A GEOLOGIC RECONNAISSANCE IN THE GULF COASTAL PLAIN OF TEXAS, NEAR THE RIO GRANDE.

By A. C. Trowbridge.

INTRODUCTION.

During June, July, and August, 1919, part of June and all of July and August, 1920, and parts of July and August, 1921, the writer, assisted by A. G. Maddren in 1919 and by W. S. Glock and Lloyd North in 1920, and associated with L. W. Stephenson, E. W. Berry, E. B. Stiles, and Señor Enrique Díaz Lozano in 1921, carried on reconnaissance work along the Rio Grande in the southern extremity of Texas. As there seems to be immediate need for a map and a brief description of the formations on the Texas side of the Rio Grande, to serve as a key for important stratigraphic work in progress both in the United States and Mexico, it has been decided to prepare and publish now a preliminary report and map, which will show the general results of the work already done.

For aid in the preparation of this report the writer is indebted to Dr. T. W. Vaughan, under whose direction the field studies were made and the report was prepared; to Dr. Julia Gardner, who identified the molluscan faunas; to Prof. E. W. Berry, who aided in the collection of the floras and identified them; to Dr. J. A. Udden, who kindly supplied well logs from the files of the Bureau of Economic Geology and Technology of the University of Texas; to Mr. C. L. Baker, with whom the writer has carried on correspondence and from whom he has received information and suggestions; to Mr. G. C. Matson, who has already covered the field and whose field notes and maps were available for the writer's use; to Mr. E. T. Dumble, who freely gave his opinion on several difficult questions; and to Mr. Alexander Deussen, who by oral conference and by correspondence gave valuable assistance. Eighty-two published articles that bear more or less directly on the problems of the region were freely consulted.

GEOGRAPHY OF THE REGION.

The region here considered is bordered on the south and west by the Rio Grande which forms the International Boundary, a part of its eastern border is the Gulf of Mexico, and on the northwest and north it is limited by the line of contact between the Cretaceous and Tertiary systems as mapped by Stephenson.[1] Roughly sketched, this line of contact extends from a point about 5 miles south of Uvalde, in Uvalde County, westward and southwestward through Pulliam, in the same county, and thence southwestward and southward through Maverick County to a point on the Rio Grande about 3 miles north of the Maverick-Webb county line and about 35 miles downstream from Eagle Pass. The eastern, northeastern, and northern boundary of the area considered is represented by a line drawn from a point about 5 miles south of Uvalde nearly southward to Carrizo Springs, in Dimmit County, thence southeastward to Hebbronville, in Jim Hogg County; thence eastward through Falfurrias, in Brooks County, and Sarita, in Willacy County, to the Gulf of Mexico. This line corresponds in part with the south and west boundary of a large area southwest of Brazos River that was surveyed by Deussen, whose report is now in press.[2] The counties included in the Rio Grande region are extreme south-central Uvalde, western Zavalla, eastern Maverick, western Dimmit, and all or most of Webb, Zapata, Jim Hogg, Starr, Brooks, Hidalgo, Willacy, and Cameron. The total area considered is about 13,500 square miles, nearly one twentieth of the State of Texas.

[1] Stephenson, L. W., The Cretaceous-Eocene contact in the Atlantic and Gulf Coastal Plain: U. S. Geol. Survey Prof. Paper 90, pl. 15, 1915.

[2] Deussen, Alexander, Geology of the Coastal Plain region of Texas: U. S. Geol. Survey Prof. Paper 126.

The region defined above lies wholly within the Rio Grande Plain of Hill and Vaughan.[3] The Balcones faulted zone, which separates this plain from the Edwards Plateau, lies 20 to 75 miles north of the Cretaceous-Eocene line. At the landward edge of the territory the elevation above the Gulf averages about 800 feet, and from this elevation there is a gradual slope to sea level at the Gulf. Although no part of the region has high relief, the part along the Rio Grande from the Webb-Maverick county line to Fort Sam Fordyce is notably rougher than that farther away from the river and that along the Gulf.

The rough belt near the river is commonly spoken of as "the breaks of the Rio Grande," and its roughness is due to the erosional work done by many intermittent tributaries. The width of the belt is not the same throughout but is determined in any area by the length of the tributary streams there. These streams average not more than 15 miles in length, but as most of them have only shallow valleys in their upper stretches the "breaks" they form are generally less than 15 miles wide. Although the relief at most places in this belt does not exceed 100 feet, there are localities where the tops of the highest hills stand more than 250 feet above the Rio Grande. In general both the relief and the roughness decrease with the decrease in average altitude downstream. It is in this belt that the best and the most numerous exposures of the rock formations are found.

The more nearly flat land east of the "breaks" is divided into two parts by a conspicuous cuesta known as the Bordas scarp. This scarp and the trench cut by the Rio Grande are the only notable topographic features of the region.

The Bordas scarp crosses the northeast border of the territory mapped at a point 7 miles northeast of Torrecillas, about 38 miles east of Laredo and 100 miles from the Gulf, and from this point it extends southwestward to Torrecillas, thence southward to Ojuelos, and thence in a somewhat irregular course, generally southward and a bit eastward, and is cut through by the Rio Grande at Rio Grande City. In general the scarp follows the course of the base of the Reynosa formation, whose resistant rocks produced it. As the land slopes steeply westward and almost imperceptibly eastward from its crest this scarp is conspicuous only if viewed from the west.

The area between the breaks of the Rio Grande and the Bordas scarp is not rough. Its gentle southward and eastward (Gulfward) slope is broken only by shallow valleys of the heads of tributaries of the Rio Grande, the many low hills due to the outcrops of the lenses of rock slightly more resistant to subaerial erosion (which is here of slight effect), and the scattered depressions scooped out by the wind and the corresponding slight elevations formed by material blown from the depressions. Few square miles in this plain have a relief of as much as 50 feet, and some of them, so far as the eye can see, are almost flat.

Except an area of sand dunes, which covers about 2,800 square miles, chiefly in Willacy, Brooks, Hidalgo, and Jim Hogg counties, and a narrow strip extending for 20 miles along the river between Rio Grande City and Sam Fordyce, the part of the region east of the Bordas scarp is notably flat. The areas near the scarp, however, are slightly more undulatory than the areas near the coast, where the surface generally stands less than 50 feet above sea level and where there is no visible relief except that produced by an occasional "clay butte" or a shallow stream channel or "resaca." This smoothness, however, is broken by the channel of the Rio Colorado, a distributary of the Rio Grande, which in places is 40 feet deep and has vertical walls.

In the sand belt the relief is measured by the heights of the dunes and the depths of the "blow-outs," but even there it does not exceed 25 feet on an average and 60 feet at a maximum.

The lower Rio Grande region, which is the southernmost part of the United States except southern Florida and the Florida Keys, receives much heat through insolation, and its temperature is therefore high. The average annual temperature is about 72° F., and the range is from 20° in January to 110° in July. The sensible heat of summer is greatly reduced by constant east winds of the monsoon type. The nights are comfortable, except a few during which cloudiness retards radiation and the wind dies down. The region is semiarid. There are long periods of drought, and when it does rain the water falls in great quantities, so that dry creek beds run full and roads become arroyos.

[3] Hill, R. T., and Vaughan, T. W., Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Tex.: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 193-322, 1898.

The rainfall in 1910 was 12 inches, in 1915 16 inches, and in 1916 14 inches. The rainfall at Eagle Pass in 1908 was 15.16 inches and in 1909 8.63 inches. At some places there was no rain at all for three years prior to the fall of 1918.

The vegetation, which varies in luxuriance with the rainfall, consists of wild grasses, mesquite, guajillo, catclaw, prickly pear, and other forms of cactus, and many other plants, which together make up what is known as chaparral or brush. Large trees are found only along the main streams, where pecans grow, and on dunes in the sand belt, which bear live oaks. The open grassy prairie on the coastal flats is broken here and there by dense thickets of low live oak brush.

STRATIGRAPHY.

GENERAL FEATURES.

The beds of rock dip at low angles Gulfward from the Cretaceous-Eocene line, and successively younger formations are therefore exposed at the surface in wide belts east and southeast of that line. The Rio Grande flows in general southeastward in a course that is oblique to the strike of the formations but that is at some places parallel with the strike and at others parallel with the dip. It flows from older to younger beds, but its gradient is so slightly less than the dip of the beds and so nearly parallel with the strike for considerable distances that the formations change only at intervals of many miles along the river.

The formations are of Tertiary and Quaternary age. Eocene formations, which lie unconformably on Cretaceous formations along the irregular north boundary, continue at the surface eastward along the Texas-Mexican Railroad as far as Torrecillas and southward and southeastward along the Rio Grande almost to Sam Fordyce. Oligocene and Miocene formations, which are exposed on the Gulf Coastal Plain farther north, do not outcrop in the lower Rio Grande region, the Oligocene probably because they do not exist here and the Miocene because they are covered by a great overlap of Pliocene rocks. Pliocene, Pleistocene, and Recent deposits are exposed at the surface over wide areas east of the Bordas scarp. (See Pl. XXVIII.)

CRETACEOUS SYSTEM.

Rocks of Cretaceous age crop out extensively in the Edwards Plateau, in the northern part of the Gulf Coastal Plain, and elsewhere in Texas, and form a great system, but these areas lie outside of the region here described. This system in Texas has long been well known, chiefly through the earlier work of R. T. Hill.[4] More recently Udden [5] and his assistants have published a summary of the geology of Texas, in which the Cretaceous rocks are classified, described, and interpreted, and L. W. Stephenson is now completing certain work north of the Cretaceous-Eocene line.

THE CRETACEOUS-EOCENE LINE.

As Stephenson [6] has recently reported on the contact between the rocks of the Cretaceous and the Tertiary system in the lower Rio Grande region, the writer gave relatively little attention to this line of stratigraphic division. The line is shown on the map essentially as it was drawn by Stephenson, and the contact, at least between the Rio Grande and Nueces River, is essentially as he describes it. There is no marked lithologic break at the contact, though Stephenson found evidence of physical unconformity in Texas, as did Baker [7] on the Mexican side of the border, but the systemic significance of such unconformities is difficult to recognize, especially in parts of the geologic column where locally unconformities are common. The faunal break, however, is great and its significance is unquestionable. Not a single species is common to the faunas below and above the break and many genera that occur in the Cretaceous are missing in the Eocene. As Vaughan [8] pointed out in 1900, it is clear that the unconformity at this horizon is really great, even though lithologically and stratigraphically it appears insignificant. In the Rio Grande region a long time must have elapsed between the end of the recorded Cretaceous and the beginning of the recorded Eocene.

TERTIARY SYSTEM.

EOCENE SERIES.

The history of Eocene classification in the West Gulf Coastal Plain has been long and complicated. Many synonymous and overlapping formation names have been used, and correlations have been made which have later been

[4] Hill, R. T., The Texas section of the American Cretaceous: Am. Jour. Sci., 3d ser., vol. 34, pp. 287-309, 1887.

[5] Udden, J. A., Baker, C. L., and Böse, Emil, Review of the geology of Texas: Texas Univ. Bull. 44, 1916.

[6] Op. cit., pp. 169-181.

[7] Baker, C. L., personal communication.

[8] Vaughan, T. W., Reconnaissance in the Rio Grande coal fields of Texas: U. S. Geol. Survey Bull. 164, pp. 35-36, 1900.

found to be incorrect. The following classification seems to represent the present knowledge of the Eocene series in this region:

Frio clay } (of Jackson age).
Fayette sandstone }
Claiborne group:
  Yegua formation.
  Cook Mountain formation.
  Mount Selman formation.
Wilcox group:
  Bigford formation (chiefly contemporaneous with Carrizo sandstone but in part younger).
  Carrizo sandstone.
  Indio formation.
Midway formation.

These formations are lithologically so very similar that their discrimination as units in mapping is extremely difficult, and the lines of contact shown on the map should therefore be considered only tentative, though there are slight differences in the rocks, which, taken together with their more significant faunas and floras make it possible to separate the formations with some confidence.

MIDWAY FORMATION.

Distribution.—The formation once known as the "Basal or Wills Point clays," now called the Midway formation, crops out only in a short and narrow belt in southern Maverick County. Its outcrop is not a continuous belt along the Cretaceous-Eocene line of contact, for it is overlapped in southern Uvalde, western Zavalla, and northeastern Maverick counties by strata of Wilcox age. The outcrop is also obscured by patches of gravel belonging to the Reynosa formation, of probable Pliocene age.

Relations to adjacent formations.—The Midway formation lies disconformably on the Escondido formation of the Cretaceous system. There is also a great time break at this horizon and another at the top of the Midway, where it is overlapped by strata of Wilcox age. The unconformable contact between the Midway below and the Wilcox above is well exposed (1) at the north end of the westward-facing bluff of the Rio Grande in extreme southern Maverick County, 2 miles north of the Webb County line, and (2) on the west wall of the valley of Frio River at Bob Evans's apiary (Myrick's lower apiary of the Uvalde folio), in Uvalde County, 12 miles east of the Rio Grande region, as mapped in this report. In each of these sections the line between the Midway and Wilcox formations is the edge of an erosional surface and the basal Wilcox is conglomeratic, the pebbles being worn fragments, fossils, and concretions of iron carbonate derived from the underlying Midway. There is a great unconformity between the Midway and the Reynosa, the gravels of the Reynosa having been deposited on a surface which bevels the Midway and all other Eocene strata.

Character.—The Midway formation consists chiefly of shale, but includes interbedded lenses and layers of sandstone and limestone. At the base of the formation in some places there are thin and discontinuous beds of conglomerate containing abraded fragments of rock and fossils derived from the underlying Escondido formation. Heavy ledges of limestone overlie the conglomerate or form the basal beds when there is no conglomerate. The limestone is gray, compact, and in some places crystalline, and it contains fossils. The beds are at few places more than 1½ feet thick and are interbedded with greenish-gray sand 1 to 2 feet thick. The shale is generally dark, and some beds are black, but the colors include green, brown, gray, bluish gray, and blue. Some of the beds are notably pure, but many are sandy or silty and gypsiferous. Individual beds do not exceed 40 feet in thickness. The beds of sandstone are gray, yellowish, brownish, or greenish, and are irregularly and thinly bedded. Many are micaceous and some are glauconitic. Most of them are rather soft, but some are firm. They vary in texture but are generally fine grained. Throughout the formation, but chiefly in the shale, there are numerous concretions, which range in diameter from 6 inches to 10 feet, are generally flat or biscuit-like, and consist chiefly of limestone. Many are septaria or "turtle stones." Some of the smaller ones are pyritized, some are clay ironstones, and some consist of iron carbonate.

A typical section of the formation on the Texas side of the Rio Grande, a mile below the Blessé ranch, on the Mexican side, is given below:

Section of the Midway formation in Texas near the Blessé ranch, Mexico.

	Feet.
Shale	7
Iron concretions	1
Shale	5
Concretionary sandstone	1
Blue-black shale with abundant *Venericardia smithii*	12
Concretionary iron bed containing *Venericardia smithii*	1

	Feet.
Dark-gray shale containing disc-shaped iron concretions and a few gastropods	25
Thin and irregularly bedded sandstone, interbedded near the top with sandy shale	15
	67

Thickness.—As the dip of the Tertiary formations may not be entirely deformational but may have been in part original, the usual methods of determining thickness from the outcrops are of no great value. In any case, the Midway formation is probably nowhere exposed in its full thickness because of the Wilcox overlap. Only where it has been drilled through for oil or water and where its base and top can be determined from the log or from samples of the core can its true thickness be estimated. Only one such boring is known in the Rio Grande region—the L. E. Hanchett oil-prospecting well, 10 miles west of Carrizo Springs. The log of this well shows that the formation is 194 feet thick. The average of all estimates of its thickness outside of the Rio Grande region but near it is 216 feet.

Fossils.—The fossils collected from the Midway formation of this and neighboring districts by the writer and others are listed below:

Aporrhais sp.
Callocardia ripleyana (Gabb).
Calyptrophorus velatus subsp. compressus Aldrich.
Cerithium penrosei Harris.
Cerithium? sp.
Crassatellites gabbi (Safford).
Cucullaea (macrodonta subsp.?) texana Gardner.
Cypraea sp.
Enclimatoceras vaughani Gardner.
Fusus ostrarupis Harris.
Leda milamensis Harris.
Lithophaga sp.
Mesalia pumila subsp. wilcoxiana Aldrich.
Mesalia sp.
Modiolus saffordi (Gabb)?
Natica sp.
Ostrea crenulimarginata Gabb.
Ostrea pulaskensis Harris.
Plejona limopsis (Conrad).
Plejona rugata (Conrad).
Pseudoliva ostrarupis Harris.
Teredo maverickensis Gardner.
Turris anacona (Harris).
Turritella alabamiensis Whitfield.
Turritella humerosa Conrad.
Turritella mortoni Conrad.
Turritella nerinexa Harris.
Venericardia bulla Dall.
Venericardia (alticostata subsp.?) hesperia Gardner.
Venericardia smithii Aldrich.
Venericardia (alticostata subsp.?) whitei Gardner.
Yoldia eborea (Conrad).

WILCOX GROUP.

SUBDIVISIONS.

A thick set of lithologically complex beds lies stratigraphically between the top of the Midway and the base of the Mount Selman formation. These beds have been variously known as the "Lignitic," the "Sabine," the "Sabine River," and the "Timber Belt," each of these names including all strata between the top of the "Basal clays" (Midway formation) and the base of the "Marine beds" (Claiborne group). Owen[9] first segregated a notably sandy phase of the "Lignitic" and called it the Carrizo sandstone, from the town of Carrizo Springs, where it is characteristically developed and well exposed. After the upper sands were separated and named the underlying beds were correlated with the Wilcox of Mississippi and called by the same name. Vaughan[10] considered the Carrizo formation a transgressive phase of the Wilcox. More recently Udden, Baker, and Böse[11] have tentatively considered it the oldest formation of the Claiborne group. In a still later geologic publication of the University of Texas Liddle[12] placed the Carrizo of Medina County in the Claiborne group without qualification. Deussen[13] found that it lay unconformably on Wilcox beds and unconformably beneath the Mount Selman formation between Brazos and Nueces rivers, and Baker[14] reported an unconformity between the Carrizo and underlying beds of Wilcox age on the Arroyo del Amole, on the Mexican side of the Rio Grande, across the river from the Chupadero ranch. As unconformities are common in the Wilcox and as neither the Wilcox nor the Carrizo contains fossils other than plants that had not been critically studied, the age of the Carrizo sandstone was an open question until 1921, when fossil plants were collected under the direction of E. W. Berry from the lower beds of the Wilcox, from the Carrizo, and from beds above the Carrizo but below the Mount Selman. As a result of these studies of the flora and an investigation of the lithology of the lignitic beds, the Wilcox is here recognized as

[9] Owen, J., Report of geologists for southern Texas: Texas Geol. and Min. Survey First Rept. Progress, for 1888, pp. 69–74, 1889.

[10] Vaughan, T. W., Index to the stratigraphy of North America (by Bailey Willis and others): U. S. Geol. Survey Prof. Paper 71, p. 726, 1912.

[11] Op. cit., pp. 83–84.

[12] Liddle, R. A., The geology and mineral resources of Medina County: Texas Univ. Bull. 1860, pp. 87–93, 1918 [1921].

[13] Deussen, Alexander, Geology of the Coastal Plain region of Texas: U. S. Geol. Survey Prof. Paper 126 (in press).

[14] Baker, C. L., personal communication.

a group, consisting of three formations, here named, in ascending order, the Indio formation, the Carrizo sandstone, and the Bigford formation.

INDIO FORMATION.

Name.—The strata overlying the marine Midway formation and underlying the Carrizo sandstone are here called the Indio formation. These strata have until now been known as the Wilcox formation, for they were believed to represent all the deposits of Wilcox age in this region. The new formation name is made necessary by the fact that the Wilcox as here developed becomes a group divisible into three formations, of which the Indio is the basal one. The Indio formation is named from the old Indio ranch, in Maverick and Dimmit counties, which includes most of the area of outcrop of the formation.

Character.—Although it is made up of an intricate mixture of sediments, the Indio formation consists chiefly of thin-bedded and laminated argillaceous sand and arenaceous shale but includes some layers of massive clay and lenses and layers of sandstone. The clay and shale are greenish or bluish gray and light chocolate-brown, and most of them are gypsiferous. The sandstone is gray, yellow, green, and brown, is not notably cross-bedded, and is of various textures. It includes also some beds of lignite and many calcareous and arenaceous concretions, most of them flat, biscuit-shaped, or millstone-shaped bodies.

Until recently no marine sediments have been found in the Wilcox group except along Sabine River, but the discovery of marine Foraminifera between 125 and 148 feet from the surface and 500 feet above the base of the Indio formation in the L. E. Hanchett oil drillings Nos. 1 and 2, about 10 miles west of Carrizo Springs, in Dimmit County,[15] shows that the Gulf advanced over the low-lying lands at least once for a short time during the Indio epoch. Beds of *Ostrea tasex* Gardner also are known west of the Hanchett wells and at and south of the Glass ranch headquarters, in Maverick County, and in the San Pedro sheep pasture, 19 miles southwest of Carrizo Springs, in Dimmit County. This form is similar to *O. crenulimarginata*, which is of Midway age, but is not identical with it. The oysters and the Foraminifera appear to occur at the same horizon.

The formation is partly marine and partly nonmarine and was deposited on both sides of a shore line on the landward side of which the land was low and on the opposite side of which the sea was shallow. The shore line probably oscillated back and forth slowly during Indio time.

Distribution.—The Indio formation crops out in the Rio Grande region in a belt 10 to 14 miles wide in western Dimmit, southeastern Maverick, and northwestern Webb counties, where it is exposed in practically its full thickness. Here it adjoins the Midway on the west and the Carrizo on the east. Farther north, in Maverick County, the Indio overlaps the Midway and rests upon the Cretaceous. Still farther north, in western Dimmit and Zavalla counties and eastern and northeastern Maverick County, the Indio is in turn cut out by a great overlap of the Carrizo on the Cretaceous. In the extreme northeast corner of the region the Indio crops out again between the Cretaceous and the Carrizo where Nueces River has cut through the overlying and overlapping Carrizo sandstone.

Thickness.—The thickness of the Indio recorded in the Hanchett wells, in Dimmit County, is 648 feet, and as these wells are only about a mile west of the eastern boundary of the formation at a point where the belt of outcrop is widest, the maximum thickness of the Indio exposed probably does not exceed 700 feet. Other layers that are covered by the Carrizo overlap may or may not overlie those which crop out.

Fossils.—With the exception of Foraminifera, oysters, and a few fossil leaves, the Indio formation is faunally and florally barren in the Rio Grande region. The protozoans include *Nodosaria*, *Textularia*, and *Globigerina*. The mollusks are *Ostrea tasex* Gardner and *Levifusus* sp. cf. *L. trabeatoides* Harris.

Fossil plants were found (1) on the west wall of the valley of Nueces River a mile below Pulliam ranch, (2) on the east wall of the valley of Nueces River at the big bend 1¼ miles above the Uvalde-La Pryor road crossing, (3) in the clay pit at the end of the unused aerial tram south of Elmendorf, Bexar County, and (4) at the Schuddemagen ranch, 10 miles south of Sabinal, Uvalde County. Localities 3 and 4

[15] Well log and description of samples supplied independently by J. A. Udden and C. L. Baker.

are outside the Rio Grande region. A list of identified species follows:

- Anona ampla Berry.
- Anona eolignitica Berry.
- Cyperites sp. Hollick.
- Ficus mississippiensis Berry.
- Nectandra sp.
- Oreodaphne obtusifolia Berry.
- Rhamnus coushatta Berry.
- Sabalites grayanus Lesquereux.
- Sapindus linearifolius Berry.

CARRIZO SANDSTONE.

Distribution.—The base of the Carrizo was located by Owen [16] at a point 10 miles west of Carrizo Springs, and the formation, which is made up of sandy beds, extended eastward to the base of the "Marine beds," east of Asherton, occupying a belt about 20 miles wide. When it is traced southward, however, the belt of sands becomes narrower until, at the Rio Grande, it is only 3 miles wide. The strata that cover it here are not prevailingly sandy and are what is here called the Bigford formation. North of Carrizo Springs the Carrizo formation spreads northwestward to the Cretaceous rocks, overlapping both the Indio and the Midway. Northeast of Carrizo Springs, outside the region shown on the map, the belt of Carrizo sandstone becomes narrower, the Bigford formation here also probably wedging in between the Carrizo and the Mount Selman.

Relations to adjacent formations.—The Carrizo sandstone rests unconformably upon the Indio by overlap. In the area east of the outcrop of the contact, however, where the full thickness of the Indio is represented, the similarity of the flora indicates that the relations are conformable. The relation between the Carrizo and the Bigford formation is apparently conformable. Differences in flora suggest a break between the Carrizo and the Mount Selman, and there are indications of unconformity where the two come together in the railroad cut 3 miles west of Big Wells, an exposure 15 miles east of the Rio Grande region.

Character.—The Carrizo formation is decidedly more sandy than the other formations of the Wilcox group, the Indio formation below and the Bigford formation above, and the beds of sandstone in the Carrizo are more firmly cemented. Some of them are cemented and crystallized into a good grade of quartzite. Many of them are highly ferruginous, but some are gray or white, colors denoting little iron. The sand and the sandstone are characteristically cross-bedded. Owing to inequalities from place to place in the firmness of the cement erosion has in some places produced castellated forms, notably south of Chupadero ranch, in northwesternmost Webb County. The sandy beds vary greatly in texture. In the quarries around Carrizo Springs and for some distance north of that place the rock is fine grained, but in many other localities it is medium and even coarse grained.

The Carrizo sandstone includes also thin beds and lenses of clay of various colors and beds of limestone, yellow on weathered surfaces and light chocolate-brown inside, forming concretions, rough beds, or lenses, botryoidal bodies, and irregular masses. Cone-in-cone structure is fairly common in the beds of fine texture in which calcareous and argillaceous material are mixed in about equal proportions.

Thickness.—The thickness of the Carrizo sandstone as estimated by Owen [17] is 200 feet. Between a point 10 miles west of Carrizo Springs and a point 3 miles west of Big Wells, however, its thickness is probably more than 400 feet, there being at least 200 feet of strata exposed west of Carrizo Springs. At the Rio Grande, where the sandy belt is narrow, its thickness is estimated at 118 feet. At another point between the river and Carrizo Springs it appears to be about 392 feet. Where the Carrizo overlaps the Indio and Midway north of Carrizo Springs it is doubtless very thin. The average of all previous estimates is 250 feet. It evidently varies greatly in thickness, and the average is now put at 325 feet.

Fossils.—Invertebrate and vertebrate fossils have not been found in the Carrizo sandstone. Poorly preserved fragments of plants have often been noted, but the flora was not critically studied until 1921, when E. W. Berry accompanied the writer to the field and made collections. Identifiable leaves were found in a short arroyo in the east wall of Nueces River valley three quarters of a mile below the Uvalde-La Pryor road crossing and in the Bell quarries, southwest of Carrizo Springs, from which Carrizo sandstone was taken to build the courthouse and other buildings in Carrizo Springs.

[16] Owen J., Report of geologists for southern Texas: Texas Geol. and Min. Survey First Rept. Progress, for 1888, pp. 70-74, 1889.

[17] Owen, J., idem, p. 72.

The list given below shows, according to Berry, that the Carrizo is of Wilcox and not of Claiborne age, a fact which is in harmony with the lithology and stratigraphy of the sandstone and the associated beds.

Acrostichum sp.
Anona ampla Berry.
Anona wilcoxiana Berry.
Banksia puryearensis Berry.
Canavalia eocenica Berry?
Cassia tennesseensis Berry?
Cinnamomum vera Berry?
Dryophyllum tennesseensis Berry?
Eugenia grenadensis Berry.
Ficus mississippiensis (Lesquereux) Berry.
Gleditsiaphyllum eocenicum Berry.
Heterocalyx n. sp.
Mespilodaphne coushatta Berry.
Myrcia vera Berry.
Nectandra pseudocoriacea Berry.
Oreodaphne obtusifolia Berry.
Oreodaphne puryearensis Berry.
Palmocarpon butlerensis Berry.
Persea longipetiolatum (Hollick) Berry.
Sabalites grayanus Lesquereux.
Sophora wilcoxiana Berry.
Sterculia wilcoxensis Berry.

BIGFORD FORMATION.

Name and distribution.—Most of those who have visited this region have believed that the Carrizo sandstone is continuous from the top of the Indio formation (the old Wilcox formation) to the base of the Mount Selman, and it appears to be continuous at the type section of the Carrizo near Carrizo Springs and in that latitude, but south of Carrizo Springs the sand and sandstone of the Carrizo give place along the strike to clay, thin-bedded sandstone, and lignite. To these beds, which consist so largely of clay that they can not be called Carrizo sandstone, the name Bigford is here given, from Bigford ranch, which is practically the only habitation in their belt of outcrop, where the beds are well exposed along the river within the ranch. The outcrop widens toward the south from 2 miles at the boundary of the Rio Grande region, southeast of Carrizo Springs, to about 12 miles at the Dimmit-Webb county line. The Rio Grande has exposed the beds in its north bluffs for 20 miles. Between Carrizo Springs and Big Wells, outside of the Rio Grande region, the formation is entirely absent. It may wedge in farther north, for similar beds appear to occur in well logs and in exposures along Nueces River southeast of Crystal City.

Character.—Lithologically the Bigford formation consists chiefly of clay of many colors and of subordinate quantities of gray, green, and brown sandstone, which is at most places not cross-bedded. It contains many beds of lignite, the heaviest 20 inches thick, and some lens-shaped concretionary masses. It contains no paper shales and sands, such as occur in the Indio, nor any thick, cross-bedded, and commonly quartzitic sands, such as occur in the Carrizo.

Relations to adjacent formations.—Although the Bigford formation is at least fairly distinct lithologically, it is not believed to represent, except in its uppermost part, a period of time entirely separate from the Carrizo epoch. The greater part of the formation probably grades along the strike into beds in the middle and upper parts of the Carrizo sandstone, and if so is contemporaneous with those beds. At some places, however, the uppermost part of the Bigford rests with apparent conformity on the Carrizo sandstone. The Bigford strata appear to represent a lagoon and tidal-flat phase of a stage of deposition during which the Carrizo sandstone was deposited at or landward from the shore line.

Thickness.—The Bigford formation ranges in thickness from about 80 to about 470 feet.

Fossils.—The only fossils found in the Bigford formation are some leaves of a few species of plants, which were collected at a place on Concillas Creek a quarter of a mile below the point where it is crossed by the road from Bigford ranch to Apache ranch, about half a mile from the Rio Grande, where two sets of beds of clay, sandstone, lignite, and lignitic clay are separated by an erosional unconformity. Leaves occur both below and above the unconformity but were collected only from the upper set of beds, in which they are best preserved. The forms identified are as follows:

Anacardites grevilleafolia Berry.
Banksia puryearensis Berry.
Canna eocenica Berry.
Cassia marshallensis Berry.
Cyperites sp. Hollick.
Inga wickliffensis Berry?
Juglans schimperi Lesquereux.
Mimosites variabilis Berry.
Mimusops mississippiensis Berry.
Myrica wilcoxensis Berry.
Sabalites grayanus Lesquereux.
Sophora wilcoxiana Berry.

Berry reports that this is a Wilcox flora, one distinctly older than that in the base of the Mount Selman formation, which is of Claiborne age.

CLAIBORNE GROUP.

The "Marine beds" of earlier writers included the strata between the top of the "Lignitic" and the base of the Yegua. These beds are now separated into two formations, the almost unfossiliferous marine beds below constituting the Mount Selman formation and the highly fossiliferous marine strata above constituting the Cook Mountain formation. The overlying Yegua formation, which contains Claiborne fossils, is also included in the Claiborne group.

MOUNT SELMAN FORMATION.

Character.—The chief constituent of the Mount Selman formation is clay, and exposed sections of it are therefore rare except at places along drainage lines where thin ledges of sandstone and limestone hold up the clay in vertical faces. There are large flat areas where the formation is not exposed but where the shallow surficial drainage channels are so universally clayey that the underlying formation must be chiefly if not entirely clay or shale. The sections exposed probably exaggerate the proportion of sandstone in the formation, for they occur only where lenses of the more resistant materials are most abundant. The clay is gray, black, greenish gray, and bluish gray where fresh and yellow or buff where weathered. Some of the beds are sandy and some are limy, but most of them consist chiefly of stiff, compact clay, plastic and sticky when wet and hard but with a fracture like that of starch when dry. The beds of clay contain a large quantity of gypsum in lenses, beds, stringers, joint fillings, and irregular crystal aggregates. Most of it is the transparent platy variety, but some masses of bladed crystals are brown.

The sandstone occurs in layers and lenses, some of them 25 or 30 feet thick for short distances. The sand is coarse, medium, and fine, most of it is micaceous, and some is glauconitic. The beds are fairly well consolidated but are not quartzitic. The formation includes a few thin lenses of gray limestone.

Coal, both lignitic and bituminous, is a common constituent of the Mount Selman formation. It has been mined at Minero, Dolores, Cannel, and Santo Tomas, in Webb County. There are two main producing coal beds and several thinner beds, less pure, which are not worked. The coal beds here are about one-third of the distance from the top to the bottom of the formation, but beds occur nearer its base upstream from Palafox and almost at its top near the mouth of Arroyo Santa Isabella, and well logs show that coal beds occur throughout the whole thickness of the formation.

The Mount Selman formation contains throughout, from bottom to top, many calcareous concretions, chiefly in the clay and shale. Most of them are composed of compact, fine-grained, pure, almost lithographic limestone. On the outside they are pale yellowish gray or buff; on the inside they are light chocolate-brown or gray. Nearly all of them are septarian, and the fractures are filled with calcite. They are of diverse sizes and forms. The smallest are about the size of a pea and the largest are 6 feet in diameter; some are cylindrical, resembling pipe stems, some are biscuit-shaped, and some are nodular and extremely irregular. The average concretion is a foot in diameter and spheroidal in form.

Distribution.—The surficial distribution of the Mount Selman formation is shown on the map. The formation extends downstream along the Rio Grande from a point 6 miles above Palafox to the mouth of Sambarieto Creek, about 8 miles above Laredo, a distance of about 26 miles measured in a straight line. The course of the river is irregularly oblique to the strike, however, and this distance is not a measure of the width of the belt of outcrop, which is about 16 miles wide and of nearly uniform width. The western boundary of the formation, which is the Claiborne-Wilcox line of contact, is not sharply defined. In general it marks the line that separates beds of clay, sandstone, and lignite that contain no molluscan fossils and few concretions but that carry a Wilcox flora (the Bigford formation), from beds of gypsiferous, highly concretionary clay interbedded with beds of sandstone and limestone carrying unmistakable though few and fragmentary marine fossils. The Mount Selman-Cook Mountain line, on the east side of the belt, separates the Mount Selman material from the sandy, highly fossiliferous, red-weathering Cook Mountain formation, which stratigraphically overlies the Mount Selman.

The Mount Selman formation, though it contains marine rock, is evidently not entirely of marine origin. The coal and the sediments that carry land plants were doubtless deposited in isolated coastal basins and lagoons and perhaps to some extent on tidal flats.

Thickness.—The minimum measured thickness of the formation is 225 feet and the maximum is 707. Deussen assigns to it an average thickness of 350 feet in the area next north of the Rio Grande region. The average within the Rio Grande region is 618 feet.

Fossils.—The Mount Selman formation is not highly fossiliferous, yet a few poorly preserved forms of both animals and plants have been recognized. The mollusks so far recognized are *Cornulina armigera* Conrad, *Cytherea* sp. cf. *C. trigoniata* var. *winnensis* Harris, *Ostrea* sp., *Plejona petrosa* (Conrad), *Protocardia* sp., and *Venericardia planicosta* Lamarck.

Only two collections of Mount Selman plants were made by the writer. They are fragmentary and obscure, but Berry has identified them provisionally as *Apocynophyllum grevilleafolium* Berry, *Coccolobis claibornensis* Berry, *Ficus newtonensis* Berry, *Geonomites* n. sp., and *Myrcia* n. sp.

COOK MOUNTAIN FORMATION.

Distribution and relations.—The Cook Mountain formation is the upper and highly fossiliferous part of what has been known as the "Marine beds." Its outcrops lie in a belt averaging 13 miles in width where it includes the full thickness of the formation, extending from the northeast border of the region at and west of Encinal, almost due south for about 40 miles to a point where the base of the formation is cut off by a bend in the Rio Grande 8 miles above Laredo. From this point for a distance of about 70 miles down the river the strike of the formation is almost parallel to the general course of the river. The river cuts the top of the formation—the Cook Mountain-Yegua line—15 miles upstream from Roma. Thus the formation is exposed in the "breaks of the Rio Grande" for a distance of 75 miles. The towns included within the belt of outcrop are Encinal, Laredo, San Ygnacio, Zapata, and a large number of places inhabited by Mexicans.

This change in the strike from west of south to east of south so as almost to correspond with the course of the Rio Grande from Laredo to Roma was not known to all previous workers. Dumble,[18] for instance, continuing the west of south by east of north strike, draws the Cook Mountain-Yegua contact line across the river 8 miles below Laredo, the Yegua-Fayette line about 4 miles above Zapata, and the Fayette-Frio line on the Texas side a mile or two below Rio Grande City. The true structure was first pointed out by Vaughan,[19] who had collected Claiborne fossils far down the Rio Grande and understood that they came from the "Marine beds." Thus much of what Dumble has considered Fayette was recognized by Vaughan as Cook Mountain. This fact explains Dumble's insistence that much if not all of the Fayette formation is of Claiborne age.

Character.—The Cook Mountain formation is primarily sandy, and the sand is more or less firmly cemented. Most of the rock is medium grained, but there are beds of fine-grained and coarse-grained sandstone. The beds are brown, red, yellow, green, and gray and are commonly ferruginous, micaceous, and glauconitic. Many of them are cross-bedded and ripple marked. Interbedded with the sandstone is some yellowish, bluish, and greenish-gray or chocolate-colored clay and a few thin lenses of gray limestone. The sandstone and at some places the clay contains large, dark-gray, hard-centered, crystalline limestone concretions, some of which are fossiliferous. The lower two-thirds of the formation weathers characteristically into red sandy soils; the upper third at most places weathers gray. All the soils derived from the Cook Mountain formation support vegetation, which is unusually luxuriant.

Thickness.—The estimates of the thickness of the Cook Mountain formation range from 187 to 668 feet, and average 422 feet.

Fossils.—The formation everywhere contains abundant fossils, by which it can be distinguished from the Mount Selman below and the Yegua above; indeed it can thus be distinguished from all other formations in the region, for its faunas are larger and more

[18] Dumble, E. T., Geology of Southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, p. 916, fig. 1, 1903.

[19] Vaughan, T. W., Contributions to the geology and paleontology of the Canal Zone, Panama, and geologically related areas in Central America and the West Indies: U. S. Nat. Mus. Bull. 103, 1919.

diversified than those of any other Tertiary formation in Texas. The faunas within the formation present four more or less distinct facies.

One of these faunas is found at the base of the formation. The complete specific list is as follows:

Anomia ephippoides Gabb.
Buccinanops sp. cf. B. ellipticum Whitfield.
Callocardia astartoides Gardner.
Callocardia sp. cf. C. bastropensis (Harris).
Callocardia sp.
Cerithium texanum Heilprin.
Cerithium webbi Harris.
Corbula (Cuneocorbula) conradi Dall.
Drillia? sp.
Egerella sp.
Epitonium sp.
Lacinia alveata Conrad?
Leda sp.
Levifusus trabeatoides Harris?
Levifusus sp.
Lucina sp.?
Natica dumblei Heilprin.
Olivula staminea Conrad.
Olivula sp.
Ostrea alabamiensis subsp. georgiana Conrad (small).
Polynices arta (Gabb).
Pseudoliva vetusta Conrad.
Sinum declivum Conrad?
Solen sp.
Tuba antiquata Conrad.
Turritella sp.
Venericardia planicosta (Lamarck).
Yoldia sp. cf. Y. psammotea Dall.

A second fauna occurs in the lower part of the Cook Mountain formation but above the basal beds. A complete list of species follows:

Acteon pomilius Conrad.
Adeorbis? sp.
Anomia ephippoides Gabb.
Architectonica sp. aff. A. acuta Conrad.
Benoistia? sp.
Cadulus sp.
Callocardia astartoides Gardner.
Callocardia bastropensis (Harris).
Callocardia sp.
Cancellaria panones Harris.
Cancellaria sp.
Cardium (Cerastoderma) harrisi Vaughan?
Cardium (Cerastoderma) ouachitense Harris?
Cassis? sp.
Cerithium sp.
Cochlispira sp.
Corbula (Cuneocorbula) conradi Dall.
Crassatellites sp.
Crepidula sp.
Cylichna sp. cf. C. jacksonensis Meyer.
Drillia nodocarinata (Gabb)?
Drillia texacona Harris.
Egerella sp.
Epitonium trapaquara (Harris).
Eucheilodon sp. cf. E. reticulatoides Harris.
Eucheilodon? sp.
Lacinia alveata Gabb.
Latirus moorei Gabb?
Leda bastropensis Harris.
Leda compsa Gabb.
Lima harrisiana Aldrich.
Lucina sp. cf. L. ozarkana Harris.
Mesalia clabornensis Harris.
Murex (Odontopolys) sp.
Natica dumblei Heilprin (large).
Natica semilunata Lea.
Nucula mauricensis Harris.
Olivula staminea Conrad.
Ostrea alabamiensis subsp. georgiana Conrad (small).
Ostrea sellaeformis Conrad?
Ostrea sp.
Pholadomya sp.
Plejona petrosa (Conrad).
Plejona precursor (Dall)?
Plejona sp. cf. P. haleiana (Whitfield).
Plejona sp.
Polynices arata (Gabb).
Protocardia sp. cf. P. gambrina Gabb.
Pseudamusium sp.
Pseudoliva sp. cf. P. vetusta Conrad.
Pteropsis lapidosa Conrad.
Pyrula (Fusoficula) sp. cf. P. texana Harris.
Sinum declivum (Conrad).
Solen sp.
Surcula gabbi Conrad.
Teinostoma? sp.
Tellina mooreana Gabb?
Tellina sp. A.
Terebra texagyra Harris.
Terebra houstonia Harris.
Tornatina sp.
Tortoliva texana Conrad?
Tuba antiquata Conrad?
Turbonilla? sp.
Turricula sp.?
Turris sp.
Turritella nasuta Gabb.
Venericardia mooreana (Conrad).
Volvula sp.
Yoldia sp. cf. Y. psammotea Dall.
Yoldia sp.

The middle part of the Cook Mountain formation carries a third fauna, the names of the species of which follow:

Ancillaria sp.
Architectonica sp.
Callocardia astartoides Gardner.
Callocardia bastropensis Harris.
Callocardia sp.
Cancellaria sp.
Cerithium texanum Heilprin.
Corbula (Cuneocorbula) conradi Dall.
Corbula sp.
Diplodonta sp.

Distorsio septemdentata Gabb.
Drillia sp. cf. D. enstricina Harris.
Egerella sp.
Fusus sp.
Gaza? sp.
Lacinia alveata Conrad.
Latirus moorei Gabb?
Leda bastropensis Harris.
Levifusus sp.
Lucinia? sp.
Martesia sp.
Mesalia claibornensis (Conrad)?
Modiolus (Brachidontes) texanus (Gabb).
Natica dumblei Heilprin (large).
Natica dumblei Heilprin (small).
Natica semilunata Lea.
Olivula staminea Conrad?
Ostrea alabamiensis subsp. georgiana Conrad.
Ostrea sp.
Phos sagenus (Conrad)?
Pinna sp.
Plejona petrosa (Conrad).
Plejona sp.
Polynices arata (Gabb).
Psammobia? sp.
Pseudoliva ostrarupis subsp. pauper Harris.
Pseudoliva vetusta Conrad?
Pteropsis lapidosa Conrad subsp.?
Pteropsis sp.
Pyrula texana Harris?
Rimella sp. cf. R. texana Harris.
Siliqua sp.
Sinum declivum (Conrad)?
Sphaerella sp.
Surcula gabbi Conrad?
Teinostoma? sp.
Tellina sp. cf. T. mooreana Gabb.
Tellina sp. cf. T. tallecheta Harris.
Tellina sp. A?
Trinarcia declivis (Conrad).
Turris vaughani (Harris).
Turris sp.
Turritella nasuta Gabb.
Venericardia mooreana Gabb.
Venericardia sp.

Finally, a fourth Cook Mountain fauna is widely distributed at the top of the formation. This fauna marks the Cook Mountain-Yegua contact. The most prominent forms are a large variety of *Natica dumblei*, which is associated with *Ostrea georgiana*. Most of this fauna is contained in the limestone concretions, not all of which, however, carry fossils. Many of the shells have been rolled and abraded and perhaps concentrated before the concretions were formed. A list of the species making up this fauna follows:

Arca sp.
Callocardia astartoides Gardner.
Callocardia sp. cf. C. trigoniata Lea.
Calyptrophorus sp. cf. C. valatus Conrad.
Corbula (Cuneocorbula) conradi Dall.
Fusus? sp.
Natica dumblei Heilprin (large).
Ostrea sp.
Polynices arata (Gabb).
Polynices gibbosa (Lea).
Solen sp.
Tellina mooreana Gabb?
Tellina sp. A?
Tuba antiquata Lea?
Turritella sp.
Venericardia sp.

YEGUA FORMATION.

The Yegua, the youngest of the Claiborne formations, lies with some indications of unconformity upon the Cook Mountain and underlies the Fayette, of Jackson age.

Distribution.—The map shows the distribution of the formation at the surface in the lower Rio Grande region. The belt of outcrop varies in width from 4½ to 17 miles, the variation being probably due to an irregular overlap of the Fayette. The outcrop within the region is confined to Webb and Zapata counties and a small part of western Starr County.

Character.—About 90 per cent of the formation in this area appears to be dark gray, black, red, pink, purple, green, and brown selenitic carbonaceous clays. The predominant color is dark gray, and the material weathers into dark-gray clay soils. There are also many beds, lenses, and seams of soft gray and buff sands and sandstones, most of them thin. Dark, irregular limestone concretions occur sparingly in the clay.

Thickness.—The average thickness of the strata assigned to the Yegua outside the Rio Grande region is 817 feet, and the range is from 375 to 1,400 feet, but in this region the average thickness of the beds exposed, so far as it can be determined, is only about 406 feet.

Fossils.—Although Dumble [22] reports *Tellina mooreana* Gabb, *Turritella houstonia* Harris, and *Natica recurva* Aldrich from beds in Mexico identified as Yegua, it seems likely that the beds from which they were collected should be included in the Cook Mountain of the Rio Grande region. Leaves are also reported to have been found in the formation at places outside the region, but none was found inside. The only fossil seen in the Yegua in the region covered by

[20] Dumble, E. T., Tertiary deposits of northeastern Mexico: California Acad. Sci. Proc., 4th ser., vol. 5, No. 6, p. 177, 1915.

this report is *Ostrea georgiana*, and even this occurs more sparingly in the Yegua than in the Cook Mountain below or the Fayette above. In the Rio Grande region the deposits classified as Yegua are more closely allied faunally with the Jackson than with the Claiborne, but elsewhere the reverse is true. Possibly only the upper part of the Yegua occurs here, and this part may be really of Jackson age. Until this can be demonstrated, however, the Yegua will all be classed as of Claiborne age.

FAYETTE SANDSTONE.

Character.—The materials of the Fayette formation are fairly characteristic, although they are lithologically like those of the Cook Mountain formation, with which they are likely to be confused, but the fauna and flora are definite and on the whole the formation is not difficult to recognize in the field.

The Fayette contains more sand and sandstone than any other kind of rock, yet it is not so sandy in the Rio Grande region as it is farther north and east. The sandstone is exceedingly variable—in color almost white, gray, greenish gray, buff; in texture fine, medium, and coarse; in consolidation ranging from loose sand to quartzitic sandstone. The most characteristic feature of the sandstone is that it is fossiliferous. It is commonly laminated and cross laminated in intricate patterns. Interbedded with the arenaceous beds there are many beds and lenses of sandy and limy greenish-gray, pink, and red shale and clay. Limestone is scarce but not entirely absent. Beds of white volcanic ash are found in the formation at several places. Large, dark, crystalline limestone concretions are common. Silicified wood occurs abundantly, chiefly in the clays but in the sandstones as well. Most of the silica is opal, but chalcedony is found also. The silicified wood is characteristic of the formation in this region.

Thickness.—The thickness of the formation in this region averages not more than 360 feet, about 100 feet less than the average thickness elsewhere.

Fossils.—The formation contains a single identifiable fossil, a large variety of *Ostrea georgiana* Conrad. The rich Claiborne fauna attributed to the Fayette by Dumble is Cook Mountain, as explained on page 94, but a number of species of fossil plants are found in the ash beds and some in the sandstones. The best collections were obtained at points $2\frac{1}{2}$ and $4\frac{1}{2}$ miles north of Miraflores ranch, in Zapata County. Berry has identified the following forms:

Apocynophyllum 2 n. sp.
Bombacites n. sp.
Cinnamomum sp.
Coccolobis n. sp.
Conocarpus eocenicus Berry.
Diospyros n. sp.
Inga n. sp.
Mespilodaphne n. sp.
Myristica catahoulensis Berry (?).
Nectandra n. sp.
Papilionites n. sp.
Pisonia n. sp.
Sabalites vicksburgensis Berry.
Sapindus dentoni Lesq.
Sapotacites n. sp.
Spohora claibornensis Berry (?).
Terminalia phaeocarpoides Berry.
Ternstroemites n. sp.

Berry regards these plants as of middle or upper Jackson age and states that they indicate a warm, probably subtropical climate, with local or seasonal aridity, probably without general deficiency in rainfall. Although some of the formation is marine, much of it, as the plants suggest, was doubtless deposited subaerially on coastal sandy and clayey plains. The character of much of the formation indicates deposition in shallow water that was subject to considerable agitation.

FRIO CLAY.

In the Frio formation there are 100 to 400 feet of gray, greenish and yellowish gray, red, pink, and blue pure and sandy clays and a very few seams of gray sandstone, 1 to 8 inches thick. Perhaps the pink color, doubtless due to weathering, predominates in the exposures, practically all of which are shallow. Nearly everywhere the clay is checked by joints in which secondary calcium carbonate occurs in thin plates, and it contains many small calcareous nodules and some small masses that appear to be rolled balls of calcareous mud. Some of the clay is gypsiferous. With the exception of an occasional oyster bed (*Ostrea georgiana*) and a very few fragments of silicified wood the formation contains no fossils. Some of the beds of volcanic ash, notably those at Rio Grande City and at and in the neighborhood of La Loma de la Cruz east of Rio Grande City, at least one of which is 60 feet thick, are in the Frio formation rather than in the Fayette. These ash deposits, however, unlike those in the Fayette, carry no fossil plants; but it should be noted that not all the ash in the Fayette is leaf-bearing.

MIOCENE SERIES.

OAKVILLE SANDSTONE.

Deussen [21] describes and maps in the area covered by him south and west of Brazos River to the border of the lower Rio Grande region a thin formation of white and light-gray quartzitic sandstone, which he calls the Oakville sandstone. This formation is also mentioned by Dumble,[22] Udden,[23] and others. As mapped by Deussen, it lies in a belt a mile wide along the west foot of the Bordas scarp, between the Frio and Reynosa formations, east of Torrecillas, in Webb County, at the north border of the Rio Grande region, but the writer found no certain evidence of the outcrop of this sandstone, although it is doubtless overlapped by the Reynosa, which forms the Bordas scarp. In the lower Rio Grande region the Frio clay seems to continue well up the west slope of the scarp and there to be in contact with the Reynosa formation. Where the Rio Grande has cut across the Bordas, exposing a section, the Reynosa lies directly upon the clay and ash of the Frio formation. Nor does the Oakville appear between these two formations, in the 15 miles of the exposure of their contact in a direction roughly parallel to the dip between Rio Grande City and Sam Fordyce. In roads, pastures, and fields between Randado and the Webb-Zapata shallow oil field and elsewhere along and near the Bordas, to the west, there is a deep white or gray sand which may have been derived from the Oakville. The same kind of sand, however, is commonly found east of the Bordas, where it is derived from the Reynosa formation. It even appears to be derived from the Reynosa west of the Bordas, where there are outliers of the Reynosa.

There are in the region, however, rather thick Miocene sediments, which are overlapped by younger formations. Driller's samples taken at depths ranging from 4,325 to 4,500 feet in the Niels Esperson oil test, 15 miles east of Brownsville, have furnished many invertebrate fossils, of which Dr. Julia Gardner has identified 23 species, all of Miocene age. The exact position of these fossils in the Miocene can not be determined, but according to Dr. Gardner the single fauna represented should probably be assigned to a formation near the top of the lower Miocene or the base of the middle Miocene.

[21] Deussen, Alexander, Geology of the Coastal Plain region of Texas: U. S. Geol. Survey Prof. Paper 126 (in press).

[22] Dumble, E. T., Problem of the Texas Tertiary sands: Geol. Soc. America Bull., vol. 26, pp. 449 et seq., 1915.

[23] Udden, J. A., Baker, C. L., and Böse, Emil, Review of the geology of Texas: Texas Univ. Bull. 44, p. 97, 1916.

PLIOCENE SERIES.

LAPARA SAND AND LAGARTO CLAY.

The Pliocene Lapara and Lagarto formations, described by Deussen,[24] Dumble,[25] and Udden, Baker, and Böse,[26] from areas farther north, do not outcrop in the Rio Grande region. If they were deposited there they have been covered by the overlapping Reynosa formation.

TERTIARY (?) SYSTEM.

PLIOCENE (?) SERIES.

REYNOSA FORMATION.

Name.—In 1890 Penrose [27] described a deposit of limestone containing many pebbles and cobbles under the name "Reynosa limestone," from the town of Reynosa, Tamaulipas, Mexico. This limestone overlies what was then called the Fayette sand at Reynosa, directly across the Rio Grande from Hidalgo, Tex. Penrose found Recent shells embedded in the surface of exposures of this formation, and thinking it was Recent, included it in his "post-Tertiary formations." In 1891 Hill [28] described remnants of a formation that consisted of coarse and fine gravel cemented by a calcareous matrix and that occupied terraces 400 to 1,000 feet above the Rio Grande to the north of this region. This he called the Uvalde formation. Dumble [29] applied the name Reynosa division to the series of deposits forming the plateau between Nueces and Rio Grande, which he called the Reynosa plateau.

[24] Deussen, Alexander, Geology of the Coastal Plain region of Texas: U. S. Geol. Survey Prof. Paper 126 (in press).

[25] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 963-975, 1903.

[26] Udden, J. A., Baker, C. L., and Böse, Emil, op. cit., p. 90.

[27] Penrose, R. A. F., jr., Report of geology for eastern Texas: Texas Geol. Survey First Ann. Rept., pp. 57, 58, 63, 1890.

[28] Hill, R. T., Notes on the geology of the Southwest: Am. Geologist, vol. 7, pp. 366-370, 1891.

[29] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, p. 560, 1894.

He stated that the "Reynosa limestone" of Penrose formed the top member of his Reynosa division, which rested on the Lagarto formation. These downstream deposits to which Dumble applied the name Reynosa are now known to be the same as the upstream remnants to which Hill applied the name Uvalde, and the necessity for discarding one of the names has become apparent. In view of the fact that Reynosa as applied to a part of this formation has priority over Uvalde, and that the downstream deposits perhaps afford a better type locality, the name Reynosa has been adopted by the United States Geological Survey and "Uvalde" formation has been abandoned. The outcrop of the formation is continuous from Torrecillas and Rio Grande City eastward. In the area west of the Bordas scarp it occurs as remnantal patches, some of them doubtless reworked. These materials were included by McGee in his "Lafayette," a name no longer recognized as applicable to any geologic formation.

Distribution.—The map shows the distribution of the Reynosa formation in the lower Rio Grande region. Its resistant layers hold up the Frio clay; its base forms the Bordas scarp, from which it dips at a very low angle eastward, outcropping in a north-south belt 40 to 65 miles wide. In much of this area, however, its outcrops are obscured by the wind-blown sands of the sand belt. West of the Bordas it occurs only in patches that occupy the highest elevations.

Relations to adjacent formations.—The Reynosa lies unconformably on all older formations. The dip of the formation is much less than that of the older formations, and as the surface on which it lies is almost flat, it bevels the older formations. This structural unconformity, which is shown on the map, is well seen in the bluffs of the Rio Grande between Rio Grande City and Sam Fordyce. After the deposition of the Oakville, and doubtless after Lapara and Lagarto time, the strata of the region were slightly tilted and a flattish surface was developed across their beveled edges, and on this surface the Reynosa formation was deposited. In this area it is unconformably overlain by the Beaumont clay.

Character.—The Reynosa formation is an intricate mixture of gravel cemented by lime carbonate, uncemented gravel, limestone in which are embedded pebbles and cobbles, almost gravelless limestone, sand, sandstone, gravelly sand, and a relatively small amount of clay.

About 1 per cent of the pieces of gravel are over 4 inches in diameter, and the largest measure 8 inches. About a third of them are of sizes between 1½ inches and 4 inches; another third go through the 1½ inch screen but are caught on the ⅝-inch; and nearly a third goes through the ⅝-inch screen. The patches of gravel near the Rio Grande are a bit coarser than those farther away, and those inland and near the Balcones scarp seem to be somewhat coarser than those away from the river but nearer the Gulf. The gravel includes about 77 per cent of chert, limestone, and vein quartz, materials derivable and doubtless largely derived from the Edwards Plateau, and about 23 per cent of igneous rock, most of them derived from the western Cordillera. Some of the vein quartz may have been derived from points west of the plateau, but on the other hand some of the igneous rocks may have been derived from plugs near the Balcones scarp. Where the gravel overlies the Fayette and Frio formations it includes some silicified wood. Most of the pebbles and cobbles are well shaped by abrasion, many of them are highly polished, and some show bruises made by hard impact during transportation. The gravel deposits are roughly sorted into lenses and pockets of different textural grades.

The limestone is gray and sandy and weathers into rough, irregular surfaces, due to irregular concretions and impurities. In places it has surficially a tufaceous appearance. Its basin, rims, terraces, channels, and concentric banding are suggestive of deposition by springs. The patches south of Espejo ranch, in north-central Webb County, and at Carrizo Springs are clearly spring deposits, but these are not typical, for they contain little or no gravel.

The sand and the sandstone are gray or brown or red and almost universally weather into a dark-red sand. The grains are quartz coated with red iron oxide, but in places where this red coating has been worn off by the wind the sand is gray, or even white.

The few clays are generally sandy, but some are almost fat. Below Rio Grande City the Reynosa formation includes mud balls of Frio clay.

The surficial material derived from the Reynosa is typically deep-red, pink, or gray sand, through which white or gray limestone projects at many places.

Thickness.—The thickness of the formation is not definitely known. The patchy deposits west of the Bordas do not exceed 30 feet in thickness except at a very few places, but at the east border of the main belt of outcrop the formation may be 500 feet thick or more, and around the borders of the Rio Grande region it is 200 to 600 feet thick.

Fossils.—No fossils have been found in the Reynosa formation except the remains of Recent land snails, crayfish, jackrabbits, and a few other animals, which have become embedded in the surface as the limestone has been dissolved and reprecipitated, and except the fossils originally deposited in the formations from which the gravel was derived.

Origin.—To attempt at this time a complete explanation of the conditions under which this complex formation was deposited and cemented would be premature. In the main it is of fluvial origin. At least the gravel and the interbedded sand and clay were laid down by streams. Hill and Vaughan[30] gave an excellent description of the landward facies of the formation and interpreted it as residual material washed out from the Edwards Plateau in late Tertiary time and deposited on the downthrown side of the Balcones fault in fan-shaped areas. Perhaps, owing to peculiar climatic conditions, as suggested by Deussen,[31] some of the limestone was deposited by ground water while the main mass of the formation was being laid down by streams. Some of the limestone also appears to have been deposited at the surface by springs that rose through the gravel.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

LISSIE GRAVEL.

North of the Rio Grande region Deussen finds in valleys in the Reynosa formation a deposit of uncemented gravel without limestone, reaching in places a thickness of 900 feet. These are the "*Equus* beds" of earlier writers, so called because they contain the remains of Pleistocene horses. This gravel was doubtless derived from the Reynosa, which was uplifted and eroded before the main body of Lissie gravel was deposited. No exposure of this material was seen in the Rio Grande region, but perhaps it may be hidden beneath the sand of the sand belt and the Recent delta deposits of the Rio Grande or overlapped by the Beaumont clay.

BEAUMONT CLAY.

Name and distribution.—Throughout the west Gulf Coast province there is a coastal belt of clay of varying width, from which deposits of silt, sand, and gravel project up along the main river valleys in the form of terraces. These terrace deposits are called the Leona formation.

The Beaumont formation has been called the "Coast clays" and the Port Hudson clay, but it is not known to be the same as the typical Port Hudson formation of Louisiana. It is correlated in time with the Columbia formation of the Atlantic coast. The term Beaumont, which was first employed by Kennedy,[32] is used to designate the formation in this region. This formation is covered by Recent wind-blown sand for about 50 miles southward from the north border of the Rio Grande region, and still farther south by the younger clays and sands that form the present delta of the Rio Grande, but it is exposed at some places in the narrow strip north of the sand belt, within the sand belt where at places it has been uncovered by the migration of dunes, and south of the sand belt above high-water mark in the Rio Grande. Its areal distribution is shown on the map.

Character.—The Beaumont formation consists of blue and red calcareous clay, weathering yellow, a small number of thin lenses of sand, and a few scattered concretions of limestone. It includes also, as shown by well logs, a few beds of gravel which are not exposed at the surface and do not belong to the underlying Lissie and Reynosa formations. That part of the formation near the Rio Grande is coarser than that elsewhere. Much of this material was swept down the Rio Grande and reworked

[30] Hill, R. T., and Vaughan, T. W., Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Tex.: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 244-247, 254-255, 1898.

[31] Deussen, Alexander, orali nformation.

[32] Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, pp. 20, 27, pls. 1 and 2, 1903.

more or less by Gulf currents before it was deposited. The surficial material of the formation in this belt is chiefly dark-gray clay loam overlain by a thin sheet of drifting sand.

Fossils.—No fossils were found in the coastal belt of this region, but oyster beds are reported from the formation at some places farther north.

LEONA FORMATION.

Distribution.—In the valleys of the Rio Grande and of Frio, Leona, and Nueces rivers there are a number of terraces, all of them lying at levels between the Reynosa upland plain and the present flood plains of the streams. Such terraces are also found for a few miles up the larger tributaries of the Rio Grande. Hill and Vaughan [33] first described these deposits in the upper Nueces drainage basin as the Leona formation. They also mention [34] the Rio Grande terraces and state that they are undoubtedly of the same age as the Leona formation. Certainly there are no greater differences, either in topographic position or in material, than would be expected in deposits of this sort and of the same age but in different drainage basins. Deussen,[35] on the other hand, believes that the Leona formation is older than the terraces of the Rio Grande. He correlates the Leona with the terraces in the basin of San Antonio River at San Antonio, and as the remains of vertebrates have been found in the terraces at San Antonio which identify them in age with the "*Equus* beds," he correlates the Leona formation with the Lissie. No vertebrate fossils have been found in the deposits on the Rio Grande, and these terraces appear both to Deussen and to the writer to be continuous with the Beaumont clay and of the same age. As no formation corresponding to Deussen's Lissie could be found in the lower Rio Grande district, as Udden, Baker, and Böse [36] correlate the Lissie with the Reynosa and the "*Equus* beds" with the Beaumont, as identical invertebrate fossils occur abundantly in both the Rio Grande and the Nueces terraces, as in neither drainage basin have vertebrate fossils been found, and as both the Rio Grande terraces and the Leona formation occupy topographic positions from 20 to 60 feet above present stream beds and from 75 to 150 feet below the Reynosa plain, the terraces in the Rio Grande basin are included, for the present at least, in the Leona formation, and the Leona formation is correlated in time with the Beaumont clay.

Character.—The Rio Grande and Nueces terraces are composed mainly of light-gray and buff silt but include some sand and fine gravel. The terraces are flat topped and have steep riverward slopes. At most places there are two or three rather than a single terrace. At Palafox, for instance, there are three terraces above the present flood plain of the Rio Grande, one 21 feet, another 32 feet, and a third 63 feet above the level of the river when it was at a higher stage than the normal. These terraces converge downstream, to the south, becoming fewer in number until they merge into a single terrace. Hand-level traverses carried from the river to the top of the main terrace at several places gave the results shown below. The places are listed from north to south, and the apparent discrepancies are due to the fact that the several traverses were made at times when the water was at different stages.

Elevation of terraces along the Rio Grande above level of water in river.

	Feet.
Mouth of San Lorenzo Creek	50
Bigford ranch	45
Apache ranch	43
Minero	55
Laredo	60
Fordyce	61
Ramereño	61
Chapeño	42
Salineño	52
Santa Margarita	52
Three miles below Roma	34
Five miles above Rio Grande City	36
Rio Grande City	26
Garcia	24

Fossils.—The Leona formation has yielded several fresh-water and air-breathing mollusks. The specific list includes:

Bulimulus dealbatus Schiedeanus.
Helicina tropica Pfeiffer.
Lampsilis purpuratus Lamarck?
Planorbis tricarinatus Say.
Polygyra texasiana Mori.
Unio tetralasmus var. camptodon.
Unio tetralasmus vas. manubius Gould.

These forms are Pleistocene or Recent. The heavy dentition on the unios as compared with those now living in the Rio Grande and its

[33] Op. cit., pp. 253-254, 275-276.
[34] Op. cit., pp. 251-254.
[35] Deussen, Alexander, oral information.
[36] Op. cit., pp. 99 and 102.

tributaries suggests Pleistocene age rather than Recent. The fact that the streams have degraded their beds as much as 60 feet since the deposits in which the shells are inclosed were laid down also indicates a considerable lapse of time. The deposits are correlated with the Beaumont, which is classified as Pleistocene. The Leona formation is therefore regarded as of Pleistocene age.

RECENT SERIES.

FLUVIATILE DEPOSITS.

Delta deposits are still being formed at the mouth of the Rio Grande. Below Closner, where the normal flood plain merges into the delta, large areas are still subject to flood. What is known as the "Mission ridge," utilized for the railroad, the main automobile road, and the "valley" towns—Mission, McAllen, Pharr, San Juan, and Donna—stands above flood waters and is included within the Beaumont formation, but even here the land slopes away from and toward the river from the axis of the ridge. Other towns in the "valley," including Llano Grande, Mercedes, Harlingen, Raymondville, Lyford, Sebastian, and Brownsville, are likely to be flooded in years of high water, such as 1909, 1919, and 1922. These towns are on higher land, however, and are now largely protected by great irrigation canals and their borrow pits. Breaks occur in the river banks as far upstream as a point above Mission, and old river channels or "resacas" are found on the widening flood plain. These resacas extend down the valley as far as Donna, where they concentrate into the definite channel of the Rio Colorado, which thus becomes a distributary of the Rio Grande. The channel of the Rio Colorado is as much as 40 feet deep where it is deepest, near Harlingen, and 200 feet wide. It carries safely the flood waters of the Rio Grande except at times of the highest floods, when the water breaks through on both sides of Mercedes and flows into the basin of Lake Tiocano and thence northward toward Raymondville, eastward toward the Gulf (crossing the St. Louis, Brownsville & Mexico Railway south of Lyford), and back again southeastward to the Rio Colorado near Harlingen. Much of this water never reaches the Gulf, for the surface is so flat and grassy and the Gulfward slope is so low that the water stands in shallow depressions and behind irrigation canals, and there evaporates or seeps into the porous silts and sands. The area that is subject to flood is mapped as Recent fluviatile deposits. The Rio Grande flood plain above Closner is too narrow to be mapped separately from the Leona terraces and the Tertiary formations where the Leona is missing.

Only the surficial part of this deposit is nonmarine. The area having been reclaimed from the Gulf by the deposition of sediments brought down by the Rio Grande the lower beds are marine, for they contain marine Foraminifera, which are found where the beds are penetrated by wells. The material seen in surface exposures is a mixture of highly calcareous and somewhat selenitic gray, blue, red, and brown clay, checked by joints filled with calcium carbonate, gray micaceous sand, gray silt, and some pebbly sand, the whole impregnated with small white pellets of lime carbonate. The clay greatly predominates.

On the surface of the delta, particularly along the coast from Raymondville to Brownsville, there are numerous mounds, 5 to 30 feet in height, made of clay and known as "clay buttes." Though several diverse suggestions as to the origin of these mounds have been offered, the suggestion made by Coffey,[37] that they are "clay dunes," seems most reasonable. Most of them lie on the leeward side of shallow depressions, which are doubtless the source of the material of which they were formed. Many of these depressions contain salt lagunas.

Fresh-water and land shells, bones, logs, leaves, and other organic matter, all Recent in age, are found in the fluviatile deposits in considerable abundance.

WIND-BLOWN SAND.

Recent deposits that are most widely distributed are the sand dunes and wind-drifted sandy plains of a large area that extends continuously along the coast southward from Baffins Bay to a point east of Raymondville and westward for 75 miles in a belt that is 25 to 50 miles wide from north to south. This area includes practically all of Willacy and Brooks counties and the northern parts of Hidalgo and eastern Jim Hogg counties. Padre Island also consists chiefly of sand dunes blown up from the beach of the Gulfward side of the island. This is an area of migrating and stationary dunes, or "medanos," and of the

[37] Coffey, G. N., Clay dunes: Jour. Geology, vol. 17, pp. 754–755, 1909.

shallow irregular depressions that are so common in all dune areas.

Near the coast, where the Beaumont clay underlies the sand, the depressions contain shallow lagunas, both salt and fresh. There are also considerable stretches of sandy prairie, and at many places where there is no surficial sand the Reynosa and Beaumont formations are exposed. The dunes are sparsely covered with live-oak trees and the prairies are dotted with patches of live-oak brush. There are also large areas of wild grasses and "sacahuista."

Most of the sand is gray or white, but some of it, especially where it overlies the Reynosa formation, is red or pink. It has been thought that all this sand was blown inland from the coast, and perhaps most of it was, although there is no greater source of sand here than elsewhere along the coast, but some of it was derived from the Reynosa formation, on which the sand in the western part of the belt lies. Here "blowholes" expose the Reynosa reddish-brown sands, and the dunes consist of this sand. Even the gray sands may be derived from the Reynosa, the colored iron coating having been abraded from the quartz grains during eolian transportation.

COASTAL DEPOSITS.

Padre Island is a long dune-covered barrier island, which is nowhere more than a mile wide. It incloses Laguna Madre, which is 4 to 10 miles wide. On the Gulf side of the island there are the usual littoral deposits. The beach is sandy and is strewn with innumerable sea shells. The water of the laguna is at most places so shallow that it can be easily waded; indeed, at some times and places it is only a mud flat incrusted with precipitated salts. At Point Isabel, however, gasoline launches ply between the mainland and the island, but long piers are necessary, and the boats drag the bottom for considerable distances out from either shore. In the laguna mud, silt, sand, shells and fragments of shells, and salt are all being laid down to form the usual lagoon deposit.

IGNEOUS ROCKS.

In southwestern Uvalde County, just outside the region and not shown on the map, there are several small exposures of igneous rocks in the form of plugs or necks. Most of them make hills, but some are exposed in stream valleys or on flat surfaces. The rocks are phonolites and basalts, which have been described by Cross.[38]

STRUCTURE.

The general dip of the strata in the Rio Grande region is eastward. North of Laredo the dip is south of east, between Laredo and San Ygnacio it is nearly due east, and below San Ygnacio it is north of east.

The averages of the dips read for the formations are shown below.

Average dip, in feet per mile, of formations in the Rio Grande region.

Beaumont clay (Pleistocene)	25
Reynosa formation (Pliocene?)	17
Frio clay	263
Fayette sandstone	201
Yegua formation	296
Cook Mountain formation	435
Mount Selman formation	180
Wilcox group (Bigford formation, Carrizo sandstone, and Indio formation)	384
Midway formation	155

These averages are probably too high, however, for the steeper dips are those that are most commonly read. At most places the strata are so nearly horizontal that the dip is not observable. The true average dip of each formation is probably less than half that given above. According to the figures given the average dip of the Eocene formations is 273 feet per mile and the Reynosa and Beaumont together average 21 feet per mile. These figures should probably be reduced to 136 and 10, respectively, or even to lower figures. The discrepancy between the Eocene and post-Eocene formations again emphasizes the structural unconformity at the base of the Reynosa.

The reconnaissance methods employed did not permit detailed structural investigations, but indications of abnormal structure were observed or were authentically reported to occur at a few places. According to Baker[39] there is an anticline about 10 miles west of Carrizo Springs, another about 15 miles southeast of Eagle Pass, and probably still another, lying chiefly in Mexico, southwest of the old Indio ranch house. The writer saw indications of the first of these. The second is described by Udden.[40] Along Nueces River

[38] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, Uvalde folio (No. 64), pp. 3, 4, 1900.

[39] Baker, C. L., personal communication.

[40] Udden, J. A., Report on a geological survey of the lands belonging to the New York & Texas Land Co.: Augustana Library Pub. 6, pp. 88-90, 1907.

below Pulliam, there are anticlines and synclines and faults of small throw. The eastward dip is somewhat accentuated at the Webb-Zapata shallow oil field, in the southeast corner of Zapata County. There are relatively steep reversed dips in the vicinity of Roma. Probably an anticline here crosses the international boundary. A large anticline has been mapped by Crider[41] east of Laredo. Normal faults of small displacement were observed on Chaparrosa Creek 11 miles west of La Pryor, and half a mile east of the Jones ranch, northwest of Crystal City.

The search for structural features in the Rio Grande region is full of difficulties and subject to inaccuracies, for formations vary in character from place to place, the beds occur in lenses and pockets, the formational contacts are ill defined, exposures are scarce, wells are few, and the logs of most of those which have been drilled are inadequate, and false bedding planes, which dip at all angles with reference to the true bedding, are abundant.

There is at least one salt dome in the region. It is about 5 miles southeast of Falfurrias and crosses the Beaumont-Reynosa contact. It is 5 miles long from east to west and 1 to $1\frac{1}{2}$ miles wide from north to south. Quaquaversal dips are not plainly seen, but a surrounding laguna of salt brine, a large body of gypsum on the southwest side, and a topographic swell that is more than 40 feet high indicate that there is a salt dome at this place. La Lomita (little hill), $6\frac{1}{2}$ miles south of Mission, on the Rio Grande, which stands conspicuously above its alluvial surroundings and exposes abnormal materials and abnormal dips may also be a salt dome, but the dips may not represent true bedding planes.

ECONOMIC GEOLOGY.

OIL AND GAS.

More than 45 separate projects are under way for the development of oil and gas in the region, but only three are producing. The locations of these projects are shown on the map (Pl. XXVIII).

In 1920 the Webb-Zapata Co. had drilled 45 wells in the southeast corner of Zapata County to an average depth of 160 feet and found some oil and a very little gas in the Fayette sandstone. The dip here is normal in direction, a few degrees south of east, and is 198 feet per mile, somewhat more than the general dip in the neighborhood. As there are no reversed dips, the oil probably occurs in a lens of sand, which plays out and is sealed up westward, for the cap rock crops out $1\frac{3}{4}$ miles west of the west border of the producing area. Eight of the wells were pumping in 1920, a gasoline engine on each. The average yield is between 3 and 4 barrels a day. As the field is more than 40 miles from the railroad at Hebbronville, and as the road is very sandy, all attempts to market the oil had failed up to the time of the writer's last visit. The oil was stored in steel tanks at the field. According to recent reports it is being marketed.

Another producing field is 25 miles south of Aguilares and 45 miles southeast of Laredo, in Zapata County. Gas only is produced. The field is developed and operated by the Border Gas Co., of Laredo. The gas is conducted through pipes to Laredo, where the company operates the city gas plant. The outcropping formation at the wells is Fayette. A little gas is obtained from a depth of 700 feet, but the main flow is obtained from a depth of 1,200 to 1,250 feet. The material penetrated in all the wells is almost entirely clay but includes thin seams of sandstone. The main gas sand lies in the basal part of the Yegua or the upper part of the Cook Mountain. The structure here also is homoclinal, the gas sand dipping eastward at the rate of 30 feet to the mile.

In the spring of 1921 oil was struck in a well of the Mirando Oil Co., in the extreme northeast corner of Zapata County. The well site is just west of the Reynosa-Frio contact, and practically the full thickness of the Frio clay is represented under it. The oil sand was struck at 1,430 feet from the surface, in the Cook Mountain formation. The first well is variously reported as having given an initial production of 20 to 100 barrels a day. The new field has been rapidly developed. In the spring of 1922 it was credited with 13 producing wells, and the estimated possible production ranged from 1,000 to 2,300 barrels a day.[42] In addition, more than a score of other wells were being drilled in other parts of Zapata and Webb counties.

This field has produced also considerable gas. The Caroline-Texas Co.'s test well near Bruni is reported as blowing 8,000,000 to 10,000,000

[41] Crider, A. F., personal communication.

[42] McGreal, P. L., Gulf coast oil operations: Oil and Gas Jour., vol. 20, No. 43, p. 18, March 24, 1922.


GEOLOGIC MAP
OF THE
GULF COASTAL PLAIN OF TEXAS
ADJACENT TO THE RIO GRANDE
Scale 1/1000000
10 5 0 10 20 30 40 50 Miles
1922
EXPLANATION
SEDIMENTARY ROCKS
QUATERNARY
Recent
Qcd
Coastal deposits
(Mud, silt, sand, shells, and fragments of shells and salt)
Qws
Wind-blown sand
(Sand dunes and wind-drifted sandy plains)
Qfd
Fluviatile deposits
(Chiefly clay, highly calcareous and somewhat selenitic, of gray, blue, red, and brown colors; checked by joints filled with calcium carbonate, gray micaceous sand, gray silt, and some pebbly sand)
Pleistocene
Qb
Beaumont clay
(Chiefly blue and red calcareous clay, weathering yellow, with some lenses of sand and a few scattered limestone concretions)
Ql
Leona formation
(Light gray and buff silt with some sand and fine gravel; deposited on terraces. Probably contemporaneous with Beaumont clay)
UNCONFORMITY
Pliocene (?)
Tr
Reynosa formation
(Intricate mixture of gravel cemented by lime carbonate, uncemented gravel, limestone with embedded pebbles and cobbles, limestone almost free from gravel, also sand, sandstone, gravelly sand, and a small amount of clay; all intermixed)
UNCONFORMITY
TERTIARY
Tfr
Frio clay
(Varicolored clay with a few seams of gray sandstone; the clays are nearly everywhere checked by joints in which secondary calcium carbonate occurs in thin plates; some of the clays are gypsiferous; some beds of volcanic ash and many small calcareous nodules are present)
Tfa
Fayette sandstone
(Fine, medium, and coarse grained sandstone of white, gray, greenish-gray, and buff colors, with thin beds and lenses of greenish-gray, pink, and red sandy and limy shale and clay; some beds of volcanic ash; crystalline limestone concretions common)
UNCONFORMITY ?
Eocene
Claiborne group
Ty
Yegua formation
(Chiefly selenitic and carbonaceous clays of various colors, but predominantly dark-gray, with thin beds and lenses of sand and sandstone; irregular limestone concretions occur sparingly)
UNCONFORMITY ?
Tcm
Cook Mountain formation
(Varicolored sandstones, ferruginous, micaceous, and glauconitic, many of them cross-bedded and ripple marked; interbedded with subordinate amounts of varicolored sandstones and thin lenses of gray limestone)
Tms
Mount Selman formation
(Chiefly clay of gray, black, greenish, and bluish colors, with some layers and lenses of sandstone and limestone; several beds of lignitic and bituminous coal; calcareous concretions abundant throughout)
EXPLANATION
Continued
TERTIARY—CONTINUED
Eocene—Continued.
Wilcox group
Tb
Bigford formation
(Chiefly clay of various colors, with subordinate amounts of gray, green, and brown sandstone and many beds of lignite. Largely contemporaneous with Carrizo sandstone but in part younger)
Tc
Carrizo sandstone
(Chiefly cross-bedded sand and sandstone; some of the sandstone cemented and crystallized into quartzite, and some highly ferruginous; thin beds and lenses of variously colored clays and limestones)
UNCONFORMITY
Ti
Indio formation
(Thin-bedded and laminated argillaceous sands and arenaceous shales, with some layers of massive clay and lenses and layers of sandstone)
UNCONFORMITY
Tm
Midway formation
(Shale with some interbedded lenses and layers of sandstone and limestone and, in places, conglomeratic beds at base)
GREAT UNCONFORMITY
Oil pool and wells
Well drilled for oil
Clay, sand, and gravel pit
Salt dome
Mine

cubic feet and the Laurel Oil Co.'s well No. 1, at Mirando, as blowing 40,000,000 cubic feet. According to Lupton [43] the Aviator well, which is about halfway between Mirando and the Mirando City pools, was brought in with an estimated production of 40,000,000 cubic feet in June, 1922. Well No. 2 of the Schott Oil Co. is also a gasser.

As the first well was not completed when the writer was last in the field the structure in the Mirando district has not been worked out. Wrather,[44] however, states that the producing sands in the Mirando and the Jennings fields are at approximately the same horizon.

The future of the Mirando field can not yet be confidently predicted, but the field will probably be thoroughly tested by the end of 1922.

Gas has been found at several other places, notably at Reiser, 2½ miles west of Aguilares, in Webb County; in the Spurrier wells Nos. 1 and 3, in western Starr County; in the Higgins Oil & Gas Co.'s wells, 15 miles southeast of Eagle Pass, in Maverick County; and in the well of the International Refining Co., 7 miles northeast of La Pryor, in Zavalla County. At Reiser, which is only a few miles northwest of the northern border of the Mirando field, the gas is obtained from the Yegua and Cook Mountain formations at depths ranging from 150 to 1,650 feet. The Spurrier wells also contain gas, though in small quantities, from the Yegua. The gas in the Higgins wells is obtained from Cretaceous beds. The well of the International Refining Co. is reported to have struck a 50,000,000 cubic foot gas blow at a depth of 1,200 feet from the surface. The outcropping formation is the Indio, and presumably this gas also comes from Cretaceous beds. The first well at Pulliam, on the Uvalde-Zavalla county line, is reported to have produced about 5 barrels of oil a day.

So far as known the results of all other tests have been negative. However, outside of the Mirando field few of the deep test wells have been completed, and oil may have been struck in wells unknown to the writer. Several of the projects, notably those of the Higgins, International, and Empire companies and the Hanchett project, have been carried on in a serious and intelligent manner, but the operators drilling many of the wells have shown neither intelligence nor diligence.

The search for oil and gas in paying quantities will be continued only with great difficulty and with large risk of money. The work of locating and mapping areas in which the structure is favorable is difficult, and even a well-developed and accurately mapped anticline may contain no oil-bearing sand. The possibility that the San Miguel formation (correlated with part of the Taylor marl and the Anacacho limestone) of the Upper Cretaceous, may be petroliferous is not unpromising. The Cook Mountain formation gives some indication of being a fairly persistent producing sand where the structure is favorable. Both oil and gas have been found in this formation in the Mirando field and in smaller quantities elsewhere. It appears to contain indigenous petroleum at Oil City, Nacogdoches County, and at Crowther, McMullen County. This formation should be tested wherever drilling is done. The expenses of development will be high, for a large part of the region is not easily accessible to railroads or seaports, and even after development there is still the problem of getting the product to market.

Probably the most promising structural features to look for and to test are salt domes. About 50 per cent of the known Texas salt domes have produced oil and some of them have produced it in large quantities. The salt dome southeast of Falfurrias was tested some years ago by the Texas Co., but with negative results. The hill south of Mission, known as La Lomita, which may be a salt dome, is now being tested by the La Lomita Oil Syndicate. Other salt domes will doubtless be discovered in the region, and petroleum may be found in them.

On the whole the prospects of the ultimate discovery of one or more highly productive oil or gas fields in this region are not discouraging, but the preliminary work should be done with great care and the money required will be expended at considerable risk.

COAL.

According to Ashley,[45] the coal which has been extensively mined at Minero, Dolores, Cannel, and Santo Tomas, in Webb County,

[43] Lupton, C. T., oral communication to L. W. Stephenson.

[44] Wrather, W. E., The Mirando Oil Co. well, Zapata County, Tex.: Am. Assoc. Petroleum Geologists Bull., vol. 5, p. 625, 1921.

[45] Ashley, G. H., The Santo Tomas cannel coal: U. S. Geol. Survey Bull. 691, pp. 251-270, 1919.

and which is in the Mount Selman formation, is probably the largest body of cannel coal of bituminous rank in the United States, if not in the world. Johnson & Coleman are taking out enough of this coal at their mine, 4 miles east of Palafox, to run their pumping plants on the river. Coal from the same formation, and probably of about the same quality, is found on Espada Creek, in Webb County, near the base of the Mount Selman formation. A 14-inch bed of coal is also reported to outcrop near the top of the Mount Selman formation on the Rio Grande at low water at and near the mouth of Arroyo Santa Isabella.

Beds of coal, probably of poorer quality, may be obtained from the Indio and Bigford formations at many places where these formations outcrop. Lignite is found at the surface and at shallow depths at places east and southeast of Dentonio and at the Mangrum and Rutledge ranches, west and south of La Pryor. It is also penetrated in wells at La Pryor. An 18 to 20 inch bed of hard, brittle, and bright coal outcrops 1½ miles above the mouth of San Lorenzo Creek, in Webb County, in the Bigford formation. There is also an exposure of coal at the mouth of the first creek south of the Apache ranch house.

At Pilotes ranch, about 10 miles north of Palafox, as many as 11 seams of coal and bone were struck in a test drilling at depths ranging from 74 to 236 feet. The surface formation here is the Mount Selman, but the carbonaceous beds are in the Bigford formation. Coal in this same formation outcrops on Concillos Creek near its mouth and on Nueces River 2¾ miles east of the Asherton-Big Wells road, a few miles outside the Rio Grande region.

Coal is reported by Judge A. F. Spohn, of Zapata, to occur just north of Zapata and in the valley of Dolores Creek near the Webb-Zapata county line. This locality is in the outcrop of the Cook Mountain formation. No coal was seen, however, in the many sections of the Cook Mountain formation examined.

WATER RESOURCES.

Deussen and Dole [46] have investigated the underground water resources of La Salle and McMullen counties, and Deussen[47] has reported on the underground waters of the whole of the southern part of the Texas Coastal Plain. The counties mentioned are close to the lower Rio Grande region and the conditions that prevail in them extend into this region.

BRICK-MAKING MATERIAL.

Few of the clays of the lower Rio Grande region are suitable for making good brick. There is an abandoned brick plant at Reiser. The pit is in uppermost Yegua or lowest Fayette, and the clay is fairly pure. Facing brick of good grade was made here. The plant was abandoned when the Border Gas Co. shut down its gas wells at Reiser, thus shutting off the gas used as fuel. At no other place in the region has facing brick been manufactured.

Along the lower Rio Grande and its main delta distributaries there are numerous pits from which material is taken by Mexicans for making crude adobe brick. The largest and most efficient plant of this kind is at Los Ebanos, about 2 miles southwest of Sam Fordyce. Beaumont terrace silts, or recent fluvial silts, are mixed with water in the pit and worked into plastic masses having the consistency of dough. This material is thrown into trays containing six brick-sized compartments, which are sprinkled with dry sand to prevent it from sticking. The clay-filled tray is then carried by hand to a sunny flat near the pit and inverted, the wet bricks being left for a time to dry. When they have dried out sufficiently they are stacked or "ricked" in open piles for further drying by sun and wind. Finally they are placed in rough kilns made of adobe bricks and baked, branches of mesquite being used as fuel. The brick is poor, but it stands fairly well the pressure of the common Mexican one-story house.

GRAVEL.

The gravel supplies of the region are plentiful, widely distributed, and of good quality. The Reynosa formation furnishes gravel of high grade for road ballast and concrete work practically wherever it is exposed, whether in the main outcrop of the formation or west of the Bordas scarp, where only patches of Rey-

[46] Deussen, Alexander, and Dole, R. B., Ground water in La Salle and McMullen counties, Tex.: U. S. Geol. Survey Water-Supply Paper 375, pp. 141-177, 1916.

[47] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, 1914; Geology of the Coastal Plain region of Texas: U. S. Geol. Survey Prof. Paper 126 (in press).

nosa are found. As only 1 per cent of the gravel is over 4 inches in diameter, as three-fourths of the pebbles and cobbles are composed of chert or other siliceous material, as the pieces are well rounded and smooth, and as the material is practically nowhere so firmly cemented as to require blasting in its excavation, this deposit makes excellent commercial gravel. There are half a dozen or more pits along the river between Sam Fordyce and Peñitas. In some the loosely cemented and unconsolidated gravel is taken out with steam shovels, and in others it is removed by hand. At some plants it is sorted by power-driven screens, and at others by hand screening. Most of the gravel is used in the valley, but some is shipped as far as Houston. At Green's, in Webb County, on the International & Great Northern Railway, where there is an outlier of Reynosa, a large pit has long been under excavation. Most of the gravel is loaded by steam shovels into cars and used as ballast on the railroad. Some of it has been used to surface a section of the San Antonio-Laredo wagon and automobile road between Green's and Webb.

SAND.

Good sand is not so abundantly produced as gravel, although there is plenty of it. The sand lenses in the Reynosa would furnish some, but they do so only where the sand is mixed with the finest grades of gravel. The sand sorted out of the Reynosa by the wind and piled into dunes in the main sand belt and elsewhere is generally pure, fine-grained quartz sand, but it is not used commercially. An abundance of sand is derived from the coastal beaches and lagoons in the sand belt also, but neither is this produced. The only sand used commercially to-day is in the Beaumont delta-like deposits at Mission and McAllen, where 25-foot lenses of almost pure-white sand, underlie clay and silt. The sand obtained at Mission sells for $2.25 a cubic yard at the pit.

GYPSUM.

The sediments of the region inclose a large amount of gypsum in thin beds, seams, plates, crystal aggregates, and larger bodies, but it is nowhere utilized.

ROAD MATERIAL.

The quartzites, sandstones, limestones, concretions, and conglomerates of the region would make good material for building roads, but as few roads have been built they have not yet been so utilized. Argillaceous and calcareous materials from the Reynosa formation have been used to harden an excellent road through the sand belt from Falfurrias to Edinburg, permitting automobile traffic into the valley from coastal points farther north.

Shallow pits are opened along the road every mile or two and the material is laid on a graded surface of sand. This road lacked about 10 miles of being completed in 1920. The same material is being used in the same way on the sandy road to Rio Grande City from Hebbronville.

CEMENT.

It is possible that a proper combination of limestone, clay or shale, and gypsum might be found for the manufacture of Portland cement, coal, oil, or gas being used for fuel, but no commercial concern has yet found this combination.

NEW SPECIES OF MOLLUSCA FROM THE EOCENE DEPOSITS OF SOUTHWESTERN TEXAS.

By JULIA GARDNER.

The new species and subspecies whose names are used in the preceding paper by A. C. Trowbridge are described below. One species that had already been described and that is here treated as a subspecies of *Ostrea alabamiensis* is considered in detail because of its abundance in the middle and upper Eocene deposits in the lower Rio Grande region.

The letters after some of the station numbers have the following significance: (a) abundant, (c) common, (p) present, (r) rare.

PELECYPODA.

Family NUCULIDAE.

Genus NUCULA Lamarck.

Nucula sp.

Plate XXIX, figure 3.

The rock in the area a little south of Laredo, in Webb County, is made up largely of a *Nucula*, which is probably distinct from any species described, though it is very close to *N. magnifica* Conrad. It is about 3 centimeters high and broad and is sculptured with prominent growth lines and a uniformly developed, subcutaneous radial threading. No hinges or perfect exteriors have been found, but the pearly fragments of the thick shell pack the matrix.

Occurrence: Cook Mountain formation. Station 7492 (p), 1 mile east of Laredo; station 8818 (a), 5 miles southeast of Laredo, Webb County.

Family OSTREIDAE.

Genus OSTREA (Linnaeus) Lamarck.

Ostrea tasex Gardner, n. sp.

Plate XXXI.

?*Ostrea multilirata* Conrad, U. S. and Mex. Boundary Survey Rept., vol. 1, pt. 2, p. 157, pl. 12, figs. 1 a–d, 1857.

Shell of only moderate dimensions for the genus, subequivalve, ovate-trigonal in outline, generally somewhat produced anteriorly; surface layer decorticated; both the right and left valves radiately sculptured with 15 to 20 fine, approximately uniform, rippling riblets, similar to those developed upon the attached valve of *O. crenulimarginata* Gabb; ligament area moderately large, somewhat flattened in the right valve, the medial depression relatively wide, broadly but not deeply excavated; growth striae obvious; lateral margins very finely crenate, the crenae persistent in some individuals around the entire inner margin; basal margin often fluted in harmony with the external sculpture; adductor muscle scar crescentic, lying below the median horizontal, moderately large, not very deeply excavated; pedal scar obscure.

Dimensions: Right valve, altitude 80 millimeters, latitude 65 millimeters; left valve, altitude 98 millimeters, latitude 72 millimeters.

Type locality: Station 8925, a quarter of a mile northeast of Glass ranch headquarters, Dimmit County, Tex.

Ostrea tasex is the analogue in southwestern Texas of *Ostrea crenulimarginata* of the Midway of Alabama. In the Alabama species, however, the right valve is smooth, but in those found along the Rio Grande the two valves are similarly sculptured. Toward the umbones the radials are sharply elevated, though they tone down into an even fluting toward the outer margin.

Ostrea tasex is probably identical with *Ostrea multilirata* Conrad, collected from the so-called Cretaceous of "Dry Creek, Mexico." Conrad's types are in the National Museum and are fairly well preserved. Nothing of the kind has been reported from the Cretaceous by later investigators who have collected extensively in the Rio Grande area. However, *Ostrea cortex*, collected at the same locality, is certainly a Cretaceous species, and until "Dry Creek" can be definitely located and the confusion in the stratigraphic relations cleared the Wilcox form may well be kept apart.

Stations in Indio formation.

8927 (c). 4 miles south of Rockdale, Milam County.

6278 (a). 11 miles south of Sabinal, Uvalde County.

3187 (r?). East side of the Rio Grande, in Maverick County, about 3½ miles above the mouth of San Ambrosia Creek.

9173 (c). 17 miles west of Carrizo Springs, Dimmit County.

8925 (c). A quarter of a mile northeast of Glass ranch headquarters, Dimmit County.

1/67 (c). 3 miles north by west of San Pedro ranch, on the Maverick-Dimmit County line.

Ostrea alabamiensis subsp. georgiana Conrad.

Plate XXIX, figures 6, 7; Plate XXX.

Ostrea georgiana Conrad, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 7, p. 156, 1834.
Dana, Manual of geology, 1st ed., p. 519, fig. 811, 1863.
Dall, Wagner Free Inst. Sci. Trans., vol. 3, pt. 4, p. 683, 1895.

Ostrea titan Conrad, Acad. Nat. Sci. Philadelphia Proc., 1st ser., vol. 6, p. 199, 1854; Pacific R. R. Rept., vol. 6, pt. 2, p. 72, pl. 4, fig. 17a; pl. 5, fig. 17a, 1857.

Ostrea contracta Conrad, U. S. and Mex. Boundary Survey Rept., vol. 1, pt. 2, p. 160, pl. 18, fig. 1 a–d, 1857.

Ostrea alabamiensis Conrad var. *contracta* Harris, Bull. Am. Paleontology, vol. 6, p. 9, pls. 3, 4, pl. 5, fig. 2, 1919.

Type localities: "Orangeburgh, S. C.; Shell Bluff and near Milledgeville, Ga."—Conrad, 1834.

Ostrea alabamiensis subsp. *georgiana* is the most conspicuous species in the later Eocene of Texas, and in many localities it is the only fossil collected. Its range of variation, like that of other oysters, is wide. Only a very small percentage of individuals retain the fine epidermal sculpture, the one constant feature, and one identical with that of *O. alabamiensis*. However, in the large mass of material available for study—several hundred individuals—certain differences in the average individual developed at the different horizons can be detected. None of the huge, very much elongated and massive shells so common in the Fayette near Roma in Starr County have been found in the Cook Mountain formation farther north. The forms occurring at this lower horizon are of only moderate dimensions, usually relatively thin and broadening at the base, and, as a rule, conspicuously laminar. This decided laminosity is one of the more persistent features of the Cook Mountain *O. georgiana*. The Cook Mountain form grades into *O. alabamiensis* though the hinge is usually heavier and more elongated. The very large, massive, narrow, and elongate individuals described by Conrad under *O. contracta* occur in considerable numbers in the Yegua, and in the Fayette this type has shut out almost entirely the smaller and thinner race of the Cook Mountain.

Stations in Cook Mountain formation.

6650 (c), 6657 (c), 6652 (c). Environs of Cotulla, La Salle County.

8816 (p). 100 feet south of windmill, Marguerita ranch, 6.4 miles west of Webb Station, Webb County.

8785 (p). 2.1 miles east of Webb, Webb County.

8841 (p). Half a mile west of triangulation station Dolores, 2 miles north of Dolores, Webb County.

8842 (p). Three-fourths mile west of triangulation station Dolores, Webb County.

8830 (p). 10 miles northwest of Laredo, Webb County.

2113 (c). 5 miles northeast of Laredo, Webb County.

8765 (r). 2.3 miles northeast of Laredo, at crossing of San Antonio road with International & Great Northern Railway, Webb County.

7492 (p). 1 mile east of Laredo, Webb County.

6058 (c) (old series). Laredo, Webb County.

8835 (a). 6 miles southeast of Laredo, Webb County.

6436 (r). La Perla ranch, below Laredo, Webb County.

8840 (c). North bank of Salado Creek, Zapata County.

9116 (c). Soledad, Zapata County.

9112 (c). 2 miles down the river from Zapata, Zapata County.

9109 (p). Rio Grande prospect, 4.8 miles southeast of Zapata, on Roma road, 2.5 miles northeast of main road, Zapata County

9110 (p). 4.8 miles southeast of Zapata, Zapata County.

9113 (c). 5½ miles southeast of Zapata, Zapata County.

9175 (p). 14.2 miles below Zapata, Zapata County.

6432 (r). Arroyo Dolores, Zapata County.

9106 (r). Zapata County.

Stations in Yegua formation.

8784 (a). 3.4 miles east of Cactus Station, Webb County.

8809 (c). 12 miles northeast of Laredo, Webb County.

8849 (p). 7 miles northeast of Laredo, Webb County.

8061 (c). 7 miles east of Laredo, Webb County.

8834 (a). 8 miles east of Laredo, Webb County.

9119 (p). 2½ miles southwest of Alejandreñas ranch, Zapata County.

7741 (r). 1 mile northwest of Pedernal ranch headquarters, Zapata County.

9182 (a). 3.2 miles northeast of Lopeño, Zapata County.

8843 (a). 23½ miles northwest of Rio Grande City, Zapata County.

9187 (p). 2¾ miles south of Romireño, Zapata County.

9188 (p). 3 miles south of Romireño, Zapata County.

Stations in Fayette sandstone.

6147 (a). C. T. Tom ranch, ¾ mile south of Campbellton, Atascosa County.

6144 (a) 6 miles east of Campbellton, Atascosa County.

6146 (p). 3 miles southeast of Campbellton, Atascosa County.

3601 (r). Winchester, Fayette County.

9094 (p). Reiser, Webb County.

9098 (c). 1.3 miles southwest of Webb-Zapata shallow oil field, Zapata County.

7740 (a). Charco Redondo ranch, Zapata County.

8060 (p). Charco Redondo ranch, Zapata County.

9179 (p). 3.6 miles northeast of Palo Blanco ranch, Zapata County.

9181 (a). 3 miles northeast of La Presa ranch house, Zapata County.

9096 (c). 3.6 miles south of Huisatche ranch, Jim Hogg County.

9192 (p). 19 miles north of Roma, Starr County.

9191 (c). 15 miles north of Roma, Starr County.
9189 (r). 7 miles above Roma, Starr County.
9193 (c). 1.7 miles northeast of Agua Dulce ranch, north of Roma, Starr County.
7493 (p). 12½ miles below Arroyo Tigre on road to Roma, Starr County.

Stations in Frio clay.

6666 (r). 9 miles north of Tilden, McMullen County.
6665 (a). One-fourth mile east of post No. 7, west of Tilden, McMullen County.
3093 (p). Fort Ringgold, Starr County.

Family PARALLELODONTIDAE.

Genus CUCULLAEA Lamarck.

Cucullaea is one of the more conspicuous fossils in the Midway of Texas. Apparently there is but a single species, though the small and poorly preserved northern forms may prove to be distinct from those of the Rio Grande province. This species is certainly not identical with *C. macrodonta*, found farther east, though the differences may not be of specific rank. Its relation to *C. saffordi* Gabb, described from a lost type two-tenths of an inch in latitude, is even less definite.

Cucullaea (macrodonta subsp.?) texana Gardner, n. subsp.

Plate XXIX, figures 4, 5.

Cucullaea macrodonta Harris (part), Bull. Am. Paleontology, vol. 1, No. 4, p. 165, 1896.
Cucullaea saffordi Harris (part), Bull. Am. Paleontology, vol. 1, No. 4, p. 165, 1896.

Shell large, heavy, inflated, the single valves rudely quadrate in outline, the double valves cordate in cross section through the umbones; umbones prominent, inflated, overhanging the cardinal area, the tips incurved and prosogyrate, slightly in advance of the median vertical; length of hinge approximately five-sixths that of the shell; anterior extremity angulated dorsally, rounding broadly into the ventral margin; base line approximately horizontal medially; posterior extremity obliquely truncate; posterior area flattened, delimited by a narrow but obtuse ridge with a shallow sulcus behind it; valves differentially sculptured, the right valve exhibiting about 30 low, broad radials separated by linear interspaces and persisting to the posterior keel, where they abruptly disappear; a very fine, close, and uniform radial cording developed upon the posterior area in some individuals, but commonly absent, as in the type, or evanescent toward the margin. Left valve exhibiting only about 24 radials distributed over the medial and anterior portions of the shell but absent upon the posterior third, narrower than those upon the right valve and separated by interspaces of a width almost equal to the radials; sculpture of posterior area similar in the two valves; incremental sculpture pronounced, particularly toward the base; hinge area of moderate width for the genus, obliquely grooved; hinge very imperfectly preserved; very narrow medially with short vertical teeth, abruptly widening near the extremities; distal teeth coarse, few in number, and rudely parallel to the hinge margin; characters of interior not known.

Dimensions: Altitude, 42.0 millimeters; length of hinge, 39.0 millimeters; maximum latitude, 47.5 millimeters; diameter, 40.0 ± millimeters.

Type locality: White Bluff, Rio Grande, Maverick County, Tex. Type, U. S. National Museum.

The specimens from Kaufman County, in the northern part of the State, are smaller than those from points along the Rio Grande. They differ, too, in the more uniform development of a radial sculpture upon the posterior area.

Cucullaea (*macrodonta* subsp. ?) *texana* varies widely in outline and to a lesser degree in detail of sculpture. The shell runs larger and heavier than the typical *C. macrodonta* Whitfield, and the sculpture of the left valve, though discrepant, is regular and differs from that of the right only in the narrower ribs, wider interspaces, and in its development over a more restricted portion of the shell. These differences, though slight, are fairly constant in the imperfect material in hand. *Cucullaea saffordi* Gabb was described from a shell 0.2 inch in latitude. This type, according to Harris, has been lost. Until the young have been correlated with adults at the type locality and the species adequately described from such material the characters of *C. saffordi* Gabb must be open to question. There is need for uncommon caution in Hardeman County, as the Upper Cretaceous and Eocene outcrops are very near to one another and were confused in some of the earlier collections.

Stations in Midway formation.

2440 (c). 4 miles east of Kemp, Kaufman County.
2439 (r). 1 mile east of Webberville, Travis County.
?6584 (r). D'Hanis-Yancey road, about 7½ miles east of south of D'Hanis, Medina County.
3180 (c). Bluff on Frio River, half a mile below Myrick's (Evans's) apiary, Uvalde County.

583 (r). 18 miles southeast of Eagle Pass, Maverick County.

4398 (p). 18 miles southeast of Eagle Pass, Maverick County.

6583 (p). Biboro Creek, just below Biboro tank, about 18 miles southeast of Eagle Pass, Maverick County.

6575 (c). White Bluff on Rio Grande, land of Indio Cattle Co., about 4½ miles west of south of Jacal ranch house, in southeastern part of Maverick County.

Family CARDITIDAE.

Genus VENERICARDIA Lamarck.

Venericardia (alticostata subsp.?) whitei Gardner, n. subsp.

Plate XXXII, figure 3.

Venericardia alticostata Harris (part), Bull. Am. Paleontology, vol. 1, No. 4, p. 171, pl. 5, fig. 3, 1896.

Not *Venericardia perantiqua* Conrad, Am. Jour. Conchology, vol. 1, p. 8, 1865.

Shell small but thick and heavy, tranversely elongated in outline, rather compressed; umbones low, broadly rounded, for the most part strongly anterior in position; lunule minute; anterior extremity bowed in front of the lunule; posterior extremity obliquely produced and broadly rounded; base line feebly arcuate; surface coarsely sculptured radially; radials usually 19 to 21 in number, broad, crowded and heavily corrugated upon the anterior and medial portions of the shell; narrow and less closely spaced posteriorly; ligament characters not known; dentition apparently normal, very poorly preserved in all the material available for study; adductor scars very distinct; pallial line simple; inner margins very coarsely crenate.

Dimensions: Altitude, 25 millimeters; latitude, 31 millimeters; semidiameter, 13.5 millimeters.

Type locality: Station 3180, Bluff on Frio River half a mile below Myrick's apiary, Uvalde County.

The new subspecies differs from *V. alticostata* s. s. and from the subspecies *hesperia* in the simple radials. *V. smithii* is larger and relatively higher as a rule, with normally over 30 radials instead of less than 25, as in *whitei*.

Venericardia perantiqua was described under the name *Cardita subquadrata* by Gabb from the Eocene of New Jersey. The casts are very imperfect, but they indicate a much compressed, trigonal to subquadrate form quite unlike anything reported from the Eocene of Texas or of the Gulf.

The form is named in honor of Dr. Charles A. White, one of the foremost of the earlier paleontologists and one of the first to collect from the Texas Tertiary formations.

Stations in Midway formation.

3180 (p). Bluff on Frio River half a mile below Myrick's (Evans's) apiary, Uvalde County.

6279 (r). 11 miles south of Sabinal, a few hundred yards south of the junction of Elm Creek with Sabinal Creek, Uvalde County.

4398 (r). 18 miles southeast of Eagle Pass, Maverick County.

Venericardia alticostata subsp. hesperia Gardner, n. subsp.

Plate XXXII, figures 1, 2.

Venericardia alticostata Harris (part), Bull. Am. Paleontology, vol. 1, No. 4, p. 171, 1896.

Not *Cardita alticostata* Conrad, Am. Jour. Sci., 1st ser., vol. 23, p. 342, 1833.

Shell of moderate dimensions, thick, porcellanous, inflated-cordate in cross section; umbones prominent, well rounded, slightly anterior in position; lunule very small, deep; anterior extremity strongly and evenly bowed in front of the lunule; posterior dorsal margin gently sloping, the posterior lateral margin obliquely truncate; base line feebly arcuate, strongly upcurved anteriorly, abruptly rounded posteriorly; general character of surface sculpture similar to that of *V. alticostata* s. s.; radials not far from 20 in number, normally tripartite on the anterior and medial portions of the shell as in *V. alticostata;* crest of radials narrow and sharply serrate; lateral "terraces" well defined; inter-radial channels broadly U-shaped; incremental sculpture very fine and sharp; heavy growth stages rarely developed; hinge and ligament characters poorly preserved; hinge plate thick, heavy; adductor scars impressed, the anterior excavated; pallial line simple; inner margins deeply crenate.

Dimensions: Altitude, 38 millimeters; latitude, 37 millimeters; diameter, 44 millimeters.

Type locality: Station 3180, Bluff on Frio River half a mile below Myrick's apiary, Uvalde County.

The subspecies *hesperia* is shorter and wider than *V. alticostata* and more inflated in the umbonal region. In sculptural characters, however, the two forms are similar.

Venericardia bulla Dall is smaller and relatively higher and has a higher and relatively heavier hinge plate and less numerous radials. In both *V. smithii* Aldrich and *V. alticostata* subsp. *whitei* the radials are simple.

Stations in Midway formation.

1/128 (p). 1¾ miles northwest of New Fountain, Medina County.

3180 (p). Bluff on Frio River half a mile below Myrick's (Evans's) apiary, Uvalde County.

3181 (p). Frio River just above waterhole opposite apiary, below Englemann's ranch, Uvalde County.

?6279 (r) (No. 274*c*). 11 miles south of Sabinal, a few hundred yards south of the junction of Elm Creek with Sabinal Creek, Uvalde County.

?4398 (r). 18 miles southeast of Eagle Pass, Maverick County.

6583 (p). Biboro Creek, just below Biboro tank, about 18 miles southeast of Eagle Pass, Maverick County.

6575 (p). White Bluff on Rio Grande, land of Indio Cattle Co., about 4½ miles west of south of Jacal ranch house, in the southeastern part of Maverick County.

Family VENERIDAE.

Genus CALLOCARDIA.

Callocardia astartoides Gardner, n. sp.

Plate XXXII, figures 4–7.

Shell small for the genus, thick shelled, trigonal, ovate in outline, astartiform, moderately compressed; umbones not conspicuous, the tips proximate and prosogyrate, slightly anterior; lunule rather wide, cordate, slightly depressed, and delineated by an incised line; escutcheon not defined; anterior extremity bowed slightly in front of the lunule; posterior end of shell obliquely truncate and feebly arcuate from the umbones to the basal margin; base line arcuate, more abruptly rounded posteriorly than anteriorly; external surface finely and evenly threaded concentrically; resting stages conspicuous, usually one strongly defined near the umbones and several not quite so prominent toward the base; a fine and regular radial lineation visible upon weathered surfaces; external ligament mounted upon a rather heavy nymph produced more than one-third of the length of the posterior dorsal margin; dentition robust; the laminar anterior cardinal of the right valve broken away; medial cardinal rather slender, cuneate; posterior cardinal produced; left anterior and medial cardinals united under the umbones to form an asymmetric V, the anterior cardinal slender, the medial cardinal relatively heavy and deltoid; posterior left cardinal broken away, doubtless very thin and laminar; a very short obtuse lateral tooth developed in the left valve, received in a corresponding socket in the right; adductor scars distinct, the anterior the more prominent; pallial sinus produced almost to the median vertical, obtusely trigonal; inner margins entire.

Dimensions: Right valve, altitude 16.0 millimeters, latitude 16.5 millimeters, semidiameter 7.4 millimeters; left valve, altitude 17.0 millimeters, latitude 17.3 millimeters, semidiameter 8.6 millimeters.

Type locality: Station 8833, about 7 miles up the Rio Grande from Laredo, at Knob Bluffs, a quarter of a mile above pump of Santa Barbara farm, Webb County, Tex.

Callocardia astartoides is a remarkable species, uniting the dentition and sinal characters of the Veneridae with the external outline and surface sculpture of certain of the Astartidae. The occurrence of so primitive a type of a highly specialized group in the early Tertiary beds is of unusual interest.

Callocardia astartoides is the dominant species at the type locality and common at a number of other localities in the Cook Mountain formation.

Stations in Cook Mountain formation.

?8850 (c). 500 yards southwest of Espejo ranch, 8 miles south of Laredo, Webb County.

8833 (a). About 7 miles up the Rio Grande from Laredo, in Knob Bluffs, a quarter of a mile above pump of Santa Barbara farm, Webb County.

8768 (c). 1½ miles north of and a trifle east of the third gate, 7 miles southeast of Velenzuela ranch house, Webb County.

8770 (c). 39.9 miles north of Rio Grande City, Starr County, on river road to Zapata, just north of Lopeño post office, Zapata County.

Family TELLINIDAE.

Genus TELLINA (Linnaeus) Lamarck.

Tellina sp. A.

Plate XXXII, figures 8, 9.

Shell large, not very thin, much compressed, transversely ovate-trigonal in outline, nearly equilateral; umbones flat, inconspicuous except by reason of their position at the apex of an angle of not far from 120°; anterior and posterior dorsal margins nearly similar, the posterior declining, perhaps, a little more steeply; lateral extremities quite sharply rounded; base line symmetrically arcuate; an inconspicuous rostral fold developed near the posterior dorsal margin, defined rather by the abrupt change in the direction of the incrementals than by its elevation; surface sculpture incremental in character, least feeble posteriorly and toward the basal margin, becoming abruptly stronger behind the rostral fold and indicating by the undulation a second very obscure fold; characters of ligament and hinge not known; adductor scars commonly quite prominent; pallial sinus obscure but apparently very deep, produced almost to the anterior adductor, not confluent below.

The species is decidedly larger than any other found in the Eocene of Texas. A latitude of 40 millimeters is not uncommon and one cast, presumably identical, reaches an altitude of 40 with a probable latitude of 60 millimeters or more. Unfortunately, only casts, some of them with a few fragments of shell adhering, are preserved.

Stations in Cook Mountain formation.

8771 (p). 4 miles southeast of Laredo, Webb County.

6404 (p). 1 mile west of Canada Verde ranch, Webb County.

6436 (c). La Perla ranch below Laredo, Webb County.

?8837 (r). 3½ miles above San Ygnacio, Zapata County.

?8770 (p). Lopeño post office, Zapata County.

Family PHOLADIDAE.

Genus MARTESIA Leach.

Martesia? laredoënsis Gardner, n. sp.

Plate XXXII, figure 10.

Shell very thin, transversely elongated, tapering posteriorly, strongly inflated; anterior third of shell cut off by a deep but narrow groove, dropped from the umbones and extending obliquely backward; umbones low, conforming to the tubular outline of the shell, prosogyrate; anterior extremity rounding smoothly into the upcurved base; posterior dorsal and ventral margins slowly converging, the narrow lateral extremity vertically truncate; shell usually decorticated but so thin that the sculpture is reflected on the cast; a concentric sculpture, incremental in character and more or less irregular, developed over the entire shell but stronger upon the anterior third; radials approximately equal in strength to the concentric rugae and, like them, somewhat irregular, developed only in front of the groove; characters of the hinge and of the interior not known.

Dimensions: Altitude, 9.0 millimeters; latitude, 20.0± millimeters.

Type locality: Station 6434, a quarter of a mile south of Espejo ranch, south of Laredo, in Webb County, Tex.

Martesia texana Harris is similar to this species in outline and general dimensions, but the umbones of the Cherokee County species are not so near to the anterior extremity, the groove cuts off decidedly more than the anterior third, and there is an apparent absence of any radial sculpture. No trace of either *M. texana* or *M. laredoënsis* has been found except at the type localities.

Station in Cook Mountain formation.

6434. A quarter of a mile south of Espejo ranch, south of Laredo, Webb County.

Family TEREDINIDAE.

Genus TEREDO Linnaeus.

Teredo maverickensis Gardner, n. sp.

Tubes of moderate dimensions, somewhat irregular in growth habit though tending to follow the grain of the wood; closely and quite sharply rugose; characters of valves not known.

Dimensions: Diameter, 6.0 millimeters; thickness of shell, 0.6 millimeters.

Type locality: Station 1/277, Rio Grande, lower end of Maverick County, about 40 feet below Midway-Wilcox contact.

This teredo, which packs a large fragment of fossilized wood, is the first that has been reported from the Midway of the Gulf. It differs from the later Eocene teredos in the less regular growth habits and particularly in the very decided, close, sharp wrinkling of the surface. The value of these differences is increased by the difference in the habitat. It is interesting to find a record of the unfortunate appetite of this animal in the Midway of Texas.

Station in Midway formation.

1/277. Rio Grande, lower end of Maverick County, about 40 feet below Midway-Wilcox contact.

GASTROPODA.

Family CERITHIIDAE.

Genus CERITHIUM Bruguière.

Cerithium? sp. A.

Plate XXIX, figures 1, 2.

Internal casts of *Cerithium*-like forms occur in considerable numbers in southwestern Texas and serve as excellent horizon markers of the Midway. These casts indicate a rudely biconic shell with the maximum diameter in front of the median horizontal. The whorls of the conch were probably about 6 or 7 in number, rudely trapezoidal in outline and increasing quite rapidly in diameter. The body was smoothly rounded in the adults, though probably rather acutely angulated in the young. Some individuals show a suggestion of an irregular *Cerithium*-like ribbing. The aperture was apparently between one-third and one-half as long as the entire shell and was obliquely lenticular in outline. A specific name is reserved in the hope that the shell may come to light later. In the meantime these easily recognizable casts may be of service in indicating the Midway age of the formation in which they are carried.

Dimensions of imperfect figured specimen: Altitude, 42.0 millimeters; maximum diameter, 21.0 millimeters.

Stations in Midway formation.

3180 (p). Bluff on Frio River, half a mile below Myrick's (Evans's) apiary, Uvalde County.

6576 (c). Land of Indio Cattle Co., 1¾ miles below White Bluff, about 4½ miles southwest of Jacal ranch house, Maverick County.

8799 (p). Texas side of the Rio Grande 1 mile below the Blessé ranch house, Maverick County.

CEPHALOPODA.

Family CLYDONAUTILIDAE Hyatt.

Genus ENCLIMATOCERAS Hyatt.

Enclimatoceras vaughani Gardner, n. sp.

Plate XXXIII.

Shell large, rather compressed toward the apex, more broadly rounded ventrally toward the aperture, obliquely flattened laterally; whorls numerous, increasing but slowly in latitude; the altitude of the earlier whorls a little more than three times their average width from suture to suture, of the later whorls a little less; final whorl of a half grown specimen rudely reniform in outline, somewhat auriculate laterally, concave, the diameter of the whorl approximately double the altitude; umbilici quite strongly depressed, their peripheries obscurely carinate; ventral saddle very broad and nearly horizontal; lateral lobes broad and very shallow; lateral saddles relatively narrow and moderately deep; siphuncle dorsad, migrating slowly toward the center with increasing age; surface not known.

Dimensions: Maximum diameter of shell, 168.0 ± millimeters; diameter of shell at right angles to maximum diameter, 140.0 ± millimeters; thickness 100.0 millimeters. Adolescent individual: Maximum diameter of shell, 93.0 ± millimeters; diameter of shell at right angles to maximum diameter, 64. 0 ± millimeters; maximum thickness, 73.0 ± millimeters. A larger but imperfect individual attains a maximum diameter of 220.0 millimeters.

Type locality: Station 3178, three-fourths mile northwest of Myrick's (Evans's) apiary, Frio River, Uvalde County.

Enclimatoceras vaughani is the Texas analogue of *Enclimatoceras ulrichi* (White), of the Midway of Alabama, a form very similar in general dimensions and outline. The adult *E. vaughani* are, as a rule, more compressed than the adult *E. ulrichi*, but the young of the two species show similar ranges of variation.

The umbilici also seem to be a little more depressed in the Texas species. The most obvious and constant difference, however, is in the outline of the lobes and saddles. The sutures in *E. ulrichi* are much more flexuous than those of *E. vaughani*. In *E. vaughani* the ventral saddle is nearly horizontal and the lateral lobes exceedingly shallow. In *E. ulrichi* the ventral saddle is perceptibly arcuate and the lateral lobes are strongly incurved. The lateral saddles are well developed in both species, though they are deeper in the Texas form.

I have the honor of dedicating this species to Dr. T. Wayland Vaughan.

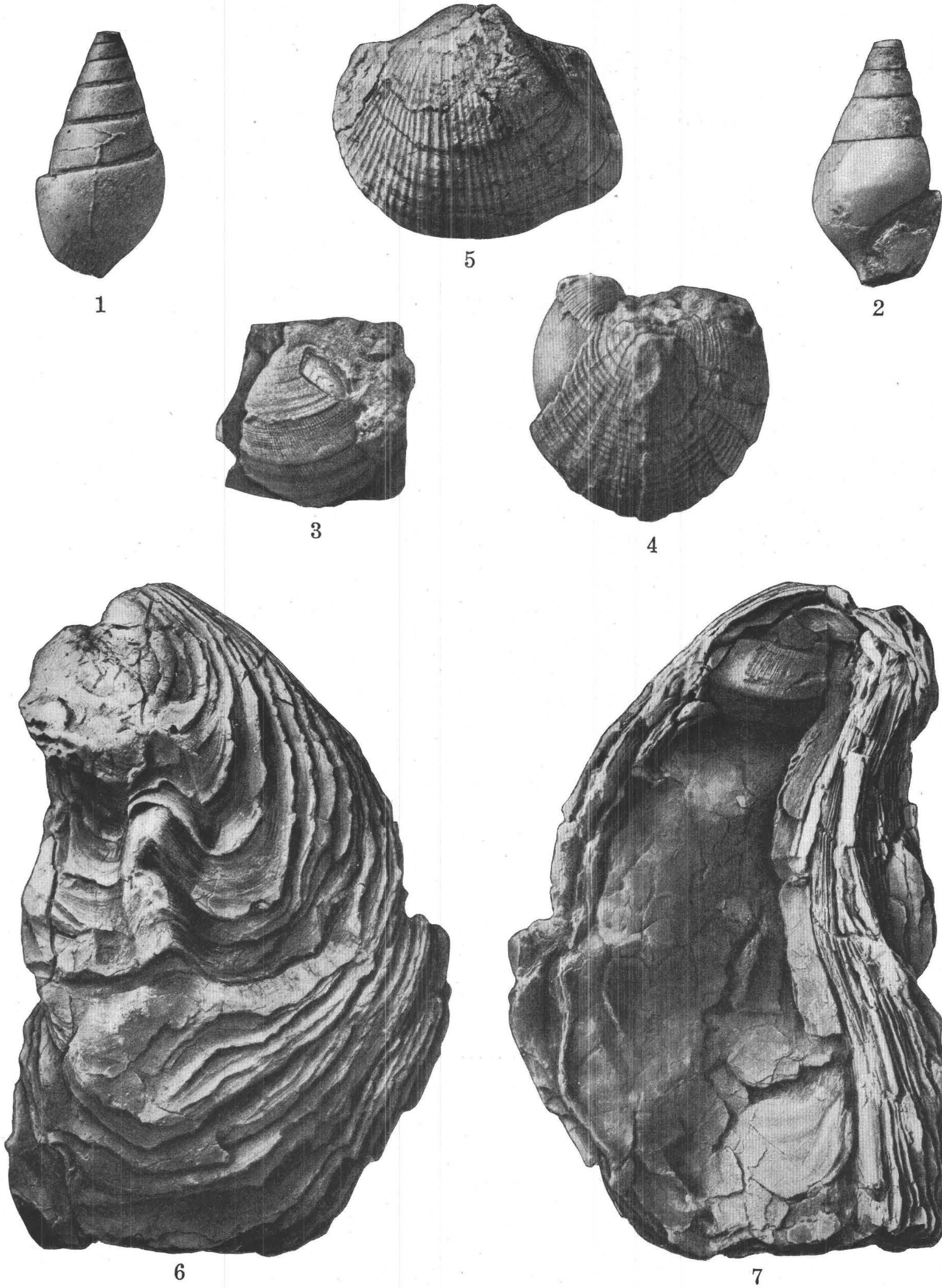
Stations in Midway formation.

3178 (p). Three-fourths mile northwest of Myrick's (Evans's) apiary, north of Frio River, Uvalde County.

3179 (p). Half a mile northwest of Myrick's (Evans's) lower apiary, south side of Frio River, Uvalde County.

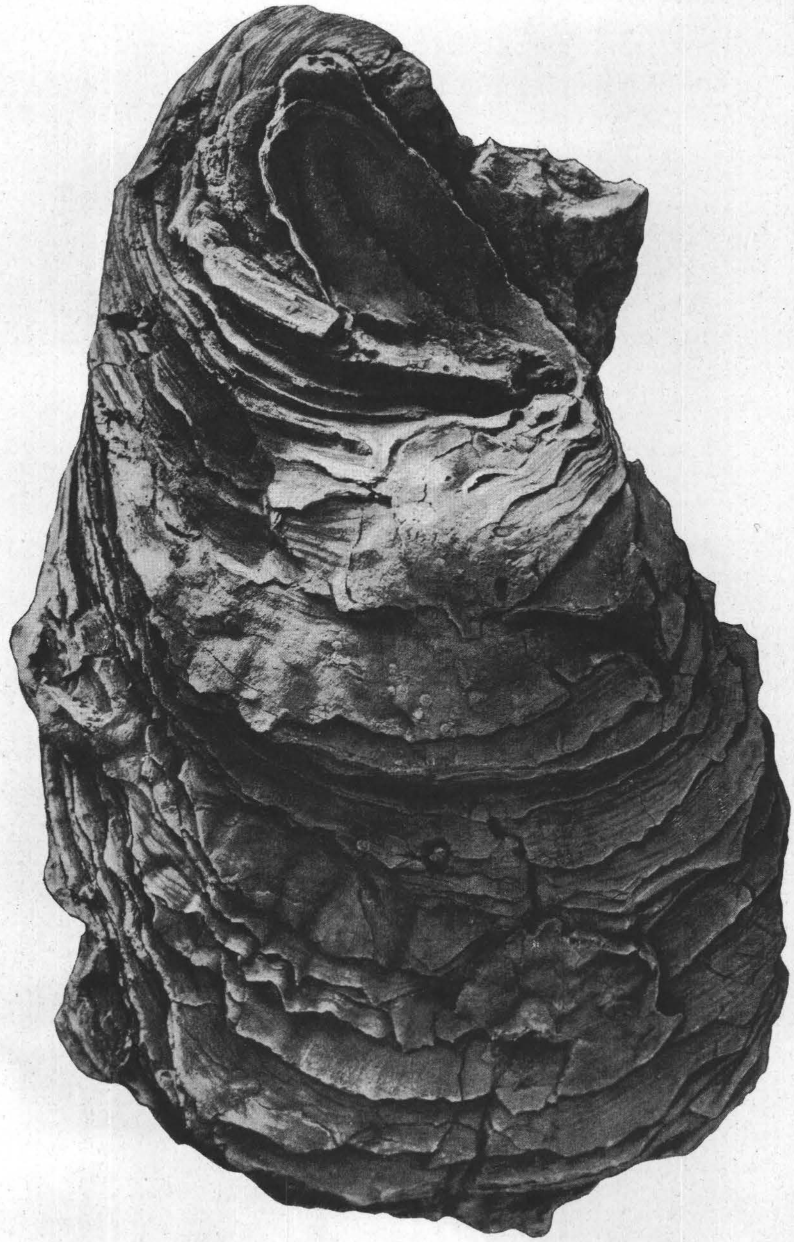
Frio River half a mile above Bob Evans's (formerly Myrick's) apiary, Uvalde County.

PLATES XXIX-XXXIII.



EOCENE MOLLUSCA FROM SOUTHWESTERN TEXAS.

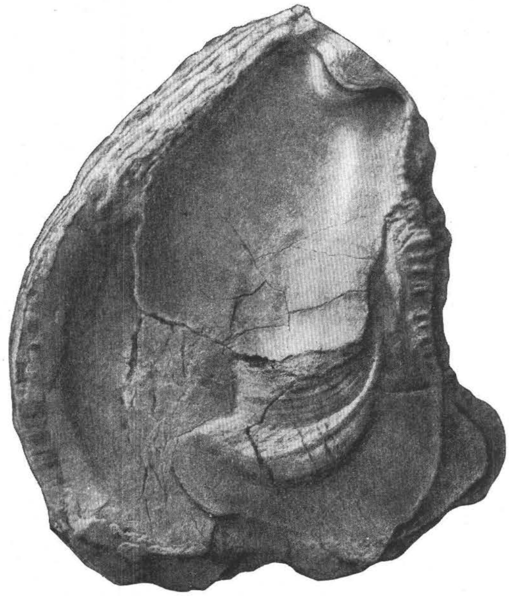
1, 2. *Cerithium?* sp. A. **1,** Dorsal view, × 1; **2,** apertural view, × 1.
3. *Nucula* sp. Exterior of right valve, × 1.
4, 5. *Cucullaea* (*Macrodonta* subsp. ?) *texana* Gardner, n. subsp. **4,** Front view, × 1; **5,** exterior of left valve, × 1.
6, 7. *Ostrea alabamiensis* subsp. *georgiana* Conrad. **6,** Exterior of left valve, × 1; **7,** interior of left valve, × 1.



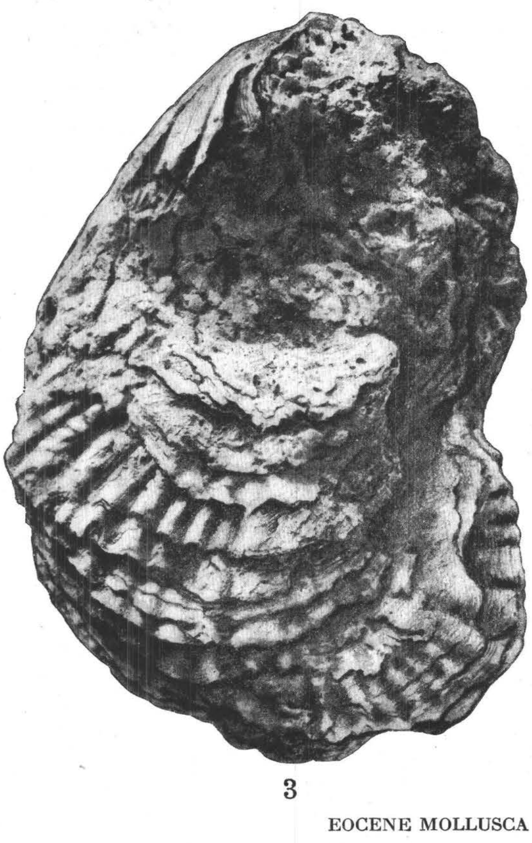
EOCENE MOLLUSCA FROM SOUTHWESTERN TEXAS.

Ostrea alabamiensis subsp. *georgiana* Conrad. Exterior of right valve, × 1.

1



2

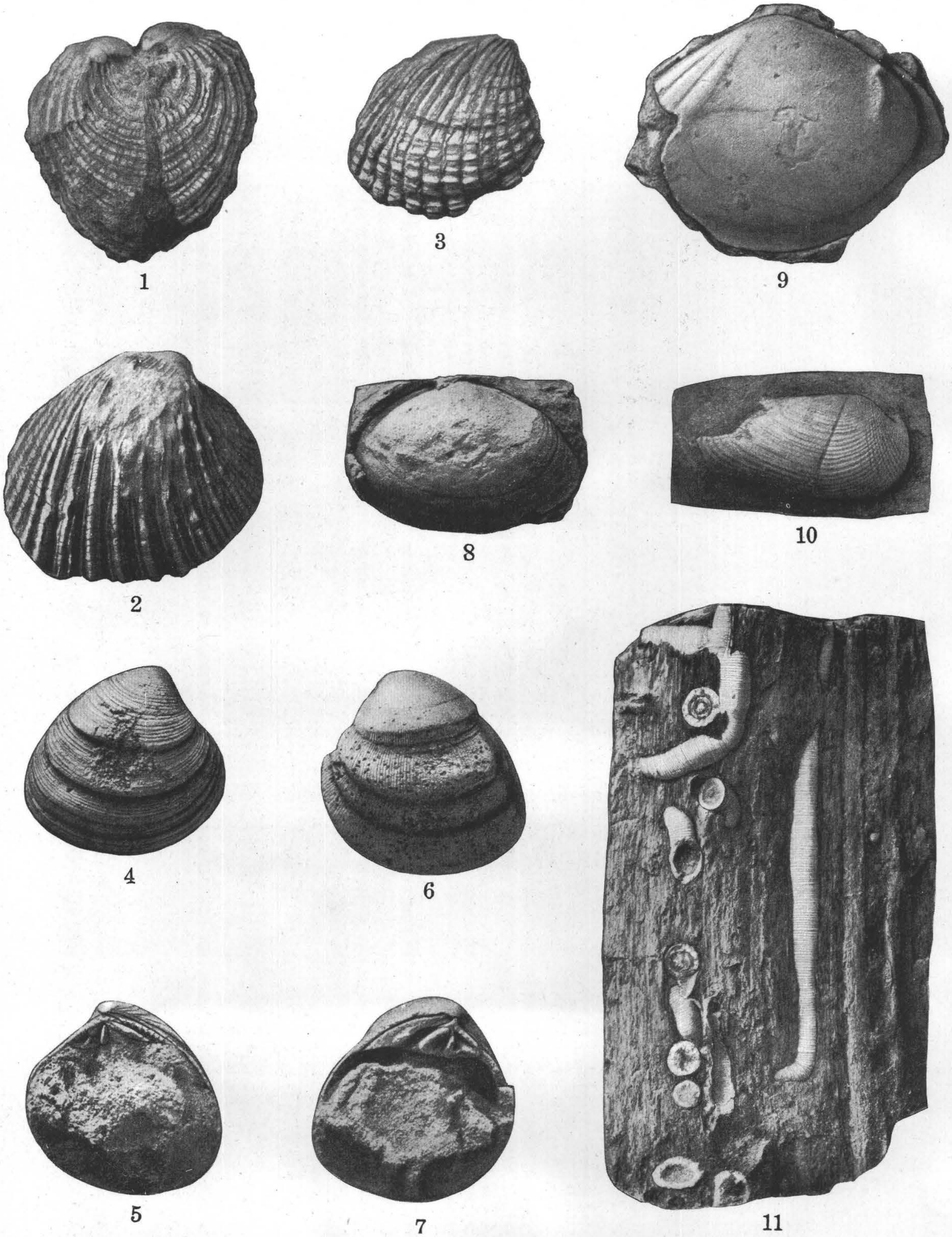


3

4

EOCENE MOLLUSCA FROM SOUTHWESTERN TEXAS.

1-4. *Ostrea tasex* Gardner, n. sp. **1,** Exterior of left valve, × 1; **2,** interior of left valve, × 1; **3,** exterior of right valve, × 1; **4,** interior of right valve, × 1.

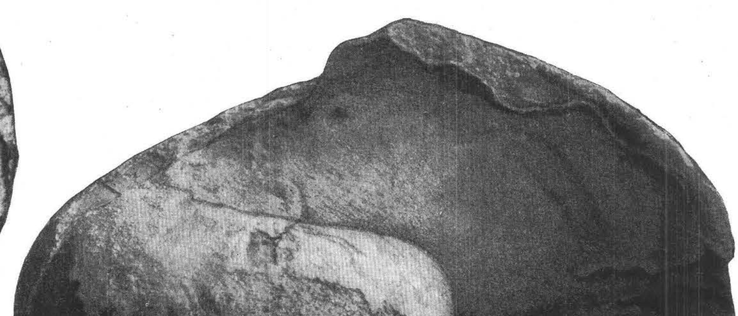


EOCENE MOLLUSCA FROM SOUTHWESTERN TEXAS.

1, 2. *Venericardia alticostata* subsp. *hesperia* Gardner, n. subsp. **1,** Front view, × 1; **2,** exterior of right valve, × 1.
3. *Venericardia alticostata* subsp. *whitei* Gardner, n. subsp. Exterior of right valve, × 1.
4–7. *Callocardia astartoides* Gardner, n. sp. **4,** Exterior of right valve, × 2; **5,** interior of right valve, × 2; **6,** exteriorof left valve, × 2; **7,** interior of left valve, × 2.
8, 9. *Tellina* sp. A. **8,** Internal cast of left valve, × 1; **9,** internal cast of left valve, × 1.
10. *Martesia laredoënsis* Gardner, n. sp. External cast of right valve, × 2.
11. *Teredo maverickensis* Gardner, n. sp. Longitudinal views and natural cross sections of tubes in fossil wood, × 1.

1

2



3

EOCENE MOLLUSCA FROM SOUTHWESTERN TEXAS.

1-3. *Enclimatoceras vaughani* Gardner, n. sp. **1,** Lateral view × 1; **2,** cross section of adolescent individual, × 1; **3,** apertural view of adolescent individual, × 1.

PRELIMINARY REPORT ON FOSSIL VERTEBRATES OF THE SAN PEDRO VALLEY, ARIZONA, WITH DESCRIPTIONS OF NEW SPECIES OF RODENTIA AND LAGOMORPHA.

By James W. Gidley.

INTRODUCTION.

On the initiative of the United States Geological Survey and with the cooperation of the United States National Museum, I was privileged during February, March, and part of April, 1921, to collect fossil vertebrates in the San Pedro Valley, Ariz., where remains had previously been located by Kirk Bryan, of the Geological Survey. The results of this expedition are here published in part.

The special problem involved was the determination of the age of the sedimentary deposits, which up to that time had been termed Pleistocene. Two localities, apparently at slightly different horizons, yielded material representing a fauna sufficiently varied and distinctive to establish their age as Pliocene.

The locality first visited is a small area of badlands about 3 miles east of the Curtis ranch, which is on the State road about 14 miles northwest of Tombstone and an equal distance southeast of Benson by road. The second locality is west of the State road about 2 miles south of Benson. These two localities are about 12 miles apart and on opposite sides of the San Pedro Valley. The first locality yielded by far the greater bulk of material, but the species represented in the collection from the second are more numerous. Stratigraphically there seems to be no difference in the level of the beds of the two localities, and structurally they are very similar, yet, so far as I am able to determine, they contain no species in common. Because of this fact, as well as the general character and assemblage of the forms represented, I am led to consider them as of slightly different age, the beds at the Benson locality being apparently the older.

Most of the mammal material is fragmentary, but several good specimens were procured, including enough material for the restoration of the dermal armor and skeleton of a *Glyptotherium* and a possible skeletal restoration of a mastodon, both from the Curtis locality. The material from the Benson locality here described was all collected at one spot, a fossil bone quarry opened up and worked by Kirk Bryan and me. Immediately associated material from this quarry includes fragmentary specimens of *Hipparion*, *Pliauchena?*, *Platygonus*, and *Pliohippus* or *Hippidium?*, together with a new species of box turtle and eight new species of birds, not all of which are satisfactorily definable from the scanty material obtained.

The greater part of the specimens included in these collections have not yet been prepared, but those belonging to the orders Rodentia and Lagomorpha have been cleaned and studied, and the new species are here described. Those from the Curtis locality were all found during the excavation of one of the mastodon skeletons. Immediately associated with them were remains of a llama, a canid, a mustilid, a small land turtle, an edentate, and two species of small birds.

A tentative list of the orders, families, genera, and species, so far as they have been determined, represented in each locality is given on page 120.

Preliminary list of fossil vertebrates from the San Pedro Valley, Ariz.

	Number of species.	
	Benson.	Curtis.
MAMMALIA.		
Proboscidia:		
Elephantidae:		
Cf. *Dibelodon*, probably n. sp.	......	2
Cf. *Gompotherium*, probably n. sp.	1	......
Perissodactyla:		
Equiidae:		
Equus, undet.	......	2
Pliohippus, undet.	1	......
Hipparion, undet.	1	......
Artiodactyla:		
Camelidae:		
Lama, n. sp.	......	1
Cf. *Procamelus*, undet.	1	1
Cf. *Pliauchenia*, undet.	1	1
Tayassuidae:		
Platygonus cf. *P. vetus*, or n. sp.	1	......
Cervidae:		
Odocoileus, n. sp.	......	1
Merycodus near *M. necatus*	1	1
Cf. *Merycodus*, n. sp.	......	1
Carnivora:		
Canids, 3 n. sp.	1	2
Felid?, n. sp.	......	1
Mustilid, sp.	1	1
Rodentia:		
Sciuridae:		
Citellus cochisei, n. sp.	......	1
Citellus bensoni, n. sp.	1	......
Geomyidae:		
Geomys parvidens, n. sp.	......	1
Geomys minor, n. sp.	1	......
Cratogeomys bensoni, n. sp.	1	......
Heteromyidae:		
Dipodomys minor, n. sp.	1	......
Muridae:		
Subfamily Cricetinae:		
Peromyscus brachygnathus, n. sp.	1	......
Peromyscus minimus, n. sp.	1	......
Peromyscus sp.	1	......
Eligmodontia arizonae, n. sp.	1	......
Onychomys pedroensis, n. sp.	......	1
Onychomys bensoni, n. sp.	1	......
Sigmodon curtisi, n. sp.	......	1
Sigmodon minor, n. sp.	......	1
Sigmodon medius, n. sp.	1	......
Subfamily Neotomeniae:		
Neotoma fossilis, n. sp.	1	......
Subfamily Microteinae:		
Neofiber sp.	......	1
MAMMALIA—continued.		
Lagomorpha:		
Leporidae:		
Lepus, 3 sp., possibly new	2	1
Sylvilagus or *Brachylagus* sp.	1	......
Edentata:		
Glyptodontidae:		
Glyptotherium, n. sp.	......	1
Total Mammalia	23	22
REPTILIA.		
Testudines:		
Testudinidae:		
Testudo, 2 sp. undet.	1	1
Kinosternodae:		
Kinosternon, new sp.	1	1
Batrachia:		
Salientia:		
Ranidae:		
Rana or *Bufo*, not yet determined	1	......
Total Reptilia	3	2
AVES.		
Galliformes:		
Odontophoridae:		
Undetermined	......	1
Colinus sp. undet.	1	......
Family undet.	1	......
Anseriformes:		
Anatidae:		
Dendrocygna, n. sp.	1	......
Branta, n. sp.	1	......
Charadriiformes:		
Scolopacidae:		
Micropalama, n. sp.	1	......
Family undet., medium-sized form	1	......
Columbiformes:		
Family undet. A pigeon somewhat smaller than the domestic dove	......	1
Passeriformes:		
Fringillidae:		
Small sp., undet.	1	......
Other passerines represented by scanty material	1	1
Total Aves	8	3

The reptilian remains, including at least two species of turtles, probably new, are being described by C. W. Gilmore, and the bird bones are being studied and will be described by Alexander Wetmore, of the Biological Survey, Department of Agriculture. The tentative lists of Reptilia and Aves given above are furnished by these gentlemen.

GEOLOGIC HORIZON AND CLIMATIC CONDITIONS INDICATED.

This preliminary study reveals little positive evidence regarding the exact geologic horizon of the beds in San Pedro Valley, beyond what is stated above. They seem to be clearly Pliocene, and the peculiar mingling of modern and more ancient forms seems to point rather definitely to a late stage of Pliocene time. Unfortunately, the material of these collections represents for the most part new species that can not be correlated with known faunas of other localities where the age of the beds has been established. However, the species are sufficiently numerous and varied to constitute a standard for comparison, and future field work in this region will almost certainly bring to light material that will definitely and correctly determine the proper sequence of these deposits.

The facts that there are here two or three species of true horse (*Equus*) and that the rodents are all referable to modern genera, some of which are found living in this general region, may suggest Pleistocene age. But to offset this evidence of a seemingly more modern fauna, the mastodons and glyptodonts are of distinctly Pliocene types, and one of the canids, though modern in skull and dental modifications, has the type of humerus belonging to the Miocene and Pliocene canids, in that the entepicondylar foramen is prominently present. This feature and the presence of *Hipparion*, *Pliohippus*, and *Merycodus*, together with the fact that the 15 or more species of rodents include no living species, constitute rather conclusive evidence of a faunal assemblage that is older than Pleistocene.

This general assemblage of species, including proboscidians, camels, horses, glyptodonts, and an extinct species of the ocellated turkey related to a group now living only in Central America and southern Mexico, suggests that the climate at the time the beds were laid down was rather warm and moist, probably subtropical or even tropical.

The presence of a true llama, the glyptodont, and a rodent belonging to a genus now living only in South America seems to indicate an intermingling of forms of South American origin, and the presence in these Pliocene deposits of a rodent and camel of definite South American living types suggests the derivation of their South American relatives from North America and favors the suggestion of an exchange of faunas between the two continents which took place somewhere near this epoch of geologic time.

DESCRIPTIONS OF SPECIES.

Order RODENTIA.

The order Rodentia is represented in the San Pedro Valley by 17 species, 11 of which occur at the Benson locality and 6 at the Curtis locality. Of these species, 15 are here described as new, and 2 are not certainly determined on the scanty material in hand. However, though all the species represented seem to be new, each is readily referable to one of ten living genera, distributed among four families—the Sciuridae, Geomyidae, Heteromyidae, and Muridae. The species belonging to the Muridae represent three subfamilies—the Cricetinae, Neotomeniae, and Microteinae.

Family SCIURIDAE.

The family Sciuridae is represented by two new species, both belonging to the genus *Citellus*.

Citellus cochisei Gidley, n. sp.

Plate XXXIV, figures 1, 2.

Type.—Portion of a right maxillary containing all the cheek teeth (catalog No. 10490, U. S. Nat. Mus.).

Paratype.—Portion of a left lower jaw (catalog No. 10491).

Locality.—Both are from the Curtis locality, in sec. 25, T. 18 S., R. 21 E., and were found in exhuming a mastodon skeleton.

Description.—Length of upper cheek-tooth series 10.5 millimeters. Molars relatively wide, m^1 and m^2 one-third wider than long; lophs and valleys simple and narrow; both posterior transverse lophs of the molars completely united with protocone, forming a short, narrow valley opening outward and extending inward not more than one-half the width of the tooth crown, as in *Cynomys*. The anterior transverse lophs are more depressed and except in m^3 are much longer than the other lophs, extending inward and upward to disppear in the anterior wall of the protocone. P^4 differs from the anterior two molars only in being less wide and in having the anterior loph relatively and actually more extended anteriorly.

In the greater width of tooth crowns, the less extent of their median external reentrant valleys, and the relative shortness of the heel of the last molar, this species suggests *Cynomys*, but it differs from species of that genus in the much more brachyodont tooth crowns, the greater relative depth of the median external reentrant valleys, and the incipiency, amounting to almost total absence, of the posterior reentrant valleys so prominent in species of *Cynomys*. The first of these features might be considered as a character of degree only, indicating less advanced specialization, but the other two I consider characters that denote relationship with the living species of *Citellus* rather than with those of the genus *Cynomys*.

The lower jaw, as indicated by specimen No. 10491, which carries the incisor and the anterior two cheek teeth, is relatively short and deep, the incisor narrow and pointed, and the cheek teeth relatively wide to a degree corresponding with those of the upper series. This species compares in size with *C. evermani*, but it differs from all the living forms in one or more of the characters enumerated above.

Citellus bensoni Gidley, n. sp.

Plate XXXIV, figures 3, 4.

Type.—A first or second upper molar of the right side and a last upper molar of the left side (catalog No. 10531, U. S. Nat. Mus.).

Paratype.—The cheek-tooth series of a left lower jaw (catalog No. 10532, U. S. Nat. Mus.).

Locality.—Both from the Benson locality.

Description.—Length of cheek-tooth series (estimated from measurements of the paratype), 10.3 millimeters; upper molar of about the same proportion as the corresponding one of *C. cochisei* at the base but much narrower at the summit, owing to the greater slope of the inner wall of the protocone; the three transverse lophs about equal in length, the posterior one being broken up into two distinct but slightly joined cuspules, the inner one of which is a rounded cone entirely disconnected from the protocone.

An upper m^3 which I associate with the type specimen, like that of *C. cochisei*, has a relatively small heel portion as compared with living species, and in addition there is a well-defined isolated cone-shaped cuspule near the center of the posterior basin.

This species seems to approach *C. beecheyi* much more closely than any other living species but differs from it in a few apparently important particulars. In *C. beecheyi* the crowns of the upper molars are relatively narrower than in the fossil species, being nearly as long as wide; the lingual wall of the protocone is less sloping, and the exterior or buccal face of this cusp is much more sloping. Other differences noted in the living species are the generally less broken up condition of the posterior transverse lophs; the somewhat shallower transverse valleys, the posterior one of which usually has a small cuspule at its external entrance; and the relatively broader and less completely inclosed posterior valley of the last upper molar.

Beyond the fact that the last lower molar, like the upper, is relatively smaller, and the valleys and cusps are somewhat more sharply defined than in *C. beecheyi*, there is little to distinguish between the lower cheek teeth of that species and *C. bensoni*.

Family GEOMYIDAE.

Three new species referable to two living genera of geomids are represented in the collection.

Geomys parvidens Gidley, n. sp.

Plate XXXIV, figures 5, 6.

Type.—The anterior portion of a skull carrying the incisors and all the cheek teeth except the first and last of the right side (catalog No. 10492, U. S. Nat. Mus.).

Paratype.—Portion of the right lower jaw carrying all the teeth except m^3 (catalog No. 10493, U. S. Nat. Mus.).

Locality.—Both from the Curtis locality.

Description.—Length of upper cheek-tooth series 5.5 millimeters; width across first upper molars (measured to outer borders) 6.7 millimeters; size small, about the same as that of *Geomys texensis;* rostrum relatively short and heavy; incisors with two very unequal grooves, the smaller one close to the inner border of the crown, the larger one almost exactly bisecting its anterior face, making the outer of the three ridges thus formed slightly but definitely largest; the cheek teeth are relatively small and not greatly expanded laterally, m^1 and m^2 being almost evenly elliptical in outline but with the outer edges slightly compressed; p^4 with anterior lobe decidedly smaller and less laterally expanded than the posterior one; m^3 as wide as long, subtriangular, relatively small.

Besides being about equal in size to *G. texensis*, *G. parvidens* is almost identical with that species in the character of the incisors, but it differs from *G. texensis* and the other living species of the genus in general in the less lateral expansion of the cheek teeth, the shorter and deeper rostrum, and the less progressive character of p^4.

The lower jaw referred to this species is relatively short, with prominent masseteric ridge and the submental foramina lying almost directly under the anterior end of the masseteric ridge. The anterior lobe of p_4 is relatively small and subcircular, with the walls very little flattened.

Geomys minor Gidley, n. sp.

Plate XXXIV, figures 7, 8.

Type.—Portion of a right lower jaw lacking the last molar (catalog No. 10494, U. S. Nat. Mus.).

Paratype.—A right upper incisor (catalog No. 10534, U. S. Nat. Mus.).

Locality.—Both from the Benson locality.

Description.—Length of cheek-tooth series (estimated) 5.4 millimeters; the jaw is slightly smaller than that of *G. parvidens* and differs from it otherwise in having the anterior masseteric area more depressed, the submental foramen slightly farther back in position, the cheek teeth relatively larger, and the anterior lobe of p_4 more nearly circular in outline; no anterior fossa between cheek teeth and coronoid process.

An associated upper incisor tooth is of appropriate size for the species It shows the characteristic grooving of a true *Geomys*, and it is this fact which has determined the generic reference of *G. minor*.

Cratogeomys bensoni Gidley, n. sp.

Plate XXXIV, figures 9–11.

Type.—A portion of a left lower jaw carrying all teeth (incisors broken) (catalog No. 10495, U. S. Nat. Mus.).

Paratype.—An upper incisor (catalog No. 10496, U. S. Nat. Mus.).

Locality.—Benson locality. The species is represented by four other pieces of the lower jaws from the same locality.

Description.—Length of cheek-tooth series 8 millimeters (measured at summits of teeth). About the size of the living species *Geomys breviceps;* cheek teeth not greatly compressed; p^4 with outer reentrant angle rather widely V-shaped, the inner one forming a distinct U; posterior wall of last molar in the type specimen with two distinct and two faint parallel longitudinal grooves forming three low but distinct closely grouped median longitudinal enamel ridges.

This species differs from all living species of geomids examined in having the area of the anterior portion of the masseteric ridge more depressed and in the position of the anterior submental foramen, which is nearly as in the two above-described species of *Geomys*. In living species this foramen is anterior to the masseteric ridge and nearly level with it. In the fossil species it is lower and more posterior in position, lying almost directly under the anterior extremity of the masseteric ridge. There is also between the cheek teeth and the anterior border of the coronoid process in *C. bensoni* a narrow but distinctly marked longitudinal fossa.

This species is referred to *Cratogeomys* on the evidence of an associated upper incisor of appropriate size which has the single groove characteristic of this genus.

Dipodomys minor Gidley, n. sp.

Plate XXXIV, figure 16

Type.—A nearly complete right lower jaw containing the incisor and the first cheek tooth (catalog No. 10499, U. S. Nat. Mus.).

Locality.—Benson locality.

Description.—Length of cheek-tooth row, measured from extreme borders of the alveoli, 4.7 millimeters; size and general jaw characters about as in the living species *Perodipus chapmani*, differing only in its more slender proportions and in the somewhat more reduced condition of the coronoid process. The fourth lower premolar, the only one of the cheek-teeth series present, is a long crowned and anteriorly curved tooth which is double-lobed, the anterior lobe having an anterior reentrant angle as in *P. chapmani*, but this tooth differs from the tooth of that species in having the posterior lobe relatively wider. Also the alveolus of the last molar is only about one-half the width of that of the other molars, indicating that this tooth is relatively more reduced than in the living species.

Family MURIDAE.

The family Muridae is rather abundantly represented at both localities. The 12 determinable species are distributed among three subfamilies, 10 belonging to the Cricetinae, 1 to the Microtinae, and 1 to the Neotomeniae.

Genus PEROMYSCUS.

Specimens found at the Benson locality are referable to three species of *Peromyscus*. Two of these are new, although one is apparently closely related to the *P. taylori* group. The other new species is more distinctive. The third, represented by a single lower jaw lacking the cheek teeth, has not been determined.

Peromyscus brachygnathus Gidley, n. sp.

Plate XXXIV, figure 12.

Type.—The greater portion of a right lower jaw carrying all the teeth (catalog No. 10501, U. S. Nat. Mus.).

Locality.—Curtis locality.

Description.—Length of cheek-tooth series, 2.8 millimeters; about the size of *P. taylori;* jaw relatively short anterior to cheek teeth; last molar very much reduced, as much as in any living species of *Onychomys*. The teeth are too much worn to determine accurately their normal height in unworn condition, but they appear to be of the depressed type of *P. taylori*.

The form and position of the anterior extension of the masseteric ridge, the general character of the coronoid region, and the relatively broadly expanded anterior lobe of the anterior cheek tooth seem to determine the generic reference of this species, but it differs from all living species of the genus in the relatively short jaw and the greater reduction of the last lower cheek tooth, which seems to have nearly or quite lost its hinder lobe.

Peromyscus minimus Gidley, n. sp.

Plate XXXIV, figure 13.

Type.—Portion of a left lower jaw carrying all the teeth (catalog No. 10500, U. S. Nat. Mus.).

Locality.—Benson locality.

Description.—Size very small, length of cheek-tooth series 2.6 millimeters; cheek-tooth cusps depressed, with well-marked cingula at the entrance of the external valley, and with tendency to inclose the internal ones by an uprising of the inner enamel wall between the cusps; anterior lobe of the first cheek tooth, p_4, relatively narrow but two-cusped at the summit; posterior lobe of last cheek tooth small, almost as much reduced as in *Onychomys*.

This species seems more nearly related to *P. taylori* than to any other living species but differs from it in having a narrow divided anterior lobe of the first cheek tooth and a more reduced hinder molar. It further differs from that species and more nearly agrees with others of the genus in the wider angle at which the coronoid portion of the ascending ramus diverges from the alveolar portion of the jaw.

P. minimus is distinguished from *P. brachygnathus* in that the jaw is somewhat more slender in proportions; the masseteric ridge is less advanced forward; the cheek teeth are slightly narrower; the anterior lobe of the first cheek tooth is narrow and double cusped, while that of *P. brachygnathus* is wider and undivided, and the last cheek tooth is somewhat less reduced.

Peromyscus sp.

Plate XXXIV, figure 14.

A second and larger species, about equaling *Peromyscus m. gambeli* in size, is represented by a lower jaw (catalog No. 10502, U. S. Nat. Mus.) lacking all the cheek teeth. Length of cheek-tooth series as estimated by measurement of the alveoli, 3.8 millimeters. This jaw, in its general form and in the position of the anterior extremity of the masseteric ridge, is sufficiently characterized to make certain its generic reference, but its specific features can not be determined until the cheek teeth are known.

Genus ELIGMODONTIA.

The genus *Eligmodontia*, the living species of which are confined to the South America continent, is represented by a single species in the fossil collection from Arizona.

Eligmodontia arizonae Gidley, n. sp.

Plate XXXIV, figure 15.

Type.—Greater portion of a left lower jaw containing the complete dentition (catalog No. 10503, U. S. Nat. Mus.).

Paratype.—Single lower jaws of two other individuals (catalog Nos. 10504, 10505).

Locality.—All from Benson locality.

Description.—Length of cheek-tooth series 3.6 millimeters; about the size of the living species *E. morgani*, but may be distinguished from it by its relatively greater depth of jaws, its decidedly shorter symphysis, and the less reduced condition of the last molar.

The anterior lobe of the first cheek tooth is distinctly notched by an anterior median reentrant angle, as is usual in *Peromyscus*, whereas in the living species of *Eligmodontia* this lobe is usually evenly convex in front. The fossil species from Arizona, however, is readily distinguished from *Peromyscus* by the characters which ally it to *Eligmodontia*, namely, by the form and position of the masseteric ridge, which extends forward to the extreme anterior border of the cheek-tooth series; by the form and situation of the capsular process for the reception of the base of the incisor, which is placed high upon the ascending ramus and is marked by a decided sulcus between it and the coronoid; and by the form of the last cheek tooth, which in species of *Eligmodontia* is more reduced than in *Peromyscus*.

Onychomys pedroensis Gidley, n. sp.

Plate XXXV, figure 1.

Type.—Portion of a left lower jaw carrying the first and last cheek teeth (catalog No. 10506, U. S. Nat. Mus.).

Paratypes.—Other lower jaw portions (catalog Nos. 10507, 10508, U. S. Nat. Mus.).

Locality.—All from Curtis locality.

Description.—Length of the cheek teeth 4.5 millimeters; size somewhat larger than *O. leu. ruidosae*, which it somewhat more nearly resembles than any other living species. It further differs from that species in its relatively greater depth of jaw, the greater degree to which the masseteric ridge is carried forward, and the somewhat less reduced condition of the last cheek tooth.

Onychomys bensoni Gidley, n. sp.

Plate XXXV, figure 3.

Type.—Portion of a right lower jaw containing complete dentition (catalog No. 10509, U. S. Nat. Mus.).

Locality.—Benson locality.

Description.—Length of cheek-tooth series 3.9 millimeters; about the size of *O. torridus* but with less reduced last molar, as in the larger species *O. leu. ruidosae*. The hinder lobe of the last molar is less reduced even than in the last-mentioned species. *O. bensoni* differs from all the living species of the genus in having more widely open valleys and less conspicuous lophs in the molar teeth; a more depressed heel on the last lower molar, which is distinctly lower than the anterior or triconid portion; and apparently a relatively larger and higher coronoid process.

Sigmodon curtisi Gidley, n. sp.

Plate XXXV, figure 2.

Type.—The greater parts of both lower jaws carrying complete dentition (catalog No. 10510, U. S. Nat. Mus.).

Paratype.—Portion of a right lower jaw with cheek teeth (catalog No. 10511, U. S. Nat. Mus.).

Locality.—Both from Curtis locality.

Description.—Length of cheek-tooth series 7 millimeters; about the size of *S. hispidus arizonae*, which it seems to resemble more nearly, but it differs from that as well as the other living species in the more open valleys of the reentrant angles, the more compressed lophs, the less hypsodont condition of the cheek teeth, the relatively deeper posterior inner reentrant valley of p_4 and m_1, and especially the form and proportions of the cusps of the last lower molar, which is relatively larger, with the hinder cusp relatively broader and fuller than in the living species. A feature that is characteristic of this and the species described below and is not observed in any of the living species is noted in the last molar, in which the great extension and flattening of the inner or lingual wall of the posterior lobe forms a sharp right angle with the posterior wall of the reentrant angle on that side.

I take pleasure in naming this species for Mr. Milton Curtis, in recognition of his efficient assistance in the field.

Sigmodon minor Gidley, n. sp.

Plate XXXV, figures 4, 5.

Type.—Portion of a left lower jaw carrying the complete dentition (catalog No. 10512, U. S. Nat. Mus.).

Paratype.—Portion of a left maxillary carrying the anterior two cheek teeth (catalog No. 10513, U. S. Nat. Mus.).

Locality.—Curtis locality. Five other lower-jaw portions, most of them with complete dentition (catalog Nos. 10514 to 10518), are also referable to this species.

Description.—Length of cheek-tooth series 4.7 millimeters; smaller than *S. medius* and decidedly smaller than any of the living species examined. This species is distinguished from the living forms by the same characters observed in *S. medius*, except that the external reentrant valleys of the upper molars (as shown by specimen No. 10513) are of the normal modern type. *S. minor* differs from *S. medius* only in its smaller size, having a relatively narrower anterior lower cheek tooth, in which the anterior lobe is relatively smaller, with the adjacent reentrant valleys nearly equal in length. The reentrant valleys of the upper cheek teeth are oblique to the same degree and of about the same proportionate depth, but the molar crowns of both the upper and lower series are less hypsodont.

Sigmodon medius Gidley, n. sp.

Plate XXXV, figures 6, 7.

Type.—Portion of a right lower jaw containing the complete dentition and an associated fragment of a right maxillary carrying the anterior two cheek teeth, possibly of the same individual (catalog No. 10519, U. S. Nat. Mus.).

Paratypes.—Four other lower-jaw portions (catalog Nos. 10520 to 10523, U. S. Nat. Mus.).

Locality.—All from the Benson locality.

Description.—Length of cheek-tooth series 5.5 millimeters; somewhat smaller than the living species *S. sanctae martae*, with which it seems to compare more nearly than with other living forms. Its resemblances are noted in the form of the anterior lobe of the first cheek tooth, in which the anterior internal reentrant valley considerably exceeds the opposing outer one in length; in the decided angulation of the posterior portion of the inner wall of the last molar; and in the relatively heavy symphysis and considerable depth of jaw. It differs from this and other living species in having the cheek-tooth crowns slightly less hypsodont, the reentrant valleys more open, and the lophs correspondingly narrower, while there is present in the last molar a small but distinct reentrant notch on its inner side opposite the posterior reentrant valley.

The two upper cheek teeth show the same character of the more open valleys observed in the lower cheek teeth. Another difference noted is the form of the external reentrant valleys of these teeth, which clearly distinguishes them from the corresponding teeth of living species. The external reentrant valleys, instead of being straight, open directly outward, while their inner portions bend backward, forming a decided angle in their posterior enamel walls. In the living species these valleys run obliquely forward and outward in a nearly straight or but slightly curved line.

Two other lower jaws in the collection (Nos. 10521 and 10522) differ slightly in minor characters from the type but are here referred to this species. These differences, which consist wholly in a somewhat smaller size and a less proportionate depth of jaw, correspond to differences observed between males an females of the living species *S. sanctae martae*. I therefore assume that the type specimen and specimen No. 10520, which agrees with it in every particular, represent males, while the smaller jaws just mentioned represent females of the species.

Neotoma fossilis Gidley, n. sp.

Plate XXXV, figures 8–10.

Type.—Portion of a right maxillary carrying the anterior cheek tooth and the alveoli for middle cheek tooth (catalog No. 10524, U. S. Nat. Mus.).

Paratypes.—Portion of a left lower jaw carrying the incisor and alveoli for the cheek teeth, and two right lower cheek teeth (catalog Nos. 10525 and 10526, U. S. Nat. Mus.).

Locality.—Benson locality.

Description.—Length of anterior cheek tooth 3.2 millimeters; width 2.2 millimeters; about the size of *N. intermedia gilva*. The following characters distinguished this from all living species: First upper cheek tooth relatively short and wide; no indication of an anterior internal reentrant valley; posterior internal reentrant valley nearly as long as the the external one; posterior notch of anterior palatial opening opposite the anterior root of the first cheek tooth.

The two lower teeth referred to this species also show distinctive characters. The anterior one (p_4) is entirely devoid of the anterior reentrant valley so prominent in such a form as *N. cinera*, and both these teeth are like the corresponding ones of this species in having the posterior external reentrant valleys pitted in a way to form a nearly circular enamel lake in well-worn teeth. These lower teeth differ from those of all living species in having the main cross lophs directed somewhat obliquely inward and backward instead of squarely across the long axis of the tooth.

The lower-jaw specimen shows nothing peculiar except that the capsular bulb at the base of the incisor is somewhat less prominent than is usual in the living species.

Neofiber sp.

Plate XXXV, figure 14.

A nearly complete cheek tooth, apparently the left upper middle one, from the Curtis locality (catalog No. 10527, U. S. Nat. Mus.), seems to represent the genus *Neofiber*. It is slightly smaller than the corresponding tooth of *Neofiber alleni*, with which I compared it, but has all its characteristics. Except the slight variation in size, they differ only in that the base of the fossil tooth is closed by the formation of rootlets, whereas the specimens of the living species examined seemed to indicate growth from a persistent pulp. However, this difference may be, in part, at least, an age character, as in the closely related genus *Ondatra*, in which both conditions are found on examining a number of specimens of various ages.

Order LAGOMORPHA.

Four species of Lagomorpha are represented in the collection, three from the Benson locality and one from the Curtis locality. They seem not to be referable to any living species, but the material representing them is too fragmentary to warrant any attempt at diagnostic descriptions.

Species No. 1.

Plate XXXV, figure 15.

Represented by a portion of a left lower jaw carrying p_4, m_1, m_2 (broken), and the alveoli for the other two cheek teeth and the incisor, from the Benson locality (catalog No. 10530, U. S. Nat. Mus.). This specimen represents a species about the size of *Lepus campestris*, or slightly smaller, and it agrees with that species rather closely both in jaw and tooth characters.

Species No. 2.

Plate XXXV, figure 11.

Represented by two upper incisors (broken), a first lower cheek tooth of the left side, and a median lower cheek tooth of the left side, from the Benson locality (catalog No. 10529, U. S. Nat. Mus.).

These teeth represent a small species about the size of *Sylvilagus aud. arizonae* or *Brachylagus idahoensis*. However, there are some peculiarities in one or another of all these teeth that make uncertain their definite reference to either of these living genera. The incisors are of a type to fit in with either genus, although there is not quite the difference in relative size of the two lobes formed by the anterior longitudinal groove. In the molar tooth the posterior lobe is about intermediate in relative size bebetween that of *S. aud. arizonae* and *B. idahoensis*, and both lobes are somewhat less laterally expanded and less sharply angulate than in either of these species. The anterior lower cheek tooth, which is of the right side, is peculiar and differs from that of any living species that has come under my observation. It is of the same general form as that of *S. aud. arizonae* but is proportionately a little wider, being nearly as wide as long, and is void of any reentrant angles except the normal two outer ones. Moreover, the posterior one of these extends but little more than halfway across the tooth. In all living forms examined this reentrant either extends entirely across to the inner wall of the tooth or meets an opposing reentrant from the inner side.

Species No. 3.

Plate XXXV, figure 13.

In the collection from the Curtis locality are a portion of a right lower jaw carrying the anterior two cheek teeth (catalog No. 10528, U.S. Nat. Mus.) and a lower right anterior tooth of a second individual, which represent a species about the size of *Lepus californicus erennicus*, or somewhat smaller. The fossil species seems to differ from the latter, however, in the proportions of all the tooth lobes which are somewhat narrower and in having the anterior lobe of the first cheek and tooth set farther inward, so that the reentrant valley faces decidedly forward and outward, instead of almost directly outward, as in the living species.

Cf. Lepus sp.

Plate XXXV, figure 12.

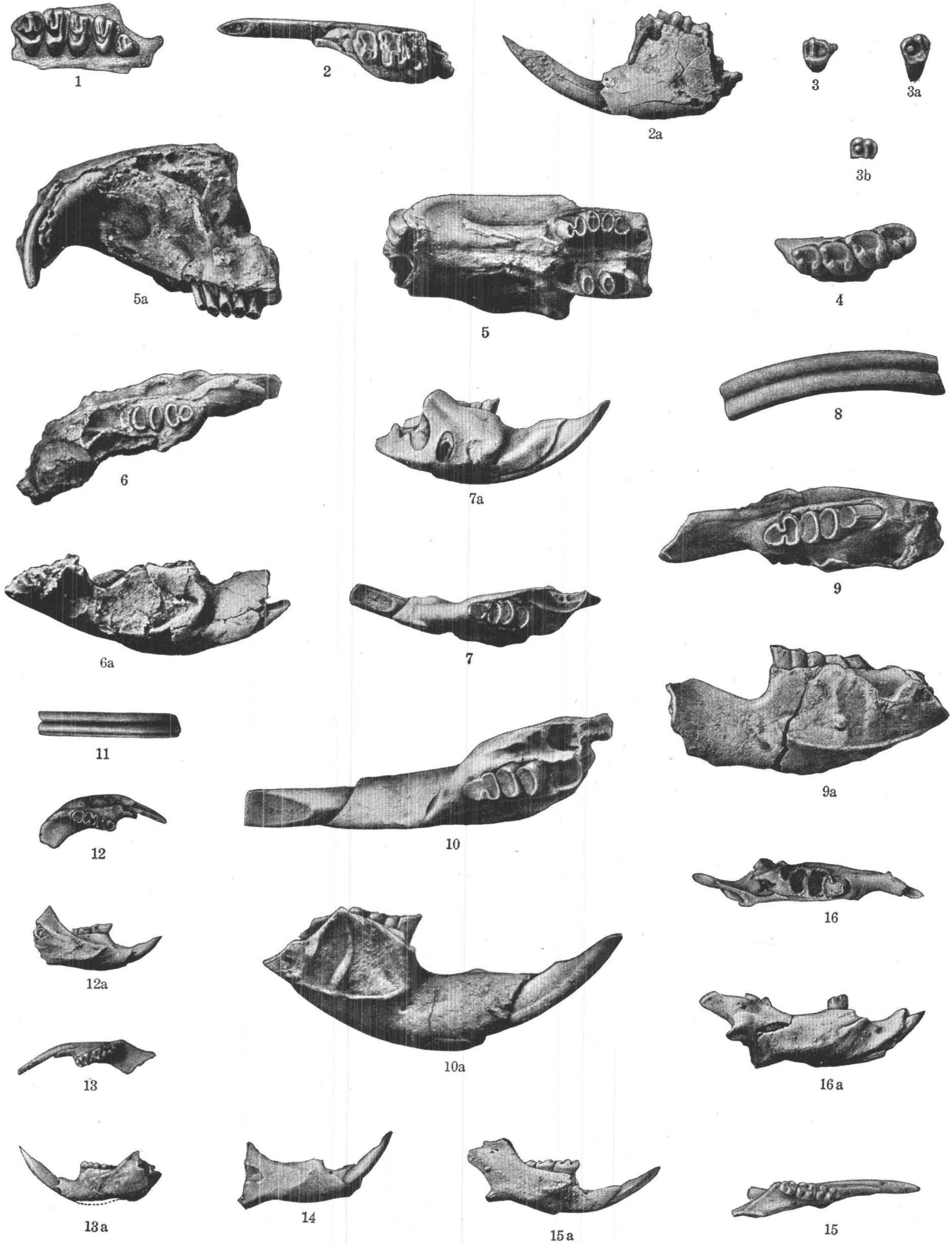
A fourth species of Lagomorpha (catalog No. 10535, U. S. Nat. Mus.) is represented in the material from the Benson locality by the two incisors of the right side in a fragment of the premaxillary. It differs from the others in having an unusually high inner ridge on the large incisor. In fact, the tooth is remarkable in that the plane of its upper face is very oblique to the perpendicular plane of the skull, as in *Ochotona*, but the plane of its lower surfaces is nearly at right angles to the perpendicular median plane of the skull, as in the true rabbits, and its summit has the characteristic wear of a short anterior chisel point and posterior ledge or shelf observed in all species of rabbits but not found in the *Pica* group. The longitudinal enamel groove is filled with cement, but this feature has not even a generic significance. As this form of incisor is suggested in some degree in certain species of *Lepus*, as *L. siamensis*, I regard the fossil specimen as belonging to that genus.

PLATES XXXIV–XXXV.

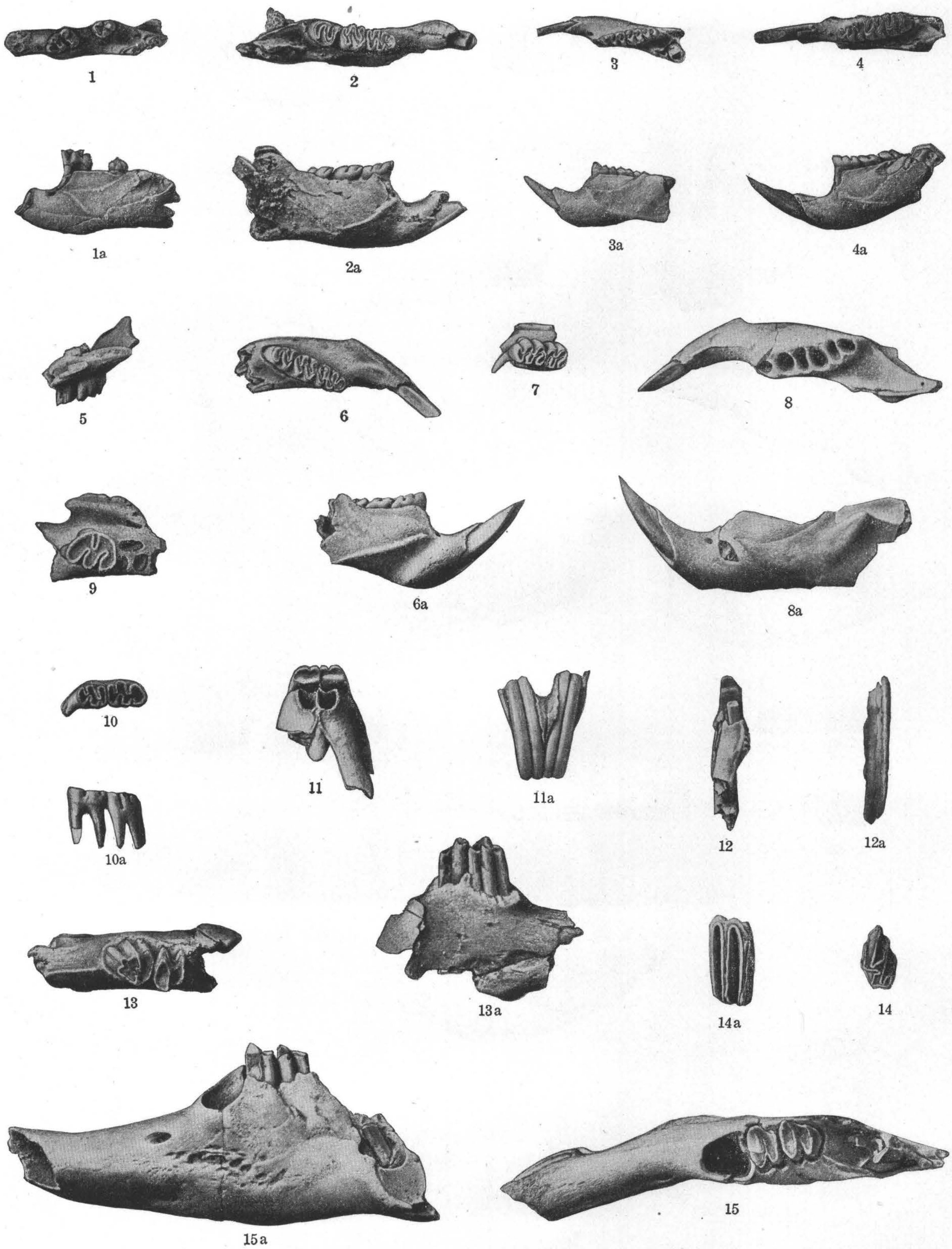
PLATE XXXIV.

[All figures about twice natural size.]

		Page.
FIGURE 1.	*Citellus cochisei* Gidley, n. sp. Type. Upper cheek teeth of right side, crown view. No. 10490, U. S. Nat. Mus	121
2.	*Citellus cochisei* Gidley, n. sp. Portion of left lower jaw, tooth-crown view; 2a, side view. No. 10491, U. S. Nat. Mus	121
3.	*Citellus bensoni* Gidley, n. sp. Type. Last left upper molar, crown view; 3a, 3b, right upper molar probably of same individual. No. 10531, U. S. Nat. Mus	122
4.	*Citellus bensoni* Gidley, n. sp. Lower cheek teeth in fragment of jaw of left side, crown view. No. 10532, U. S. Nat. Mus	122
5.	*Geomys parvidens* Gidley, n. sp. Type. Anterior portion of skull, palate view; 5a, side view. No. 10492, U. S. Nat. Mus	122
6.	*Geomys parvidens* Gidley, n. sp. Portion of a right lower jaw, tooth-crown view; 6a, side view. No. 10493, U. S. Nat. Mus	122
7.	*Geomys minor* Gidley, n. sp. Type. Portion of a right lower jaw, tooth-crown view; 7a, side view. No. 10494, U. S. Nat. Mus	123
8.	*Geomys minor* Gidley, n. sp. Upper incisor of left side, front view. No. 10534, U. S. Nat. Mus	123
9.	*Cratogeomys bensoni* Gidley, n. sp. Type. Portion of a left lower jaw, tooth-crown view; 9a, side view. No. 10495, U. S. Nat. Mus	123
10.	*Cratogeomys bensoni* Gidley, n. sp. Portion of a right lower jaw, tooth-crown view; 10a, side view. No. 10497, U. S. Nat. Mus	123
11.	*Cratogeomys bensoni* Gidley, n. sp. Upper incisor of right side, front view. No. 10496, U. S. Nat. Mus	123
12.	*Peromyscus brachygnathus* Gidley, n. sp. Type. Portion of a right lower jaw, tooth-crown view; 12a, side view. No. 10501, U. S. Nat. Mus	124
13.	*Peromyscus minimus* Gidley, n. sp. Type. Portion of a left lower jaw, tooth-crown view; 13a, side view. No. 10500, U. S. Nat. Mus	124
14.	*Peromyscus* sp. Portion of a right lower jaw, side view. No. 10502, U. S. Nat. Mus	124
15.	*Eligmodontia arizonae* Gidley, n. sp. Type. Greater portion of a right lower jaw, crown view; 15a, side view. No. 10503, U. S. Nat. Mus	124
16.	*Dipodomys minor* Gidley, n. sp. Type. Greater portion of a right lower jaw, tooth-crown view; 16a, side view. No. 10499, U. S. Nat. Mus	123



FOSSIL VERTEBRATES OF SAN PEDRO VALLEY, ARIZ.



FOSSIL VERTEBRATES OF SAN PEDRO VALLEY, ARIZ.

PLATE XXXV.

[All figures about twice natural size.]