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Figs. 1–6, June, 1961

MARINE AND LAGOONAL DEPOSITS IN CLAY DUNES, GULF COAST, TEXAS[1]

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ABSTRACT

Thin, light-weight valves of *Mulinia lateralis*, a lagoonal clam, are found evenly and naturally interbedded in clay at 8 to 33 ft above mean sea level in a clay dune of the mainland shore of Laguna Madre, the coastal lagoon of southwestern Texas. The dune is on the lee shore of a small embayment where the shells seem to have been carried from the parent lagoon by waves and currents and strewn on a mud flat normally barren of subaqueous invertebrates. The shells were then redistributed by wind over the dune. Previously, the only fossils reported from clay dunes have been foraminifera and food animals and shells of aboriginal camp sites.

The environment of the occurrence is briefly described, with a review of the origin and development of clay dunes. An irregularly distributed layer of organic and inorganic flotsam deposited on the clay dunes by storm waves is also described, and it is concluded that the *M. lateralis* shells were not similarly deposited.

INTRODUCTION

The presence of clam shells naturally interbedded in ancient sediments is usually considered as evidence that the enclosing sediments were deposited in a subaqueous environment. Alternating beds of clam shells and clay is a typical marine or lagoonal sequence. Therefore, when the occurrence of shell layers (not of aboriginal midden origin) in a clay dune formed subaerially near Port Isabel, Texas, was brought to the attention of the authors, it seemed worthy of further investigation.

This paper describes briefly the primary and secondary sedimentary features observed during a reconnaissance of the area near Port Isabel and discusses their origin. Hurricane flotsam distributed on the clay dunes is also described, and the time of deposition estimated.

LOCATION

A very shallow three-pronged lagoonal indentation lies along the western shoreline of the Laguna Madre between Holly Beach at the north and Laguna Vista at the south, both being small communities on the eastern Laguna Madre shoreline, in Cameron County, Texas, 8 to 10 miles northwest of Port Isabel. The small lagoon—here called Rio Vista Lagoon—lies 2 miles north of an east-west stretch of State Highway No. 100 between San Benito and Port Isabel (fig. 1).

Features investigated were four clay dunes along the north and east shores of the lagoon. To facilitate description, the dunes have been designated D1, D2, D3 (Loma de la Grulla), and D4 (fig. 2).

RECENT PRE-DUNE GEOLOGY

Two elevated distributaries of a Recent subdelta of the Rio Grande (Los Fresnos Subdelta), earlier than the present Port Isabel Subdelta, when active flowed westward into the Gulf of Mexico 10 to 15 miles southeast of Rio Vista Lagoon (figs. 1 & 2). One of the distributaries, Holly Beach Resaca (a Spanish word for valley) passed north of Rio Vista Lagoon, and the other, Resaca Santa Ysabel (A. E. Anderson manuscript names), passed south of it (fig. 3). Holly Beach Resaca was eroded out and its course crossed west of Rio Vista Lagoon by the younger Resaca Santa Ysabel. A fragment of a distributary older than either of the preceding (see Old Resaca, fig. 3) formed a curving ridge west of the present Rio Vista Lagoon separating it from a depression to the west now occupied by a small

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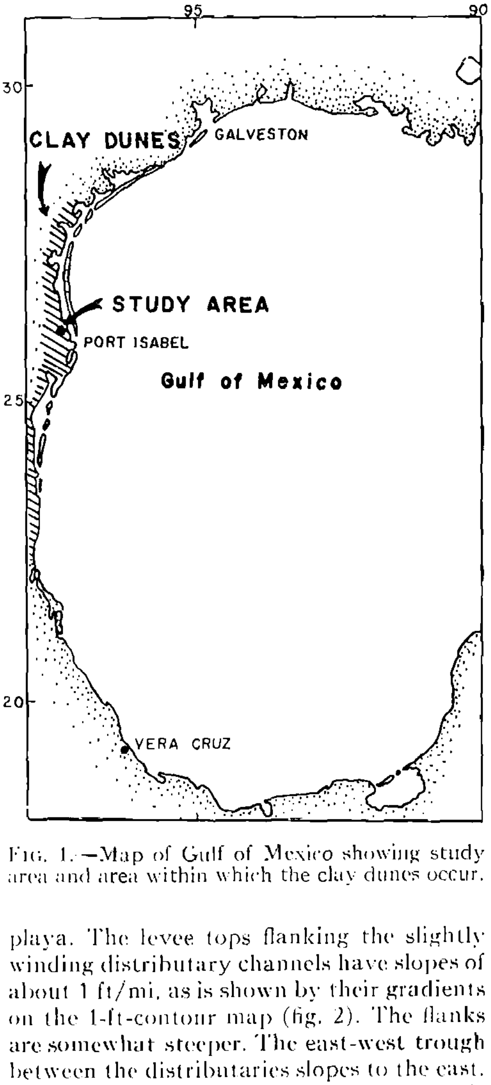

FIG. 1.—Map of Gulf of Mexico showing study area and area within which the clay dunes occur.

playa. The levee tops flanking the slightly winding distributary channels have slopes of about 1 ft/mi, as is shown by their gradients on the 1-ft-contour map (fig. 2). The flanks are somewhat steeper. The east-west trough between the distributaries slopes to the east. When the Rio Grande shifted south towards Mexico, playa lakes formed in the troughs when the climate became dry. The abandoned delta flank probably began to tilt slightly gulfward soon after the river left it. The eastern playas became flooded when the sea rose, probably about 4500 years ago. At that time the mainland delta shoreline became recessed by drowning and erosion to a maximum distance of 8 miles from the present outer shoreline (Price, 1958, p. 57) and a total distance of 25 miles from its furthest offshore limits (Price, 1954, p. 93, fig. 9). The invasion of the front of the Los Fresnos Subdelta has been gradual and may not have ended. Clay dune building began when the more pluvial climate of the period of low sealevel (late glacial) was succeeded by a dry climate probably about the time the present stillstand began. Erosion of the present delta front has been contemporaneous with the clay dune history, the sites of active dune building retreating as lagoonal shores were bluffed.

ORIGIN, HISTORY, AND DISTRIBUTION OF CLAY DUNES

Clay dunes are even-topped, ridge-shaped eolian deposits limited to the shores of clay-floored saline playas and tidal mud flats. They are numerous in the warm parts of the dry climates—dry subhumid to semiarid. Some clay dunes occur in fully arid regions. They have been recognized under various names in the Americas, Africa, and Australia. In Australia somewhat inactive crescentic clay dunes of Victoria have been described as lunettes (Hills, 1940). The dune slopes are low and the surfaces smooth except where they are bluffed or gullied, as are many in the Rio Vista area.

Clay dunes—with a high percentage of calcareous clay—are distributed along the mainland coast of the Gulf of Mexico from Rancho Tepehanje (23° 30′ N. L.) 15 miles south of the mouth of the Soto la Marina River, in Tamaulipas, to the middle of St. Charles Bay, Texas (28° 13′ N. Lat.) (fig. 1). The dunes are highest (to 35 ft) in the Rio Grande delta, becoming lower (3-ft minimum) toward the more humid climates at the north and south. Clay dunes have been described in some detail from Texas (Coffey, 1909; Price, 1933, p. 932–935, figs. 8, 10[4]; 1958, p. 56–59; Huffman and Price, 1949) and Australia (Stephens and Crocker, 1946).

Dunes of clay form because under strong, steady on-shore winds in the warm-to-hot seasons with strong insolation, the surface of a drying, saline mud flat breaks down into particles of sand size and smaller, with small grains of evaporite crystals. Dessicated

[4] Fig. 12, purporting to show clay dunes, shows mixed assemblages of dunes, including sand dunes.

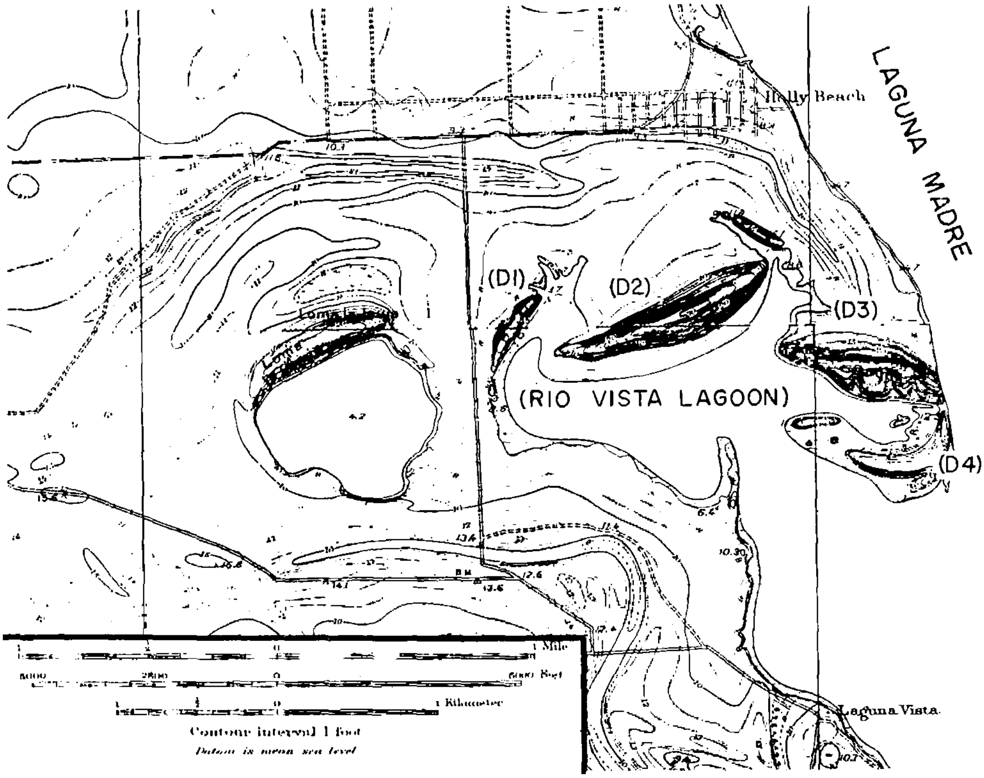

FIG. 2. Topographic map of study area (Rio Vista Lagoon and clay dunes) from United States Department of Interior, U. S. Geological Survey, topographic maps of Cameron County, Texas. Contour interval 1 foot. Datum is mean sea level. True North vertical; approximate mean declination 9°. The name Rio Vista Lagoon and the designation of clay dunes as D1, D2, D3, and D4 have been added by the authors. Note gullies and cliffs on south side of dune D3.

algal growths may add organic matter to the accumulations. The flats are those of intermittent lake shores and the shores of tidal lagoons having little or no regular daily tidal range. Two phases of deflation of the flats are recognized, a phase in which mudcrack polygon laminae break down when separated from the flat by wind as the particles are transported to the shore and a phase in which the flats sediments become granulated by the formation of evaporite crystals. The sand-sized pellets are aggregates of quartizitic sand and silt in an envelope or with a matrix of lutitic sediment. A dust cloud often envelopes the flat and dune. The lutitic aggregates break down into dust by the time the transported eolian particles reach the rear border of the dune. The eolian materials accumulate against the rising ground along shore and in obstructions such as trash-lines (flotsam) and vegetation. During moist nights after windy days, the windrows of initial dune growth take up moisture and the accumulations become temporarily plastic. The dry interiors of the dunes, although having some cohesiveness, retain a loosely porous structure, the clay seeming not to regain its initial compactness by 50 to 60 percent, nor its original structure so long as saline materials are being added to it. A granular structure may be induced in the coastal clays by soaking in brine, the clay shrinking and cracking. Whether any change in the clay molecules takes place in the saline environment has not been investigated.

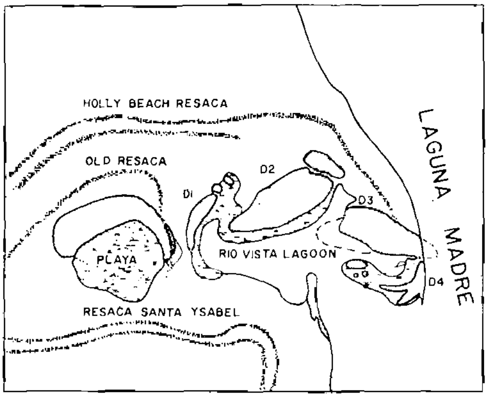

FIG. 3.—Map showing position of pre-dune deltaic distributaries (resacas) relative to present day clay dunes. Dashed line on east and west ends of dune D3 indicates probabe extent of dune before erosion.

The clay dunes of the western Gulf Coast grow only in the warm-to-hot months from March to October or November. Minor surface reworking may occur during winter droughts. Segregation of sand by rain causes a lamination of reworked dune material deposited along the edge of the flat. The dunes accumulate under warm-weather winds varying here from ENE through SE to SSW. The dunes are limited to shorelines that face these directions and all are, or have been, bordered by low flats containing more or less lutitic material. Where the sediment of the flats grades laterally or has varied in time from clay to sandy clay or clayey sand, the dune form varies toward that of a stabilized sand dune, some large interior dunes and some coastal ones being of a borderline type. As little as 8 percent of lutite is known from Australian examples to furnish enough plasticity to stabilize a clay dune without other fixing agents. Some of the interior sandy and gypsiferous clay dunes of Texas and some lagoonal accumulations containing some clay grade into eolian beach ridge and eolian beach plain forms but are limited to shores that face, or once faced, drying winds.

Clay dunes normally have only slight (intrazonal) soil zonation. The soils of dunes cut off from accessions of salty sediment by invasion of a deltaic distributary or in some other way may become fully zoned. Clay dunes are mapped in county reports covering the Rio Grande delta as Point Isabel clay and the saline flats as Lomalta clay. Sandy lee dunes of more interior coastal prairies which are related to clay dunes are mapped as Brennan soil. In Algeria, the clay dune and flats materials have been identified as a solonetz "soil" (Boulaine, 1956).

The dune-like structure of clay dunes is shown by their subdued cross-bedding and the progradation of large complex dunes toward the flats with one or two lesser, younger summits built against eroded or partly eroded surfaces of the original dunes. The late Recent age of the dunes in Texas is shown by (1) their continuing growth, (2) the absence of beveled and unconformable surfaces other than the inclined surfaces between prograding increments, (3) their 25- to 35-ft elevations where an approximate growth rate of about 0.5 to 1.0 ft per century has been estimated, and (4) by resting on late Recent sediments and topographic forms. These include: (a) the flanks, summits and eroded surfaces of Recent natural levees of deltaic distributaries, (b) banks of lately abandoned courses, (c) the sides of stream valleys entrenched in late Pleistocene time and (d) such shoreline features as small Recent creek deltas (Arroyo Colorado delta) and compound spits. Dunes bored through by Price and a few artificially excavated are seen to rest on Recent and Pleistocene beds, as at the Mud Bridge site, Airline Road crossing, Oso Creek, Corpus Christi. Completely buried clay dunes have not been recognized. Some dunes along the shores of the southern Laguna Madre are based slightly below sea level, either having sunk into older deposits by their weight or having originated before sea level reached its present level. The maximum exposed heights of coastal clay dunes, 35 ft along the Rio Grande, 27 at Corpus Christi, represent some 4500 to 5000 years of growth since the beginning of the present stillstand of sea level (Curray and Shepard, 1959; LeBlanc and Bernard, 1954).

Clay dunes were attractive camp sites for the fishing Indian tribes of the Texas coast. Two cultures have been recognized in them at Corpus Christi, an archaic culture and a late culture extending into early historic time—the culture of the Karankawas. The extensive midden strata contain large bleached bay shells—clams, oysters, and snails—some with contained or adhering small-sized lagoonal organisms, also remains of land snails and vertebrate food animals besides flint, shell, bone, and pottery artifacts. Naturally deposited fossils observed are limited to foraminifera (Price, 1934), land snails, and the thin Rio Vista molluscan layers to be described.

The net growth rate of clay dune summits is difficult to determine. Some data give a rate of 0.5 to 1.0 ft a century. In the Rio Grande delta and on Oso Creek, Corpus Christi, the archaic aboriginal artifacts (Aransas focus equivalents), lacking pottery and arrow points, extend from about the mid-heights of many dunes upward to about 4 ft below the pre-1940 summit surfaces. The upper 4 ft of 1940 contain the late culture materials (Rockport focus equivalents) with pottery, small arrow points, and, at the top, European materials including copper, iron, and deeply weathered and patinated glass bottle necks. The upper 1 ft in some 1940 dunes and some small lenses and summits in front of old dunes, lack aboriginal artifacts, the Indians having left the shorelines about 1850. The upper aboriginal culture dates from at least 1700 to 1850 and may be as early as 1500 A.D. During the 7-years drought of 1950 to 1956, some dune summits accumulated a foot or more of loosely consolidated pellet-clay and dust, now being eroded. A dune 14 ft high on a playa at the eastern side of Alazan Bay, an arm of Baffin Bay of Texas, contained an artifact layer 7 ft below its top in 1947. Taken from this layer were flint points of archaic type, a flat, bored greenstone gorget of a type found on the western coast of Mexico, a large orange-colored cobble stone, and a small carved greenstone figurine of a style of about 0 to 300 A.D. They seem to belong to the La Venta horizon.

CLAY DUNES OF RIO VISTA LAGOON

Dunes D1, D2, and D3 near Port Isabel may have started when the present Rio Vista Lagoon was a playa enclosed by the Holly Beach Resaca, the dunes accumulating along the northern and northwestern shores of the playa. However, Laguna Madre soon entered it. Dune D3 was formerly at least 0.1 to 0.25 miles longer at each end (fig. 3), judging by the slopes of its summit. Substantial erosion of dune D3 is shown by the steep bluffs on the eastern and western ends and the deeply gullied south face (fig. 2). After the Laguna Madre had entered the Laguna Vista, the low dune D4 developed on a compound spit formed by shoreline erosion of D3 and sediment drift from the north. The spit axis shifted with growth, from west to southwest and is now growing to the south. Dune D4 rises to summits only 3, 9, and 12 ft high, whereas the much older dune D3 has summits rising to 30 and 34.6 ft above mean sea level.

No artifacts, aboriginal or historical, were found bedded in the dunes of the Rio Vista area. None of the large shells of the kinds found in middens were seen in or on these dunes. A single fragment was found on the mud flat.

INTERBEDDED SHELL LAYERS IN DUNE D3

Shell layers, each about ¼-in thick, interbedded with dune clay, were exposed in a zone about 2 ft thick 30 ft above mean sea level near the top of dune D3, on the southwestern face near the western end (fig. 4). A thicker level shell layer is exposed in the east bluff facing Laguna Madre and dips down the south flank along a road at the eastern end of dune D3 (fig. 2). Throughout the exposures the shells consist mostly of disarticulated valves belonging to the clam *Mulinia lateralis*, a species now living in large numbers in the Laguna Madre. *Mulinia lateralis* is a small clam growing to a length of about ½-in at maturity. The shells in the layers were somewhat smaller than this and many were fragmented. They were densely packed and oriented predominantly with the concave side facing down. No large shells of other species were observed, but a few juveniles less than ½-inch long which belong to species reaching several inches at maturity were in the shell layers. The bed at the east end of dune D3 is 8–10 ft above mean sea level and dips north and south with the normal dune stratification. *Mulinia* shells of dune D3 seem to be the first definite marine (lagoonal) shells larger than foraminifera and not of midden origin to be reported from clay dunes.

The interbedding of the shell layers in the clay dune suggests that they were accumulated by wind, especially since the attitude of the shell beds coincides with the normal dune stratification. Although the shell layers in dune D3 strongly resemble those usually associated with subaqueous sedimentation, they were evidently deposited subaerially by moderate or strong winds.

In order to test the competence of wind in transporting *Mulinia lateralis* up a slope, the following experiments were performed. A broad, smooth board 7 ft long was adjusted so that the angle of its plane with

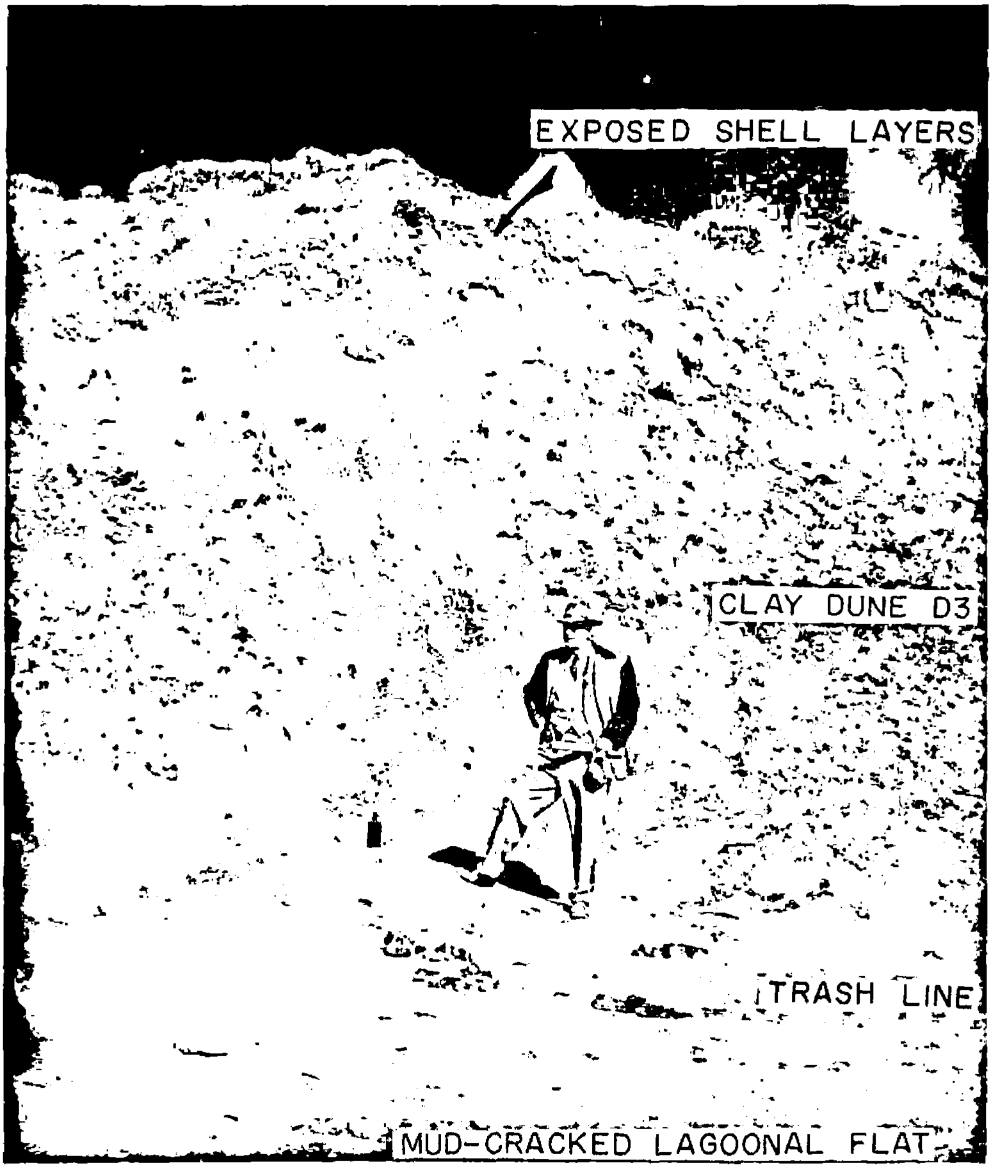

FIG. 4.— Cliffing near west end of south face of dune D3. Position of shell layers exposed near top of 30–35 ft dune are marked by arrow. Flotsam on flat with a bottle placed on end by the observers.

the horizontal could be varied. The inclined board was then placed outdoors in a position where its lower end faced a strong wind. The wind velocity was measured at 20 mph with a hand anemometer held near the base of the board. The behavior of *M. lateralis* shells dropped onto the bottom of the board was observed when the angle of its plane with the horizontal was 15°, 30°, and 45°. Shells of *M. lateralis*, and especially fragmented ones, were blown up the board at all angles tested. A few unbroken shells, oriented with the concave side down, remained on the board. These experiments show that winds of moderate velocity for the coast of Texas are capable of transporting small shells, similar to those found interbedded in dune D3, up a smooth surface.

The concave-down position seems to be the stable attitude of shells transported by wind as well as by water. Large shells of *Dinocardium robustum* weighing up to 50 gm were observed to turn from the concave-up to the concave-down position during strong winds on the beach of Mustang Island, Texas.

The altitude of the shell beds above sea level, as well as their dip, would suggest a local tectonic movement in the area, if the shell layers were interpreted as having been deposited below water. The even topography of the summits and flanks of the deltaic distributaries on and against which dunes D1, D2, and D3 lie shows that the surface deposits have not been disturbed by faulting or local warping since their deposition. This is considered as additional evidence that the shell layers were deposited subaerially.

PROBABLE SEQUENCE OF EVENTS IN DEPOSITION OF THE CLAM SHELLS BY WIND

It has been concluded that the dune D3 shell layers are of eolian origin. However, the seeming absence of such shell layers in clay dunes, except here, indicates that lagoonal mollusca can probably not live on the source flats of clay dunes, or if they ever do, that they probably cannot grow there in sufficient quantities to form layers spreading up the foreslope and over the summit of the dune, a distance usually of several hundred feet. Hence, some very unusual condition or mechanism is indicated. Such a mechanism may exist at the mouth of the Rio Vista Lagoon in the compound spit of dune D4. Just this combination of lagoon orientation, spit position, and shell occurrence may be rare. This mechanism would have been able to operate only as and after the waters of Laguna Madre—the large coastal lagoon—invaded the former inter-meander basin, creating the small tidal Laguna Vista lagoon.

On many shores of Laguna Madre, as, for example, the shores of Bird Island in the northern Laguna Madre (Price, 1958, pl. III, fig. 1), there are low beach ridges of small lagoonal shells in which *Mulinia lateralis* is abundant. We may, then, postulate that the low, narrow shore flat of the bluffed shoreline north of and including D3 may have at times had a small beach of shells and shell fragments with *M. lateralis* shells common. Winds from northerly and easterly directions would develop waves and a longshore sediment drift that might carry the shells and beach development southward along the shoreline of the spit and westward into the Rio Vista Lagoon. Such shell deposits might then be driven northward toward the flat of the D3 dune and spread over it by waves and currents acting at storm sea levels. Only moderate wave action and low floods, such as may be caused by lesser gales, would be required. After waves driven by the strong north winds of winter had moved shells around the curve of the spit and spread them on the flat during the accompanying wind tide, the strong on-shore SE winds, beginning in March, and initiating eolian clay dune activity for the year, could have blown such light shells up onto the dune. Afterward, eolian clay deposition would cover the shell layer.

This sequence of events would explain the early low deposition of eolian shells on D3 toward the east and the appearance of shells later at the west at higher levels in lesser numbers and smaller sizes. These shells, 30 to 34 ft up in the dune, would have had to travel much farther up the dune flank from the source flat than would the shells at 10 ft at the eastern end, also promoting size differentiation. The flats of the Rio Vista Lagoon contained no shells when visited in the winter of 1960.

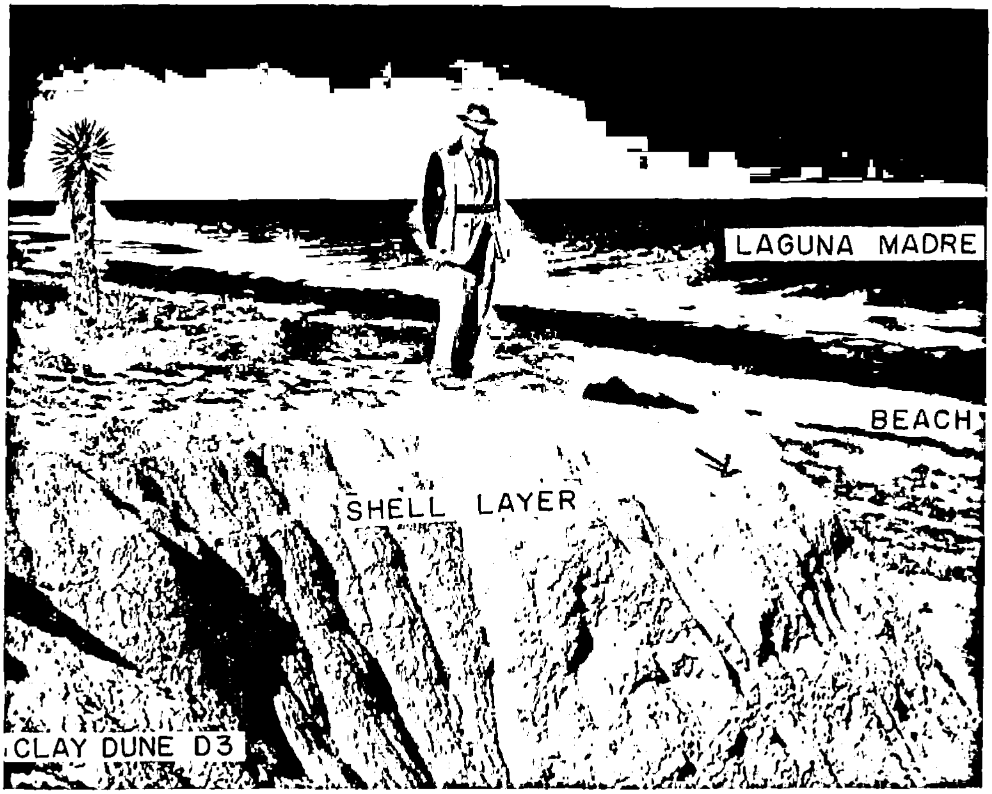

FIG. 5.—Shell layer exposed along east end of dune D3. Shell layer is marked with geological pick. Laguna Madre in background.

HURRICANE FLOTSAM

Objects interpreted as hurricane flotsam were observed in a narrow zone on the windward slopes of dunes D1 and D3. These objects included asphalt lumps, coral fragments, tropical beans, small lumps of wax or gum, pumice, scoria, slag or cinder, bottles, and timber. Shells were absent. All the material in the flotsam zone was sufficiently buoyant to be easily transported by water. The flotsam is evidently a surface deposit as none was found in place in the sides of deeply eroded gullies. Similar zones are common features in the backdune sand dunes area of Padre Island and mark the edge of high storm waters (fig. 6).

At the time of this study (January, 1960) the Rio Vista Lagoon contained little water, and strewn over the surface of its broad northern mud-flat at about 1 ft above mean sea level was a light accumulation of bottles, wood, some pumice, and mats of seaweed, all of which had remained after the withdrawal and evaporation of the water. This low flotsam had probably been derived mostly directly from the Gulf of Mexico, finding its way into the Laguna Madre through the Brazos Santiago Inlet, which is only 9 miles south of the Rio Vista Lagoon. High storm waters probably pick up flotsam previously deposited on the barrier islands as well as flotsam that accumulates in the lagoon during normal water levels and redistribute both at high levels. The height above mean sea level at which flotsam is deposited during a cyclonic storm on this coast depends on the strength, duration, and fetch of the wind, the heights and "drive" of the waves, the configuration of the shoreline of deposition, and on the time that the storm center takes to cross the Gulf of Mexico. The more slowly and the

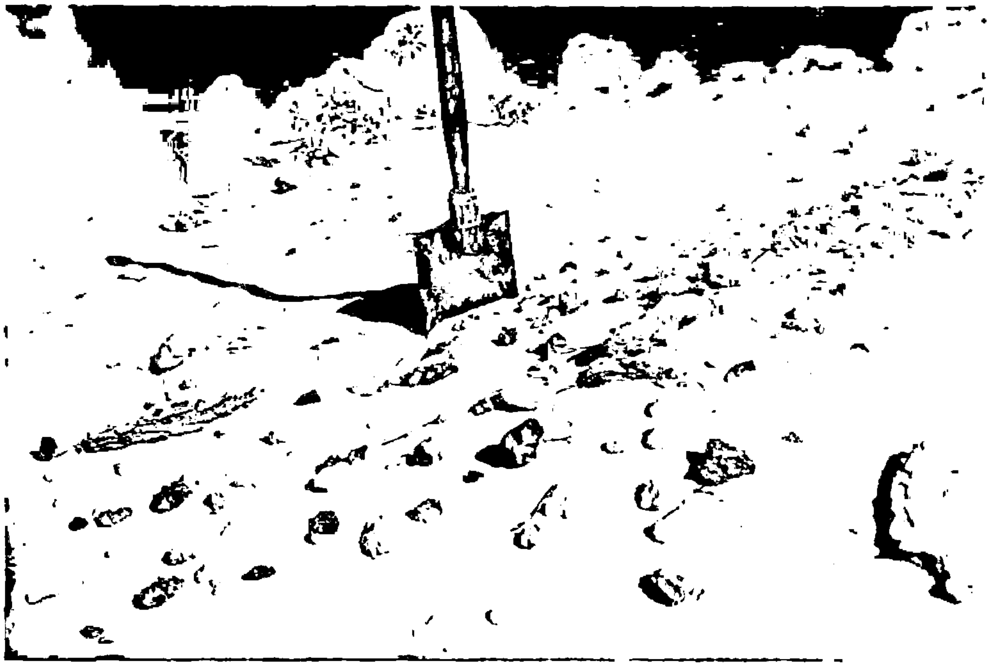

FIG. 6.—Narrow zone containing pumice, wood, pitch, coral, and other debris marking edge of high storm waters in the back dune area of Padre Island, Texas.

straighter a storm moves on the same course, the higher the flood that is built up in its area of landfall.

On dune D1 the zone of flotsam rises from 8 ft above mean sea level at the southwest end of the dune to 10 or 11 feet above mean sea level on the east slope, at a point due west of the southwestern end of D2. The abundance of flotsam diminishes north of this point, the zone dropping to 2 ft above mean sea level. This distribution occurred seemingly because dune D2 shielded the northern end of dune D1 from southeast winds and strong wave action. At the western shore the debris rose highest along the axes of minor gullies, probably because wind waves and their swash were forced higher along the gullies. Between the minor gullies the flotsam zone was discontinuous.

The narrow zone of flotsam was also observed to be fairly widely and evenly distributed at 10 to 11 feet above sea level along the northeastern, southern, and southeastern slopes of dune D3.

The difference in regularity of flotsam deposition seems to show that the maximum heights were the result of wave run-up and that wave action was more uniform along the eastern flanks of D3 than it was along the western shore of the Rio Vista Lagoon on D1. Wave run-up, however, is not considered a possible agent of emplacement of the shells as they are uniformly distributed along an even slope at a low elevation and also are evenly bedded in clay. Waves do not break against such a surface on clay without causing gully erosion and steep bluffing. The present bluffs are many centuries younger than the shell deposits.

A few pieces of pumice were found by L. G. Huntley (personal communication) 20 ft above sealevel on the eastern summit of dune D3 at the top of a steep erosional bluff; however, as the eastern summit is a picnic area, it is likely that these pieces of pumice were not in place. The remote possibility that a few pieces of flotsam might have been tossed high up on a steep bluff by large waves breaking against it is to be considered.

Some of the bottles in the flotsam zone were partly filled with sediment. Some were irridescent from exposure to sunlight. Although older looking than those on the mud flat, they had none of the deeply weathered opaque nature of the buried glass of the midden zones seen near Corpus Christi. The flotsam bottles were machine made and, therefore, were probably manufactured after World War I (Hunt, 1959). The hurricane after World War I that seems to have had the highest flood and the strongest waves here crossed the Gulf of Mexico from September 1 to 5, 1933, the center passing over the Rio Vista Lagoon. During this hurricane many sand dunes were washed away on the lower half of Padre Island and more than 40 washover channels were activated across Padre Island, some more than a mile wide (T. L. Bailey, in P. Reese, 1938 MS.). Water washing over Padre Island must have transported flotsam that had previously been deposited on this island into the Laguna Madre. A similar hurricane in 1916 (W. A. Price, 1956) deposited large driftwood logs 12 ft above mean sea level along the mainland shore of the northern Laguna Madre from Baffin Bay southward to the central mud flats, Kenedy County, but the water in the southern Laguna Madre was not raised appreciably (L. E. Rawalt, personal communication).

The flotsam zone on dunes D1 and D3 seems to be highest where high waves were driven directly against the south- and east-facing slopes. The manner in which the zone drops off to lower levels in areas protected from maximum wave height might falsely suggest a local domal up-warping if the hurricane origin of the flotsam were not recognized and if the flotsam were considered to be interbedded in the clay, rather than just a surface deposit, as it is.

SUMMARY AND CONCLUSIONS

A geological reconnaissance of interbedded shell layers in clay dunes rising from the flats of a small shallow lagoon near Port Isabel, Texas, revealed that the shells are principally submature, disarticulated, and fragmented valves of a small clam, *Mulinia lateralis*. This clam lives in large numbers in the adjacent, larger, coastal lagoon, Laguna Madre, and in bays along the Texas coast. Valves are dominantly oriented in the shell layers with the concave side down. It is concluded that these evenly bedded shells were incorporated in the dunes by wind. This conclusion is supported by experiments which indicate that moderate winds are capable of transporting shells up steep slopes. The apparently dwarfed nature of the shells in the beds might be the result of sorting by aqueous transport followed by wind sorting. If the clams lived in the small lagoon, they might have been prevented from reaching maturity because of periodic drying of the lagoon or because of their living under adverse environmental conditions. The low slopes and undisturbed nature of the shell strata would not agree with a hypothesis of wave run-up deposition which would require a beach, not a mud-flat environment.

Flotsam consisting of asphalt lumps, coral fragments, tropical beans, small lumps of wax or gum, pumice, scoria, slag or cinder, bottles, and lumber distributed on the slopes of dunes and elsewhere in the area at levels up to 11 ft above sea level are considered to have been deposited by hurricane waves, probably those of the hurricane of September, 1933 according to the known history of the area and the estimated age of manufacture of bottles in the flotsam.

ACKNOWLEDGMENTS

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