IV

Some Typical Upper Eogene Fish Scales from California

LORE ROSE DAVID

With four plates and ten text figures

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CONTRIBUTIONS TO PALEONTOLOGY

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Introduction

Fossil fish scales belonging to 16 families and to 18 genera from the California Eogene are described in this paper. The majority of the scales come from cores of the Kreyenhagen formation penetrated in oil wells of the San Joaquin Valley. In general, fish scales are plentiful in these strata, whereas there is a sparsity of such remains in the Middle and Lower Eocene.

The fossil specimens come from localities rather widely distributed, but not all occurrences of the Kreyenhagen shale have been sampled for scales. The collection shows great uniformity, so far as abundance of the more typical forms is concerned. It is certain that the important and characteristic fish types of Kreyenhagen age are well represented. The assemblage of scales does, however, contain a number of forms that are rare and too fragmentary to warrant description. Unquestionably, still other types will be found in regions not yet explored for this kind of material.

Special attention has been paid to scales of Upper Eocene age. Many of these, however, range in occurrence into the Oligocene. The Kreyenhagen formation, for example, which furnished most of the material, includes at its type locality rocks of Oligocene and Upper Eocene age (Jenkins, 1931, pp. 142–143). The present paper is concerned only with the Oligocene and Upper Eocene parts of the wells that were the sources of the fossil material. The age of the fauna is stated to be Upper Eogene rather than Upper Eocene and Oligocene, since the treatment of the Oligocene assemblages is very incomplete, and rocks of this age are represented by only thin sections in the region.

A number of new genera and species are established on the basis of scales, since the characters of these structures differ more or less markedly from those of any known form, living or extinct. It must be pointed out that in most instances the fishes to which the scales belong are not known, and the taxonomic position of the genera is frequently doubtful. Diagnoses of the genera have therefore not been given. It seems desirable not to present these diagnoses until such time as the scales and their classification are better known. The genotype species is the only one described for each of the new genera recognized in this paper. Species are described as fully as possible.

Sources of Fossil Material

The following wells in California, enumerated from north to south, were the principal sources of the material:

1. Pure Oil Company, Chowchilla No. 1, Chowchilla district, Sec. 7, T. 10 S., R. 14 E., Mount Diablo base line and meridian.

2. Seaboard Oil Corporation, Oro Loma No. 1, Sec. 12, T. 12 S., R. 11 E., Mt. Diablo B. and M.

3. Seaboard Oil Corporation, Gill No. 1, Sec. 27, T. 12 S., R. 15 E., Mt. Diablo B. and M.

4. Jergins Oil Company, Chaney Ranch No. 1, Panoche district, 330 ft. S. and 330 ft. E. of W. ¼ Sec. 29, T. 14 S., R. 13 E., elevation 392 feet, Mt. Diablo B. and M.

5. Western Gulf Oil Company, Lillis Welch No. 1, Firebough district, 680 feet N. and 990 ft. E. of SW. corner Sec. 26, T. 15 S., R. 12 E., elevation 1150 feet, Mt. Diablo B. and M.

6. Seaboard Oil Corporation, Welch No. 1, 1708 ft. S. and 2036 ft. W. of NE. corner Sec. 10, T. 16 S., R. 13 E., elevation 695 feet, Mt. Diablo B. and M.

7. Amerada Petroleum Corporation, Beer No. 1, Sec. 17, T. 26 S., R. 19 E., Mt. Diablo B. and M.

8. Texas Company, Pioneer Unit Plan Nos. 1 and 2, Sunset district: No. 1, 485.5 ft. S. and 2072 ft. E. of NW. corner Sec. 33, T. 11 N., R. 23 W., elevation 1375 ft.; No. 2, 2207 ft. S. and 2086 ft. E. of NW. corner, Sec. 33, T. 11 N., R. 23 W., San Bernardino base line and meridian.

Acknowledgments

The present study, carried on during 1942 and 1943, is one of several similar investigations conducted at the California Institute of Technology and financed by a number of petroleum companies of California. It is a pleasure to express appreciation to the following individual companies who helped to sponsor these projects: Bankline Oil Company, Continental Oil Company, General Petroleum Company, Richfield Oil Corporation, Shell Oil Company, Standard Oil Company of California, Superior Oil Company, Texas Company, Union Oil Company, Western Gulf Oil Company.

The core material from which the specimens of fish scales were collected was furnished by the Superior Oil Company, the Texas Oil Company, the Western Gulf Oil Company, the Richfield Oil Corporation, and the Ohio Oil Company of California. Dr. Chester Stock has given unstintingly of his time and effort in the supervision of many phases of this work. It is a pleasure also to acknowledge the facilities offered by the paleontological laboratory of the California Institute of Technology. Photographs of scales were taken in the laboratories of the Richfield Oil Corporation, Long Beach, California, and thanks are extended to M. L. Natland for his kind assistance.

Description of Fish Fauna

ORDER EUSELACHII GALEI

Family CARCHARIIDAE

Galeocerdo? sp.

(Text figure 1)

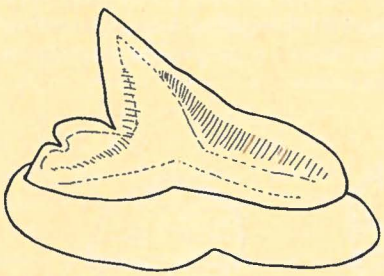

Fig. 1. *Galeocerdo?* sp. Tooth from Seaboard Oil Corp. well, Oro Loma No. 1. Kreyenhagen formation. Approx. × 9.

A small tooth of a shark, 2.3 mm. long by 3.7 mm. wide, was found in a core of the Oro Loma No. 1 well of the Seaboard Oil Corp., at depth between 3141 and 3170 feet, in the Kreyenhagen formation. The specimen evidently belongs to *Galeocerdo,* or to a related genus. Definite generic identification is difficult on the basis of a single tooth. The tooth is probably different from that of any known species. The small, compressed crown is deeply notched on one side, showing two notches in the basal part; the opposite side is concave. No serrations are observable along the cutting edge. The apex is noticeably deflected to one side. The specimen differs from known teeth of the genus in the concave outline of its unnotched side. *Galeocerdo* ranges from the Upper Cretaceous to the Recent.

ORDER ISOSPONDYLI

Suborder CLUPEOIDEA

Family DUSSUMIERIDAE

Pseudoetringus kreyenhagius, n. g. and n. sp.

(Plate 1, figure 4; text figure 2*e, f*)

L. R. David, Carnegie Inst. Wash. Pub. 551, III, p. 29, pl. 1, fig. 3, 1944.

Type. No. 10321, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4.2 mm. long by 5 mm. deep.

Type locality. Seaboard Oil Corp. well, Welch No. 1, at depth of 4037 feet. Kreyenhagen formation.

Description. A small scale which shows the following variations in measurements of length and depth (in millimeters): 5 by 5.1, 4.1 by 6, 4.5 by 5.1, 4.2 by 5, 4 by 5.1, 4 by 5, 3.9 by 4.9. Shape irregularly oblate, with a distinctly marked projection of anterior and posterior margins; edges of dorsal and ventral margins either broadly rounded or more or less straight (fig. 2*e, f*). Scale when preserved (pl. 1, fig. 4) shows considerable thickness, smooth side highly glossy; mold of smooth side shows unusually strong ridges marking transverse radii (David, 1944, pl. 1, fig. 3). If only

the impression of the coarse side is present, scale appears thin, for there is nothing to indicate its actual thickness. Scale more or less uniform, apical pole not divided from basal part by complete transverse radius. Basal part characterized by 6 to 8 pairs of strong, closely situated transverse radii, all more or less parallel; uppermost radii become short and more strongly inclined toward center of scale. Apical pole with a few (generally 5) well marked radii directed toward nucleus. Circuli restricted to basal part and small anterior sectors of apical pole at right and left of nucleus. Circuli transverse, very little rounded, widely spaced considering small size of scale; 50 in 1 mm. distance at middle of scale, 40 to 43 at outer margin in scale 4 mm. long by 5 mm. deep. Circuli increase in coarseness toward outer margin of scale, coarsest at dorsal and ventral margins. Outer border of scale folded 2 or 3 times, forming a characteristic strengthened margin.

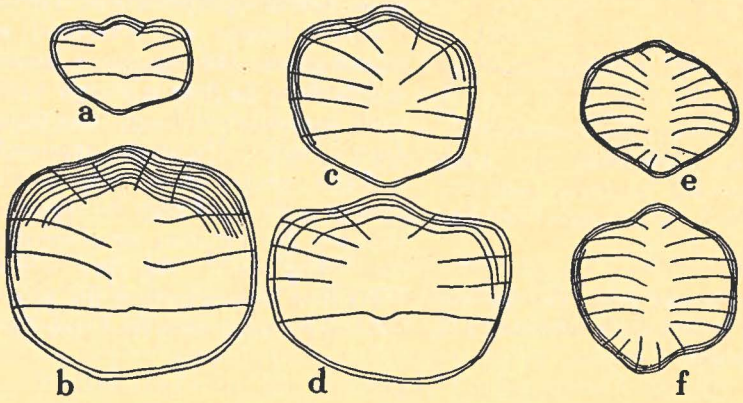

FIG. 2. *a–d, Wisslerius sardinelloides,* n. g. and n. sp. (*a, b*) Jergins Oil Co. well, Chaney Ranch No. 1. (*c, d*) Seaboard Oil Corp. well, Welch No. 1.

e, f, Pseudoetringus kreyenhagius, n. g. and n. sp. (*e*) Seaboard Oil Corp. well, Welch No. 1. (*f*) Pure Oil Co. well, Chowchilla No. 1.

Tumey and Kreyenhagen formations. × 4.

Occurrence. This form of scale is quite abundant in the Kreyenhagen shale, especially in the upper horizons. It was found in cores from the following wells: Seaboard Oil Corp., Welch No. 1, at depth between 4047 and 4245 feet; Jergins Oil Co., Chaney Ranch No. 1, at depth between 3543 and 3669 feet and between 4433 and 4460 feet; Pure Oil Co., Chowchilla No. 1, at depth between 2834 and 2859 feet; and Seaboard Oil Corp., Gill No. 1, at depth between 3988 and 4002 feet.

Relationships. Pseudoetringus shows the characters of a clupeoid fish without indication of near relationship to any Recent form. Scales of the Eogene type lack the dividing line between apical and basal parts. This fish was probably not a true herring. In the absence of this line and in the large number of paired transverse radii, the fossil shows some similarity to the Miocene *Etringus.* The latter genus, however, has an entirely different shape and a different apical structure. This small Eogene scale, with its thick, glossy structure, large number of strongly paired transverse radii, and few apical radii converging toward the center, is a distinctive type and may represent an extinct clupeoid family.

Family CLUPEIDAE. Herrings

Wisslerius sardinelloides, n. g. and n. sp.

(Text figure *2a–d*)

L. R. David, Carnegie Inst. Wash. Pub. 551, III, p. 29, pl. 1, fig. 4, 1944.

Type. No. 10322, Calif. Inst. Tech. Vert. Pale. Coll. Scale 5.2 mm. long by 7 mm. deep.

Type locality. Seaboard Oil Corp. well, Welch No. 1, at depth of 4236 feet. Kreyenhagen formation.

Description. Ovoid to quadrangular with rounded corners. Relatively large, sizes (length and depth, in millimeters) varying as follows: 8 by 9, 6.5 by 8.7, 6.5 by 7, 5.9 by 6, 4 by 5, 4 by 4.9. Basal outline more or less rounded, with middle part projecting; apical border rounded to angular. Apical part comparatively long, comprising one-third of scale length, completely divided from basal part by transverse radius. Basal region generally with 4 pairs of transverse radii, widely spaced at more or less equal distances; in smaller scales only 3 pairs present. Uppermost radii more distinctly oblique, pointing toward center; their direction may have been changed by strong folding of outer margin of scale. Circuli restricted to basal part except for small sectors in uppermost apical part. Circuli transverse; fairly fine in middle of scale, but becoming increasingly coarse toward dorsal and ventral borders with growth of scale; 47 to 50 in 1 mm. distance at nuclear center, 40 at dorsal and ventral borders of scale of 7 mm. depth, 39 in scale of 9 mm. depth, and 35 in scale of 10 mm. depth. Apical pole almost smooth, indistinct radii showing at apical border. A number of folds are seen around outer border of scale, these especially numerous on basal margin. Scale usually found with separated apical and basal parts.

The new genus is named for Mr. Stanley G. Wissler, paleontologist of the Union Oil Company, California.

Occurrence. The scale is abundant in the Tumey and upper Kreyenhagen. Well preserved specimens are commonly found in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 3570 and 3597 feet. Smaller scales of the same type are abundant in the same well from 3624 to 3864 feet. More or less fragmentary specimens are found from 4304 to 4407 feet. The scale is also abundant in the Seaboard Oil Corp. well, Welch No. 1, at depth from 4037 to 4236 feet, and in many others.

Relationships. In the shape of the apical and basal regions, and in the arrangement of the paired transverse radii, relationship is shown to *Sardinella,* a genus widely distributed today in warm seas. Close similarity is also shown to the related genus *Opisthonema,* an inhabitant of warm coastal seas. *Opisthonema libertate* from the Galapagos Islands has scales quite similar to the fossils. *Sardinella* has a greater number of paired transverse radii and more pronounced apical radii. *Sardinella sirmi* from the Philippine Islands and *S. clupeoides* from British North Borneo seem to be exceptions, but their radii are much less regularly arranged and even smaller in number than in almost any of the Eogene scales. The numerous folds along the outer margin, so characteristic of the fossil scales, are not present or are only faintly indicated in scales of Recent fish. The folds appear to develop as a result of compression of the scale during entombment in the rock. There is not much

doubt that the Eogene genus is related to the group of modern herrings comprising the genera *Sardinella* and *Opisthonema*. It differs to some degree, however, from all known living forms. This scale occurs in several groups of strata of the Kreyenhagen shale, but varies noticeably in size and to some degree also in shape. The type of scale that comes from the Seaboard Oil Corp. well, Welch No. 1, is of medium size and oval in shape. The well preserved scales of the genus found in the uppermost Kreyenhagen of the Jergins Oil Co. well, Chaney Ranch No. 1, are rounded, and are distinguished by their very large size. These may represent a different species, or a large variety. This part of the stratigraphic column correlates with the so-called Leda zone, and is higher in the section than that containing the remaining material studied. At other stratigraphic horizons the scales average much smaller.

? **Alosa ganolytoides,** n. sp.

(Text figure 3)

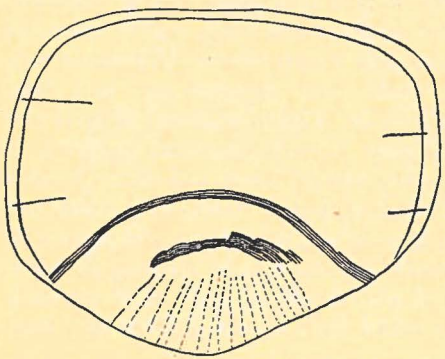

FIG. 3. ? *Alosa ganolytoides,* n. sp. Seaboard Oil Corp. well, Oro Loma No. 1. Kreyenhagen formation. × 4.

Type. No. 112, Paleontological Laboratory of the Richfield Oil Corporation, Long Beach, California. Scale 11.2 mm. long by 13.5 mm. deep.

Type locality. Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 3170 and 3200 feet. Kreyenhagen formation.

Description. Only a few specimens are known so far; a second large scale, similar to the type specimen, measures 10.5 mm. long by 11.5 mm. deep. Two smaller specimens are also available. Scales large, oblong, shadlike; basal part comprises two-thirds of scale, not distinctly separated from apical part. Numerous fine basal circuli, transverse to rounded, ending at dorsal and ventral margins; approximately 39 to 42 in 1 mm. distance. Circuli form irregular pattern and are not everywhere parallel. Pattern of basal radii not clearly shown; transverse radii present but not completely visible. Apical pole small, not always occupying entire apical margin, but restricted to a smaller sector. Apical radii form fine, broken tubercular lines; these are not so strong nor are the tubercles so numerous as in the Miocene *Ganolytes*. Not quite 4 radii in 1 mm. distance.

Occurrence. In addition to the type, there are three scales from the Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 4304 and 4330 feet.

Relationships. The scale shows resemblance to comparable structures seen in forms related to *Alosa,* as well as in the Miocene genus *Ganolytes*. *Alosa ganolytoides* is characterized by fine tuberculated and elevated radii marking the apical pole. These are considerably finer than in *Ganolytes,* but more distinct than in any of the Recent scales.

Suborder SALMONOIDEA

Family COREGONIDAE

Parastenodus gillensis, n. g. and n. sp.

(Plate 4, figure 4)

Type specimen. No. 110, Paleontological Laboratory of the Richfield Oil Corporation, Long Beach, California. Scale 5.2 mm. long by 3.9 mm. deep.

Type locality. Seaboard Oil Corp. well, Gill No. 1, at depth between 3852 and 3863 feet. Kreyenhagen formation.

Description. Round to elongate scales of medium size; a second specimen 4.1 mm. long by 5.2 mm. deep. Concentric circuli throughout scale, nowhere distinctly folded, showing slight deviations and irregularities almost everywhere. Type shows 2 fold-like curvatures of circuli at basal pole; a second scale more regularly concentric; circuli most distantly spaced toward apical pole (17 in 1 mm. distance), most closely spaced near dorsal and ventral borders (27 to 28 in 1 mm. distance). Nucleus acentral. Smooth side of scale marked by a number of tubercles in places. Annuli indistinctly shown, type probably a scale in its third year.

Occurrence. In addition to the type, only one scale was collected, in the Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 3229 and 3242 feet.

Relationships. The relationships of this salmonoid scale are presumably with the Coregonidae, as is indicated by the more or less concentric circuli that occupy the entire scale, the acentral nucleus, and the structure of the circuli. Scales of *Stenodus mackenzii* from Alaskan waters show irregularities of the circuli similar to those in the fossil form, although the Recent scales are considerably larger and more rounded. So far as the fossil is known, it cannot be assigned to any living genus. *Stenodus* seems to be the nearest living type.

Beckius plicatus, n. g. and n. sp.

(Plate 4, figure 5)

Type. No. 111, Paleontological Laboratory of the Richfield Oil Corporation, Long Beach, California. Scale 4.5 mm. long by 4.5 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 3570 and 3597 feet. Tumey formation.

Description. Scale almost quadrangular, broadening toward apical region. Basal part with sharp-angled folds, 2 in diagonal of laterobasal angles, 2 more central than these, with folds forming triangular projections of border. Nucleus central, surrounded by concentric circuli which rapidly increase in size and show typical folding of the basal part almost to the most central and smallest circuli. Circuli coarse, finest toward basal pole, 18 in 1 mm. distance toward basal border; circuli increase noticeably in width toward apical part of scale and along dorsal and ventral borders, 12 in 1 mm. distance toward apical border. Type evidently a lateral-line scale, apical circuli divided in middle.

The new genus is named for Mr. R. Stanley Beck, paleontologist, Bakersfield, California.

Relationships. The structure of the scale indicates relationship with the Core-

gonidae, although this seems to be less certain than in the preceding form. The fossil shows similarities to *Leucichthys nigripinnis cyaenopterus* from Lake Superior. In *Leucichthys,* however, the basal folds are not so well developed, nor are they symmetrical. The circuli in *Leucichthys* grow considerably wider in the apical region as in the fossil, but they remain close together along the dorsal and ventral borders. Also, in the Recent scale these structures do not show the coarseness seen in the much smaller fossil. The latter scale, with basal part divided into sharp angular folds and with circuli widening considerably toward the apical part, can be readily distinguished. A modern scale showing resemblance to the fossil form does not appear to be known, and the well preserved specimen apparently belongs to an extinct group related to the Coregonidae.

Family CYCLOLEPIDAE, new family

Cyclolepoides tuberculatus, n. g. and n. sp.

(Plate 2, figures 4, 5)

L. R. David, Carnegie Inst. Wash. pub. 551, III, p. 31, pl. 2, fig. 15, 1944.

Type. No. 10331, Calif. Inst. Tech. Vert. Pale. Coll. Scale 5 mm. long by 3.5 mm. deep.

Type locality. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth between 1851 and 1858 feet. Kreyenhagen formation.

Description. Irregularly rounded to oval scales, generally very large and thick. Occasionally small scales are present, the latter belonging possibly to a different species. Size (length and depth, in millimeters) varying as follows: 2 by 1.9, 3.1 by 3, 2.9 by 2.5, 3.9 by 2, 6.1 by 5, 7 by 5.9, 9 by 6.1, 12 by 9. Scales show simple structure, with fine concentric circuli equally marked on entire specimen. Nucleus central to subcentral, depending on shape of scale. Scale very thick. Distinct differences between coarse and smooth sides. Even and glossy in parts of smooth side (pl. 2, fig. 4); other parts marked by irregular furrows and cavities, penetrating more or less into scale, but not perforating it. Checkerboard pattern on coarse side penetrating in places through scale, especially along outer border, marking smooth side of scale with regular concentric rows of elevations that are coarser than circuli. Coarse side of scale (pl. 2, fig. 5) marked by concentric ridges of circuli, showing irregularities in places. Circuli usually marked by rows of pointed tubercles set on their upper edges. Tubercles arranged in diagonal rows, giving impression that diagonal cross-rows are present, and forming a checkerboard pattern which is distinct along outer border. Number of circuli variable, circuli most delicate in center; rings of fine and coarse circuli alternating toward outer border. The following counts in different specimens give numbers of circuli in 0.1 mm. distance found in successive rings from center of scale to outer border: Eogene scale with diameters of 7 and 8 mm.: 10, 7, 11, 7. Regenerated Eogene scale with diameters of 7.5 and 9 mm.: 7, 9–10. Eogene scale with diameters of 3 and 2.5 mm.: 10, 6, 7. Eogene scale with diameters of 1.9 and 2 mm.: 10, 7. Saucesian scale with diameters of 10 and 12 mm.: 13, 11, 8, 5½. Saucesian scale (David, 1944, pl. 2, fig. 15) with diameters of 6 and 4.9 mm.: 9, 11, 8, 6.

Occurrence. This scale is very abundant at particular horizons wherever found in the Upper Eocene. It was collected in the Eocene Kellogg shale of the Mount Diablo area. It occurs abundantly in the Western Gulf Oil Co. well, Lillis Welch No. 1,

at depth between 1087 and 1858 feet; in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 4304 and 4360 feet; in the Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 2800 and 3220 feet; in the Seaboard Oil Corp. well, Gill No. 1, at depth between 3935 and 4002 feet; in the Texas Co. well, Pioneer Unit Plan No. 1, at 8093 feet and deeper; in the Texas Co. well, Pioneer Unit Plan No. 2, at 9353 feet and deeper; and in other wells. The scale is not restricted to the Eogene, for it is found higher in the stratigraphic column, occurring in the Upper Zemorrian–Lower Saucesian. Here it is occasionally present, but is not abundant.

Relationships. Cretaceous scales of oval shape, with concentric circuli and subcentral nucleus, and without radii and ctenoid structures, have been assigned to the genus *Cyclolepis* (Cockerell, 1919). The Californian Eogene *Cyclolepoides* shows fundamentally the same structure. It is included in the Salmonoidea, following Cockerell's classification (1919, p. 181). This group of fishes shows for the most part the same type of simple scale as that so well represented by the living *Stenodus mackenzii.* The scale of *Cyclolepoides* differs in the fineness of its circuli, and in the regularly placed tubercles which follow the course of the circuli, giving the scale its peculiar pattern. The thick scales, with smooth side occasionally deeply furrowed, suggest a primitive condition, and they may represent an extinct group. These characters give the scale a typical aspect and make it easily distinguishable from all other fossil forms as well as from living Salmonoidea. It is questionable whether the scale represents a true salmonid fish. No other group is known to the writer, however, to which it might belong. The migratory habit of the form, as pointed out below, suggests a relationship to the salmons.

There can be little doubt that this fish was migratory. Annular rings of more or less crowded circuli can be seen on almost every scale, their extent varying in different scales. The length of time represented by such rings cannot be stated. The circuli nearest the middle are the densest, and those toward the outside are the least crowded, a fact which indicates that life started in fresh water and ended in a marine environment. Cockerell likewise regards the Cretaceous *Cyclolepis* as probably having had migratory habits. It is possible that the Cretaceous and Eocene forms represent a group of salmons that are extinct today. The location and depth where modern salmon feed, while in the sea, have not been definitely determined. Salmon have been reported, however, far out in the sea, beyond the continental shelves, and it is evident that feeding salmon frequent the waters of the open sea as well as those of the immediate coast (Davidson and Hutchinson, 1938, pp. 667 ff.).

The scale of *Cyclolepoides* is abundant in the Upper Eogene and may be an indicator of Eocene age. It has been found, however, in occasional core samples as high as the Lower Miocene.

ORDER INIOMI

Family ? CHLOROPHTHALMIDAE

Iniomus fossilis, n. g. and n. sp.

(Plate 1, figure 1)

Type. No. 10333, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4.1 mm. long by 4 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 3570 and 3597 feet. Tumey formation.

Description. Type and only specimen quadrangular in shape, with pronounced basilateral angles. Basal margin curved and projecting at middle; dorsal and ventral margins straight. Nucleus subapical. Basal region completely occupied by fine parallel circuli, concentric with basal, dorsal, and ventral margins; strongly bent in basilateral angle; circuli numerous, 34 to 35 in 1 mm. distance at basal border. No folding recognized. Most central circuli (about 6) wide. Apical pole almost restricted to apical margin, smooth, equipped with one row of relatively wide, probably flattened spines; 17 or 18 spines in less than 1 mm. length.

Discussion. The type is the only specimen thus far known, and is well preserved.[1]

Relationships. The scale shows the characters of the Iniomi, as indicated by the structure and position of the spines, and also by the arrangement of the circuli and the nuclear center. The circuli, however, are quite numerous for the group. The nearer relationships of the form are uncertain. It does not conform exactly to any one kind of scale in the available collections, but seems nearest to the Chlorophthalmidae in general structure. A considerable number of scales of genera of the Iniomi are still unknown, and it is possible that in future some near relatives of the fossil will be found among the living members of the group.

ORDER SYNENTOGNATHI

Family ? SCOMBERESOCIDAE. Skipjacks or Garpikes, Sauries

Praescomberesox pacificus, n. g. and n. sp.

(Plate 2, figure 3; plate 3, figure 2)

Type. No. 10325, Calif. Inst. Tech. Vert. Pale. Coll. Scale 7 mm. long by 7 mm. deep.

Type locality. Seaboard Oil Corp. well, Gill No. 1, at depth between 3895 and 3907 feet. Kreyenhagen formation.

Cotype. No. 10326, Calif. Inst. Tech. Vert. Pale. Coll. From Western Gulf Oil Co. well, Lillis Welch No. 1, at depth between 1748 and 1761 feet. Kreyenhagen formation. Scale 4.1 mm. long by 7 mm. deep.

Description. Scale type A (pl. 3, fig. 2): Subquadrangular, with round apical pole. All specimens of nearly same size: 8 by 7 mm., 6 by 6.5 mm., 6.5 by 7.1 mm. Basal border straight, meeting dorsal and ventral borders at about a right angle; apical border rounded. Circuli form only pattern on scales; these are transverse throughout scale, increasingly coarse toward basal margin, fine in apical region. Nucleus or center of scale between basal and apical parts, not clearly marked. Circuli not parallel, but slightly curved or oblique in places, sometimes bent at exterior border, directed toward apical end beyond more centrally located circuli. Latter may be shortened. Such structures are asymmetrical, since they do not reach same level at dorsal and ventral borders. Folds distinct along basal border, and folding of entire scale parallel to margin of upper half of scale, strongest along exterior border.

Scale type B (pl. 2, fig. 3): Measurements (in millimeters) of length and depth vary as follows: 4.1 by 7 (cotype), 4 by 6.5, 2.1 by 4. Scales much deeper than long, much shorter than those described under type A. Basal and apical borders more or

[1] This type of scale has been found to be very abundant in the Middle Eocene Llajas formation of Simi Valley.

less straight, dorsal and ventral margins rounded; pattern of scales more or less similar to that of type A, with transverse circuli coarser toward basal region. Nucleus hardly distinguishable in some scales; better shown in smallest scale, which may come from one extremity of body. Pattern of circuli shows irregularities toward outer margin as in type A scales. Scale not folded.

Occurrence. Though this scale is not very abundant, it was found repeatedly in the Kreyenhagen. Type A scales occur in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 3548 and 3597 feet, and in the Seaboard Oil Corp. well, Gill No. 1, at depth between 3895 and 3907 feet. Type B scales were found in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth between 1748 and 1761 feet; in the Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 3220 and 3239 feet; and in the Seaboard Oil Corp. well, Gill No. 1, at depth between 3895 and 3907 feet.

Relationships. This interesting scale is of unusual type, and easily recognized by its characteristic shape. The type A scale is rather long in proportion to its depth, the basal border is straight with sharp corners, and the apical pole is rounded. The scale is folded several times along a line parallel to the basal border. All circuli are more or less transverse, and the center of the scale, with nucleus, cannot be readily distinguished, if present at all. No modern scale of comparable structure is known to the writer. Scales with transverse circuli that are coarse in the basal part and fine toward the apical pole, and with central nucleus, are found in the Scomberesocidae among the Synentognathi. Similar scales are also found among the Carangiformes, but in this group they are more delicately constructed and smaller. The Eocene scales are more like those of scomberesocid forms. The scales of the long and slender *Scomberesox* of today are small and ellipsoid, the edges are always rounded, and they differ noticeably in shape from the large, sharp-edged fossil specimens. Greater resemblance is seen in the arrangement of the circuli, the central circuli being parallel in *Scomberesox* and the nucleus hardly distinct; the basal circuli are coarse, with the apical ones becoming progressively finer. In the Recent genus the circuli do not show irregularities toward the outer margin as in the fossil. It is quite conceivable, however, that such irregularities existed in related forms, and that the larger size and different shape of the fossils are responsible for such differences as are shown by the circuli. The scales of *Scomberesox* are comparatively robust, as in *Praescomberesox*.

The type B scales show considerable resemblance to those of type A, and their differences are probably due to differences in position on the body. Nearly all genera of the order Synentognathi show a distinct differentiation between the scales of the upper and lower parts of the body.

Since no further information is available to assist in the classification of this Eocene form, it is tentatively regarded as having a relationship with the Scomberesocidae.

Family HEMIRAMPHIDAE. Halfbeaks

Hemiexocoetus eocenicus, n. g. and n. sp.

(Plate 2, figures 1, 2; plate 3, figure 1; text figure 4)

Type. No. 10324, Calif. Inst. Tech. Vert. Pale. Coll. Scale 9 mm. long by 10 mm. deep.

Type locality. Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 3170 and 3200 feet. Kreyenhagen formation.

Description. Hemiramphidae and Exocoetidae show a remarkable differentiation in shape of their scales according to position in dorsoventral direction. Scales from different positions on the main part of the body are found in the same relative abundance in the geologic sections. The most typical scales of *Hemiexocoetus* are described below, with an indication of their probable position on the body.

Lateral scale near vertebral spine is illustrated in figure 4*a*, and in plate 2, figure 2. Largest scales on body are rounded to ovoid and show the following variations in measurements (in millimeters) of length and depth: 10 by 11, 10 by 10.8, 9.8 by 10, 8 by 7.1, 5.9 by 7.5, 6 by 7.1. Figure 4*a* depicts outline of typical scale of group; plate 2, figure 2, a regenerated scale with smooth center. A variable number of basal folds are present, rarely only 1, usually 5, of unequal width (fig. 4*a*). Shape and structure of folds very irregular; generally in middle of basal margin, sometimes spreading over major part of basal margin; extending to focus of nucleus. Nucleus occupies a central area on the scale. It is ovoid in shape, much deeper than long,

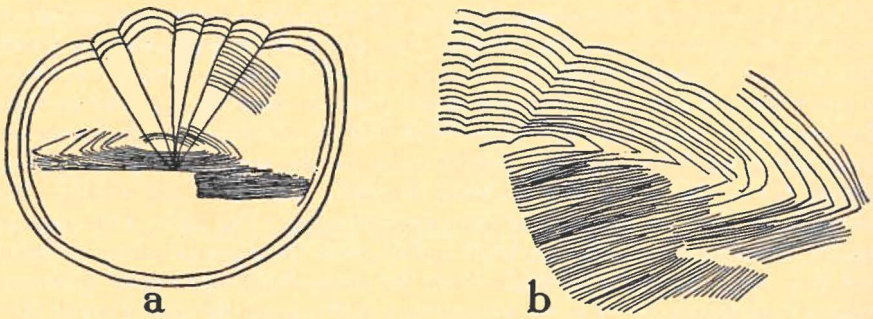

FIG. 4. *Hemiexocoetus eocenicus,* n. g. and n. sp. (*a*) Jergins Oil Co. well, Chaney Ranch No. 1. × 15. (*b*) Right side of central circuli. Western Gulf Oil Co. well, Lillis Welch No. 1. × 19.
Kreyenhagen formation.

with irregular outline. Nucleus divides basal and apical groups of circuli, with apical circuli much more closely situated. Circuli of the two groups meet in more or less pronounced angles at middle line of scale. Circuli in central area irregular, their distances widening; basal circuli follow curvature of folds; external circuli end in dorsal and ventral borders; more central ones may or may not join corresponding apical circuli. Apical circuli more strictly transverse, more concentrated than basal ones, concentration increasing toward apical margin. Regenerated scales not rare; showing smooth central part of scale of different size.

Dorso- or ventrolateral scales (pl. 3, fig. 1) ovoid, comparatively small; measurements (in millimeters) 6 by 5.1, 4 by 5, 3 by 5.2. All types of variation exist between this type of scale and that described above. Usually only 1 basal fold is present, basal margin is distinctly scalloped. Nucleus nearly central, surrounded by concentric trapezoidal circuli. Basal circuli transverse in center, strongly curved in fold, acutely curved in laterobasal angles; angles between basal and apical circuli regularly parallel; apical circuli transverse and crowded.

Ventrolateral scales (pl. 2, fig. 1) readily distinguished by their length, which is greater than the depth: 8 by 6.3, 7 by 6, 6 by 5.3 mm. Three to 4 basal folds usually present; a number of transverse and apical radii further divide the scale. Nucleus

low, below center; division between basal and apical circuli strongly pronounced. The two types of circuli meet in acute angles on a diagonal in lower half of scale; central ends of circuli widen irregularly (fig. 4*b*). Apical circuli crowded.

Small scales of same form and apparently from extremities of body are occasionally found. These show smooth centers, irregularly rounded outer circuli, and an irregular number of folds on basal border.

Number of circuli variable. The following values are found in typical specimens: in scale 9 mm. long by 10 mm. deep, basal circuli number 11 to 12 in 1 mm. distance, apical circuli 38 to 39; in scale 4 mm. long by 5 mm. deep (pl. 3, fig. 1), basal circuli 18, apical circuli 32; in scale 8 mm. long by 6.3 mm. deep (pl. 2, fig. 1), 10 in 1 mm. distance from basal border, 14 near center of basal part, 40 near apical border.

Occurrence. This scale is abundant in the Kreyenhagen and appears to be evenly distributed throughout the formation. It was found in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 1087 to 1859 feet and lower; in the Seaboard Oil Corp. well, Oro Loma No. 1, between 3170 and 3200 feet; in the Jergins Oil Co. well, Chaney Ranch No. 1, at 4278 feet and lower; in the Pure Oil Co. well, Chowchilla No. 1, at 2834 feet and lower; in the Seaboard Oil Corp. well, Gill No. 1, at 4004 feet; and in the Texas Co. well, Pioneer Unit Plan No. 1, at 8021 feet and lower.

Relationships. Hemiexocoetus is related to the Hemiramphidae and also to such forms of the primitive Exocoetidae as *Evolantia microptera.* There is no special relationship to any one form. The majority of scales show distinctly marked acute angles where the basal and apical circuli meet along a dorsoventral diagonal. This feature is more characteristic of the Hemiramphidae. In the Exocoetidae the circuli are more concentric, with median angle hardly distinct. The shape of the relatively large rounded scales of *Hemiexocoetus* agrees more with that of scales of the Exocoetidae than of the Hemiramphidae. In the latter they are nearly always deep and short. The circuli of the apical region are well marked in all the fossils, whereas the apical pole in many specimens of modern forms is often smooth or provided with only a few widely spaced lines. This may be a primitive feature in *Hemiexocoetus,* the disappearance of the apical circuli in modern scales being due to degeneration.

The fossil species shows a variety of different types of scales, similar to those seen in Recent members of the group, but not identical with those found in any one genus. It seems quite clear that *Hemiexocoetus* is an extinct type, ancestral to some of the Hemiramphidae and less advanced Exocoetidae. It may well be a primitive flying fish, like *Evolantia microptera* from the Galapagos Islands, to which it shows some similarity. The fishes of related families are pelagic swimmers; some of them go far out into the open sea (Breder, 1938, p. 114) and are truly oceanic forms. Others are inhabitants of neritic environments. It is interesting to note that Murray (1912, p. 747) regarded the Synentognathi as the most numerous surface fish which were taken on his southern route over the Atlantic Ocean. The flying fishes are most abundant in tropical and subtropical regions. Some genera, however, are found as stragglers beyond these zones, for example those which range northward to Point Conception on the Pacific Coast of North America.

Incertae sedis

A related form with scale 21.2 mm. long by 24.5 mm. deep, Univ. Calif. Mus. Pale. Coll., from U. C. locality A3290, was collected in the Upper Eocene Kellogg shale in the Mount Diablo area. This single large scale evidently represents a true flying fish.

ORDER ANACANTHINI

Family BREGMACEROTIDAE

Bregmaceros kreyenhagus, n. sp.

(Plate 1, figure 5)

Type. No. 10327, Calif. Inst. Tech. Vert. Pale. Coll. Scale 1.2 mm. long by 1 mm. deep.

Type locality. Seaboard Oil Corp. well, Oro Loma No. 1, at depth of 3220 feet. Kreyenhagen formation.

Description. Small U-shaped scales, longer than deep or as deep as long. Measurements (in millimeters) of length and depth vary as follows: 2.2 by 2, 2 by 1.8, 2 by 1.7, 1 by 0.9. Basal pole truncate, apical pole rounded, nucleus almost central, lemon-shaped, and projecting with sharp angle into basal part. Circuli concentrically rounded in apical region, corresponding to apical outline of scale. Central circuli extend beyond nucleus into basal region, where they straighten and are almost perpendicular to basal border. Outer circuli end abruptly in dorsal and ventral margins. Apical part of circuli marked by very fine crosslines; these, however, are not very distinct; tubercles present, covering center of scale, in only a few specimens. Basal circuli sometimes disconnected in fossil scales (pl. 1, fig. 5). 23 or 24 apical circuli in 0.5 mm. distance.

Occurrence. Abundant scales of this type were found repeatedly in cores from the Kreyenhagen formation: in the Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 3220 and 3282 feet; in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth between 2082 and 2100 feet; in the Jergins Oil Co. well, Chaney Ranch No. 1, at 4330 feet and lower.

Relationships. These characteristic fossil scales are easily identified as like the scales of the modern *Bregmaceros*. It is interesting to note that scales of such small size can be easily recognized in fossiliferous strata; in the Western Gulf Lillis Welch well they actually occur in comparatively coarse sandy shale. The fossil scales were compared with scales of *B. atlanticus* from Tortugas, Florida, and with the descriptions by Peabody (1931, p. 145). The general pattern of fossil and Recent specimens is very much the same. The Kreyenhagen species is readily distinguished from *B. atlanticus,* whereas Peabody finds the two Recent species very similar, except for external shape. The fossil species has much more crowded circuli than *B. atlanticus,* for in the former there are 11 to 14 circuli in 0.5 mm. distance in the basal part, whereas there are 9 to 10 in the Recent form. Similarly, in the apical region there are 23 to 24 circuli to 0.5 mm. in the fossil, and 16 to 17 in the living species. The basal circuli, furthermore, are separated by interspaces in the modern scale, whereas they are in touch with each other in the fossil. In the Recent scale the apical circuli have heavier cross sections, and larger tubercles are more generally distributed in the central part. It is not certain how these characters compare with those of *B. bathymaster* = *macclellandii*. In Peabody's drawing the basal circuli appear to be denser and the apical circuli are coarser than in the fossil form.

Bregmaceros is characteristically an inhabitant of medium depths (90 to 300 fathoms) in the open sea. The genus has been taken in shallower water (20 to 40 fathoms) extending to the margin of the neritic zone. Longley (Longley and Hildebrand, 1941, p. 35) assumes that the genus is a bottom dweller, since it has been

caught repeatedly in dredges. The young especially have been found near the surface, however, and the genus is thought to be a surface dweller by some authors. *Bregmaceros* occurs in warm waters and has a wide distribution. In the eastern part of the Pacific basin it is found off Panama and off the coast of Mexico as far north as Acapulco.

ORDER BERYCOIDEI

Family POLYMIXIIDAE. Barbudos

Parapolymixia californica, n. g. and n. sp.

(Plate 1, figure 6; text figure 5)

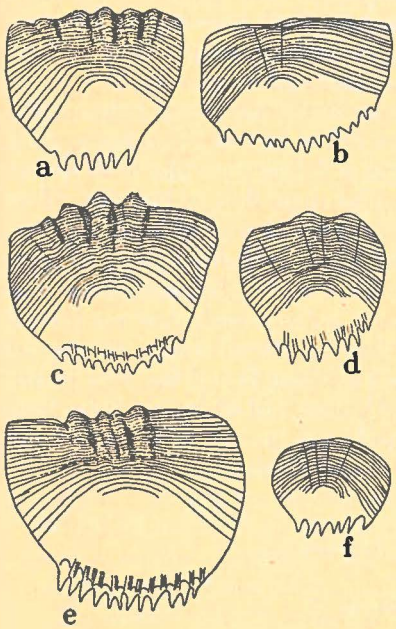

Fig. 5. *Parapolymixia californica,* n. g. and n. sp. Western Gulf Oil Co. well, Lillis Welch No. 1. Kreyenhagen formation. × 10.

Type. No. 10323, Calif. Inst. Tech. Vert. Pale. Coll. Scale 2.8 mm. long by 3 mm. deep.

Type locality. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 1087 to 1106 feet. Kreyenhagen formation.

Description. Small to medium-sized scales with length and depth measurements (in millimeters) varying as follows: 4 by 4.1, 3.9 by 4.1, 3.9 by 3.9, 3.2 by 3.7, 3 by 3.5, 3.2 by 3.2, 3 by 3.1, 3 by 3, 2 by 2.5, 1.9 by 2.1. Basal margin almost straight, apical margin broadly rounded, continuous with dorsal and ventral margins, anterolateral angle pronounced. Basal region with an irregular number of folds. These do not reach nucleus, but extend from one-third to one-half length of basal region; folds stand high and as a rule do not come in contact with one another, but are separated by an unfolded section of circuli. Circuli curved in folded area, but not sharply divided into sections as in the majority of percomorph scales. In larger scales, folds generally situated in center of anterobasal part. In scales of more normal size, folds distributed irregularly over all of anterior part of scale, with the central folds more pronounced. Nucleus in center of scale or slightly toward apical end. Circuli restricted to a part of basal region. Circuli above nucleus incomplete, not reaching dorsal and ventral margins, curved, with anterolateral angle not always marked. Circuli toward base parallel to nucleal ones in center, continuing toward dorsal and ventral borders after a sharp, often angular turn in apical direction, distance between circuli widening toward outer margin. Circuli near basal border more or less completely transverse, with short curves at dorsal and ventral ends; these circuli separated by less distance than central ones; approximately 12 circuli in 1 mm. distance near basal border, 10 near center of scale, in specimen 3.9 mm. long by 4.1 mm. deep. Apical pole provided with at least one series of well defined spines, supported by

apical keels in apical ridges. Occasionally a double row of spines can be observed. Spines vary in length, evidently not always completely preserved. Scale, when preserved, often clear brown, glossy, sometimes black, with luster of mother of pearl, or replaced by pyrite.

Occurrence. This scale is very abundant everywhere in the Upper Eocene of the San Joaquin Valley, and is a good horizon marker for the deeper parts of the Kreyenhagen. In the Jergins Oil Co. well, Chaney Ranch No. 1, it is abundant at 4050 feet, and it occurs in the Seaboard Oil Corp. well, Oro Loma No. 1, at 3141 feet and deeper. It is also present in the Seaboard Oil Corp. well, Welch No. 1, at 4220 feet and deeper; and in the Seaboard Oil Corp. well, Gill No. 1, at 4039 feet and deeper. In the Western Gulf Oil Co. well, Lillis Welch No. 1, it occurs from 716 feet downward and is extremely abundant at 1087 feet. The scale is found also in the Refugian stage, and occurs in the Amerada Petroleum Corp. well, Beer No. 1, at depth from 3557 to 3567 feet, and more frequently in the Eocene at depth from 3927 to 4080 feet. In the Texas Co. well, Pioneer Unit Plan No. 1, the scale occurs at a depth of 8021 feet and deeper; in the Pioneer Unit Plan No. 2, at a depth of 9212 feet.

Relationships. Parapolymixia has the characters of the specialized scales of the Polymixiidae. The Eocene genus shows the characteristic basal folds, arrangement of circuli, and position of nucleus of the Recent genus *Polymixia.* The fossil species described here has smaller scales and of more regular shape than in *Polymixia;* they usually present only one row of spines, whereas a number of rows of spines are present in the modern genus. The Polymixiidae are a very specialized group of berycomorph fishes, and are inhabitants of seas of medium depth. *Polymixia* appears to be usually caught in depths from 190 to 350 fathoms, and apparently does not descend to very great depths. The range of the family does not extend beyond the tropical and subtropical zones. *Polymixia* is found in the Caribbean Sea off the West Indies. It is likewise found off Madeira, off the Hawaiian Islands, and off Japan. It has been recorded from Tortugas (Longley and Hildebrand, 1941, p. 52), with 2 specimens from 45 to 60 fathoms and 5 specimens from 140 to 197 fathoms.

Family BERYCIDAE. Alfonsinos

Beryx san-joaquinensis, n. sp.

(Plate 3, figure 3; plate 4, figure 1; text figure 6*c*)

Type. No. 10328, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4.1 mm. long by 3.7 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 3570 to 3597 feet. Tumey formation.

Description. Scale coarse, rectangularly oblong to elongately rounded; measurements (in millimeters) of length and depth vary as follows: rectangular scales, 2.9 by 3.9, 3.1 by 2.1, 3.1 by 3.9, 3.1 by 4, 4 by 4.6; rounded scales, 4.1 by 5, 5 by 5.1. Basal part in rectangular scales angular, laterobasal angles well formed; dorsal and ventral sides curved as characteristic of genus, but not strongly concave. Smooth side showing strong angular growth lines, concentric to external margin. Basal pole not folded or weakly folded. Central sector of basal part vertically protruding above remaining part of scale. Nucleus above center; coarse circuli present on basal part above nucleus, irregularly rounded to elongate, widely spaced, 22 in 1 mm.

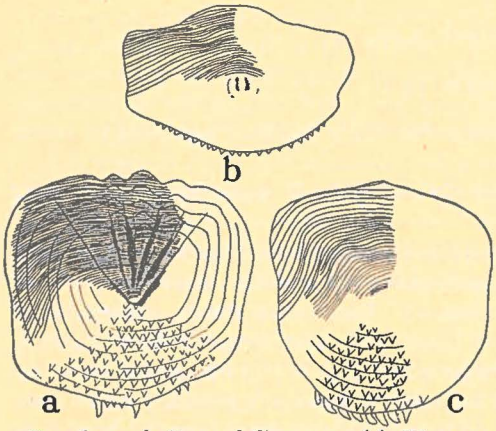

FIG. 6. *a, b, Beryx kcli,* n. sp. (*a*) Diagram after type, no. 10329 C.I.T. Scale 4.1 mm. long by 4 mm. deep. Richfield Oil Corp. well, K.C.L. No. 1. (*b*) Scale 3.2 mm. long by 4.1 mm. deep. Richfield Oil Corp. well, K.C.L. No. 1. Zemorrian stage.

c, Beryx san-joaquinensis, n. sp. Type, no. 10328 C.I.T. Scale 4.1 mm. long by 3.7 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

All × 8.

distance. Laterobasal angle rounded, circuli abruptly bent outward above the laterobasal diagonal and ending in dorsal and ventral margins. Part of scale below nucleus smooth. Apical region has scattered spines which are usually lost with actual scale, but are indicated by cavities or by corresponding elevations when only mold of smooth side is present. Some spines indistinctly visible at apical margin. Elongately rounded scales (pl. 3, fig. 3) are probably atypical scales of same form: basal part strongly elevated, circuli rounded, occupying upper two-thirds of scale, leaving a triangular sector of apical pole smooth. Growth lines well marked in basal part.

Occurrence. The scale has been found abundantly in the Jergins Oil Co. well, Chaney Ranch No. 1, from 3570 to 3597 feet and also between 3624 and 3647 feet.

Beryx eogenus, n. sp.

(Plate 4, figure 3)

Type. No. 118, Paleontological Laboratory of the Richfield Oil Corporation, Long Beach, California. Scale 4.5 mm. long by 5 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 3570 and 3597 feet. Tumey formation.

Description. Scale rectangular with more or less deeply concave dorsal and ventral borders, as in *Beryx splendens.* Measurements (in millimeters) of length and depth vary as follows: 4.5 by 5, 4 by 5 (lateral-line scale), 3.1 by 3.5, 1.5 by 2. Few basal folds, if any, projecting as sharp triangles in center of otherwise truncate basal border. Growth lines well marked on smooth side of scale. Central sector of basal part feebly elevated beyond remaining part of scale. Moderately dense transverse circuli present, densest above nucleus, widening toward dorsal and ventral borders. Basolateral angles rounded, not very well defined. Apical part generally smooth, spines restricted to one row at apical border, spines strengthened by apical ridges protruding into apical part of scale.

Occurrence. Scales moderately abundant in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 3570 to 3647 feet.

Beryx kcli, n. sp.

(Text figure 6*a*, *b*)

Type. No. 10329, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4.1 mm. long by 4 mm. deep.

Type locality. Richfield Oil Co. well, K.C.L. No. 1, at depth from 6443 to 6452 feet. Zemorrian stage.

Description. The Lower Miocene form is described here in order to give more detailed information concerning the generic characters and for comparison with the Eocene forms, which are as yet little known. Scale rather small, rectangular in shape; measurements (in millimeters) of length and depth vary as follows: 4 by 5, 4 by 4, 3 by 3.5, 3 by 2.8, 1 by 1.9. Deeper scales (fig. 6*b*) (3 by 4 mm.) found occasionally, probably atypical scales of the same form. Basal pole generally with a number of strong undulations at its center, folds projecting as sharp triangles beyond an otherwise truncate basal border. Apical pole rounded; pronounced concentric growth lines visible in basal and apical regions. Growth lines in basal part dividing folds or undulations into a number of sections, which form characteristic pattern on central basal sector of scale, and are especially clear on mold of smooth side. Dorsal and ventral margins concave. Central sector of basal part vertically elevated above remaining part of scale. Dense transverse circuli present in basal part (36 in 1 mm. distance), more or less straight in center, not following undulations and growth lines. Central circuli very short, rapidly increasing in length toward basal border, bending apicad in laterobasal diagonal, apical ends of circuli more widely spaced. Spines irregularly distributed over apical part, spines preserved only when scale itself is present; in impressions of scales, spines are indicated by triangular cavities with elevated margins. Rather strong spines indicated in some specimens along apical border. Rectangular scales (fig. 6*b*) with central nucleus; circuli transverse in basal region, short in center and rapidly increasing in length; one row of spines evidently present along apical margin, otherwise smooth.

Occurrence. This scale is very abundant in the Zemorrian (Temblor) of the southern San Joaquin Valley, and is found throughout this stage. It is especially abundant in the Richfield Oil Corp. well, K.C.L. No. 1, and in the Union Oil Co. well, Gibson No. 7.

Relationships. The three fossil species described above are nearly related and are probably identical with the very distinctive scale of the genus *Beryx*. Of the Eogene forms, *B. eogenus* comes nearer to the scale of the Recent genus than does the coarser scale of *B. san-joaquinensis*, which may very well represent a different genus. The Miocene species *B. kcli* approaches the modern scale most closely, and description of this abundantly occurring species seems advisable, to facilitate recognition of the generic characters in these fossil scales. The scales of the genus are evidently very brittle, and are lost in most instances. If the scale is preserved, the coarse side is attached to the rock, and the spines are visible only through the scale. Spines in *Beryx* are irregularly scattered over the apical part, being often broken and turned upward vertically. Their position is indicated in the drawings by triangles, since it was not possible to draw the actual shape, which is only indistinctly seen through the scale. *Beryx kcli* has small scales in which the depth is not quite so great as in Recent *Beryx*. Dorsal and ventral margins are concave, although not so strikingly so as in Recent species and as in some of the known Cretaceous forms. The central sector of the

basal region is strongly raised vertically, and basal and apical parts are divided by a groove which is typical of the genus. Spines, inserted in triangular cavities, are scattered over the apical region in the Miocene and Recent forms. Spines are less numerous in the Eogene forms and may be restricted to one row in some of the scales. Circuli are restricted to the basal part and show the same pattern in *B. ḳcli* and *B. eogenus* as in modern scales of the genus. They are coarser and more rounded in *B. san-joaquinensis*. The Miocene species shows strong undulations in the basal part, whereas in *B. splendens* only weak folds, if any, are present. In *B. eogenus* a few less pronounced folds are present; none is developed in *B. san-joaquinensis*. The basal undulations, where present, together with the marked growth lines give a characteristic pattern of irregular triangular elevations to the fossil scale, which make it easily recognizable.

Beryx san-joaquinensis is readily distinguished from the two other species by the very coarse circuli, the absence of folds in the basal part, and the different shape of the scales. *Beryx eogenus* is larger than *B. ḳcli* and has slightly coarser circuli and fewer basal folds; apical spines are less numerous and the row of spines along the apical border is stronger.

Beryx is a cosmopolitan genus of the warm open seas. Species are known from moderate depth (424 fathoms), and others occur in rather deep water. The genus is known off Madeira and Cuba, in the Gulf Stream, and off Japan and Australia. There seems to be no record from the eastern Pacific Ocean.

The actual range of the fossil species is difficult to determine. *Beryx ḳcli* is very abundant in the Lower Miocene of the southern San Joaquin Valley. It may well have become extinct by Middle Miocene time. The Eogene *B. san-joaquinensis* shows more primitive characters, indicated by its coarser pattern. It may be restricted to the Eocene. *Beryx eogenus* is related to the Miocene and to modern forms.

ORDER PERCOMORPHI

SUBORDER PERCOIDEA PERCIFORMES

Family MORONIDAE. WHITE PERCHES

Paramorone eocenica, n. g. and n. sp.

(Plate 3, figure 5; text figure 7*a, b*)

Type. No. 10317, Calif. Inst. Tech. Vert. Pale. Coll. Scale 5.5 mm. long by 5 mm. deep.

Cotype. No. 10319, Calif. Inst. Tech. Vert. Pale. Coll. Scale 3 mm. long by 3 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 3624 to 3647 feet. Tumey formation.

Description. Type specimen is a well preserved scale from lateral part of fish; external border of apical pole missing, this part being seldom present in fossil percomorph scales. Cotype is a scale from anterodorsal part of fish. Lateral scales quadrangular, slightly longer than deep in type. Basal part divided into folds of subequal size (7 in type); most central folds extending from basal border to nucleus. Basal border almost straight, very little scalloped in region of folds. Nucleus subapical, surrounded by 3 or 4 concentric circuli, forming a sharp angle toward the

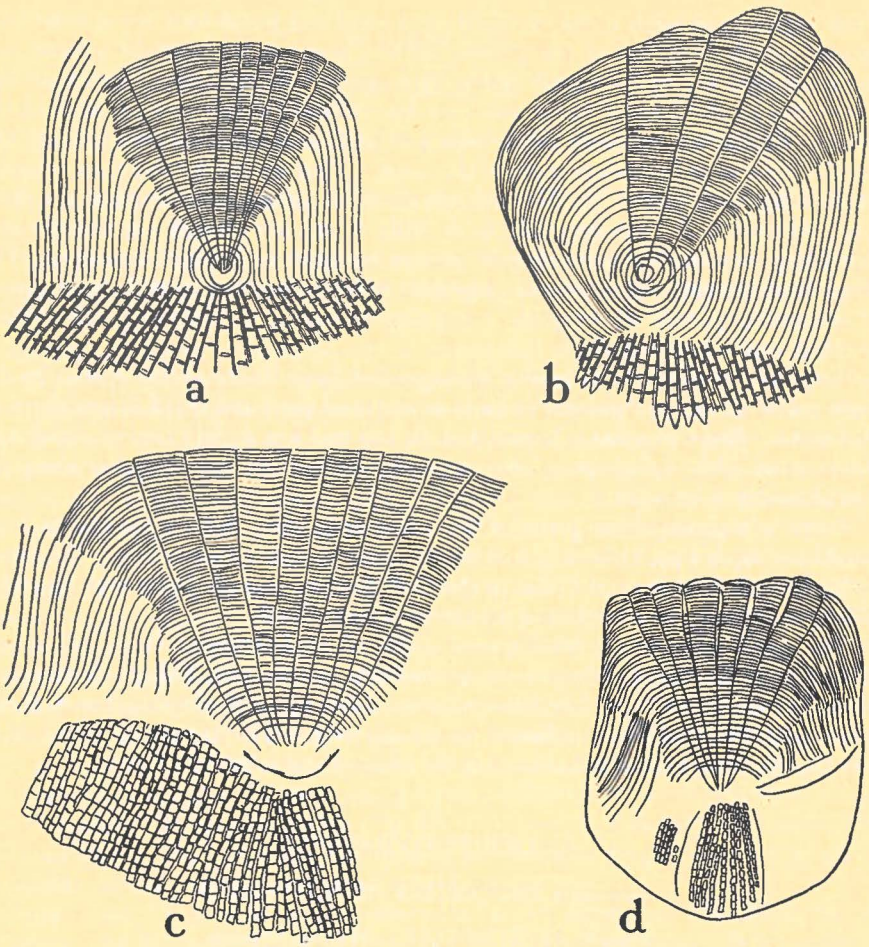

FIG. 7. *a, b, Paramorone eocenica,* n. g. and n. sp. (*a*) Nuclear center of type, no. 10317 C.I.T. Jergins Oil Co. well, Chaney Ranch No. 1. (*b*) Cotype, no. 10319 C.I.T. Scale 3 mm. long by 3 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation. × 20.

c, d, Kreyenhagenius joaquinensis, n. g. and n. sp. (*c*) Nuclear center of type, no. 10318 C.I.T. Seaboard Oil Corp. well, Gill No. 1. (*d*) Cotype, no. 10320 C.I.T. Scale 3 mm. long by 2 mm. deep. Seaboard Oil Corp. well, Oro Loma No. 1. Kreyenhagen formation. × 20.

apical end of the scale. Circuli in dorsal and ventral triangle of basal part coarse, almost straight, 21 or 22 in 1 mm. in nuclear region. Circuli in central basal sector much finer, almost twice as numerous, divided into small sections by folds, 31 in 1 mm. distance at basal border of scale. Central circuli form rounded and wide latero-basal angles along diagonals of scales, beyond which they end between or continue into the coarser circuli of the dorsal and ventral sectors. Apical pole divided from basal part by an almost straight line. Apical part divided into numerous comparatively coarse, vertically projecting radii, 17 or 18 in 1 mm. distance below nucleus. Radii more or less straight, showing little ornamentation, subdivided into rectangular,

rodlike elements, longer than broad. Spines present only in cotype, stout, little longer than broad. Scale folded many times, in regular intervals parallel to borders of basal part. These folds do not correspond to annular rings; type scale probably 3 to 4 years old. Cotype with asymmetric shape and reduced number of folds typical for scales of anterodorsal body region in this group of fishes, otherwise showing characters of species.

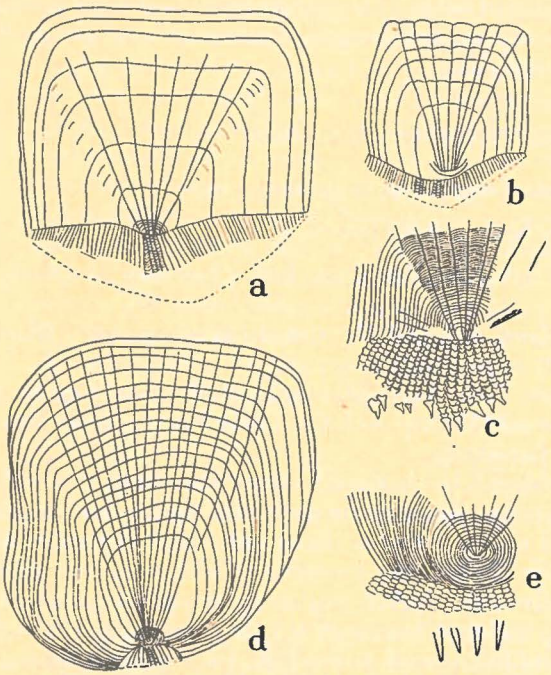

FIG. 8. *a, c, Lompoquia* cf. *culveri* (Jordan). (*a*) Diagram of scale from Mulholland Highway, Santa Monica Mts., Middle Mohnian. × 10. (*c*) Nuclear center of scale from Mulholland Highway, Santa Monica Mts., Middle Mohnian. × 20.

b, Lompoquia cf. *retropes* Jordan and Gilbert, from Axis Oil Co. well, Rowland No. 1, Delmontian stage, Upper Miocene. × 10.

d, e, Cynoscion cf. *eprepes* (Jordan). (*d*) Diagram of scale from Petroleum Securities Oil Co. well, Burbank No. 1, McLure shale, Upper Miocene, Upper Mohnian. × 10. (*e*) Nuclear center of scale from Petroleum Securities Oil Co. well, Burbank No. 1. × 20.

Occurrence. Type and cotype come from the Jergins Oil Co. well, Chaney Ranch No. 1, where the scale occurs down to 4404 feet. The scale has been found elsewhere in the Kreyenhagen, and is probably not rare at shallower depths of the Upper Eocene and Oligocene.

Relationships. The scale as compared with the majority of Recent percomorph scales is characterized by coarseness of structure, especially in the nuclear region. In general, greater coarseness can be considered as a primitive character. Ornamentation of the apical radii also is little developed, and the radii appear as almost straight lines vertically projected. A somewhat similar structure prevails in the living genus *Morone,* especially in the European species *Morone labrax* (see Meek, 1916, pl. 10). The nuclear structure in *Morone* is less coarse, however, and the basal radii are not directed straight toward the apical pole, but are bent toward the nucleus. *Paramorone* can be considered a distant relative of the existing Moronidae. This family lives today along the borders of the ocean, frequently entering brackish water and rivers. It is sometimes confined to fresh water. The genus *Morone* in America is restricted to the Atlantic border of the continent. The Moronidae occupy a temperate to tropical habitat. The Eocene form did not necessarily have the same habitat, as it is only distantly related to modern forms. Percomorph fishes came into existence at the end of the Cretaceous and developed rapidly throughout the Tertiary. The

developmental changes probably involved changes in environment as well. Presumably the Eocene *Paramorone* lived in coastal waters; it is doubtful whether it entered fresh water.

In the Upper Miocene of California two sciaenid genera, *Lompoquia* and *Cynoscion*, present the most abundant spiny-rayed fishes. The nuclear structure in these genera is considerably finer than in *Paramorone*, and the apical features are more advanced. Figure 8 shows these forms for comparison.

Family DENTICIDAE. Dogs-teeth

Kreyenhagenius joaquinensis, n. g. and n. sp.

(Plate 3, figure 4; text figure 7*c*, *d*)

Type. No. 10318, Calif. Inst. Tech. Vert. Pale. Coll. Scale 5 mm. long by 5.8 mm. deep.

Type locality. Seaboard Oil Corp. well, Gill No. 1, at depth of 4051 feet. Kreyenhagen formation.

Cotype. No. 10320, Calif. Inst. Tech. Vert. Pale. Coll. Scale 3 mm. long by 2 mm. deep. Specimen from Seaboard Oil Corp. well, Oro Loma No. 1, at depth from 3220 to 3229 feet. Kreyenhagen formation.

Description. Lateral scales rounded to fan-shaped, deeper than long; type well preserved, ends of apical radii missing. Apical part large, measuring one-third length of scale in type. Cotype a small scale as found in dorsal and ventral extremities of body in these fishes. Basal region divided into a number of folds, 9 in type, their basal border extending along entire scale, all folds originating in nucleus, forming a typical fan. Basal border weakly scalloped, basal ends of folds projecting in rounded curves. Nucleus subapical, divided by a smooth groove from apical region. Nucleus marked by circuli overlying it horizontally, these slightly rounded, increasing rapidly in width, most central ones coarsest. Circuli become fine toward basal border. Horizontal circuli form wide, rounded angles along diagonals of basal region, their ends directed toward dorsal and ventral borders of scale in its anterior two-thirds. Central circuli divided by folds; 31 circuli in 1 mm. distance starting with lowest horizontal one, 48 in 1 mm. distance at basal border. Circuli in dorsal and ventral basal sections of scale that are free from folds are farther apart, but feeble, and of varying length, their ends curved outward, directed toward dorsal and ventral borders of scale. About 24 circuli in 1 mm. distance in sections dorsal and ventral to the nucleus. Groove dividing nucleus from apical region wide and well marked. Circuli seemingly not continued beyond groove and around nucleus. Apical region divided from basal part by a subtriangular space with lowest point in center. Apical region divided into numerous radii, 24 in 1 mm. distance in center. Radii flat, strongly projected vertically, subdivided into a number of quadrangles with their dorsal and ventral sides rounded to angular. Radii not always developed in atypical scales, or not occupying entire apical region, as shown in cotype. Folding of scale around outer margin not very apparent.

Occurrence. This scale was found in the Kreyenhagen of the Seaboard Oil Corp. well, Gill No. 1, and in the same formation penetrated by the Oro Loma well No. 1. It also occurs in the Jergins Oil Co. well, Chaney Ranch No. 1, at a depth of 4330 feet and deeper. It is evidently an Upper Eocene scale characteristic of shallow-

water deposits. It is rare everywhere in the Kreyenhagen shale where it has been found.[2]

Relationships. The scale shows no particular resemblance to that of any known living form, but seems to be distantly related to the Denticidae. *Kreyenhagenius* has the fan-shaped structure of the scales seen in some members of this family. It differs in that its outline is rounded, the ends of the folds project less beyond the basal margin, and the folds do not have pointed ends. The nuclear structure, character of the folds, and central circuli resemble comparable features seen in the Denticidae, but the dorsal and ventral circuli, although bent at their ends, do not show the typical rounded outward curvature of these structures in the Denticidae and in the related Sparidae. Moreover, the dorsal and ventral circuli are farther apart. *Kreyenhagenius* was probably related to the Denticidae or to the primitive Sparidae, and may represent an ancestral type featured by the shape of the scale and by the structure of dorsal and ventral circuli. *Dentex* has been found in Upper Eocene marine sediments of Europe, and related forms should be expected in corresponding deposits of America. The Denticidae are essentially inhabitants of warm climates. Typical sparid scales are represented in the Miocene of California by *Plectrites* and *Rhythmias* (see David, 1943, p. 28, fig. 66; 1944, pl. 5, fig. 50).

Family ? CHILODIPTERIDAE

Praegaleagra pupensis, n. g. and n. sp.

(Text figure 9)

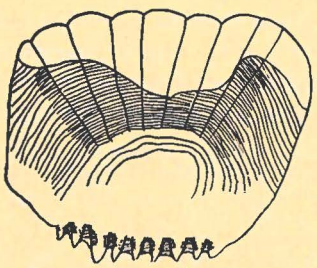

FIG. 9. *Praegaleagra pupensis,* n. g. and n. sp. Type, no. 10332 C.I.T. Scale 2.6 mm. long by 3 mm. deep. Texas Co. well, Pioneer Unit Plan No. 2. Kreyenhagen formation. × 32.

Type. No. 10332, Calif. Inst. Tech. Vert. Pale. Coll. Scale 2.6 mm. long by 3 mm. deep.

Type locality. Upper Eocene deposits of Texas Co. well, Pioneer Unit Plan No. 2, at depth between 9700 and 9707 feet. Kreyenhagen formation.

Description. Only regenerated scales present, these slightly deeper than long. Approximately 7 subequal folds in basal part, basal margin scalloped, edges of folds rounded; basal radii strong, sectioning circuli, not continued into regenerated part. Circuli more or less concentric with margin of basal part of scale, curved in region of folds and continuing around laterobasal angles, the latter being rounded; dorsal and ventral sectors of basal part with less crowded, irregular circuli, in part ending in dorsal and ventral margins, in part toward apical portion, circuli probably more regular in an original not regenerated scale. Nucleus evidently subapical. Apical pole smooth, without circuli or ctenoid structures, equipped with one row of irregular simple strong spines, projecting vertically in subapical marginal field, incompletely preserved.

Only the type and cotype of this form are known.

Relationships. It seems difficult to place the small scale that shows the basal struc-

[2] This type of scale has been found to be extremely abundant in the shallow-water deposits of the Middle Eocene Llajas formation of Simi Valley.

ture of perciform fishes and an apical pole simply equipped with a row of strong vertically projecting spines. Somewhat similar scales are found in certain deep-sea percomorph fishes, as *Galeagra, Bathysphyraenops,* and others. All these genera are attributed to the Chilodipteridae, and *Praegaleagra* is tentatively placed in the same family. It differs from related genera in the structure and crowded nature of the circuli. The scales of *Galeagra* are much smaller than those in the fossil form; other related genera have larger scales. Although the small fossil form is not well known, its particular features are sufficiently characteristic to permit a recognition of its relationships.

Suborder PERCOIDEA CARANGIFORMES

Family CARANGIDAE. Jacks

Caranx orolomaensis, n. sp.

(Plate 1, figures 2, 3)

Type. No. 10330 Calif. Inst. Tech. Vert. Pale. Coll. Scale 1.8 mm. long by 2 mm. deep.

Type locality. Seaboard Oil Corp. well, Oro Loma No. 1, at depth from 3141 to 3170 feet. Kreyenhagen formation.

Description. Scales small, ovoid; typical measurements (in millimeters) of length and depth are 1 by 1.2, 2 by 2; elongate scales that measure 4 by 2 mm. are rare. Simple, degenerate scales with central nucleus; circuli irregularly rounded, concentric, irregularly angular but not symmetrical on both sides of mediolateral diagonal. Occasionally present are elongate scales with pointed apical pole. Circuli coarser at one side, probably basal region, 38 to 42 in 1 mm. distance, more numerous at other side, 54 to 58 in 1 mm. distance. In larger, elongate scale, 44 circuli in 1 mm. distance.

Occurrence. This scale is not rare in the Kreyenhagen of the Seaboard Oil Corp. well, Oro Loma No. 1, at depth from 3141 to 3242 feet. It also occurs in the Kreyenhagen of the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 1579 to 1605 feet, and in the Jergins Oil Co. well, Chaney Ranch No. 1, from 4304 to 4330 feet.

Relationships. This small scale is not unlike many of the degenerate scales of the carangids of today, for example *Hemicaranx, Caranx,* some members of *Seriola,* and others. Degenerate scales like the fossil, with irregularly rounded circuli that are more widely spaced at one side and are irregularly angled, are found in some species of the above-mentioned genera, whereas the majority of the carangid forms have distinctly symmetrical scales. The counts of the circuli in the fossil form are nearly comparable to those of living forms, although in the former the circuli appear coarser. The latter appearance may be an optical effect, due to stronger shadows. Scales shaped like that seen in plate 1, figure 2 occur also in Recent fishes with the more typical rounded ones. Definite generic allocation of the type is difficult with only the scale available. It seems best under the circumstances to include it with the common *Caranx.* This form and *Hemicaranx* are inhabitants of warm climates. This type of carangid scale has heretofore not been found fossil in California. It is distinguished from the other known types by its small size and irregularly rounded circuli.

Suborder SCOMBROIDEI

Family SCOMBRIDAE. Mackerels

Eoscombrus chaneyensis, n. g. and n. sp.

(Plate 4, figure 2)

Type. No. 116, Paleontological Laboratory of the Richfield Oil Corporation, Long Beach, California. Scale 3.9 mm. long by 3.5 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 3570 to 3597 feet. Tumey formation.

Description. The small ovoid type is the only scale collected so far. Less well preserved scales with apical and basal borders parallel may belong to this form. Scale simple, radial structure in basal part, fine concentrically rounded circuli in basal part, asymmetrically angular in apical part. 19 (near basal border) to 22 circuli in 1 mm. distance. Apical part divided into numerous apical radii toward apical border, protruding toothlike beyond border. Nucleus central, wide, probably regenerated, ornamented with indistinct tuberculations.

Relationships. The type scale shows the very typical characters of the Scombridae, with the asymmetrically angular, concentric circuli and the apical radii. As a whole, the scale is much coarser than those of the Recent mackerel.

Faunal Assemblages and Zoning of Sections

Table 1 gives a list of all the species of fish found in the Upper Eocene of the San Joaquin Valley. The abundance of individual kinds is given, as based upon the frequency of their occurrence in the entire Upper Eocene section of the valley. The nearest living relatives of the fossils are indicated, as well as the presence or absence of the families and genera in the Miocene.

The different kinds of fossil fish listed in the table are not equally distributed throughout the stratigraphic succession, and several subdivisions are therefore distinguishable. Two of these units can be readily recognized in a number of the subsurface sections, whereas in others only the lower one of the two is present. Furthermore, two zones may be determined within the latter. The first one of these may be subdivided in some cases. The chart, figure 10, attempts to establish a correlation between the occurrences of the fossil material of Kreyenhagen age, and shows the frequency of occurrence of the more abundant forms. It should be remembered that only a limited number of samples are available for scale study from most of the wells, and this limitation is responsible for the gaps in the sequence of samples shown in the chart. The information concerning fossil scales thus far obtained from the Kreyenhagen is incomplete. It seems entirely possible that more information can be obtained from some of the wells. In the Seaboard Oil Corp. well, Oro Loma No. 1, and in the Seaboard Oil Corp. Gill and Welch wells only the core samples indicated in the chart were available for study, although considerable coring was actually done.

No fossil scales were collected by the writer in surface outcrops of the Kreyenhagen formation. However, material made available from the Kreyenhagen of

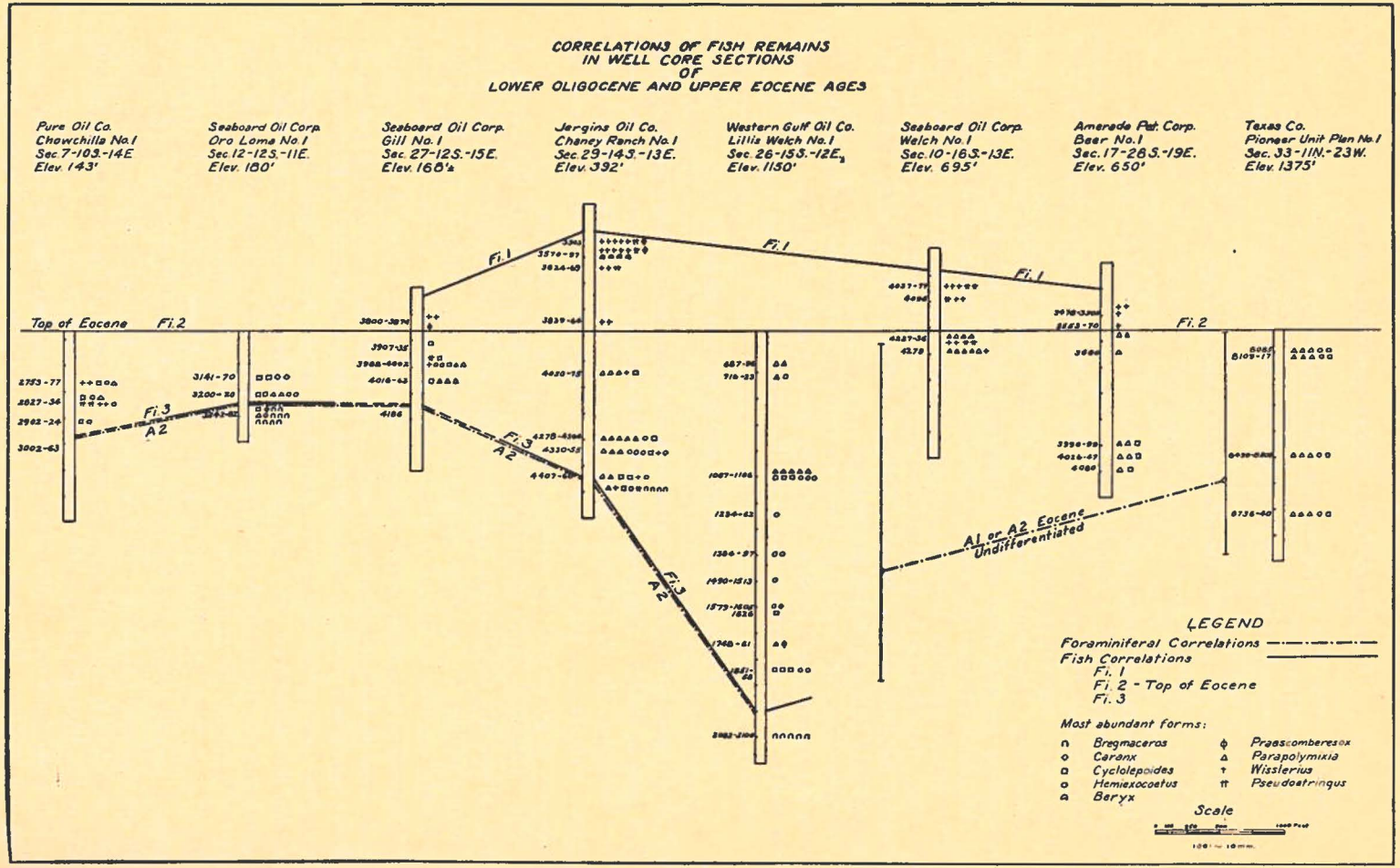

FIG. 10. Correlation of fish remains in well-core sections of Lower Oligocene and Upper Eocene ages, San Joaquin Valley, California

the North Coalinga district (Cantua–Salt Creek–Domengine region), Fresno County, corresponds well to that determined in the well cores. Zones Fi 1 and Fi 2 are well represented.

TABLE 1

LIST OF FAMILIES, GENERA, AND SPECIES OF FISHES FROM LOWER OLIGOCENE AND UPPER EOCENE DEPOSITS, SAN JOAQUIN VALLEY, CALIFORNIA

Family, genus, and species	Relative abundance*	Occurrence in California		Nearest living relative
		Miocene	Mio-Oligocene	
Carchariidae	....	+	+	
Galeocerdo? sp	R	..	..	Galeocerdo
Dussumieridae	....	+	+	
Pseudoetringus kreyenhagius	A	..	..	?
Clupeidae	....	+	+	
Wisslerius sardinelloides	A	..	..	Sardinella
? Alosa ganolytoides	R	..	..	Alosa?
Coregonidae	....	?	+	
Parastenodus gillensis	R	..	..	Stenodus
Beckius plicatus	R	..	..	Leucichthys?
Cyclolepidae	....	..	+	
Cyclolepoides tuberculatus	AA	..	+	?
? Chlorophthalmidae	....	..	..	
Iniomus fossilis	R	..	..	Chlorophthalmus?
? Scomberesocidae	....	+	+	
Praescomberesox pacificus	M	..	..	Scomberesox?
Hemiramphidae	....	+	+	
Hemiexocoetus eocenicus	AA	..	..	Evolantia
Bregmacerotidae	....	..	..	
Bregmaceros kreyenhagus	A	..	..	Bregmaceros
Polymixiidae	....	..	..	
Parapolymixia californica	AAA	..	..	Polymixia
Berycidae	....	..	+	
Beryx san-joaquinensis	AM	..	+	Beryx
Beryx eogenus	M	..	+	
Moronidae	....	..	..	
Paramorone eocenica	M	..	..	Morone
Denticidae	....	..	?	
Kreyenhagenius joaquinensis	M	..	?	Dentex
? Chilodipteridae	....	..	..	
Praegaleagra pupensis	R	..	..	Galeagra?
Carangidae	....	+	+	
Caranx orolomaensis	M	..	?	Caranx
Scombridae	....	+	+	
Eoscombrus chaneyensis	R	..	..	Scomber

*R, rare; M, moderately represented; A, abundant; AA, very abundant; AAA, extremely abundant.

Three distinct fish-scale assemblages are recognized as a result of the studies of the well-core samples. In the stratigraphic sequence from top to bottom these are designated Fi 1, Fi 2 (or Fi 2*a* and Fi 2*b*), and Fi 3. They are described individually as follows:

Assemblage Fi 1

The upper assemblage is of Oligocene age and is characterized by an abundance of the clupeoid fishes *Pseudoetringus* and *Wisslerius*. Either form may occur in abundance; sometimes both are found, sometimes only one. *Praescomberesox* and *Cyclolepoides* are present, and *Paramorone* may be characteristic. Other types are occasionally present. This assemblage is clearly represented in the uppermost Kreyenhagen of the Jergins Oil Co. well, Chaney Ranch No. 1, where *Wisslerius* abounds. Here berycid fishes are also very abundant. These strata correspond to the so-called Leda zone. In the Seaboard Welch well at a depth from 4000 to 4100 feet clupeoid fishes are well represented. The Salt Creek section also shows this assemblage clearly; in its upper 200 or 300 feet *Pseudoetringus* is by far the most abundant fossil. *Wisslerius, Paramorone,* and *Hemiexocoetus* ? occur. In the Seaboard Gill well the zone is less clearly marked, from 3800 to 3900 feet. In the Pure Oil Co. Chowchilla well the evidence is not clear.

Assemblage Fi 2

The top of Fi 2 is marked by a great abundance or dominance of *Parapolymixia.* In certain strata this form is the only fish fossil present, and it may occur repeatedly, as in the Texas Co. well, Pioneer Unit Plan No. 1. In other horizons *Hemiexocoetus* and *Cyclolepoides* are found associated with *Parapolymixia,* and either one of the former may be fairly abundant. The three genera are the most abundant types; other forms may appear, but never in significant numbers. Fi 2 is the most characteristic assemblage of the Kreyenhagen wherever this formation occurs. The position is clearly indicated in the wells shown in figure 10. The characteristic scales of this assemblage occur in some wells in a stratigraphic sequence of considerable thickness. That part of the assemblage which is featured by a dominance of *Parapolymixia* appears to correspond to the top of the zone (Fi 2*a*) and of all strata of Eocene age. It is underlain by strata in which the occurrence and frequency of the three principal forms varies, and *Parapolymixia* is not necessarily present (Fi 2*b*). In the Salt Creek section Fi 2 is found in the lower part of the stratigraphic succession within a thickness of 150 feet or more.

Assemblage Fi 3

In a number of wells faunal changes, indicated by the fossil fish scales, are noticeable in the samples from the lowest Kreyenhagen. Abundant specimens of *Bregmaceros* were found in these wells. This fish has not been observed in higher horizons. *Caranx* is also moderately abundant at this stage, but not higher. *Kreyenhagenius* occurs, and *Cyclolepoides, Praescomberesox,* and *Hemiexocoetus* are present in moderate numbers.

The zoning attempted above is based on a limited number of samples. It will probably undergo change and refinement with the acquisition of further information. The distinction between Fi 1 and Fi 2 appears to be clearly estab-

lished in all sections where both assemblages occur. Fi 2*a*, Fi 2*b*, and Fi 3 cannot be readily differentiated in all sections.

Ecologic Significance of Kreyenhagen Fish Scales

Bathymetric Conditions

The fossil fish-scale assemblages found at different horizons of the Kreyenhagen formation reflect the presence of varying bathymetric conditions. Slight changes in the environment furnish a plausible explanation for the sequence of scale assemblages in the Upper Eogene. Fi 1 was deposited in a neritic environment. In support of this view may be cited an abundance of herrings, presence of percomorph fishes as well as Synentognathi and *Beryx*, and the rare occurrence of an Iniomi. A deep neritic habitat appears to be the most likely place of accumulation for this faunule. Doubtless a much greater variety of types will be found when the assemblage is better known.

In the larger part of the Kreyenhagen shale occurs Fi 2, which furnishes a very peculiar and interesting assemblage. Three genera are represented in the main: *Parapolymixia*, a scale very much like that of the living barbudo; *Hemiexocoetus*, a primitive flying fish; and *Cyclolepoides*, related to the salmons. These are the most characteristic Upper Eocene scales from the San Joaquin Valley, and they are found in all well cores taken from the Kreyenhagen formation. It appears likely that they are characteristic of other Upper Eocene deposits in California. A few similar scales are known from the Kellogg shale of the Mount Diablo region. A bathypelagic environment of medium depth is a likely place for a common occurrence of these three forms in such large numbers, generally unaccompanied by other types. The Hemiramphidae and the Exocoetidae, to which families *Hemiexocoetus* shows relationship, are pelagic, with members living in either neritic or oceanic environments. Some of these fishes swim far out in the ocean. *Cyclolepoides* is a salmonoid fish of unknown relationships. Its habitat is difficult to determine. It is known, however, that feeding salmon of today frequent the water of the open ocean, as well as that adjacent to the coast. Both forms therefore might be expected far out in the open sea, beyond the province inhabited by the majority of neritic fish. Furthermore, oceanic currents may transport to sea the scales held in suspension, their final resting place depending on the rate of settling of such scales. The most diagnostic scale is that of *Parapolymixia*, which occurs abundantly and with regularity. *Polymixia*, although occasionally caught nearer shore, is essentially a fish of medium depths (150 to 350 fathoms) and evidently does not descend to greater depths. A bathymetric zone of medium depth was apparently the scene of accumulation of the principal assemblage from the Kreyenhagen. It represents an environment in the depth of the oceanic province beyond reach of neritic forms. Deposition did not occur at greater depth, however, and probably a depth beyond 400 fathoms was not reached. The Kreyenhagen formation is considered to have accumulated in a marine trough of north-south extension. The sediments in which the Fi 2 scale assemblage occurs may well have been deposited in the central and deepest part of such a large marine province.

Fi 3 is recognized in a few thin sections at the base of the stratigraphic column. This assemblage shows an increase in variety of forms. The strata continue farther down as sandy or silty beds which are barren or in which the scales are poorly represented. This assemblage was deposited in shallower water than that in which Fi 2 accumulated. It still represents, however, a bathypelagic habitat, as is shown by the abundance of *Bregmaceros*.

Temperature

All the families and genera found in the Kreyenhagen and still existing today live principally in tropical seas, although some are also represented in temperate waters. There are no forms present that are restricted to temperate water, but a number of genera are known only from warm seas, for example, *Galeocerdo, Bregmaceros, Polymixia,* and *Caranx*. The evidence thus strongly suggests that a warm climate prevailed at the time of the Kreyenhagen deposition.

Comparison with California Fossil Fish Assemblages of Post-Eocene Age

Of the 16 families found thus far in the California Eogene, 10 are known from the Miocene (see table 1). Of the 18 genera, only 3 are found in the Miocene, and these occur only in the lowermost formations of that epoch or in the Mio-Oligocene. None of the genera is known from Californian deposits of an age older than Eocene or younger than Miocene. The Oligocene fauna is little known, but is likely to show similarity to that of the Eocene. The differences that exist between the Eocene and Miocene fish faunas are probably due in large measure to difference in temperature. Differences in geographic location of the majority of the Eocene deposits must likewise be considered in accounting for the faunal changes which ensued with the coming of Miocene time.

Correlation of Fish Scales and Foraminifera

On the basis of foraminifers, Laiming (1941) divided the Kreyenhagen into three zones, A1 to A3 inclusive. According to him: "A1 is characterized by the common occurrence of *Plectofondicularia jenkinsii* restricted to this zone, and associated with *Planularia markleyana, Eponides pygmaea,* and *Robulus welchi.*" Furthermore: "A2 is characterized by the restricted occurrence of *Uvigerina churchi* associated with *Uvigerina garzaensis, Bulimina corrugata, Gyroidinia orbicularis* var. *planata,* and *Plectofrondicularia packardi.*" Additional foraminifera are recorded from the lower part of A2. Zone A3 is recognized in only a few sections, and none of these is included in the material studied for the present report.[3]

The relation of the horizons containing the fish-scale assemblages to the foraminiferal zones appears to be as follows: The principal part of the section in which fish scales are preserved (Fi 2) corresponds either to zone A1 or undifferentiated A1 and A2, but is younger than typical A2. Fish assemblage Fi 3,

[3] Information concerning foraminiferal zones furnished by Boris Laiming in letter dated May 19, 1943.

in so far as it is present and determinable, may correspond to A2. Quite often, however, A2 is situated in the lower part of the section, in which fish scales are not present or are at best poorly preserved. *Bregmaceros,* a fish characteristic of Fi 3, has one of the smallest known types of fish scale and may be readily overlooked. At other localities in the Kreyenhagen, fish scales occur higher in the section than the established foraminiferal zones, and the foraminifera are sparsely represented. That part of the section in which fish-scale assemblage Fi 1 occurs is considered by students of foraminifers as representing the Tumey formation, of Lowermost Oligocene age.[4]

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[4] Oral communication from R. Stanley Beck.

PLATES

Plate 1

Eocene scales, San Joaquin Valley, California

Fig. 1. *Iniomus fossilis*, n. g. and n. sp. Type, no. 10333 C.I.T. Scale 4.1 mm. long by 4 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

Fig. 2. *Caranx orolomaensis*, n. sp. Elongate scale 4 mm. long by 2 mm. deep. Seaboard Oil Corp. well, Oro Loma No. 1. Kreyenhagen formation.

Fig. 3. *Caranx orolomaensis*, n. sp. Type, no. 10330 C.I.T. Scale 1.8 mm. long by 2 mm. deep. Seaboard Oil Corp. well, Oro Loma No. 1. Kreyenhagen formation.

Fig. 4. *Pseudoetringus kreyenhagius*, n. g. and n. sp. Smooth side of scale 5 mm. long by 5.1 mm. deep. Pure Oil Co. well, Chowchilla No. 1. Kreyenhagen formation.

Fig. 5. *Bregmaceros kreyenhagus*, n. sp. Coarse side of scale 2 mm. long by 1.2 mm. deep. Seaboard Oil Co. well, Oro Loma No. 1. Kreyenhagen formation.

Fig. 6. *Parapolymixia californica*, n. g. and n. sp. Type, no. 10323 C.I.T. Smooth side of scale 2.8 mm. long by 3 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1. Kreyenhagen formation.

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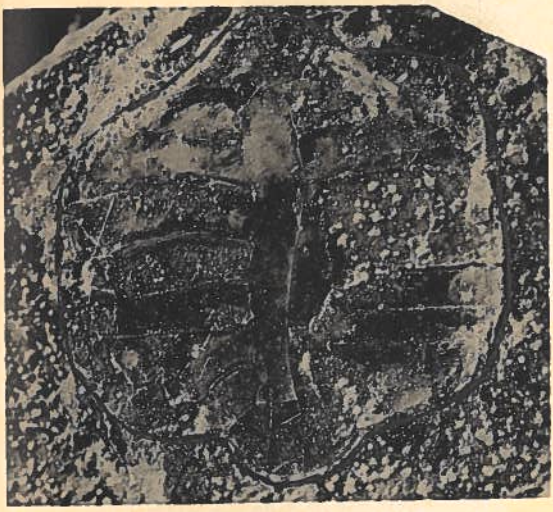

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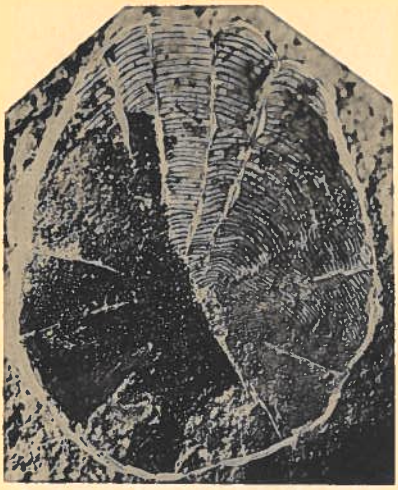

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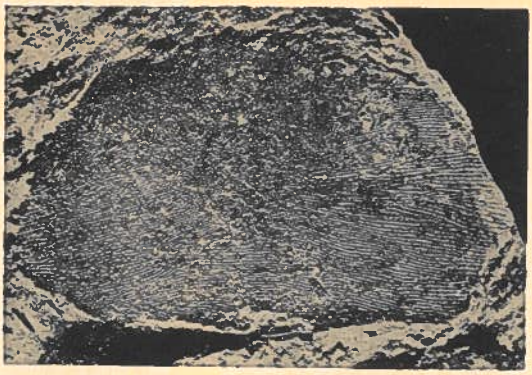

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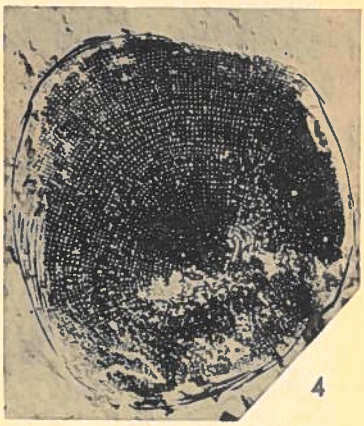

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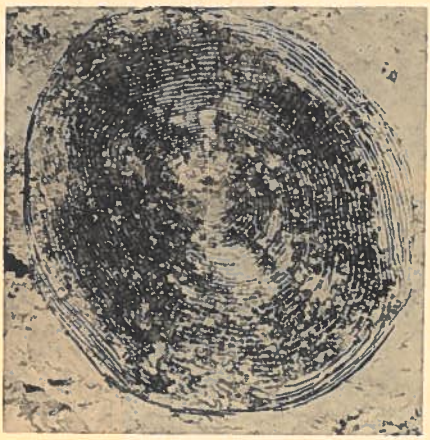

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Plate 2

Upper Eocene scales, Kreyenhagen formation, San Joaquin Valley, California

Fig. 1. *Hemiexocoetus eocenicus,* n. g. and n. sp. Scale 8 mm. long by 6.3 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1.

Fig. 2. *Hemiexocoetus eocenicus,* n. g. and n. sp. Coarse side of regenerated lateral scale 9.8 mm. long by 10 mm. deep. Seaboard Oil Corp. well, Gill No. 1.

Fig. 3. *Praescomberesox pacificus,* n. g. and n. sp. Cotype, no. 10326 C.I.T. Scale 4.1 mm. long by 7 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1.

Fig. 4. *Cyclolepoides tuberculatus,* n. g. and n. sp. Glossy side of scale 2 mm. long by 2.8 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1.

Fig. 5. *Cyclolepoides tuberculatus,* n. g. and n. sp. Coarse side of scale 4 mm. long by 2.5 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1.

Plate 3

Eogene scales, San Joaquin Valley, California

Fig. 1. *Hemiexocoetus eocenicus,* n. g. and n. sp. Scale 4 mm. long by 5 mm. deep. Seaboard Oil Corp. well, Gill No. 1. Kreyenhagen formation.

Fig. 2. *Praescomberesox pacificus,* n. g. and n. sp. Scale 8 mm. long by 7 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

Fig. 3. *Beryx san-joaquinensis,* n. sp. Scale 5.75 mm. long by 5.6 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

Fig. 4. *Kreyenhagenius joaquinensis,* n. g. and n. sp. Type, no. 10318 C.I.T. Scale 5 mm. long by 5.8 mm. deep. Seaboard Oil Corp. well, Gill No. 1. Kreyenhagen formation.

Fig. 5. *Paramorone eocenica,* n. g. and n. sp. Type, no. 10317 C.I.T. Scale 5.5 mm. long by 5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

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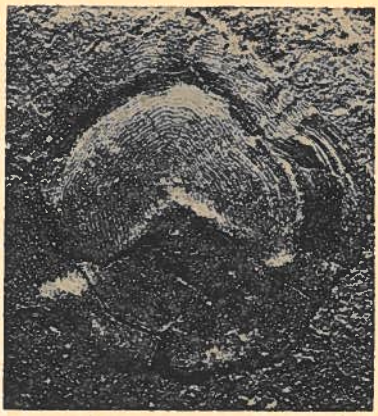

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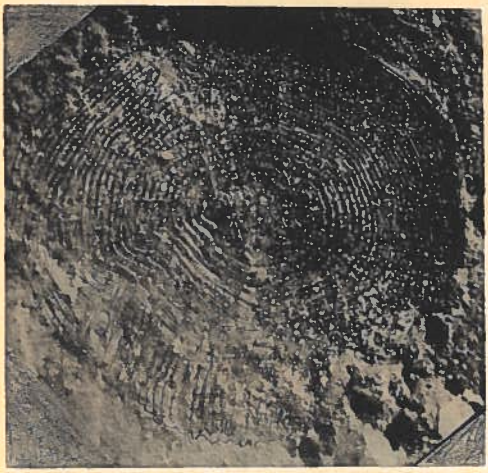

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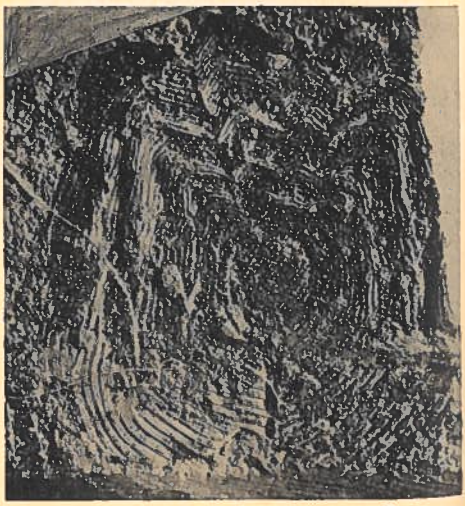

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Plate 4

Eogene scales, San Joaquin Valley, California

Fig. 1. *Beryx san-joaquinensis,* n. sp. Scale 4 mm. long by 4.9 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

Fig. 2. *Eoscombrus chaneyensis,* n. g. and n. sp. Type, no. 116 Richfield Pale. Lab. Scale 3.9 mm. long by 3.5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

Fig. 3. *Beryx eogenus,* n. sp. Type, no. 118 Richfield Pale. Lab. Scale 4.5 mm. long by 5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

Fig. 4. *Parastenodus gillensis,* n. g. and n. sp. Type, no. 110 Richfield Pale. Lab. Scale 5.2 mm. long by 3.9 mm. deep. Seaboard Oil Corp. well, Gill No. 1. Kreyenhagen formation.

Fig. 5. *Beckius plicatus,* n. g. and n. sp. Type, no. 111 Richfield Pale. Lab. Scale 4.5 mm. long by 4.5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.