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THE CENOZOIC DEPOSITS OF TEXAS.

The purpose of this paper is to give a brief account of the Cenozoic deposits of Texas as they are now understood, and to make such correlation of the various horizons as may appear to be warranted by the stratigraphical position and fossil contents.

The statements are based, partly on my own field work, partly on that of other members of the survey, and the paleontological studies of Cope, Harris, and Cragin, the details of which have been given in previous publications or will appear in the Fifth Annual Report of the Geological Survey.

EOCENE.

So far as known, all of the deposits referable to the Eocene Tertiary in Texas are confined to the Coastal Slope. They have been divided as follows:

3*d* Frio clays.
3*c* Fayette sands.
3*b* Yegua clays.
3*a* Marine beds.
2 Lignitic beds.
1 Will's Point or Basal clays.

Basal Clays.—The basal beds of the Eocene consist of stiff laminated clay, yellow, red, blue or bluish green in color, with some laminæ and beds of sand, boulders and indurated strata of calcareous material, containing in places many fragments of shells. The boulders are irregularly distributed through the clay, and sometimes form continuous bands for considerable distances, as in the vicinity of Tehuacana. Another phase assumed

by the lime is the small cauliflower-like concretions which abound in certain beds. Gypsum crystals are also plentiful.

In areal distribution the Basal clays are principally found north of the Colorado river, and, although a few localities are known south of that stream, the beds are, for the most part, obscured by overlap.

Typical exposures of the beds can be found in the vicinity of Elmo, Will's Point, Tehuacana, and on the Rio Grande near the Maverick-Webb county line.

The fossils, which occur in pockets, have been determined by Harris, who assigns the beds to the horizon of the Midway stage of Alabama. Characteristic fossils are:

Ostrea pulaskensis Har., *Cucullæa macrodonta* Whitf., *Yoldia eborea* Con., *Crassatella kennedyi* Har., *Pleurotoma ostrarupis* Har., *Volutilithes rugatus* Con., *V. limopsis* Con., *Pseudoliva unicarinata* Ald., *Aporrhais gracilis?* Ald., *Enclimatoceras ulrichi* White.

Lignitic Beds.—These beds are composed, for the most part, of siliceous sand of various colors, usually much cross-bedded, micaceous and often containing specks or grains of glauconite. Clays of various colors occur, laminated, as interbedded and interlaminated sands and clays, and in massive beds. Lime is present in the form of nodules, concretions and beds of siliceous limestones. Gypsum is also found in places. Brown coal and lignite beds, varying from a few inches to ten and twelve feet in thickness, are of frequent occurrence, and traces of oil and gas are found. Silicified wood is common. Iron occurs in the form of pyrites, and also in nodules, strings and small seams of clay ironstone.

The upper portion of the beds is composed of a series of red and white sands and white clays—the Carrizo sands of Owen and Queen City beds of Kennedy.

The lignitic beds are well marked from the eastern limit of the state to the Rio Grande, forming, as a usual thing, gently rounded hills covered with forests of oak. Typical exposures may be found at Athens, Calvert Bluff, Rockdale, Lytle, Carrizo Springs, etc

The fossils, which, according to Mr. Harris' determinations, are those characteristic of the Lignitic of Alabama, include the following:

Dentalium micro-stria? Heilp., *Pleurotoma moorei* Gabb, and numerous others which are common to these beds and those underlying or overlying them.

In addition to the invertebrate forms these beds also contain a varied and well preserved flora which has not yet been studied.

Marine Beds.—The Marine beds are composed of sand, with considerable amounts of glauconite, clays and iron ores, and are the principal fossil-bearing beds of the series. The lower beds contain extensive deposits of ferruginous sandstones and laminated iron ores, while the upper comprise brown fossiliferous sand, green sand marls, stratified black and gray sandy clays and green clays, and are the principal fossil-bearing beds of the substage. Thin beds or laminæ of carbonate of iron occur throughout the entire section, but the heavier beds or ore deposits are found toward the top of the lower beds. The lower ores are laminated, while those above are nodular.

The surface exposure of the Marine beds forms a broad ridge or range of hills crossing the state from the east, where it forms the greatest elevation of that portion of the Eocene belt, to the southwest. Its topography is the consequence of the resistance of the iron ore caps of the eastern plateaux or hills to erosive agencies, and the similar service of the brown sandstones of the west. In areal extent this is the most widely distributed of the sub-divisions of the Eocene.

In elevation it varies from 375 to 700 feet above sea level.

The fossils are very abundant and well preserved, and among those characteristic of it may be noted:

Ostrea alabamiensis Lea, *O. sellaeformis* Con. var, *divaricata*, Lea, *Anomia ephippioides* Gabb, *Modiola houstonia* Harris, *Yoldia claibornensis* Con., *Venericardia planicosta* Lam., *Semele linosa* Con., *Terebra houstonia* Har., *Cancellaria gemmata* Con., *Marginella semen* Lea, *Terebrifusus amœnis* Con., *T. costatus* Lea, *Levifusus trabeatoides* Har., *Nassa texana* Gabb, *Murex vanuxemi* Con., *Dis-*

tortrix septemdentata Gabb, *Mesalia claibornensis* Con., *Turritella nasuta* Gb., *Natica limula* Con., *Sigaretus declivis* Con., *S. inconstans* Ald., *Belosepia ungula* Gb.

Yegua Clays.—This sub-division was proposed to include the gypseous and saliferous clays, lignites and sands lying between the Marine beds and the sandstones of the Fayette with which they were united in the first use of that name. The area occupied by them is, for the most part, only gently rolling, except toward the southwest, where it sometimes happens that considerable hills occur, the summits being capped by the harder sandstone or quartzite of the Fayette beds.

The clays are dark blue, weathering to a dirty yellow, with a profusion of crystals of gypsum. In places the clays are massive, at others laminated. The sands are gray and white, often laminated or cross-bedded, but sometimes massive. The fossil wood contained in them is simply silicified and not opalized, as in the succeeding beds. The brown coal and lignite deposits of this sub-division are as extensive as those of the Lignitic stage, beds with a measured thickness of sixteen feet having been observed on the Colorado.

While the lithological characters of the Yegua clays are clearly marked and plainly traceable entirely across the state, its fauna connects it directly with the Marine beds. Typical exposures of the beds may be seen near Alto and Lufkin, on the Yeguas in Lee county, and between Pleasanton and Campbellton.

In addition to the many forms common to this and the Marine beds, the following seem to belong exclusively to the Yegua:

Tellina mooreana Gabb var., *Turritella nasuta* var. *houstonia* Har., *Natica recurva* Ald.

Fayette sands.—This name was originally applied by Penrose to the entire series of deposits between the top of the Marine beds and the base of the Coast clays. It is used here, with a greatly restricted significance, for that sub-division of the Tertiary to which the name is most applicable. This is a series of sands and sandstones with some clays, which contain a large amount of opaline and chalcedonic materials. The sands are

usually coarse, angular to rounded in shape, forming sandstones of variable degrees of hardness, highly quartzitic in places, and cemented by an opaline matrix at others. Large quantities of opalized wood occur, and chalcedony is abundant, especially in the southwest, where it forms the centers of geodes, the septa of septaria, and even fills crevices in the sandstone. Beds of volcanic dust and siliceous sinter also occur interbedded with the clays and lignites. In the Nueces valley cone-in-cone structure is widely developed, and considerable aragonite occurs in the basal portion of the bed. Many of the clays are white, and of sufficient purity to be valuable for the manufacture of the finer grades of earthenware. The beds of lignite are, for the most part, small and unimportant.

There is no sharp line of demarkation between these beds and the Yegua clays below, but the change in the character of the sediments has caused a corresponding change in the topography. The gently rolling area of the Yegua clays is bordered on the south by a disconnected range of hills, whose northward-facing scarps and bluffs (often 150 feet in height) can be traced from Rockland, on the Neches, westward, by Riverside, Muldoon, and Tilden, to the Rio Grande. Southward from this scarp the descent is more gradual. The influence of these beds of sandstone on the course of the rivers which cross them is very marked, producing a sharp east or northeast deflection, such as that of the Trinity on the northern boundary of Walker county.

While the Fayette beds of the eastern part of the State are almost without invertebrate fossils, so far as determined, the fauna increases toward the Rio Grande, and on that river includes large beds of immense oysters. The forms specially characteristic of it are:

Ostrea alabamiensis var. *contracta* Con., *Siliqua simondsi* Har., *Ceronia singleyi* Har., *Cornulina armigera* var. *heilpriniana* Har., *Cerithium pliciferum* Heilp.

It is connected with the underlying beds by such forms as *Nucula magnifica* Con., *Venericardia planicosta* Lam., *Corbula ala-*

bamiensis Lea., *Levifusus trabeatoides* Har., *Pseudoliva vetusta* Con., *Calyptrophorous velatus* Con.

The flora of this sub-stage is quite varied, and some of the forms very well preserved, but up to the present no study of it has been made.

Frio clays.—The Fayette subdivision passes upward into a series of gypseous clays with sand and sandrock, differing greatly lithologically from the underlying beds. This subdivision is therefore proposed for them. According to Kennedy, they are not present (in this form at least) on the Neches river, but I found them well developed on the Frio and Nueces.

The clays are dark colored, greenish gray, red or blue, usually massive, with quantities of gypsum and with calcareous concretions arranged in lines, giving them a stratified appearance. The sandy clays are laminated and bedded, green, red or blue in color, and interbedded with brown and green sandstone, which is concretionary and, in places, highly indurated. Brown sands overlie these, and are followed by laminated chocolate clays containing concretions of crystalline limestone with manganese dendritions. These clays weather white, as at the mouth of the Frio.

Typical exposures: Between Weedy creek and Oakville on Atascosa and Frio rivers, and on the Nueces south of Tilden.

While the fossils are not very abundant, enough were found to determine its close relationship with the underlying beds. The *Ostrea*, *Corbula*, etc., are distintly lower Claiborne forms.

So far as our observations go, this is the highest bed referable to the Eocene and from the evidence now before us it appears that there are no deposits in the State belonging either to the Upper Claiborne, Vicksburg, or Jackson, since no fossils characteristic of either of these stages have yet been found.

The Texas Eocene, as a whole, is therefore composed of a series of comparatively shallow water deposits, laid down during a period of slow and gentle oscillations. Numerous local uncon-

formities exist between the several subdivisions, and even among the beds of the same subdivision. The Carrizo sands show a more or less wavy structure throughout their extent, and this is continued upward into the Marine beds. Some portions of the Marine beds seem to have been subjected to erosion before the deposition of the Yegua clays, and faults of slight throw are quite common. As a whole the beds thicken from the Colorado-Brazos divide to the eastward and toward the Rio Grande and are also more indurated in the latter region. The general dip is south to southeast 10 to 50 feet per mile, although reverse dips are common in places.

The fossils which these beds hold in common with deposits of similar age of the Pacific slope, some of which are not found in the Tertiary of the Atlantic coast, bear evidence to the fact that the Gulf of Mexico was at that time connected with the waters of the Pacific. The fossils common to these deposits and the Tejon beds are, according to Harris:[1]

Whitneya (*Strepsidura*) *ficus* Gabb, *Natica ætites* Con. equiv. to *Nevireta secta* Gabb, *Solarium alveatum* Con. equiv. to *Architectonica cognata* Gabb, *Solarium amœnum* Con. equiv. to *Architectonica hornii* Gabb, *Cardita hornii* Gabb equiv. to *Venericardia planicosta* Lam.

The influx of large amounts of hydrous silica, beds of siliceous sinter and volcanic ash, and the development of cone-in-cone structure in the upper portion of these deposits is worthy of note as indicating the manner in which these Tertiary deposits became a land area.

NEOCENE.

Beds of Neocene age are found both in the Coastal slope and on the Llano Estacado. They probably exist in the trans-Pecos district also, but have not as yet been positively identified. The deposits include beds both of Miocene and Pliocene age, and the following division is proposed:

[1] Science, August 16th, 1893.

	Coastal slope.	Llano Estacado.
	2 b Reynosa	
Pliocene	2 a Lagarto	
	2 Lapara	Blanco
Miocene	1 a	Goodnight
	1 Oakville	Loup Fork

MIOCENE.

The Loup Fork beds of the Llano Estacado are composed of alternating beds of bluish and almost pure white sand, capped by a conglomerate of siliceous pebbles in white sand matrix. In areal extent they are found overlying the Triassic of the Plains throughout its northern portion, but extending to the south only as far as Mulberry canyon. The fauna, as described by Cope,[1] in addition to a number of species hitherto found only in beds of the Loup Fork terrane, and thus fixing the age of the Texas bed, contained two new forms: *Protohippus pachyops*, Cope, and *Procamelus leptognathus*, Cope.[2]

On the Coastal slope the Frio beds of the Eocene are succeeded by a series of deposits, which in a general way resemble the underlying Fayette sands, and have hitherto been regarded as a part of those beds. While it is possible to distinguish between them, the differentiation is complicated in many instances by the overlap of still later beds largely derived from both these and the Fayette, and therefore bearing a very close resemblance to them lithologically.

The deposits are those of rapid currents of shallow water. Grits and coarse sand, cross-bedded,[3] with some beds of clay but oftener with balls, nodules or lenses of clay imbedded in the grit. Some of the sand forms a sandrock which is apparently firm and hard, but much of it is so feebly coherent as to fall apart on a

[1] Fourth Annual Report, Geological Survey of Texas, Part II., pp. 18–40.

[2] Professor W. B. Scott regards these beds as equivalent to the Archer beds of Florida, which Dall, for stratigraphic reasons, places in the Pliocene. Bull. Geol. Soc. Am., vol. ii. p. 595.

[3] Cf. Loughridge, Tenth Census of the U. S., Cotton Production of the State of Texas, p. 21.

slight blow of the hammer. Local beds of conglomerate occur, and, on the Nueces, a heavy bed of black flint gravel was traced from its outcrop until the dip carried it below the water line.

As I now understand this division, the base is found at La Grange bluff, described by Penrose,[1] and it embraces the beds from which the fossils came which were reported by Shumard (Trans. St. Louis Academy, 1863, p. 140) and determined by Leidy (Proc. Phil. Ac. Nat. Sc., 1865, p. 176, and 1868, p. 231, etc.).

Mill creek, between Brenham and Burton, marks a lithological change, the rocks west of that stream, which are the lower, being more compact than those east, which at Brenham have the character of cross-bedded grits with pebbles of clay, containing water-worn cretaceous fossils, as well as numerous fragments of the bones of vertebrates. A similar division was noticed east of La Grange.

On the Nueces the beds, which are here highly saliferous, are well exposed from Oakville to Fort Merril, at which place they are overlaid by the Pliocene. Here begin the silicifications of portions of the materials, which becomes a more and more prominent feature of the deposits further west.

Among these silicifications may be mentioned the rocks, known as Las Tiendas, on the road between San Diego and Tilden. On the outside these rocks resemble masses of light-colored flint, the surface of which is highly polished by blown sands. Closer examination shows that they are simply portions of the interbedded clays and sands of the Oakville beds, which have become silicified without destroying the original structure of the beds. Thus the bedding and lamination is apparent in portions of the mass, and the siliceous pebbles, so common in the unaltered beds, are found in these masses also.

To the same age as the Oakville beds I have also referred the range of hills in the valley of the Nueces, known as the Picachos.

These hills, running northwest and southeast, are nowhere

[1] First Annual Report, Geological Survey of Texas, p. 54.

over 100 feet higher than the valley in which they stand, but their serrated tops give them the appearance of a range of eruptive hills. The beds here, unlike those at any other place in the Texas Tertiaries, stand at high angles, and have a dip of 75 to 80 degrees to the southeast.

The materials of which they are composed are claystones interbedded with porcelaneous and siliceous rocks, partly flinty, partly opaline, with bands and network of chalcedony and with seams of ferruginous material. A few seams of calcite, in the form of dog-tooth spar, and a bed of aragonite, 20 feet in thickness, banded in brown and white and much knotted and twisted, are found. The true opaline character of the rock was shown by an analysis by Dr. Mellville, and the present condition may be regarded as the result of infiltration of hydrous silica in hot solution into the Tertiary marls, and their consequent alteration. A number of specimens collected show that the marl was cracked in every direction, and that these fissures are now filled with chalcedony, while the marl is changed to a porcelaneous substance.

The sands and clays of this division form the scarp known as the Bordas, which forms the southern border of the Nueces valley from Dinero to Los Angeles. It also caps many of the outlying hills in the valley.

Only a few fossils have been found, but such as are determinable—*Protohippus medius* Cope, *P. perditus* Leidy, and *P placidus* Leidy, *Aphelops meridianus* Leidy, etc.—are sufficient to determine its age as Loup Fork.

The exact relation of these beds and those found in boring the Galveston deep well has not been determined, since no deposits containing similar marine Miocene fossils have been found at the surface on the Coastal slope. The relationship of the Deep Well Miocene and deposits of Florida and the West Indies is shown by Harris[1] in his report on the organic remains from that boring.

On the Llano Estacado there is no great break between the

[1] Fourth Annual Report Geological Survey of Texas, p. 118.

Loup Fork beds and the Blanco or Pliocene, but they are directly connected by a deposit which has been called the Goodnight beds. The fauna, according to Professor Cope, contains forms which are found in the underlying Loup Fork, and others which extend upward into the overlying Blanco, as well as three which are peculiar to itself—*Protohippus lenticularis* Cope, *Hippidium interpolatum* Cope, and *Equus eurystylus* Cope. It is possible that more detailed investigations of the upper portion of the Oakville beds above Lapara creek, and between Brenham and Long Point, may furnish evidence of a similar condition.

PLIOCENE.

The Blanco beds—Pliocene of the Llano Estacado are composed of clays and sands interbedded with diatomaceous earth and capped with calcareous sandstone and limestone. They constitute the eastern scarp of the Plains from the Double Mountain Fork of the Brazos river on the south, to Palo Duro Canyon on the north, resting directly on the red clays of the Triassic.

The vertebrate fauna of these beds is described in the Fourth Annual Report of the Texas Survey, Pt. ii, pp. 47–74.

The species are: *Testudo turgida* Cope, *T. pertenuis* Cope, *Crecoides osbornii* Schuf., *Megalonyx leptostomus* Cope, *Canimartes cumminsii* Cope, *Borophagus diversidens* Cope, *Felis hillanus* Cope, *Tetrabelodon shepardii* Leidy, *Dibelodon humboldtii* Cuv., *D. tropicus* Cope, *D. præcursor* Cope, *Equus simplicidens* Cope, *E. cumminsii* Cope, *E. minutus* Cope, *Platygonus bicalcaratus* Cope, *Pliauchenia spatula* Cope.

On the Coastal Slope the beds are grits and clays overlaid by light colored clays, gravel, and tufaceous limestone. In this area I have suggested the following divisions: Lapara, Lagarto, and Reynosa-Orange sand.[1]

The Lapara division, as shown on Lapara creek and on Hog

[1] McGee, in the Twelfth Annual Report of the U. S. Geological Survey, has correlated the Reynosa and Orange sand with his Lafayette formation; but I retain the names originally given to these beds for purposes of description, and their precise relations to the Lafayette formation can be determined later.

Hollow, on the opposite side of the Nueces, consists of sands and clays interbedded and somewhat cross-bedded. The sands are coarse and sharp, often forming grits, and including pebbles of clay and calcareous concretions. The clays are jointed and parti-colored—light red, green, etc.—and in some localities appear as a conglomerate of clay pebbles. Fragments of bone are common in them, but they are often so worn as to prevent recognition. The fossils were submitted to Professor Cope, who pronounced the horizon to be the Blanco, and states that nothing from either locality indicates a horizon as low as the Loup Fork. Similar deposits were observed on the Southern Pacific railroad between La Grange and Columbus, and in the vicinity of Brenham.

The Lagarto division includes a series of sands and clays of a different character from the Lapara, and overlying them. It comprises light colored clays—lilac, lavender, sea-green, greenish brown and mottlings of these colors—jointed and showing many slips. In places the upper portion contains a considerable amount of sand, gravel, or lime, and the change in a single stratum from one kind of rock to another takes places within a very few feet. In localities where the lime predominates it closely simulates the Reynosa. Where the limestone or calcareous sandstone caps the clays, strings of limestones extend downwards into them for a distance of six or eight feet. The clays contain quantities of semi-crystalline limestone pebbles with manganese dendritions, and, indeed, manganese appears to be one of the characteristics of the clay wherever found. The upper portion of the beds is usually a sandstone. No fossils have been found in them.

Reynosa division.—Lithologically this is the most characteristic of all of the Neocene deposits. While I use the name given it by Penrose in 1889, it had been observed previously by Schott and Shumard, both of whom referred it to the Cretaceous. This reference, made on lithological grounds alone, has in its favor the fact that there are many localities where the Reynosa deposits so closely resemble those of the Austin limestone that, were they found within the Cretaceous area, they would be passed without

question, even by those better acquainted with the Cretaceous than were these observers. Loughridge, in his Report on Cotton Production, (Tenth Census Report), comes nearer the truth when he refers it to the Port Hudson.

The very variable series of beds intended to be included in this division, has, usually, at the base a conglomerate of pebbles of various sizes, imbedded in a lime matrix, often indurated, sometimes tufaceous, sandy or even clayey. Above this is often, but not always, a series of interbedded clays, limy clays, limy sands and sandstones with some pebbles. This closely resembles the Lagarto clays. The whole is capped by the Reynosa limestone. This is a tufaceous lime rock, but often so mixed with clay or sand as to lose that character. There are few exposures which show the entire series of beds. In places along the middle Rio Grande, the basal bed of conglomerate is all that is present, while on the divides the basal and uppermost beds are usually found, but without the intermediate Lagarto.

The Reynosa, in its typical form, is only found west of the Colorado, so far as I have observed. East of the Guadalupe the lime is gradually replaced by iron, the Orange sand phase appears in the Colorado drainage and east of that stream becomes the prevailing form, although some lime is present at many localities. This change is obviously due to the fact that in the western part of the State the erosion of the Cretaceous limestones furnished the materials for the Reynosa, while in the east the ferruginous beds of the Tertiary supplied the materials for the Orange sand.

No fossils have been found in this deposit which can certainly be said to be indigenous to it. A number of shells of Bulimus were found imbedded in an upper crumbly layer of it, but they are simply on the surface and are probably later.

No other bed of the Tertiary has anything like so wide a distribution as this. I found it at the top of the escarpment of the Llano Estacado in Garza county, at the point marked "11" on the map of the Llano Estacado accompanying the Third Annual Report of this Survey, and also just south of Big Springs, resting on the northern slope of the Cretaceous hills. Cummins has

traced it over a large portion of the Plains, and while we have no record of it on the top of the Cretaceous plateau between Big Springs and the Nueces canyon, it may be there, and have been overlooked owing to its close resemblance to Cretaceous materials. In the canyons, however, on the southern edge of the plateau, its presence has been reported by Hill and Taff, and I have traced its continuation southward from the line of the Southern Pacific railway to San Diego. While no direct connection of these beds with those of the Llano Estacado has been observed, their lithological identity and stratigraphical relations to the Blanco beds below and the Equus beds above seem to warrant the conclusion that a connection did exist either across or around the Plateau.

While erosion has removed the Reynosa from a large part of the Guadalupe and Nueces valleys, it still caps the divides and higher elevations and forms the surface of that plateau between the Nueces and the Rio Grande which is in many respects the homologue of the Llano Estacado, and may well be called the Reynosa plateau. On this plateau it attains an elevation of over eight hundred feet above sea level in an area which appears on all topographic maps as lying below the 200 foot contour.

In the Orange sand area the conditions are somewhat different. The beds do not appear to have covered the entire area, as did the Reynosa, but to have been laid down in drainage channels, lakes or bays among the islands or promontories of Eocene materials.

The Neocene deposits, taken as a whole, represent a period of lacustrine, fluviatile and estuarine deposits. With the exception of the fossils obtained from the Galveston deep well there is nothing to indicate marine conditions anywhere in the region during Neocene times.

At the close of the Pliocene the beds were elevated and subjected to considerable erosion prior to the deposition of the Pleistocene. The Sun mound, west of Waller, is an outlier of the Orange sand, and Damon's mound, in Brazoria county, seems to belong to the Reynosa, although many miles to the seaward

of any other exposure referable to that horizon. Every contact which I have observed also bears evidence to the fact.

PLEISTOCENE.

The Pleistocene deposits include the Equus beds and connected deposits found along various rivers and creeks; the Coast clays and their extensions along rivers and creeks and contemporaneous deposits of the Seymour plateau; and the later river, creek and surface deposits either of aqueous or subaerial deposition.

Equus beds.—In the valleys and depressions hollowed out by the erosion of the Pliocene materials were laid down the ash-colored limy sands and gravel which constitute the typical Equus beds of San Diego and southwest Texas and the more ferruginous beds of the same age east of the Colorado. So far as I have observed them they rest with great unconformity upon the Reynosa, indeed, there is no equal unconformity visible between any other two series of beds in the Texas Cenozoic.

The deposits consist, in their typical exposures, of limy conglomeritic ashy material, containing pebbles derived from the underlying Reynosa. The beds are without trace of stratification, except that here and there through them the calcareous matter appears as a line of nodules, or bed of pebbles will follow a straight line for several feet. The beds are usually ashy yellow in color, but lighter in places, and grade upward into a grayer and more sandy body, and then into a black soil. Their ashy appearance is one of their distinguishing characteristics. When damp they are easily dug into, but when dry are very hard. The vertebrate fossils, to which they owe their name, are found in the lower portion of the beds, while they are rare in the upper or grayer portion, which carries instead a number of forms of land and fresh water shells. However, no line of division can be drawn between the two portions as the change is very gradual.

The thickness of the beds, so far as observed, is in no place over 20 feet, and they appear to occur in detached and irregular basins, usually connected directly with some drainage channel,

present or past. The Equus beds of the Llano Estacado are similarly related to the underlying Blanco beds, and in one instance, on Wild Horse creek, rest directly on the Trias. In addition to the typical locality at San Diego, these beds are found at many other localities on the Coastal slope, some of which have been noted in the publications of Cope and Leidy and others by this Survey. They also extend up the river valleys for considerable distances, as is proved by the presence of characteristic fossils from the second bottom deposits as far inland as Austin. The species described from the Plains are as follows:

Testudo hexagonata Cope; *T. laticaudata* Cope; *Mylodon? sodalis* Cope; *Elephas primigenius* Blum; *Equus excelsus* Leidy; *E. semiplicatus* Cope; *E. tau* Owen; *E. major* Dekay; *Holemeniscus sulcatus* Cope; *H. macrocephalus* Cope.

From the San Diego beds the following have been reported:

Cistudo marnockii Cope; *Elephas primigenius* Blum; *Canis sp. Glyptodon petaliferus* Cope; *Equus tau* Cope; *E. semiplicatus* Cope; *E. excelsus* Leidy; *E. occidentalis* Leidy; *E. crenidens* Cope.

In addition to these many others have been reported from localities to the eastward, proving the existence of the beds over a large portion of the Coastal slope.

The shells collected from the upper part of the San Diego beds and determined by J. A. Singley are as follows:

Bulimulus dealbatus Say; *Physa gyrina* Say; *P. heterostropha* Say; *Patula alternata* Say; *Planorbis lentus* Say; *P. bicarinatus* Say; *P. parvus* Say; *Amnicola peracuta* P. & W.; *Unio texasensis* Lea; *U. sp.?*, *Sphærum elevatum* Hold.?; *Helicina orbiculata* Say; *Helix texasiana* Mor.

Coast clays.—The Coast clays which are regarded as the western extension of the Port Hudson group of Hilgard, and as belonging to the Champlain Period of Dana, underlie the greater part of the area of the coast prairies. They form a wide belt lying between the Reynosa and the sandy coastal strip, and in many places stretch to the very shores of the bays which border the gulf.

The Coast clays are for the most part heavy limy clays of vari-

ous colors, yellow, red and blue in places, in others olive green and brown. They are interbedded with sand, contain nodules and concretions of lime, are often high in iron, and the sand, which for the most part is uncompacted, at times forms concretionary masses of considerable size. These clays vary from east to west in accordance with the varying character of the beds from which they were derived, being more silty eastward and denser toward the west.

In the only contact of any extent which I have seen, that on the Brazos river east of Sealy, the Coast clays rest unconformably upon the Equus beds, as they do upon the Reynosa further west, in such places as the Equus are lacking. In them have been found several varieties of land shells, and fossil vertebrates occur at many localities. They too, stretch inward for many miles along the river channels forming the second bottoms, and even the highlands, as proved by the fossils secured from such deposits. These are usually characterized by *Elephas* and *Equus* remains. Similar remains as well as those of smaller animals, are also found in the body of the deposit itself.

These clays have been studied very little. The exposures are so very few and usually so widely separated, the fossils so scattered, and the economic questions outside artesian water and agriculture, so few, that they have not received the attention they deserve. It seems probable, however, that when more thoroughly studied, they will be separable into two portions, the lower being much darker and more evenly bedded than the upper or massive beds.

The evidence before us now, however, is to the effect that the second bottoms of the rivers are by no means referable to any one division either of the Pliocene or Pleistocene, but that they comprise deposits ranging in time from Blanco to Recent.

Either to this or to the upper Equus horizon must also be referred the brown silty clay which is found on some of the divides in the Coastal slope. In places this carries land shells and exhibits a loess-like structure. It is well developed on the divide between the Nueces and the Leona, and has been observed in many other localities.

The Seymour Plateau, which is referred to this horizon because of its mid-Pleistocene, or at least post-Equus fauna as determined by Cope, stretches northeast from the Texas and Pacific railway west of Sweetwater, with a width varying from 16 to 50 miles, to Red river, north of Vernon, a total length of 160 miles. The western border of this ancient lake is sharply defined by a range of gypsum hills, as may be seen on the Fort Worth and Denver railroad east of Quanah. In elevation it varies between 1200 and 1600 feet above sea level, and although at present cut through by many streams, whose beds are sometimes 150 feet below the plain, the general flatness of its surface is still well preserved.

Of the latest of the divisions of the Pleistocene little can be said, because it has been studied least of all. It comprises the sands of the immediate coast area, which stretch inland in places for 50 miles and more; the later stream gravels, and other deposits of gravels and sands which are found on the surface at many localities. The sand dunes of the west and southwest also belong here.

CONCLUSIONS.

None of the beds of the Eocene having yielded fossils characteristic of horizons higher than the lower Claiborne, the deposits referable to that series are confined to its basal portion.

Certain forms indicate a connection of the Eocene waters of the Texan region with those of the Pacific.

In the Texan region dry land probably existed from mid-Eocene times far into the Miocene.

Although there is a possibility that the lower portion of the deposits referred to the Miocene may prove a little earlier, the fossils so far discovered belong to the upper portion of that stage—the Loup Fork.

The exact relation of the Loup Fork and the marine Miocene of the Deep well is undetermined,

There exists, both on the Llano Estacado and on the Coastal slope a series of beds, overlying the Loup Fork and underlying

the Equus beds which contain a "fauna more nearly and strictly Pliocene than any of the lacustrine terranes hitherto found in the interior of this continent."[1] This stage culminated similarly both on the Stockaded plain and on the Coastal slope.

The strong unconformity existing between the Equus beds and the Pliocene deposits, together with their relations to the overlying Coast clays, seem sufficient warrant for making them the base of the Pleistocene.

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[1] Cope. Fourth Annual Report Geological Survey of Texas. Pt. II, p. 47.