

Certain Recent Geological and Biological Changes in South Texas, with Consideration of Probable Causes

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INTRODUCTION

The writers, separately engaged in field work in the coastal region of Texas in geology and biology, have observed evidences of rapid recent changes in the biota of the coastal prairies. Association through programs of The Texas Academy of Science² led to pooling of information and contemplation of causes of the changes. The senior author has sought evidence of concomitant and possibly related geological changes in the same region and has found some evidence that such changes have been in progress. The information on late geological and biological changes in South Texas is collated and presented here with speculations on basic causes for the diverse phenomena.

GEOLOGICAL OBSERVATIONS

The Texas Coast contains many segmented bays and tidal estuaries. Its rivers are in general not navigable today. During historic and pre-historic times in the Recent geological period there has been a notable amount of silting of rivers and inner segments of bays. Outer bay segments have remained strikingly static with regard to silting, except that where ship channels have been dug silting has taken place widely over the bays as well as adjacent to the courses of the channels.

The last great expansion of ice sheets over the continents occurred toward the close of Pleistocene time and caused a notable fall of sea level, resulting in entrenchment of rivers and the cutting of gorges in the soft valley-fill material and other soft coastal sediments inside the present coast lines, as well as on the now submerged parts of the continental shelves. These gorges seem to have reached a depth of at least 240 feet near the present coastlines. The Recent period began with the rise of the sea accompanying the melting and retreat of the ice sheets. This rise of sea level

¹The senior author is responsible for the geological portion of this paper, while the remarks on biological changes are the result of collaborative effort. The responsibility for the discussion of animals belongs to the junior author.

²The senior author read a paper entitled "Climatic changes versus overgrazing in South Texas" at the meeting of the South Texas Branch, Texas Academy of Science, May 10, 1942. The abstract will probably be published by the Academy. The conclusions followed Kirk Bryan's conception of late slight, climatic change as the most probable explanation of the vegetational changes here discussed. Bryan set forth this idea in "Pre-Columbian agriculture of the Southwest, as conditioned by periods of alluviation," *Annals, Assoc. Amer. Geographers*, 1941, vol. 31, 219-42. The basic data of Bryan's article, or some of them, have lately been brought into serious question by work done in the same areas by C. W. Thornthwaite and associates and reported in the paper entitled: "Climatic and accelerated erosion in the arid and semi-arid Southwest, with special reference to the Polacca Wash drainage basin, Arizona," *Tech. Bull. 808, U. S. Dept. Agri.*, 1942, by C. W. Thornthwaite, C. F. Stewart Sharpe and Earl F. Dosch.

Since the scene of these studies is remote from the Texas coast, the writers of the present article omit consideration of Bryan's postulated epicycle of aridity of climate beginning about 1880.

caused progressive silting of the entrenched valleys and resulted in filling of gorges, and the formation of flood plains terminating at the heads of the now embayed mouths of rivers emptying into the Atlantic and Gulf of Mexico. A few of the rivers emptying into the Gulf have developed deltas, the flood plains having advanced to the coast, filling the temporary embayed estuaries.

Few studies have been made to determine how much of the late silting of tidal bodies of water and coastal rivers occurred after the white man arrived in North America. It has not been determined, for example, whether the late silting of the inner segments of present bays is a normal extension of flood plains or has been caused in significant part by acceleration of erosion since settlement of the country. It seems to be established by many studies, however, that man's occupancy of territory suitable for grazing and farming has often led to depletion of vegetational cover of the land and locally resulted in gullying, loss of soil water and lowering of the water table. Such accelerated erosion has occurred to some extent in Texas and must have caused accelerated alluviation of coastal bodies of water.

In South Texas, some of the earliest depletion of the vegetational cover of which the writers have learned began during serious droughts occurring in the decades 1880 to 1890 and 1895 to 1905. Some of this depletion has recently been repaired since the unprecedented rainy seasons of 1941-42.

The following observations of silting since the arrival of the white man in Texas are not based upon exhaustive studies of the scattered historical data available. They are offered here to indicate that there is a problem which geologists may attack and which seems to be related to the problem of late biological changes in the same region.

Former (Restricted) Navigability of Some Texas Rivers

At least three rivers of Texas were navigated in colonial times, which, according to report, have not since been navigable. At least, they are no longer navigated. San Felipe de Austin, early administrative center of the Austin Colony, is located on the south bank of Brazos River in Austin County, some 50 miles west of Houston. There was a dock or docks, and some sorts of boats, including a gunboat, used the dock. There was a certain amount of navigation of the river, perhaps never without difficulty, from its mouth to San Felipe during the colonial period, 1820 to 1840. According to local report, there would have been little chance of navigating the river to that point in 1928, when the writer visited San Felipe.

In 1925, large lakes in the flood plain of Colorado River in Matagorda County fed a gravity irrigation system having its intake a few miles above Bay City, 20 miles from the Gulf. Subsequently, an abandoned, heavily silted river channel was cleared below and the lakes drained. The reestablishment of a narrow channel along the course of the choked river bed led to the widening of the channel by erosion of considerable alluvium during the next flood and the formation of a small delta in Matagorda Bay. The material eroded, which had filled the former channel, was one of the locally celebrated "rafts" of the Gulf Coast. It was stated by a local surveyor and other reliable residents that the main "raft" had begun to form about the time of the Civil War and that it had choked the river to

Bay City in the period 1865-1925; also that the river had formerly been navigable to Wharton, 20 miles farther up stream. It was to restore the former navigability of this river and prevent flooding of bordering lands during periods of high water that the channel was opened to the bay, chiefly by dynamiting the "raft." Aerial surveys were made by the War Department to assist in the work of opening this river to navigation. The surveys showed the extensive choking of the stream bed in several former positions. The "raft" consisted of silt held by water-logged timber. It is said to have started with a jam of floating wood caused by a chain stretched across the river in the effort to salvage timber.

Between 1846 and 1865, or at least during the time of the Mexican and Civil wars, steamboats were active on the lower Rio Grande from Brownsville, Texas, to the opposite town of Matamoros, Mexico, and thence to the Gulf, 20 miles away. Captains Richard King and Mifflin Kenedy, later be-

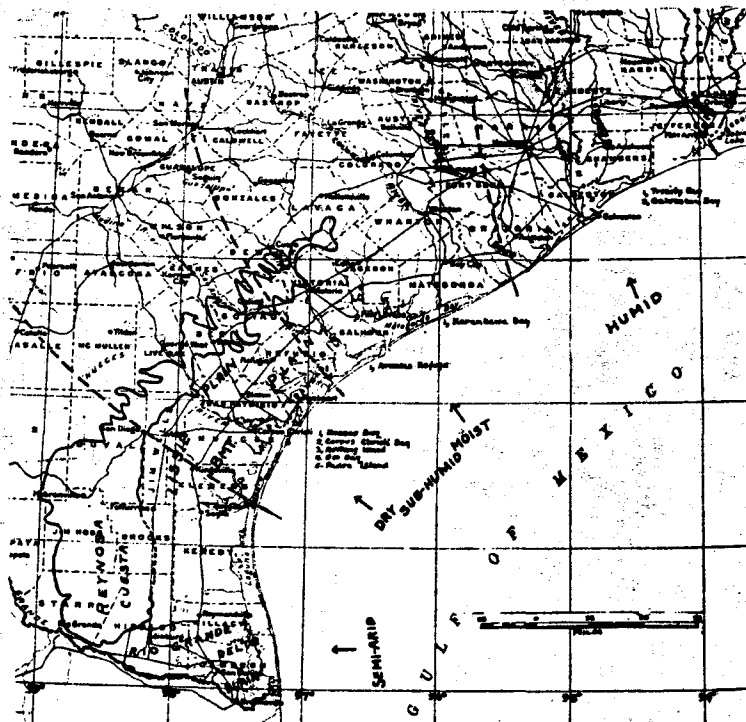


FIGURE 1

Climatic zones of South Texas, after Thornthwaite. Major physiographic divisions of the smoother coastal plains (coastal dispositional planes) are shown. Boundary between Beaumont (Bmt.) and Lissie plains is irregular and is not shown.

coming cattle barons of South Texas, conducted the steamboat operations. According to Bartlett (1856), in 1846 the river could not be ascended, but he said it could be made navigable to Laredo for boats of four feet draught. The river is open today and it cannot be said that boats of some sort could not still navigate it. That river navigation for anything but rowboats has not been regularly carried on there since 1865 may be due to economic as well as physical factors, but the presumption is strong that silting had a prominent part in the change of conditions.^{2a}

Silting of Bays and Estuaries

Coast charts show that Trinity Bay, the northeastern arm of Galveston Bay, is silting up due to the underwater extension of deltaic sediments of Trinity River. (Figure 1.) This seems to have begun when the river flood plain advanced to the head of the Trinity Bay segment, after filling a more interior segment of the drowned valley. Since 1880, this delta has advanced the length of the bay. The first grazing and cultivation (cotton) up-stream occurred in 1820-40.

The Nueces River is slowly filling Nueces Bay while the outer segment, Corpus Christi Bay, seems to have remained static until ship channels were dredged across it in the past two decades. The recorded silting of this bay (comparison of 1880 and 1937 coast charts) grades from 4 feet near the

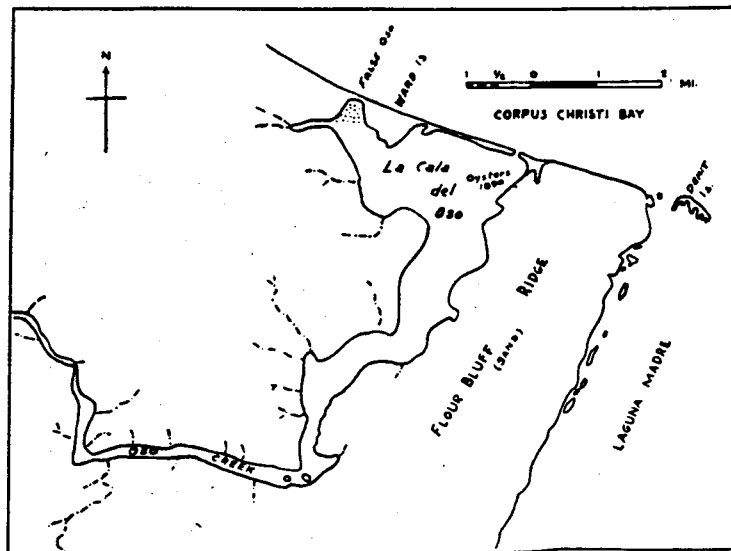


FIGURE 2

Oso Creek and its tidal bay (la Cala del Oso), south shore of Corpus Christi Bay, Nueces County, Texas.

^{2a} Reid's Tramp (See Footnote 12a) says that in 1855 a small steamer was accustomed to make occasional trips up the lower Guadalupe River from Victoria to Hines Bay without obstacle.

ship channel to less than 1 foot at the south shore. Proof that some of this silting antedated the channel is not in hand.

Oso Bay is the expanded coastal part of the tidewater portion of Oso Creek (Figure 2), a tributary of Corpus Christi Bay. The creek rises in swales on the prairie, the headwater drainage area lying 15 to 20 miles west of Corpus Christi. The prairie in the elbow of the creek south and southeast of Corpus Christi is the site of one of the earliest cattle ranches of Nueces County, the Villarreal ranch, granted by the Mexican state of Tamaulipas in 1831. On a portion of this ranch, acquired in 1840 by H. L. Kinney, the original settlement of Corpus Christi was made.

As early as 1889, the prairie in the elbow of Oso Creek was thickly covered with thorny brush. Robert Poenish, farmer, now owning extensive holdings there, states that he so found it when he settled there that year. Only a few farmers had made clearings in the area at the time of this settlement, and they had cleared and owned only a few small tracts, usually of 40 to 80 acres in size. Previously the land had been used for ranching, presumably with no more than a few small garden tracts planted. Clearing of the brush over a large part of the elbow of Oso Creek and the adjacent prairie south, southeast and southwest of Corpus Christi was begun in 1899 and by 1902 most of the land was under cultivation. This clearing was part of a campaign to raise winter vegetables for shipment by rail, according to the statement of C. E. Coleman, a leading vegetable buyer and shipper of this region and originator of the movement. About 1910-15, during the boyhood of Congressman Richard M. Kleberg, the route from Kingsville to Corpus Christi which lay west of the elbow area is said by him to have been open prairie. It has since grown up in brush.

The writer has attempted to ascertain to what extent silting in the Oso estuary followed grazing and cultivation in the Oso Creek area. Clay dunes (Price 1933, Fig. 8)) line the western shore of this small bay. They have been formed by silt blown from mud flats exposed immediately offshore to the east. These dunes must be several centuries old as they contain flint points apparently older than those last used by the coastal Indians, the Karankawas, with other Indian midden materials in a sandy layer which runs through some of the dunes at their mid-height, or about six feet above the original land surface. However, water several feet deep was found at the south shore of Ward Island in the mouth of Oso Bay in the decade 1870-80 when "Red" John Dunn, ranger and well-known resident of Corpus Christi (now deceased), worked there at a "hide and tallow factory." This "factory" had a dock on the south shore of the island to which boats "of fair size" came and departed loaded. He stated to the senior author, about 1933, that shallowing of the bay at the site of this dock occurred "a long time ago." During the last decade rowboats are said to have been unable to approach the site of the dock.

Mr. Robert Poenish states that he fished oysters in the northeastern part of Oso Bay between 1890 and 1900. By 1929, when the senior author first saw this bay, it was quite shallow and Mr. Poenish states that it has been "many years" since there were oysters in it. Much of the east side of the bay has been filled artificially in the last two years.

Mr. Poenish states that in 1890 to 1900 there were boards in the so-called "False Oso," then silted up, remaining from "mud-shell" operations. Such operations are normally carried on by dredging and it was his belief that the "False Oso" probably carried water at the time of this operation. However, it is possible that someone attempted to secure shell here otherwise than from boats, or that it was attempted during times of high wind-tides when water enters the channel. The "False Oso" is a broad, silted and abandoned channel between Ward Island and the mainland.

From the foregoing it appears that Oso Bay had partly silted up before the white man came and that some water deep enough for oysters and boats remained 40 years after the first settlement by Spanish-Americans, and twenty years later when the first farmers came; also that appreciable silting occurred after the farmers cleared and drained their lands.

From these data alone it is not possible to determine satisfactorily the full history of the later silting. From other information it is known that the coastal prairies of the Corpus Christi area on blackland soil, such as covers the Oso elbow, were typically treeless and brushless when first seen by the white men. The brush of the elbow area possibly came in after the initial grazing by domestic herds of the Villarreal and Kinney ranches. If the "mud-shell" story is correctly interpreted, the silting which had been going on before grazing also continued during grazing. After the brush was cleared and farming commenced, additional silting occurred. Finally, the bay has been much shallowed and narrowed by artificial filling within the past two years. The presence of the oysters in 1890 suggests that silting had been slow at least until late years and that acceleration of silting came only with the advent of the clearing made by the farmers. Drainage ditches dug along the roads during the farming period certainly accelerated erosion and silting.

Drying Up of Perennial Streams; Eastern Reynosa Cuesta, South Texas

Observations of a resident surveyor and civil engineer of the Corpus Christi hinterland, a man² locally well known for accuracy, show that small streams of the eastern flank of the Reynosa cuesta (Figure 1) or "plateau" (Price 1933a), which came under his observation about 1870, have since dried up and have for several decades been only intermittent in flow. Specific ground-water studies of these streams have not been made. The drying up of the streams so long ago can not be ascribed to discharge of ground waters from bored wells, as it was the drought of 1896 to 1903 which brought the first boring of water wells in this region. Edward L. Caldwell³ of Corpus Christi, whose firm has for many years furnished well materials throughout this region, states that the first sales of pipe to line (case) bored wells were made about 1895. The area was settled by Spanish-Americans prior to 1836, and probably as early as 1820. Ranching and subsistence farming were carried on by these early settlers. Their wells were hand dug, mostly at ponds or along water courses.

²C. F. H. von Blucher, County Surveyor of Nueces County for many decades; recently deceased. Oral statements to his son, Conrad M. Blucher, present county surveyor, and to W. Armstrong Price.

³Oral statement to Price.

GEOLOGICAL AND BIOLOGICAL OBSERVATIONS

*Filling of Laguna Madre by Sediments and Thinning of Vegetation
On Padre Island*

Laguna Madre, the section of the coastal lagoon between Corpus Christi Bay and the Rio Grande, now has only small areas of open water in comparison to its great size (4 to 10 by 125 miles), as shown by aeronautical charts of the U. S. Coast and Geodetic Survey. Marine navigation charts of the survey, however, show open water once to have been rather general over the lagoon. The basic work on marine charts was done in 1881, with minor revisions in 1909 covering only the navigable waterway along the mainland. The aerial maps were made in the decade 1930-40. Widespread filling of the lagoon has taken place. A map published by the Texas Game, Fish and Oyster Commission (1929-30 yearbook, p. 56) shows a great encroachment of low sand foreland from Padre Island, the offshore bar separating the lagoon from the Gulf. The encroachment is in the open water of the lagoon just north of the mouth of Baffin Bay (Figure 1). The compiler of the yearbook, J. G. Burr, predicted that Baffin Bay would in a matter of years be cut off from the upper Laguna by further encroachment of the foreland. Twenty miles below the mouth of Baffin Bay, the Laguna is completely divided today and Padre Island is connected with the mainland except at the highest tides, when water a few inches deep connects the upper and lower Laguna. This change has taken place since the mapping of 1881.

An item related to the late sanding-up of large parts of the lagoon is the thinning of vegetation on Padre Island. In a statement to the senior author a retired foreman of the Laureles Headquarters of the King Ranch, confirmed by John Kenedy of the Kenedy Ranch, said that Mifflin Kenedy, founder of the ranch, found Padre Island when first seen by him, "as green as a garden." Pat Dunn, former owner and ranchman of Padre Island, recently deceased, said that this verdure disappeared sometime after 1870, along with the numerous cotton-tail rabbits and spotted skunks which formerly inhabited it. Today, jack-rabbits and coyotes are the conspicuous large mammals of the island. Green meadows are scattered over the inner parts of the island, but up to 1941 large parts were bare sand, and in general it had the appearance of a desert. The "suddenness" of the disappearance of the skunks and rabbits, as reported by Dunn, may have been only the layman's somewhat sudden realization of the effects of a more gradual change, or their departure may have been hastened by the effects of a severe drought. That the vegetative denudation was not quite so sudden is indicated by the fact that men living today, whose age is about fifty years, can remember when Padre Island was "green." The same change took place on Mustang Island, just to the north. Bailey (1905) states shin-oaks up to eight feet tall extended along the bay shore of the upper end of Padre Island for seven miles. Wild celery abounded in the lagoon. A few willows, buttonbush and huisache grew on the north end and center of the island, while salt grass and waxy and creeping plants grew on the south part.

Today all the woody vegetation has disappeared², the wild celery has gone from the lagoon and the southern portion of the island is almost bare of grass. The great reduction in the vegetative cover of the sand has permitted hurricane tides and winds, and normal winds, more readily to carry sand from the beach and dunes across the island into the lagoon. Thus depletion of vegetative cover "after 1870" promoted filling of the lagoon.

Mr. Burton Dunn of Corpus Christi, son of Pat Dunn, reports that sheep were grazed on the island at an early date, but only for a few years because of the depredations of coyotes. Also, the sand began to "blow" following the grazing of sheep and an ensuing series of dry years prevented restoration of the range. Whether there had been a noticeable reduction of the vegetative cover before the sheep were run, seems not to be clear from the available record. In the present ranching, Mr. Dunn reports that only 800 calves a year are branded on the north 25 to 30 miles of the island, whereas, in the 1880's, the number for the same area was 1,600. There has been no decrease in the size of this part of the island since that time. On the south 50 miles of the island no cattle now range. Mr. Burton Dunn reports there has been "no grass" there since it was severely denuded by high water of the 1933 hurricane. The northern part of the island was also flooded, but less eroded and, according to Mr. Dunn, this area has more grass now than at any time in the past forty years. There has been very heavy rainfall in this region during the past two years, (Gunter, 1941).

An event in this filling of the Laguna Madre was described to the senior author by one of the owners of the King Ranch. In the strong hurricane of 1919, Gulf waters poured over Padre Island and its dune wall as a hurricane "tide." Cattle, driven into the lagoon before the offshore wind, were later overwhelmed by quicksand following the entry of the Gulf waters. After the storm, three thousand pairs of horns were counted sticking up out of the sand of the lagoon bottom. The assumption is that this quicksand was largely composed of sand newly entering the lagoon from the Gulf, the beach and higher parts of the island with the hurricane tide. Much of the general filling of the lagoon has probably been by wind-blown dune and beach sand from Padre Island, which has been carried into the Laguna at an increased rate by the prevailing southwest winds, since the onset of denudation of the vegetation of Padre Island. Some sand may have been blown in from the land by hurricanes, for the prairie is deeply sand covered south of Baffin Bay for a distance of fifty miles.³ During hurricanes the transportation of dune and beach sand by wind is greatly increased up to the time when all is soaked by rain and flood waters. Airplane photographs of the island show its western side to be composed of great overflow fans of sand washed by flood waters from the Gulf pouring through high-level gaps in the line of sand dunes which faces the Gulf of Mexico. If the vegetative cover had remained intact these movements of sand would have been considerably reduced.

²Photographs "from Padre Island, locality unknown," show that some brush plants were killed by moving dunes. A reliable report received as this goes to press is that a pond on Padre had oak brush a few years ago and may still have it. However, no dunes formed by north winds or other offshore winds occur in the region.

semi-arid zone), during his boyhood (1903-1912) and were said to have been killed by a drought occurring "not long before," the date of which he did not know. The occurrence of such a great stand of dead trees was, however, then considered a unique phenomenon by mature men of that time and place. It is noteworthy that by no means all the mesquites were killed. These observations suggest that no such severe drought had previously occurred during at least the latter part of the preceding century in the region where the trees were killed. Dobie (1929, p. 202) said that the terrible droughts of the previous fifty years killed many live oaks on the South Texas plains but no chaparral¹ thickets. Knight confirms the latter observation. If the trees killed were badly diseased or otherwise enfeebled, these observations do not indicate it, as the number of trees killed was too great.

Northward Spread of Mesquite

The memory of the progressive spread of the mesquite and other elements of the spiny brush or chaparral of South Texas is strong among the older people of the coastal country (Barton 1924, p. 721). Many statements made to the writers between 1925 and the present also evidence it. These statements were made by ranchmen, lawyers, surveyors, bankers and merchants from Victoria to Corpus Christi. Soldiers returning from World War I were in some cases astonished to find prairies grown up in brush. Mesquite and other brush has long been present in the border counties and some adjacent districts of the state and the region was known as the "brush country" (Dobie 1929). The coastal prairies north of Nueces River, however, were conspicuously treeless, brushless and covered with high grass, when first seen by Anglo-Americans, and so continued until about 1870 to 1880. Since that time mesquite has covered large areas of the coastal region² northward and eastward to the Colorado River. Dobie (1929, p. 203) remarks that the brush is "stabbing a great range to death." Lehmann (1941) lists the encroachment of mesquite and other kinds of brush onto open prairie land as an extremely important factor in reducing the range of Attwater's prairie chicken in Refugio and other counties to the south and west: "Within the memory of living men, extensive prairies have been transformed into brush jungles." He further says that hundreds of thousands of acres of what was once tall-grass prairie are now brush land. He lists lowering of the water table³ as one cause of brush encroachment. The northeastern boundary of mesquite today is approximately the mid-

¹The word *chaparral* has been in current use in Texas for a century or more. Although now popularly used for any kind of thorny brush, the Texas-Mexican has always had a more precise botanical usage for it (Dobie 1929, p. 202). The term is properly employed for a plant assemblage in which *Acacia amentacea*, the "chaparro prieto," or black chaparral, is an important member (Clover 1937). The same term has long been used by Pacific Coast botanists for oak-brush and other brush assemblages.

²The data collected by the writers refer chiefly to the history of the mesquite on the coastal Beaumont deltaic plain and the adjoining Lissie plain (Barton 1930 a, b; Price 1933b, p. 115). These have been characteristically treeless north of Nueces River except for sandler parts of the Lissie (Figure 1).

³The text does not indicate that Lehmann had made specific local applications of this factor, but only that he reported it as a possible cause. There is no information in hand for this region to connect brush encroachment with water table lowering except adjacent to stream valleys. The broad interstream areas may not have suffered important water table change during the period of mesquite encroachment.

In recent years the Game, Fish and Oyster Commission has been much concerned about the oversalting of Laguna Madre, which kills large numbers of fish, and has cut one pass through Padre Island to the Gulf (completed in April, 1941) in hopes of alleviating this condition. The pass filled, and recutting was completed in November, 1942. Burr, in the paper cited above, the junior author and others, have collected samples of lagoon waters in this region which, in some cases, were three times as salty as sea water. The data are mostly unpublished. It is assumed that, since the filling of the Laguna, the water on shallow flats becomes warmer and the rate of evaporation has increased. Young men who sailed the Laguna fifteen years ago say much of the old open water is gone. It would follow that the development of oversaline conditions occurring aperiodically every ten years or so, in dry years, has been more frequent since the turn of the century, but on that there is no information due to lack of records in former years. If the denuded state of the southern half of Padre Island continues, and if the northern part is again denuded, filling of the Laguna will continue and there is nothing that man can do to minimize or alleviate the development of oversaline conditions.

The filling of Laguna Madre is not an isolated phenomenon. There are no specific data at hand to establish the rate of filling over a century, but there seems to have been an acceleration since 1880. It is certain that a critical stage of shallowing has been reached since 1880, when the survey for the hydrographic charts was made.

Other factors than sand transportation have been slowly active to a minor extent in the filling of Laguna Madre. The accumulation of the bodies of marine grasses and algae, gypsum deposition (Baker 1929), and the calcareous shells of worms and other organisms have played their part. Shallowing of the lagoon and the occurrence of droughts would cause an increase in gypsum precipitation. The precipitated salts would be renewed by inflowing tides. It is a common phenomenon for dredges to find large bodies of crystalline and alabaster gypsum in the coastal bays.

It is concluded that the disappearance of much of the native vegetation of Padre and Mustang Island—noticeable some years after 1870—accelerated the rate of filling of the Laguna Madre by sediments and that the incidence of droughts combined with the activities of grazing animals was responsible for the creation of desertic conditions between 1880 and 1941.

BIOLOGICAL OBSERVATIONS

Century-old Trees Killed by Drought

C. F. H. von Blucher, surveyor, formerly cited, stated to J. P. McAuliffe, Weather Bureau observer at Corpus Christi, that he saw numerous oak trees that were killed by drought in the early 1880's. Some of these he estimated to have been as much as 100 years old. Local Weather Bureau data begin with 1886 and show the next severe drought to have been in 1896-1903. Launce Knight of Corpus Christi states that thousands of dead mesquite trees were scattered through the brush of Dimmit, La Salle, Maverick, Webb and Zapata (counties bordering the Rio Grande in the

line of the wet half of Thornthwaite's (1931, 1941) sub-humid zone (Figure 1). The Colorado River is the approximate boundary of typical mesquite in the coastal prairie section. The most eastward stand of mesquite known to the writers is at the San Bernard River, east line of Wharton County, where the mesquite meets palmetto.¹⁰ The brush is, of course, cleared from large areas for farming, but soon grows again in abandoned fields.

Two things have happened with respect to the spread of brush, especially mesquite. It has advanced several miles eastward and has grown up thicker in areas formerly occupied. Bailey (1905) gave a map showing the territory of Texas where mesquite grew. The eastward border roughly followed the 98th meridian south to Travis County from where it then ran southeastward to Calhoun County and the Lavaca River. Today the area of typical mesquite growth extends as far east as the Colorado River in Matagorda County and stragglers extend beyond. Thus the mesquite has traversed some 50 miles in less than 50 years.

On December 27, 1851, John Russell Bartlett and his party of the Mexican Boundary Commission left Ringgold Barracks for Corpus Christi. He stated (Bartlett, 1856) that dense chaparral covered a belt of 5 to 6 miles wide there along the Rio Grande. Havard (1886) said at Rio Grande City (Ringgold) the belt of dense woody vegetation was 30 miles or more wide.¹¹

On p. 529 (1856), Bartlett states, "The land near Corpus Christi is very fertile. Groups and belts of timber are found near the coast; but after leaving this, a vast undulating prairie extends from the Nueces to within three or four miles of the Rio Grande. This plain is covered with richest grass, and abounds in mustangs, deer, antelope and large herds of beef cattle."

Havard (1886) said that the area included between the coast and the Rio Grande was sandy, dry, riverless and mostly covered with fair grass. Zones of chaparral and small timber traversed it in several directions but he said it was "entitled to consideration under the heading of prairie—." He further said that "from Laredo approaching Corpus Christi" the chaparral becomes thicker. Around San Diego¹² the vegetation was dense.

Havard specifically described the vegetational characteristics on the route from Laredo to Corpus Christi. Although the routes traveled were not the same, a reading of Bartlett's and Havard's accounts leaves the impression that the brush was growing thicker in the interval, some 30 years, between them. Whether or not this is correct, it is true that this process has gone on in parts of that area in later years, as is evidenced by statements such as that of Congressman Richard M. Kleberg, cited above. It has also gone on north of the Nueces River as shown by many statements to

¹⁰Mesquite on the abandoned delta plain, palmetto below on modern flood plain.

¹¹The flood plain is 5 to 6 miles wide here, trending eastward. Brush would grow most heavily along the terrace scarps which are four in number, two on each side of the river. The 30 mile belt might have been parallel with the river or might have referred to the north-south belt of the Reynosa cuesta or "plateau" with its sand and its shallow-lying and outcropping caliche, typically brushy today. Bartlett might not have mentioned this belt.

¹²Reynosa cuesta.

the authors made by residents of areas as widely scattered as San Patricio, DeWitt and Calhoun counties, as well as areas lying in between. These are much too numerous to cite in detail.

The rate of "march" of the mesquite and other brush northward and eastward is not definitely known. Mesquite appeared thick in Calhoun County^{22a} areas 25 years ago. Since then it has traversed about 50 miles eastward. Between 1870-80 and 1943 the area of heavy brush growth has spread at least from Kleberg County to Matagorda County, a distance of 175-200 miles, although large parts of the country are still open prairie.

The huisache is a thorny brush of the Southwest. In the typical mesquite country, it grows in low, moist places. As the mesquite vanishes eastward through increasingly humid land the huisache climbs up on the prairie and largely takes its place. It reached the Louisiana line many years ago (Bailey, 1905). Apparently, it may be looked upon as an advance agent of the chaparral.

The change from grassland prairie to woody vegetation has gone on in areas of the State other than the coast, as is evidenced by the following statement taken from Goodrum (1942, p. 5):

"In early years following the arrival of white men in the Edwards Plateau, the region was essentially a prairie area with tall grasses covering the hills and with timber restricted to the margins of waterways. According to early accounts, prairie game such as antelope, buffalo, and prairie chickens were plentiful while deer and turkey were few. The game was promptly exploited and cattle raising became the chief industry. In subsequent decades, however, land use practices of the settlers caused the grassland to decrease in extent until the region came to be principally woodland."

Northward and Eastward Spread of Animals from the Southwest

No detailed ecological study of the South Texas brushlands has ever been made. However, the fauna of the brush country is quite different from that of the coastal prairie upon which it is encroaching, and it may be conceded as a fact that some vertebrates and a large number of invertebrates are spreading northward and eastward with the brush.

Locality records for many animals are fragmentary and the importance of records is highlighted by their absence. There is some information concerning the spread of certain vertebrates northward and eastward from the Southwest.

Bailey (1905) stated that armadillos were common in southern Texas from the lower Rio Grande to Matagorda Bay and to the mouth of the Pecos and Llano. He said they had been taken in Burnet County and at Austin and Elgin and reported from Inez, Elgin, Seguin, Columbus, Nava-sota and as far east as Antioch on Nevil's Prairie. He said they were generally believed to be extending their range eastward and northward, but whether this was a real extension of the range, or an increase in numbers

^{22a}John C. Reid, in "Reid's Tramp," (pub. 1858, see "Frontier Times," Bandera, Texas, May, June, 1943, Vol. 20, Nos. 8, 9, pp. 137-145; 167-175) states that brush (chaparral) grew (on the sand ridge) at Powder Horn (3 mi. w. of Port O'Connor) on Matagorda Bay in 1855 but grass and no mesquite inland (across the coastal prairie) until Goliad was reached (on Reynosa cuesta).

throughout an established range, was not entirely settled. He said as a rule they did not extend east of the semi-arid or mesquite country. Bailey gave the general distribution, which evidently did not include stragglers, as shown by the above locality records, as running from Stephens County diagonally through Williamson, Travis, and Victoria Counties, to Jackson County on Matagorda Bay.

About 1910 when Dr. J. T. Patterson was carrying on his classical studies on the embryology of the nine-banded armadillo, *Dasypus novemcinctus texanus* (Bailey), the animals were not numerous in central Texas. Later they became very common and were generally recognized to be spreading rapidly across the state. About 1925, the late Prof. George Williamson, of the Louisiana State Normal College, became interested in recurrent reports of armadillos in western Louisiana. He at first thought that the animals were brought in by increasing automobile tourists following the First World War, but later decided that they were moving in without assistance. In 1926 John K. Strecker published records of the armadillo in northwestern Louisiana. Two years later he published records (Strecker, 1928) from northeastern Louisiana. Twelve years ago, William J. Tucker of the Texas Game, Fish and Oyster Commission predicted that the armadillo would soon reach the Mississippi River. Lowery (1936) has discussed the movement of the Texas armadillo into Louisiana and gives records of animals taken east of the Mississippi River in December, 1935. He stated that, since the Colorado, Brazos, Trinity, Neches, Sabine, Red, Ouachita and Atchafalaya rivers have proven not to be geographical barriers to the northward spread of the animal from the "land of cacti and horned toads," it could be expected to cross the Mississippi River and extend eastward. In a letter to the junior author dated May 2, 1942, he says that a number of animals have been killed east of the Mississippi and that, since the armadillo likes pine woods, the Southern pine belt will be a perfect avenue for its spread to the Atlantic Ocean. Seton made the same observation some years ago.

While the spread of the armadillo is not limited by the spread of South Texas brush, yet it is a synchronous phenomenon. The Louisiana swamps and forests are as humid as they were thirty years ago and the present environment of the animal there is quite different from that of central Texas of thirty years back. While the armadillo prefers dry pine woods in Louisiana, as stated by Lowery, it at least crosses swampy regions. The junior author saw one in the lowlands of Avoyelles Parish¹³ in August, 1940. The spread of animals in the space of a few years from a region with one type of climate to a region with a different climate and very different environment raises many questions.

According to H. P. Attwater (Bailey, 1905) the first armadillo seen in Calhoun County, Texas, was observed in 1886 and in June, 1904, they were very common. H. C. Oberholser stated that as late as 1900 they were uncommon around Port Lavaca (Bailey, 1905). According to Phil Goodrum, of the Texas Game, Fish and Oyster Commission, the first armadillos seen east of the Trinity River were noted in 1902. From this information and

¹³Crossed by the Red River and Mississippi River flood plains.

that cited from Louisiana, we can infer that the animal extended its range roughly 400 miles in 54 years. In 16 years it extended its range, so far as the evidence shows, 150 miles to east of the Trinity River.

According to Taber (1940), a definite northern invasion by the coati mundi, *Nasua narica*, is taking place in the southern parts of New Mexico and Arizona. During the past two decades the coati mundi has risen from the ranks of a rare animal to that of a common part of the native fauna of that region. Three records, two of which are recent, given by Taber from the Rio Grande region of Texas, and a record from California (Hall 1940), are not free from the suspicion that the animals escaped from captivity. Another unpublished record of the animal from the Aransas Refuge (Figure 1), Aransas County, Texas, by Ernest G. Marsh, Jr., is in the same category. Time will tell the story of the spread, if spread it be, of the coati mundi into South Texas.

H. C. Blanchard, former warden for the National Audubon Society, has given information on the roadrunner or paisano, which is considered to be an arid-land bird. In 1887 there were no paisanos along the Texas Coast, but they approached to within fifty or a hundred miles of it in the south and west. Today they are present along the coast, and within the last three years Blanchard has seen them between Houston and Beaumont. They have also been seen lately by other observers as far east as Tyler, Crockett and Sherman, Texas. J. Frank Dobie, who has observed the paisano for many years as layman, wrote the junior author that he had no specific information but was under the impression that the bird has extended its range eastward, but not to anything like the extent of the armadillo. During June, 1939, Marshall V. Clark and a crew with the Civil Aeronautics Authority saw two paisanos at Vinton, in southwestern Louisiana. George H. Lowery, Jr., of the Louisiana State University, Museum of Zoology, previously cited, has several paisano records and one specimen from near Shreveport in northwestern Louisiana, all taken in recent years. This species is not listed from Louisiana in the recent publication by Oberholser (1938). The bird is definitely spreading eastward.

Recently (1941), Texas Game, Fish and Oyster Commission biologists have found that the chachalaca, a gallinaceous game bird of Mexico and the Rio Grande Valley, has extended its range northward to northern Willacy County and along the river through Zapata County. The whitewing dove is still concentrated in the Rio Grande Valley and was formerly found in numbers only as far north as Duval County, Texas. They have recently been reported in numbers as far north as Bandera County. This may be to some extent a reoccupation of former range. The Inca dove of the Southwest was seen in Louisiana for the first time seven years ago (Daigre, 1936). These isolated facts are without significance unless coupled with future data, but it is felt that such observations should be summarized now to stimulate further investigation of the suggested spread.

It is well known that the coyote is spreading eastward and northward and is now established in some places east of the Mississippi River. The jackrabbit is spreading eastward, and there are some indications that the prairie dog is doing the same thing. The relationship, if any, of the east-

ward movement of these animals to that of Southwest Texas animals is unknown. A contrary migration of plant or animal species in the region, if it has occurred, has not been encountered.

DISCUSSION

There are, so far as we can ascertain, only two logical explanations of the changes described here. One is overgrazing, which would bring about thinning of cover, increased evaporation, increased rate of run-off and resultant general lowering of the water table. The second is an epicyclic or progressive change in climate tending to more arid conditions, the effect of which may or may not have been increased by overgrazing. It is difficult to demonstrate clearly that one or the other of these two factors was dominant in producing the changes or was alone operative.

The biological data assembled make it evident that some of the larger animals of the Southwest, as well as leading elements of the South Texas brush land fauna, are spreading eastward and northward from the Texas-Mexican border region. No movement in the reverse direction has been observed in the same region. The armadillo has covered about 400 miles in 50 years. Some animal species of the region now in the doubtful class may prove later to be spreading in these directions, as is suggested by meager data.

The movement of the animals has been coincident with the spread of thorny brush or chaparral. The brush has advanced northward and northeastward from the Mexican Border region. Some of the animals have run ahead of the brush which seems to have stopped its movement in a fundamental climatic transitional zone, the sub-humid zone (Thorntwaite 1931; 1941). This zone is halved by the line along which precipitation and evaporation are believed to be balanced. This thorny brush, in which mesquite is prominent, is a characteristic of the dry zones and nowhere in Texas has invaded the humid zone as it is currently mapped.¹⁴

It seems that, prior to the coming of the white settlers, the thorny brush was excluded from the fertile coastal prairies, being present only here and there in small areas of special soil and edaphic conditions. These coastal prairies had a covering of grassy vegetation—a vegetational climax, or stabilized growth. Beginning at different times in different places, but generally occurring in the coast prairies coincidentally with the coming of the Anglo-American rancher and farmer, the thorny brush spread into the area of depleted grass and occupied it, *but only to the outer boundary of the dry climatic zones, to which it seems to be restricted.* Here it has halted for two decades of the senior author's observation and for a much longer period from the accounts of others. Similar grazing, or over-grazing as is generally charged, occurred across this line along the northeastward extension of the same geologic and geomorphologic formations and units; namely, the coast prairies and the outcrop of the Beaumont formation with its blackland soils. It is to be particularly noted that the thorny brush¹⁵ did not replace the depleted virgin prairie growth in the humid zones. Other vegetation, not the chaparral brush, followed the original grasses there.

¹⁴Not including huisache which extends to the Louisiana line.

¹⁵Excepting the huisache.

The climatic map, Figure 1, shows that, *within the limits of the coast prairies*, the animals and plants here noted moved from more arid to less arid country, but the most conspicuous plant association, the spiny chaparral brush, did not cross a fundamental climatic line. Therefore, it is possible that the initial movement was merely one within a climatic zone, the brush replacing the grass vegetation as the latter was depleted by grazing animals. Before it can be established that the movement of the brush has a climatic significance through having had an impetus in a climatic change, the subject would have to be studied over the entire state.

If it should be shown that the brush frontier everywhere in Texas moved from more arid to less arid country, it would still have to be shown that the replaced vegetation had not established itself in marginal more moist parts of the arid zones at some previous time during a fluctuation of climate and was not a temporary hold-over.

The spread of the animals with that of the brush may be an example of an upset biological adjustment resulting in a dispersion of diverse forms. Once dispersed, the barriers which would hold one form might not—and seemingly did not—hold other forms. Hence, the outrunning of the brush by the armadillo.

The geological evidence of recently accelerated silting and erosion now in hand is incomplete. However, taken with the biological and human changes in the coastal region, a historic picture begins to emerge. The history of changes brought about by man on the North American continent goes back to the earliest days of settlement along the Atlantic coast. First came the slaughter of inconceivable numbers of wildfowl, then of larger game animals, buffalo, antelope and others. Concomitantly there was the introduction of domestic animals. The grazing animals introduced had different habits from the wild species displaced. Man restricted their movements and controlled, to some extent, their food. Cutting and burning of forests, fencing and draining of lands, pollution of streams, the clearing of protecting brush from streams, occupation of springs, close settlement of large areas and all the multitudinous operations of an expanding civilization produced tremendous changes in the native fauna and flora.

The coast of Texas was late in being settled. The light and slow occupation by the Spanish-Americans began in 1749 on the Rio Grande, spreading slowly northeastward to the Nueces, with outpost communities to the northeast. The Anglo-Americans began to come in from the east and north about 1825-28 and rapidly increased. However, heavy settlement of some parts, such as the Rio Grande delta, came much later. It was heavily settled chiefly after 1916.

With this background of extensive changes, the migrations of plants and animals here discussed may seem minor elements of a complex and incompletely known whole. However, the following suggestions are advanced as a working hypothesis to explain the observed changes.

It is suggested that the mesquite and other brush had, during the period of aboriginal occupation, become stabilized on lands which these plants had seized at some prior time and were excluded from other lands on which prairie grasses had become well established. These plant assemblages, so

far as the coast prairies of South Texas are concerned, remained stabilized until the time of the introduction of large herds of grazing animals by the Spanish-Americans.

Even this invasion did not seriously affect the prairie vegetation, at least not over the land north and east of the areas of their heaviest occupation, that is, not north of Kleberg County or east of Duval County. With the coming of herds of grazing animals to the blackland prairies of the coast and the great expansion of the cattle business in 1870 to 1880, the prairies began to be overgrazed and the mesquite to invade them. At the same time there occurred several severe droughts. The incidence of the droughts increased the damage done to the grass by cattle and allowed the soil to begin to blow under the action of the exceptionally steady and strong hot-weather winds of this region. The damaged soil, under continued grazing, did not allow the grasses to reestablish themselves after the droughts, and the brush encroached still further. While the grass was depleted and before the establishment of the following brush, soil erosion occurred, only the flatness of the prairies preventing it from being widespread and severe. The drought upset the balance of nature then existing and many species began to migrate. The movement observed in Texas is northeastward and eastward.

As farmers began to displace ranchers over large areas, their operations further depleted and displaced the grass, but they also cleared out the brush, planting crops. As farming increased, the need for drainage was felt and extensive drainage-ditch systems were constructed. These were largely left unprotected by sodding or other lining, resulting in much additional erosion of the prairies. Earth from the spoil banks was washed into the ditches by rain and some of the loose material was gradually transported by storm run-off to streams and estuaries.

The occupation of the Texas Coast by man seems to have caused a certain amount of acceleration of the normal rate of silting. This silting is noticeable, even without records and quantitative observations, but the flatness of the prairies and the small amount of total topographic relief has prevented it from being large, or its increase rapid. Without full records it is difficult to determine the time, or times, of the amounts of definite acceleration of erosion and silting.

Taylor (1934) has called to attention the significant fact that one extreme year or time of climatic or other environmental stress may initiate more changes in the animal and plant life of an area than a hundred or more normal years. The droughts in Texas of the 1880's, early 1900's, 1917 and early 1930's must have had great influence in bringing about the changes noted in these pages. Whether they alone could have produced all these changes in the same environment in the absence of the white settlers and their introduced stock, it is impossible to say. However, it is evident that variations of the weather, particularly the local incidence of severe droughts, were important in the history here outlined.

SUMMARY

1. Some perennial streams of the eastern Reynosa cuesta, South Texas, dried up about 1870 and since have been only intermittent in flow.

2. Silting of an isolated estuary was first noted between 1870 and 1890, prior to cultivation but not prior to grazing in the region. There is some evidence that inner segments of coastal bays also seem to have been silting more rapidly in recent years.

3. Padre Island, the southernmost barrier island of the Texas Coast, was green until shortly after 1870 when it became greatly denuded of vegetation and the fauna changed. Extremely rapid filling of the lagoon, Laguna Madre, has taken place since the first maps were made in 1881, chiefly by sand from Padre Island carried into the Laguna by hurricanes and the southeast winds and presumably at an increased rate since denudation of the island. The record rains of 1941 and the heavy precipitation of 1942¹ have restored much of the green cover of the northern half of the island—that least disturbed by the numerous hurricane tides of the past decade.

4. Century-old live oak trees and many mesquites were killed in South Texas in the early 1880's.

5. Since 1870 mesquite, chaparral and other thorny brush from the Southwest has covered the coastal prairie northward and eastward from the Nueces River to Karankawa Bay—and also areas eastward to the San Bernard River—and within the memory of living men, hundreds of thousands of acres of tall grass prairie have been transformed into brush jungles.

6. The *coati mundi* has in recent years become established in southern New Mexico and Arizona and there are indications that it may be invading Texas. The roadrunner has spread eastward in recent years to East Texas and has recently been seen in Louisiana. The armadillo has spread from the "land of cacti and horned toads" to points east of the Mississippi River, covering a distance of 400 miles or more, in fifty years. There are indications that other elements of the biota are spreading northward and eastward. Contrary migrations in the region have not been observed or reported.

7. It is concluded that these changes were brought about by farming, draining, grazing and other influences of the white settlers, coupled with a series of hard droughts in South Texas beginning in the 1880's.

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¹Average yearly rainfall at the Corpus Christi Weather Station is 27 inches. In 1941 the excess was 15.13 and in 1942 it was 6.67 inches.

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A Preliminary Report on the Miocene Vertebrate Faunas of Southeast Texas*

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Early in 1938 the writer was brought to Texas A. & M. with the intention of preparing a report upon the collection of vertebrate fossils that had been secured by the late Dr. Mark Francis. The collection contained both Miocene and Pleistocene material, mostly from the Gulf Coast and to a large extent from the eastern half of the State. It had been acquired over a period of thirty years and represented dozens of localities as well as hundreds of donors.

Dr. Mark Francis deserves special mention here, since to him we are indebted for no small part of the information set forth in the following pages. Dr. Francis was a veterinarian, for many years dean of the veterinary school, but from the turn of the century on, the collection of fossil vertebrates was his avocation. Unlike most amateurs, he wanted his collection

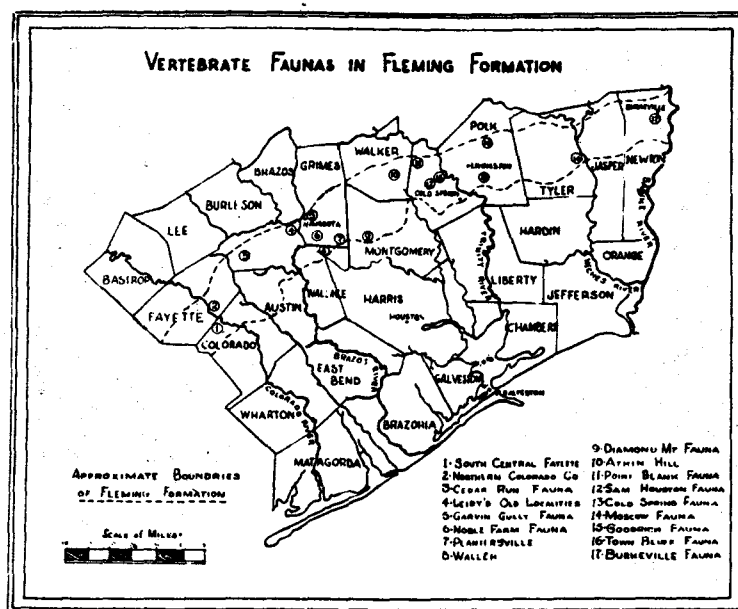


Fig. 1. Approximate Boundaries of Fleming Formation.

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