ash beds laminated with clay-size ash in the upper 1 foot.

93' fine-grained, friable, buff sandstone.

20' blue-gray, carbonaceous siltstone.

50' massive, unsorted, cobble conglomerate, as previously described; this bed forms a strong outcrop due to the resistance of the component cobbles. This is mapped as the base of the Carlotta formation; the contact is gradational.

Scotia Bluffs sandstone (1860')

300' massive, friable, buff-weathering, clean, well-sorted, fine-grained, feldspathic sandstone. This sandstone forms cliffs and makes strong outcrops indicating a certain amount of induration. Local ferruginous cementation forms red-brown concretionary lenses. The only true indication of bedding is a slight shadowy banding due to a slight vertical variation in grain size. In the middle part are several pebble streaks and 2-inch beds of polished black chert pebbles. No fossils are present in this or other beds above.

200' poorly exposed siltstone at the base, grading up into alternating siltstone and silty sandstone and fine, friable, soft sandstone with clots and pebbles of siltstone in the upper part.

60' massive, buff sandstone near the base grading up into silty, fine sand. Numerous slump effects, (depositional features), include: irregular lenses of rounded chert pebbles and siltstone clots at variance with the bedding, and masses of sandstone at variance with the bedding. Some molluscs are present (the highest marine fossils in the section).

500'	upper 200' is massive, strong outcropping, buff-weathering, compact, fine-grained sandstone with occasional thin, 1/4 inch thick, silty partings. The middle 150 feet is alternating sandstones, 1 to 5 feet thick, and siltstones, 1 inch to 1 foot thick. The lower 150 feet is massive, strong outcropping, buff sandstone with 1 to 5-inch siltstone beds at 5-foot intervals.
400'	poorly exposed; principally siltstone and mudstone with some minor sands; contains some forams, "upper Pico" types.
400'	the upper 150 feet is massive, fine-grained, buff-weathering sandstones alternating with thinner sandy siltstones and silty sandstones. The sands range from 10 to 25 feet thick. *Pecten caurinus* and *Cerastoderma meekianum* are common. The middle 150 feet has alternating 1-foot silty fine-grained sandstones and 1-foot gray siltstones. *Pecten caurinus* is common. The lower 100 feet is massive, buff-weathering, fine-grained sandstone with numerous silty 1/2 inch partings at 1 to 10 foot intervals.

Rio Dell formation (3610')

1400'	poorly exposed; principally massive, spheroidal-weathering, dark gray mudstone and some phantom-banded siltstone and mudstone. The lower part is more silty. 200 feet above the base is 1 foot of diatomaceous mudstone with thin, white laminae of diatomite.
500'	alternating, thin, 4 to 12-inch sandstones and 2 to 6-inch siltstones. 150 feet from the top is 50 feet of light gray to off-white, weathered diatomaceous siltstone and thin, gray-white, papery, diatomaceous shale with some white laminae of diatomite.
250'	poorly exposed massive siltstone with common molluscs, especially *P. caurinus*. Some large orange limestone nodules are 2 feet in diameter.
600'	poorly exposed; predominantly siltstone with thin sandstones at 5 to 10-foot intervals. Contains some "Pico" forams: especially *Uvigerina peregrina* and *Bulimina subacuminata*. At the base is a 2-foot sandstone deposited on an irregular, cut surface of dark gray mudstone (diastem of uncertain importance).
500'	poorly exposed buff-weathering siltstones with a few thin sandstones.
60'	alternating, fine-grained, compact sandstones, ranging from 6 inches to 8 feet in thickness,

and siltstones averaging 6 inches to one foot thick. There are numerous irregular ferruginous concretionary masses in the sandstones.

300' poorly exposed siltstone except for a 50-foot soft sand 200 feet below the top. (The base of the Rio Dell is placed tentatively at the bottom of this siltstone member. No definite point can be established but the important change in strike of the beds below and faunal evidence indicate that this is approximately the base. The unconformity exposed at the coast is either lacking distinctive features or is obscured.

<u>Eel River formation (600')</u>

600' principally massive, nodular-weathering, tough, dark gray mudstone in the upper part becoming more silty in the lower part. There are a few thin sandstones and a 20-foot series of alternating sandstones and mudstones at the top. The exposures are poor in much of the section and the siltstones are often deeply weathered buff to rusty brown. "Repetto" forams (<u>Bulimina subcalva</u>, <u>Eponides tenera</u>, and <u>Plectofrondicularia californica</u>), are present. The thickness is somewhat uncertain due to the lack of good exposures. At the base is a 3- to 7-foot brown, fine-grained sandstone with 3 inches of glauconite sand at its base. Associated with the glauconite are small, rounded, chert pebbles and some 1/2 inch rounded pebbles of gray diatomaceous siltstone. This sand appears to be deposited on an irregular surface of diatomaceous buff siltstone. This sand is established as the base of the Eel River formation. In the road cut it is offset by numerous small faults.

<u>Pullen formation (600')</u>

600' principally weathered, creamy-buff, brittle, diatomaceous siltstone with a few thin feldspathic sandstones in the upper part. There is a one 1-foot sand 20 feet below the top. In the lower part the siltstone has a rusty color on fracture surfaces and several thin glauconitic sandstones are exposed. These sands have been leached and altered to a limonite gossan. A few ashy beds are present. The base is not clearly exposed but exposures in a 3-foot road cut of Pullen and Yager can be traced to within 5 feet of each other. No evidence of faulting exists and no basal sands are present. The Pullen is believed to overlie the Yager unconformably on the basis of attitudes.

Yager formation

Not measured; olive drab shale and biotitic graywacke.

PRICE CREEK SECTION

(Section measured from base of Pullen formation in contact with the Yager near Pullen farmhouse. Point is near a south branch of Price Creek and near great bend in Price Creek in sec. 5, T. 1 N. R. 1 W. Highest stratigraphic beds included are those immediately underlying Scotia Bluffs sandstone which crosses Price Creek near Weymouth Inn, sec. 27, T. 2 N. R. 1 W. Scotia Bluffs sandstone is not included in the section because it is poorly exposed.

WILDCAT GROUP (top to bottom), Scotia Bluffs sandstone

unmeasured, base is picked as a buff-weathering sandstone; the sandstone contains a few molluscs, is friable, soft, and greater than 150 feet thick.

Rio Dell formation (6000')

700' alternating very fine-grained, silty sandstones and mudstones, and some siltstone-mudstone phantom-banded alternations; some sands to 3 feet thick; dips very steep to overturned leading to some doubt as to thickness.

1900' massive dark gray mudstone members, and some phantom-banded alternations; occasional limy sandstones and a few thin, friable, fine-grained sandstones.

800' alternating sandstones and mudstones; average 2- to 4-inch sands and 4- to 8-inch mudstones (rhythmic); a few thin limestones.

200' massive mudstone with a few thin alternating sandstones near the base.

500' massive, spheroidal weathering, dark gray mudstone.

100' alternating friable, fine-grained, silty, gray sandstones and mudstones; in the lower part the sands average 2 to 3 feet thick while the mudstones are 6 to 18 inches thick; in the upper part there are two thick sands, one 10 feet and one 8 feet.

50' massive mudstone.

100' alternating sandstones, averaging 1 to 3 feet, and siltstones, averaging 1 to 6 feet.

450' alternating thin sandstones and mudstones or siltstones; the fine-grained, friable sandstones average 6 inches to every 5 feet of mudstone, a few are 2 feet thick.

1200' massive, spheroidal weathering, dark gray mudstone except for a few thin, fine-grained, gray sandstones averaging 2 inches thick.

Eel River formation (1700')

1630' massive, dark gray, tough siltstones, mudstones, and occasional glauconitic sandstones. The mudstones are often glauconitic and weather with a rusty-brown stain on fractures; they contain occasional forams. At least nine prominent glauconitic, tough, tight, silty, sometimes limy, fine to medium-grained sandstones are present; glauconite varies from 10 percent to 70 percent of the total volume and the color varies from green-black to greenish-gray or rusty brown when weathered. The sandstones vary from 3 to 30 feet thick; the highest of these is picked as the top of this unit. There are a few, thin, friable, non-glauconitic sands.

70' glauconitic sandstone and a lenticular conglomerate. The section includes a basal 35 feet of fine to medium-grained, glauconitic, greenish-gray, compact sandstone, 2 feet of lenticular conglomerate made up of cobbles of orange-weathered limestone, and fine rounded pebbles, 5 feet coarse, glauconitic sandstone, 1 foot of sandstone with borings, and 27 feet of glauconitic sandstone (as previous).

Pullen formation (950')

750' massive, dark gray-black (when fresh), brittle, occasionally diatomaceous, mudstone with abundant forams locally; weathers with a rusty-brown fracture coating. Some small *mud pectens* (*P. pedroanus* ?). There are occasional glauconitic siltstones. The section is not completely exposed. Mohnian forams are present in the lower 300 feet.

50' massive, buff to dirty white, rusty streaked, compact, fine-grained, feldspathic sandstone; this sandstone is high in quartz and feldspar, and low in ferro-magnesians. Contains a few pelecypod casts. This sand is equivalent to the basal Pullen sandstone at Eel River. The sandstone is here more friable and clean. Exposures are incomplete and the thickness is not accurate.

150' sandy gray siltstone with some mudstone containing Mohnian foraminifera.

Base not exposed, 50-foot gap in exposures between the lowest Pullen and the highest

Yager. The contact is believed to be an angular unconformity.

<u>Yager formation</u>

Unmeasured thickness of hard graywacke and shale.

SECTION FROM THE TEXAS COMPANY

"EUREKA" 1, TABLE BLUFF

(Well drilled 1934-35; data furnished by Mrs. Margaret Moore Hughes; summary below is writer's interpretation of notes taken during the drilling of the well by Donald Hughes. Thicknesses are true, because of dip of beds, but dips were low enough so that error is small.)

WILDCAT GROUP, Carlotta-Scotia Bluffs undifferentiated (812'?)

250'	green-gray, fine to coarse, unconsolidated, often iron oxide stained, dirty sandstone; soft, gray siltstones and claystones; and occasional conglomerate lenses. The contact with the overlying Hookton is vague and this thickness is approximate.
460'	gray, fine-grained, friable, feldspathic sandstone except for a 6-foot gray siltstone at the top, and occasional conglomerates. There are a total of 11 conglomerates which average 1 to 4 feet in thickness; most of the pebbles are rounded, hard cherts, basalts and other Franciscan types, which average 1/2 to 1/4 inches in diameter, with a few beds ranging to small cobbles. Fragments of poorly preserved molluscs and pieces of carbonized wood are locally abundant in the sandstone.
40'	gray, compact siltstone.
62'	massive, gray, friable sandstone becoming very fine-grained near the base; contains several pebble "streaks", a few molluscs, and a layer of very abundant echinoids (<u>Anorthoscutum oregonense</u>), near the base.

<u>Rio Dell formation (3837')</u>

802'	gray, compact siltstone interbedded with some very fine-grained, gray, compact silty sandstones; a few forams are present; <u>Elphidium oregonense</u>, <u>Elphidium hughesi</u>, and <u>Globigerina bulloides</u>; probable "upper Pico" correlation.

1485' mudstone and siltstone with mudstone more common in the upper part; a few thin, friable sandstones. Probably "upper Pico", (Hughes).

350' section continues as above; forams present indicate correlation with "middle Pico," (Hughes).

307' section continues as above; forams are "lower Pico" types such as *Bulimina subacuminata*.

893' mudstones alternating with numerous, fine-grained, friable or compact, gray sandstones; many are 1 or 2 feet thick and fairly well-sorted; a sandstone at 44 feet above the base has numerous thin layers of lignitic material. There are a few thin, white, ashy streaks 500 feet above the base. "Lower Pico" forams are present (*B. subacuminata*).

Eel River formation (and partly?) Pullen formation (1155')

509' mudstone and siltstone with a rare thin sandstone. 94 feet from the top is abundant carbonaceous material; occasional mollusc fragments are present, and some good "Repetto" forams are identifiable although many are leached out. Some of the mudstones are glauconitic (in 1950 some of these glauconitic cores had a brown iron oxide stain due to the weathering of the cores within a core house for 15 years). Forams below the upper 200 feet of this member bear a close resemblance to the assemblage below the "lower Pico-Repetto" contact in the coast section (Hughes). *Plectofrondicularia californica*, *Bulimina inflata*, and *Cassidulina californica* are present 250 feet from the base.

424' hard, compact, rather brittle, dark gray mudstone which is massive and somewhat fractured; there are a few mollusc fragments and an *echinoid* petal 100 feet from the top (perhaps *Brizaster* sp. or *Schizaster stalderi* ?). Forams are rare and poorly preserved; *Bolivinita quadrata* near the base. The lower 30 feet is somewhat silty and a few thin sandstones are present.

222' predominantly sandstone: the upper 80 feet is fine to medium-grained, dark greenish-gray, glauconitic, poorly sorted, rather hard sandstone; a few feet of sandstone is less well-cemented and shows cuts of petroleum. The middle part, 76 feet, is massive, friable, very fine-grained, silty, gray sandstone with occasional limy layers. The lower 66 feet is hard, slightly glauconitic, fine to medium sandstone with a few hard siltstone members. Hughes reported *Haplophragmoides*, and *Cyclammina sp*. from a siltstone 48 feet above the base (he lists these two forms from the Pullen formation in the coast section). This is the basal member of the Wildcat group observed in the well.

Yager formation

Underlying the Wildcat group is 185 feet of Yager, part of an unmeasured thickness of hard graywacke with numerous calcite veins and shale pebbles.

GENERALIZED SECTION IN THE FRESHWATER CREEK

UPPER ELK RIVER AREA

(Section represents composite of details from various exposures and sections).

WILDCAT UNDIFFERENTIATED (principally upper Pliocene)

800' maximum thickness, usually not over 500 feet of section; mostly gray siltstone and mudstone with occasional sandstones. The section varies greatly even in local areas. A basal conglomerate is common; the fragments vary from small rounded pebbles to boulders of schist over 30 feet in largest dimension. Glauconitic sandstone is sometimes present at the base. Pholas borings sometimes are found in the huge schist boulders or in the underlying Yager sandstones. Some pelecypods are present at or near the base; near the upper north fork of Elk River are abundant *Glycimeris subobsoleta* and some *Pecten caurinus*; in Freshwater Creek, at the north edge of the Fortuna Quad., are numerous *Securella* staleyi and *Cerastoderma meekianum*. Forams are mostly middle to upper "Pico" types. A few samples taken at the base of the exposed Pliocene in the upper Elk River area have contained forams of "Repetto" type. Most of the Wildcat (undifferentiated) in this area is deeply weathered and poorly exposed.

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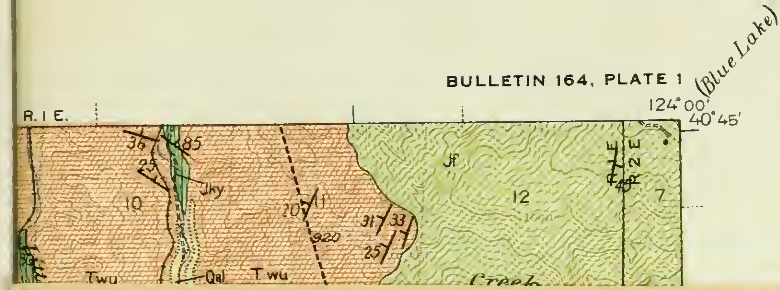
BULLETIN 164, PLATE 1



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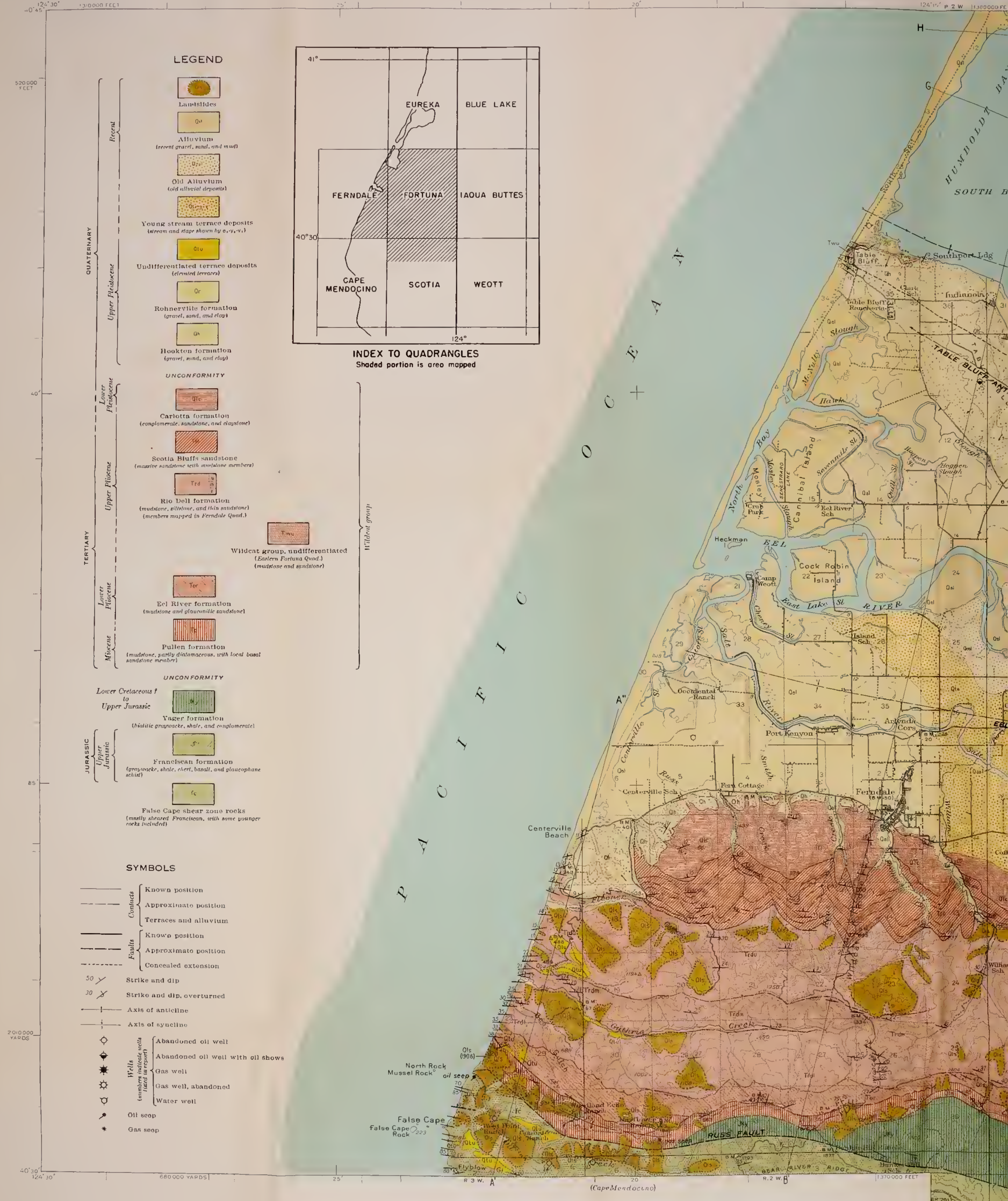


GEOLOGIC MAP OF THE EEL RIVER VALLEY AREA CALIFORNIA

By B. A. Ogle

Scale 1/62500

Contour interval 50 feet, (except Scotia Quad., 100 feet)

Datum is mean sea level

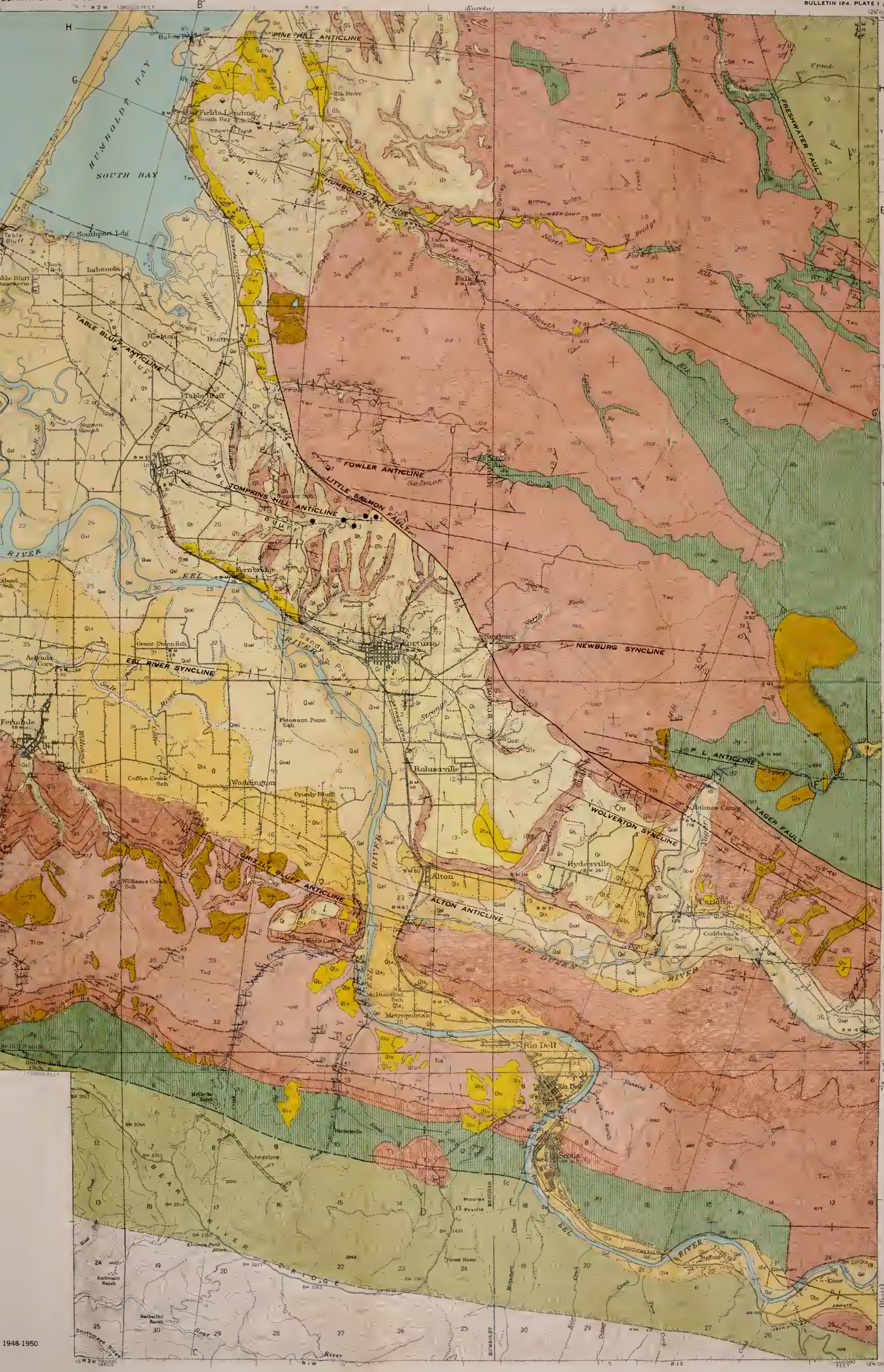
1953

Base from U. S. G. S.
Ferndale, Fortuna, and Scotia Quadrangles

Geology surveyed in 1948-1950

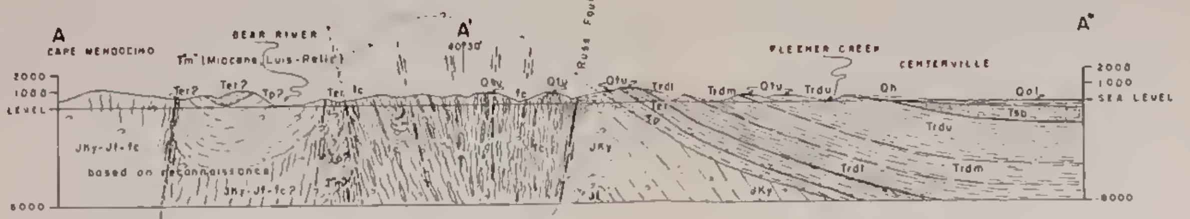
STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

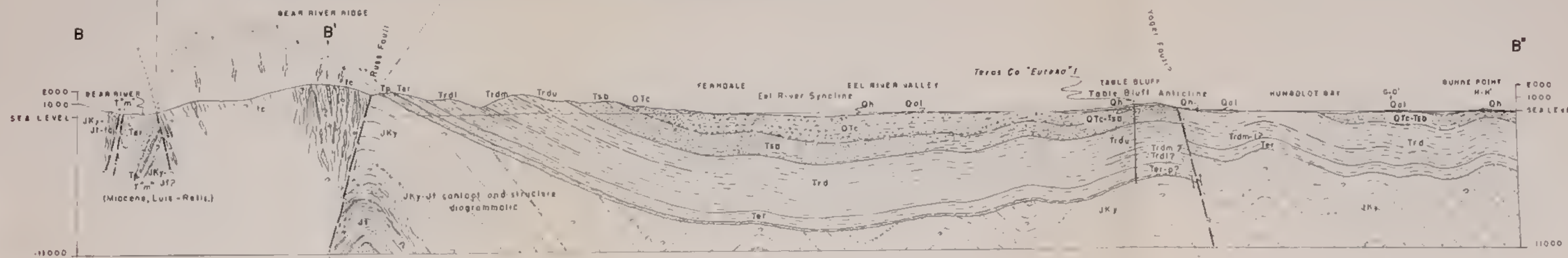
BULLETIN 164, PLATE 1

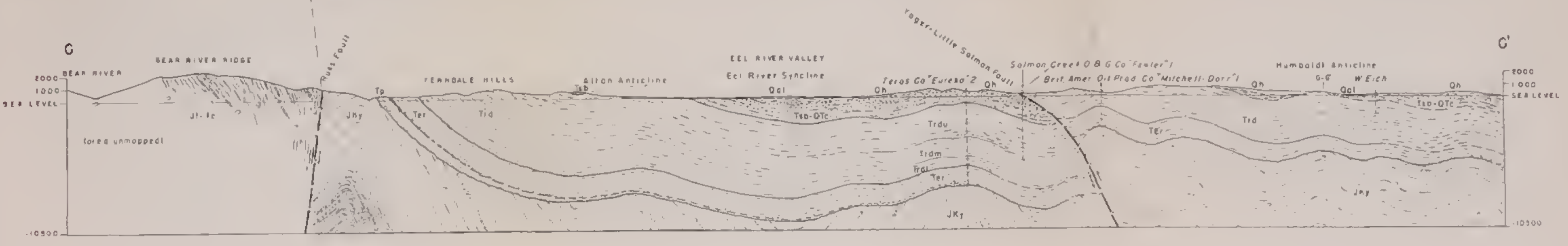


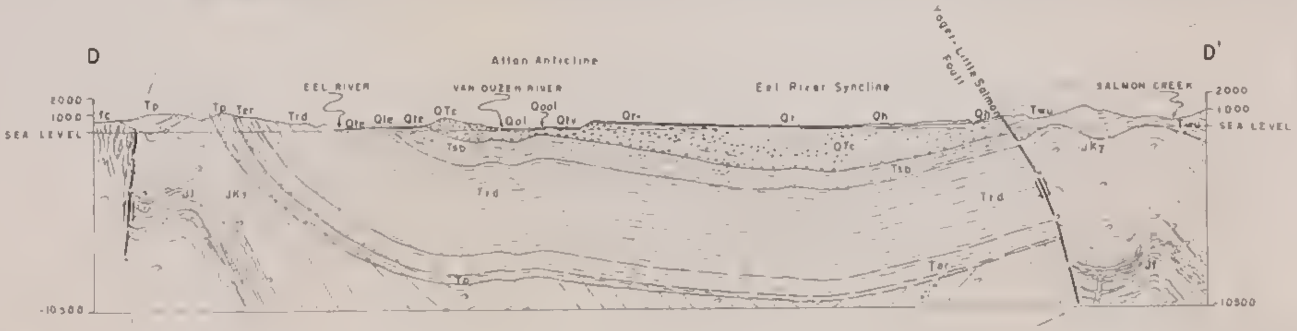
1948-1950

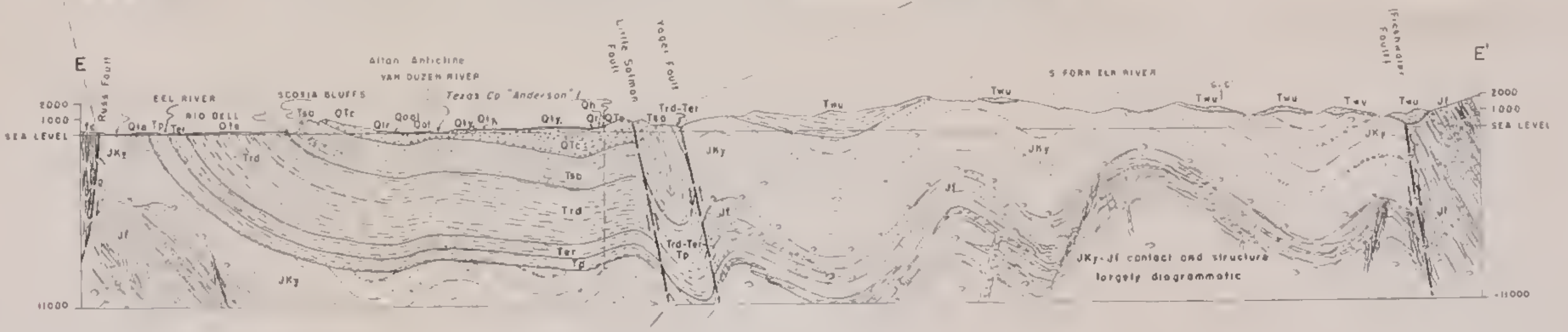
STRUCTURE SECTIONS ACROSS THE EEL RIVER VALLEY AREA, CALIFORNIA

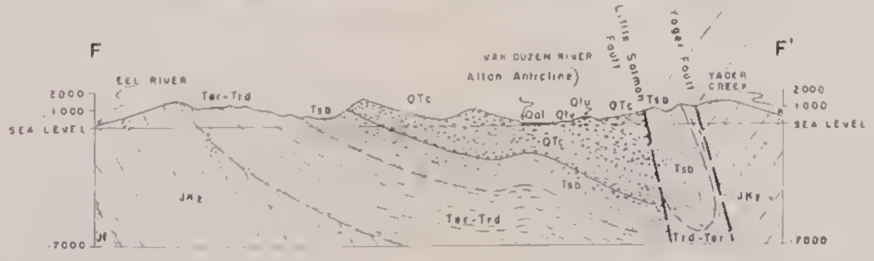


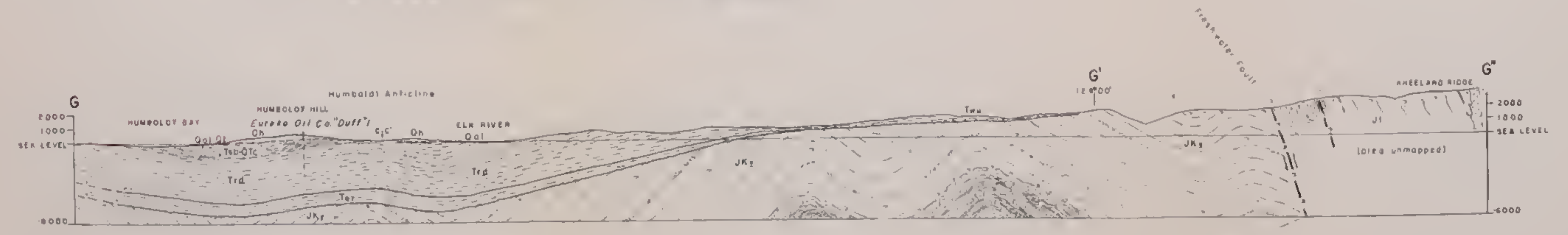












By B. A. Ogle

EXPLANATION

QUATERNARY — Recent

Qal
Alluvium
recent gravels, sands, muds

Qoal
Old alluvium,
old alluvial deposits

QUATERNARY — upper Pleistocene

Qte,-y,-r,
Young stream terrace deposits
stream and stage shown as e,-y,-r,

Qtu
Undifferentiated terrace deposits
elevated terraces

Qr
Rohnerville formation
gravels, sand, and clays

Qh
Hookton formation
gravels, sand, and clays

UNCONFORMITY

QUATERNARY — lower Pleistocene (Wildcat Group)

QTc
Carlotta formation
conglomerate, sandstone, claystone

TERTIARY — upper Pliocene (Wildcat Group)

Tsb
Scotia Bluffs sandstone
massive sandstone with mudstone members

Trd (u, m, l)
Rio Dell formation
mudstones, siltstones and thin sandstones
(members mapped in Ferndale Quad.)

Twu
Wildcat Group
undifferentiated

TERTIARY — lower Pliocene (Wildcat Group)

Ter
Eel River formation
mudstones and glauconitic sandstones

TERTIARY — Miocene (Wildcat Group)

Tp
Pullen formation
mudstones, partly diatomaceous, with
local basal sandstone member

UNCONFORMITY

JURASSIC-CRETACEOUS — upper J.- lower K.?

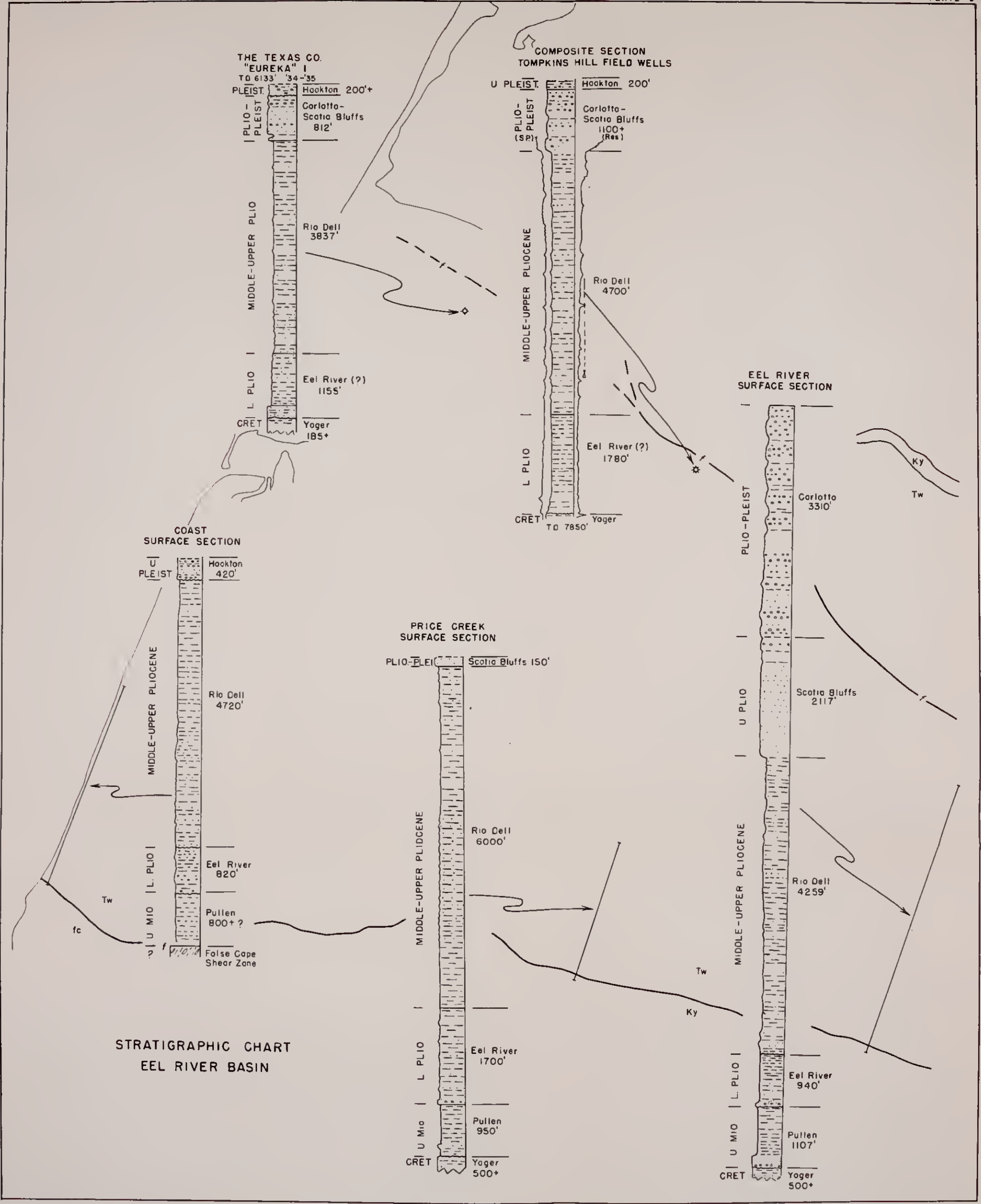
JKy
Yager formation
biotitic graywacke, shale, conglomerate

?

JURASSIC — upper

Jf
Franciscan formation
graywacke, shale, chert, basalt,
glaucophane schists

fc
False Cape Shear Zone rocks
mostly sheared Franciscan
with some younger rocks included



STRATIGRAPHIC CHART
EEL RIVER BASIN

CHECK LIST FORAMINIFERA AND OTHER COMPONENTS, WILCOAT GROUP

- ■ abundant
- ● common
- ○ rare
- X present

Formation		Locality	S & S	Angulogerina aff. hughesi (Galloway and Wissler)	Bolivina spissa Cushman	Buliminella elegantissima (d'Orbigny)	Cassidulina californica Cushman and Hughes	Cassidulina limbata Cushman and Hughes	Cassidulina lomitensis Galloway and Wissler	Cassidulina translucens Cushman and Hughes	Cibicides mckannai Galloway and Wissler	Elphidium aff. granulosum (Galloway and Wissler)	Elphidium sp.	Frondicularia advena Cushman	Gyroidina gallowayi	Planulina ornata (d'Orbigny)	Pullenia quinqueloba	Pullenia sp.	*Pulvinulinella pacifica Cushman	Uvigerina peregrina Cushman	Uvigerina sp. (costate)	Bulimina aff. pulchella d'Orbigny	Eponides aff. campanulata	Eponides pulvinulinaeformis	Gaudryina triangularis Cushman	Globigerina various sp.	Nonionella miocenica Cushman	Nonion pompilioides Fichtel and Moll	*Pulvinulinella bradyana Cushman	Bulimina subcalva Cushman and K.C. Stewart	Angulogerina angulosa (Williamson)	Bolivina aenariensis (Costa)	Bolivinita angelina Church	Bulimina subacuminata Cushman and R.E. Stewart	Bulimina rostrata H.B. Brady	Cassidulinoides parkeriana (H.B. Brady)	Clavulina communis d'Orbigny	Dentalina sp.	Valvulineria sp.	Fissurina sp.	Gyroidina subtenera	Nodogenerina lepidula (Schwager)	Nodosaria tosta (Schwager)	Nodosaria sp.	Plectofrondicularia californica Cushman and Stewart	Cassidulina cushmani Stewart and Stewart	Robulus sp.	Anomalina aff. limbata Terquem	Anomalina sp.	Globorotalia canariensis (d'Orbigny)	Textularia sp.	Sigmoilina sp.	Eponides tenera (H.B. Brady)	Nonion barleeanum (Williamson)	Nonion umbilicatula (Montagu)	Angulogerina pliocenica	Nodosaria koina Schwager	Uvigerina proboscidea Schwager	Pullenia sphaeroides (d'Orbigny)	Bolivina advena Cushman	Bolivina decurtata Cushman	Bolivina lomitensis Galloway and Wissler	Bolivina aff. marginata Cushman	Bolivina pygmaea H.B. Brady	Bolivina sinuata Galloway and Wissler	Buliminella henryana Cushman and Kleinpell	Cassidulina crassa d'Orbigny	Cassidulina modeloensis Rankin	Cibicides altamiraensis Kleinpell	Eponides healdi R.E. and K.C. Stewart	Nonion cf. costiferum (Cushman)	*Pulvinulinella subperuviana Cushman	*Pulvinulinella capitanensis Cushman and Kleinpell	Uvigerina hootsi Rankin	Gumbelina sp.	Cassidulina tortuosa Cushman and Hughes	Nonion scapha (Fichtel and Moll)	Arenaceous general	radiolaria and diatoms	sponge spicules	echinoid spines	forams	fish bone fragments	fish teeth	bird bones	pyrite aggregates	pyrite casts	glauconite	micas (especially biotite)	quartz	feldspar	glass shards	ferromagnesians	calcite	rock fragments	carbonaceous fragments
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*"Pulvinulinella" superseded by "Epistominella" 1944

*Notes:

S&S - Stewart and Stewart (1949) Coast section

uu - "upper unit", 500' - 2300'

mu - "middle unit", 2300' - 4500'

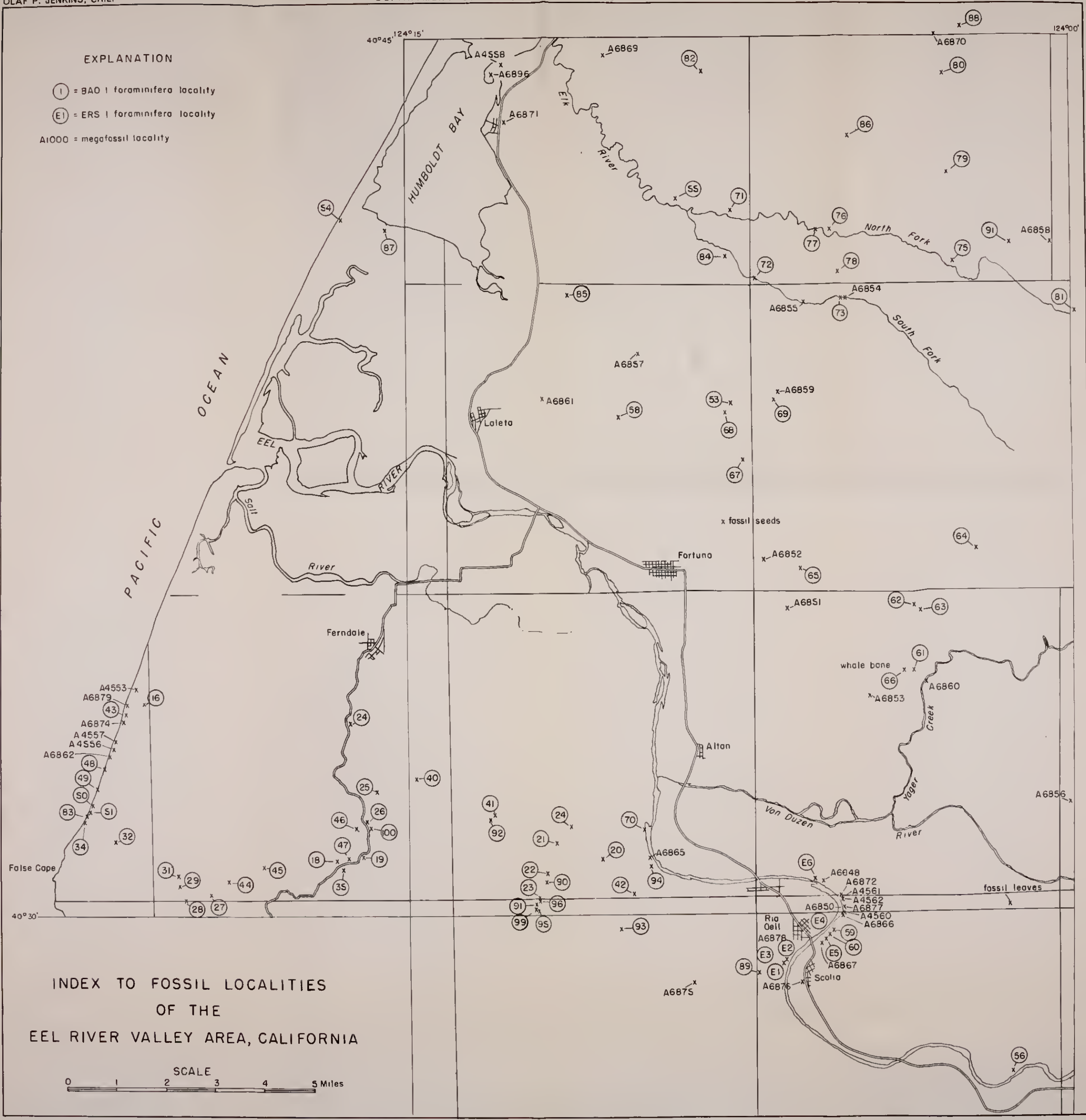
lu - "lower unit", 4500'-base

(see text, "Geology of the Eel River Valley Area")

CHECK LIST OF MEGAFOSSILS FROM THE WILDCAT GROUP

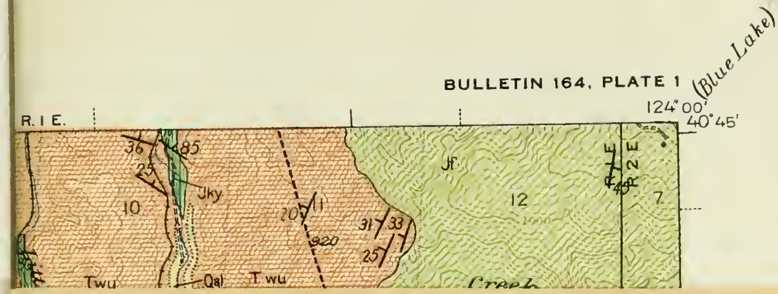
	A4551	A4552	A4553	A4554	A4555	A4556	A4557	A4558	A4559	A4560	A4561	A4562	A6848	A6849	A6850	A6851	A6852	A6853	A6854	A6855	A6856	A6857	A6858	A6859	A6860	A6861	A6862	A6863	A6864	A6865	A6866	A6867	A6868	A6869	A6870	A6871	A6872	A6873	A6874	A6875	A6876	A6877	A6878	A6879
Gastropoda																																												
Amphissa columbiana Dall						X																																						
Antiplanes perversa (Gabb)						X	X																																					
Argobuccinum arnoldi Martyn																								X																				
Argobuccinum scotiaensis Martyn						X																X																						
Colus jordani(Dall)																																												X
Natica russa Gould	X		X	X																																								
Neptunea lawsoni (Martyn)																																X												
Neptunea lirata (Martyn)						X																																						
Neptunea cf. N. venturaensis (Waterfall)							X																																					
Polinices lewisii (Gould)																														X														
Polinices sp.																	X																											
Thais canaliculata(Duclos)																																			X									
Thais lamellosa(Gmelin)	X					X																				X									X			X						
Pelecypoda																																												
Acila empirensis Howe				X																		X			X																			
Anadara cf. A. osmonti (Dall)																																									X			
Cardita cf. C. ventricosa Gould			X			X																																						
Cardium (Cerastoderma) meekianum Gabb			X									X													X					X	X											X		
Cardium sp.																										X										X								
Compsomyax subdiaphana gibbosus (Gabb)			X				X																																					
Compsomyax n. sp. ○		X																																										
Glycymeris subobsoleta Carpenter																							X																					
Lithophaga sp.																																								X				
Lucina acutilineata Conrad																			X																									
Lyonsia californica Conrad																																				X								
Macoma nasuta (Conrad)								X										X								X		X					X											
Mercia oregonensis(Conrad)			X																																									
Mytilus californianus Conrad																		X									X								X									
Mytilimeria sp.																					X																							
Nuculana sp.				X																																								
Ostrea lurida Carpenter								X																		X								X										
Pandora grandis Dall																	X																									X		
Pecten (Patinopecten) healeyi Arnold							X																																					
Pecten (Patinopecten) caurinus Gould		X	X				X			X					X										X					X														
Protothaca staminea (Conrad)																										X		X																
Psephidia lordi var. barbarensis Arnold											X		X													X																		
Pseudamusium pedroanus (Trask)							X		X																																			
Pseudamusium n. sp. ○																																							X					
Saxicava sp.																																								X				
Saxidomus nuttalli (Conrad)																										X																		
Schizothaerus nuttallii (Conrad)																																						X						
Securella staleyi (Gabb)	X													X																	X				X									
Siliqua patula (Dixon)																X	X																											
Solemya ventricosa (Conrad)																			X																									
Solen sp.																	X																											
Spisula albaria (Conrad)														X											X										X									
Spisula brevirostrata Packard	X		X																																									
Spisula catilliformis Conrad																									X																			
Spondylus n. sp. ○																																									X			
Teredo sp.																													X				X											
Thracia trapezoides Conrad															X																													
Thyasira disjuncta (Gabb)																			X																									
Yoldia sp.																																											X	
Scaphopoda																																												
Dentalium sp.							X																									X												
Echinoidea																																												
Anorthoscutum interlineatum (Stimpson)																																					X							
Anorthoscutum oregonense (W.B. Clark)																									X																			
Anorthoscutum sp.				X																																								
Brisaster n. sp. ○																								X																				
Cirripedia																																												
Barnacle fragments																												X							X									

new species=○



INDEX TO FOSSIL LOCALITIES
OF THE
EEL RIVER VALLEY AREA, CALIFORNIA

BULLETIN 164, PLATE 1



BULLETIN 164, PLATE 1