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Nueces River Delta Plain of Pleistocene Beaumont Formation, Corpus Christi Region, Texas[1]

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Abstract The surface of the Beaumont Formation in the Corpus Christi region of Texas preserves a relict depositional pattern laid down by a Pleistocene Nueces River during an interglacial or high sea-level stage like the present. The depositional pattern can be interpreted either as (1) that of a small meandering stream, similar to the present Nueces, undergoing numerous course changes (avulsions) and terminating in a small delta, or (2) that of a large multi-active distributary delta, similar to the present Mississippi River. Hydrologic considerations and comparisons with the contemporaneous Trinity, Brazos, and Colorado delta plains, some of their Holocene successors, and the Holocene Rio Grande and Mississippi deltas seem to rule out the second hypothesis.

The sediments directly underlying the delta plain are largely fine grained—about 75 percent clay and about 25 percent very fine to fine sand.

Both the areal extent and the assignment of the delta plain to the Beaumont Formation are controversial. Early mappers depicted it as larger in area. Most recent workers have assigned it to the Montgomery Formation ("upper" Lissie) or its equivalents. Depositional patterns, local surface gradient changes, and air photo patterns are of greater utility in correlation than similarity of regional gradients and soil types upon which previous correlations were based. A consequence of this assignment is the contemporaneity of the Beaumont-age delta plain and the relict Ingleside barrier offshore from it.

Introduction

The Nueces River Pleistocene delta plain, one of several in the Gulf Coast region of Texas assigned to the Beaumont Formation and its equivalents, presents a relict depositional surface and fairly well-defined depositional topography. Others include the delta plains of the Sabine, Neches, Trinity, Brazos, Colorado, Guadalupe, and Rio Grande Rivers. Some of their early Eocene (Wilcox) predecessors were examined by Fisher and McGowen (1967). Like the deltas in the dry pluvial lakes of the western United States, and those in the drained proglacial lakes in northern United States, they are readily accessible and observable on dry land. This fact has not been widely recognized in the recent explosion of interest in deltas (*e.g.*, Fisher *et al.*, 1969; Morgan, 1970).

This paper, the result of a reconnaissance study, has two major purposes. The first is to describe the geomorphology and sediments of a depositional unit, a delta plain, within the Pleistocene Beaumont Formation and to suggest contrasting hypotheses of origin which may aid in interpretation of similar units of the subsurface. The second is to explain my identification of the Beaumont Formation in the Corpus Christi region, where most previous workers have considered it to be absent. Traditional criteria, such as regional slope and diagnostic soils as lithologic units, are compared with the concept of the formation as a depositional unit controlled by eustatic changes of sea level.

Stratigraphic Framework and Problems

The basic assumptions of this paper follow the general scheme worked out by the late H. N. Fisk and his associates (see Bernard and LeBlanc, 1965, p. 145–151 for detailed account and references) for the eustatic control of deposition of Gulf Coast Pleistocene formations. In general, the scheme proposes that the several Pleistocene formations were laid down during the "interglacials," periods of high sea level perhaps similar to the present. The formations

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overlie each other unconformably and are exposed in belts parallel with the coast, with successively younger formations cropping out nearer the present shoreline. The outcrop areas of the older formations have been progressively more dissected and tilted gulfward more steeply. During the "glacials," sea level went down as water was removed from the oceans to form ice. The erosional unconformities between the formations were formed during the periods of lower sea level, when streams entrenched their valleys and flowed across the continental shelf.

The term "correlation" is used in this paper under the assumption of eustatic control and refers to both its homotaxial and its time (synchroneity) meanings. The formation names are used as both rock units and time-stratigraphic units.

The youngest Pleistocene formation which has an extensive coastwise distribution is referred to herein as the "Beaumont Formation," following the usage on the "Geologic Atlas of Texas" (Texas Univ. Bur. Econ. Geology, 1968a, b). A partial stratigraphic synonymy for the Corpus Christi region and the region around the type locality at Beaumont, Texas, is given in Figure 1.

The Beaumont Formation and its Louisiana equivalent (the Prairie Formation) were deposited largely as a series of extensive alluvial and deltaic deposits extending from the Rio Grande region of Texas to the Holocene floodplain of the Mississippi River in Louisiana. Bernard and LeBlanc (1965, Figs. 4, 5) show some of the local subdivisions but do not differentiate the Beaumont Formation from among the several Pleistocene formations in the Corpus Christi region. Other writers (Price, 1947, Fig. 1; 1962, p. 22; Doering, 1956, Figs. 7, 8) assign almost all the sediments in the Corpus Christi region to the Pleistocene formation next older than that of the Beaumont type locality. I revert essentially to the interpretation shown by Darton *et al.* (1937), where the youngest Pleistocene formation for the Beaumont type locality and the Corpus Christi region are correlative.

The presence of the Beaumont Formation in the region requires a revision of current ideas on the relative age of the Ingleside[3] barrier is-

[3] Segments of this relict barrier near Corpus Christi were named "Live Oak mature offshore bar" (Price, 1933, p. 918–920); local names were assigned to several more distant segments (*cf.* Bernard and LeBlanc, 1965, Figs. 4, 5). The lagoonal area was re-

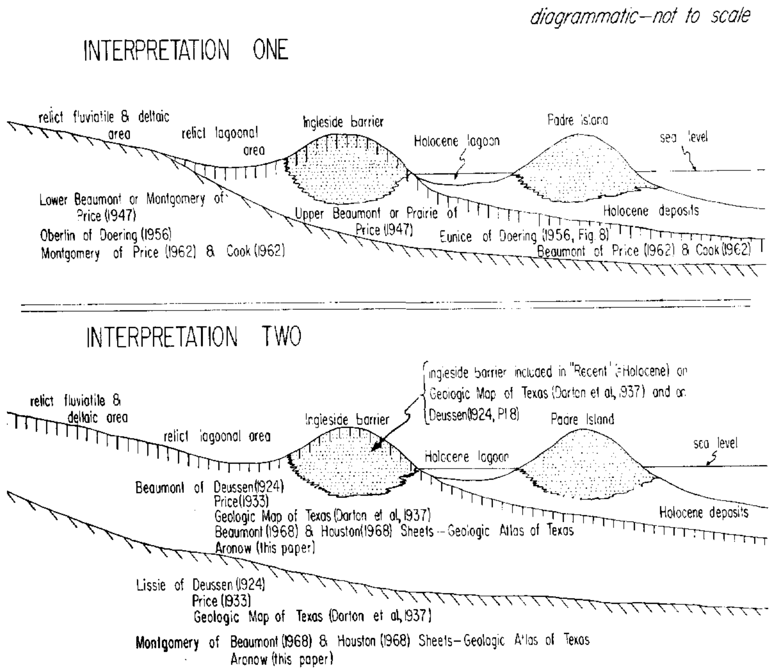


FIG. 1.—Diagrammatic cross section showing two interpretations of stratigraphic relations between Ingleside barrier and adjacent deltaic sediments. References in diagram to Beaumont (1968) and Houston (1968) are for Texas Univ. Bur. Econ. Geology (1968a, b), Geologic Atlas of Texas sheets.

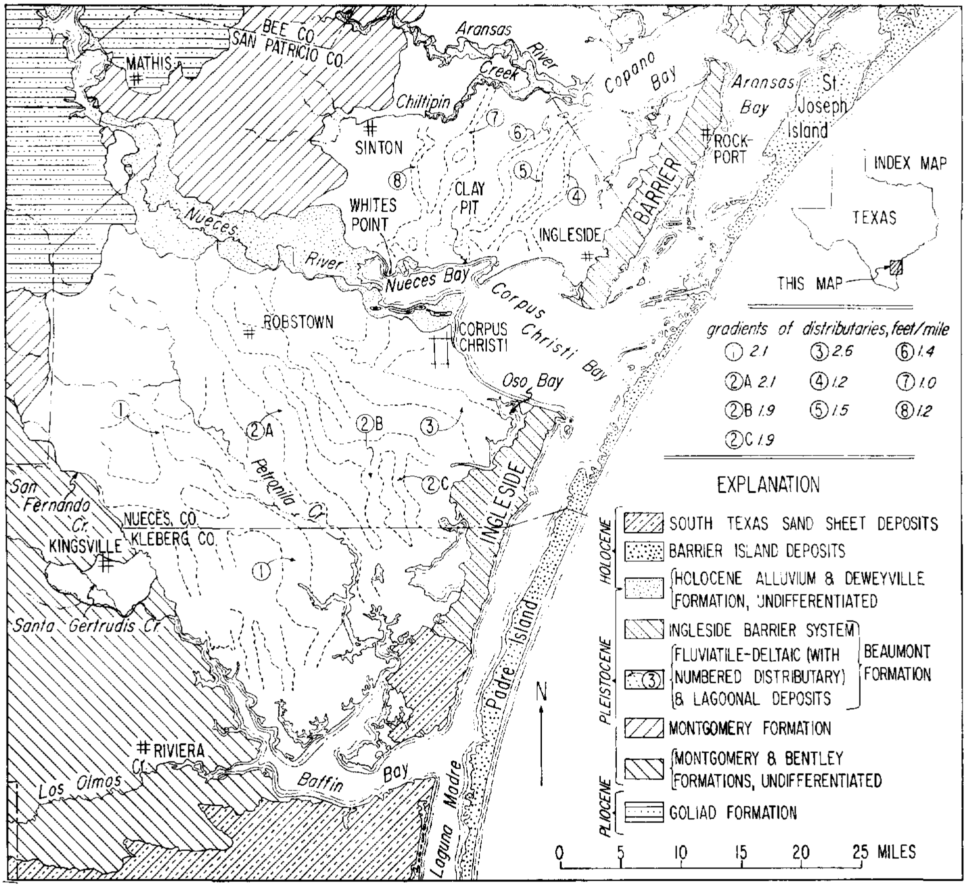


FIG. 2.—Geologic map of Corpus Christi region, Texas.

land system (first described by Price, 1933). Most recent writers believe that the relict barrier island was deposited in the Corpus Christi region offshore from an older delta, from which it was separated by an unconformity indicative of a eustatic cycle. A modern analogy is the Holocene Matagorda Island offshore from the Beaumont-age Colorado delta (Bernard and LeBlanc, 1965, Fig. 4). However, I believe that the barrier and delta were deposited contemporaneously as were the Holocene Rio Grande delta and Padre Island (Lohse, 1962, p. 41–42). Figure 1 presents this difference in viewpoint graphically.

ferred to as the "Ingleside terrace." Price, in later discussions (1958, p. 44; 1962, p. 22–23), adopted the term "Ingleside barrier." This name is used collectively in this paper for the entire group of barrier segments, although the community of Ingleside is on the relict lagoon.

Description of Delta Plain

The deltaic plain of the Pleistocene Nueces River covered by the Beaumont Formation extends about 1,600 sq mi. The surface depositional pattern of the plain is shown on the geologic map (Fig. 2).

The difference in width of the distributaries between the two sides of the river on the geologic map is probably an artifact caused by the use of two sets of air photos, taken at different times of the year with the soils exhibiting different moisture contents and states of cultivation. A reasonable estimate of the width of the distributaries for both sides of the river would be about 0.5 mi. On the air photos they generally show a wispy or smoky pattern, indicative of lighter colored sandier soils and soil complexes (Fig. 3). The intervening areas generally are underlain by the darker Victoria clay (soil type).

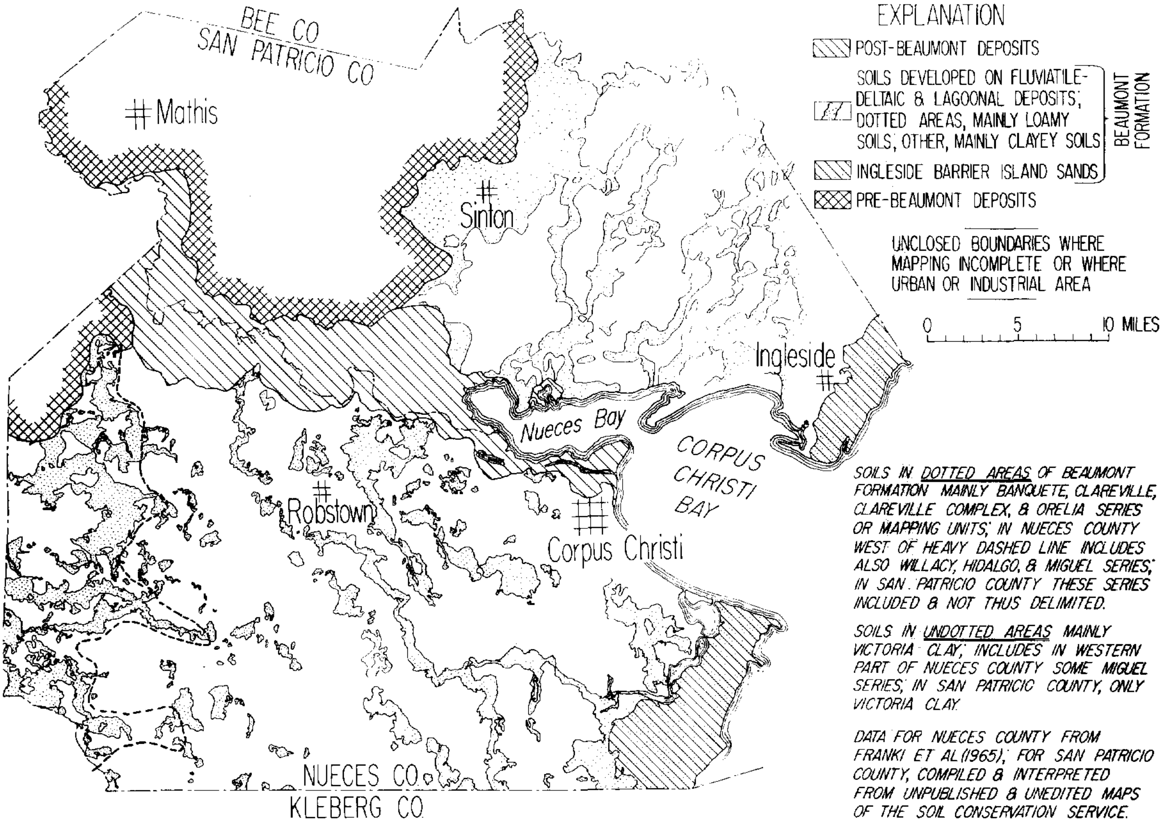


FIG. 3.—Generalized soils map of Nueces and San Patricio Counties, Texas.

Price (1933, Fig. 3, p. 915, 922–924) first noticed the pattern in the course of his field work and interpretation of early soils mapping in south Texas (Mangum and Westover, 1911; Coffey, 1912). Price in his description emphasized the ridgelike character of the pattern both on the ground and on topographic maps. My field observations and examination of air photos and topographic maps suggest that ridges are few except in the peripheral delta-front area in Kleberg County (Fig. 4). The paucity of ridges on the topographic maps may be partly an artifact of the contour interval. Among the areas of prominent ridges are the terminal parts of distributaries 2B and 2C (Figs. 2, 5), as pointed out by W. A. Price (oral commun., 1969). My impression in the field is that distributary areas are comprised mostly of shallow (deflation?) hollows occupied by the Banquete clay soil, and separated locally by very slight residual ridges. Some of these hollows can be seen in Figure 6, as well as on the published soil maps of Nueces County (Franki *et al.,* 1965). Clarification of the actual form of these subtle relief features awaits the production of 1-ft contour interval maps.

On air photos, some distributaries give a faint suggestion of small-scale meandering stream patterns—either the edges of closely spaced depressions, or depressions whose locations were controlled by a meandering channel.

Despite the probably tectonic distortions of the delta plain surface (Price, 1933), the clearly defined regional slope away from the Holocene position of the Nueces River is discernible (Fig. 5). The directions of the present surface gradients suggest the form of a low, areally distorted cone with the axis of the Deweyville and Holocene alluvial fill along a radius of the cone. Present gradients of the distributaries are given in Figure 2; the southern distributaries have somewhat steeper gradients than those in the north. Most distributaries cross the regional topographic contours; in a few places some parallel them, probably indicating later

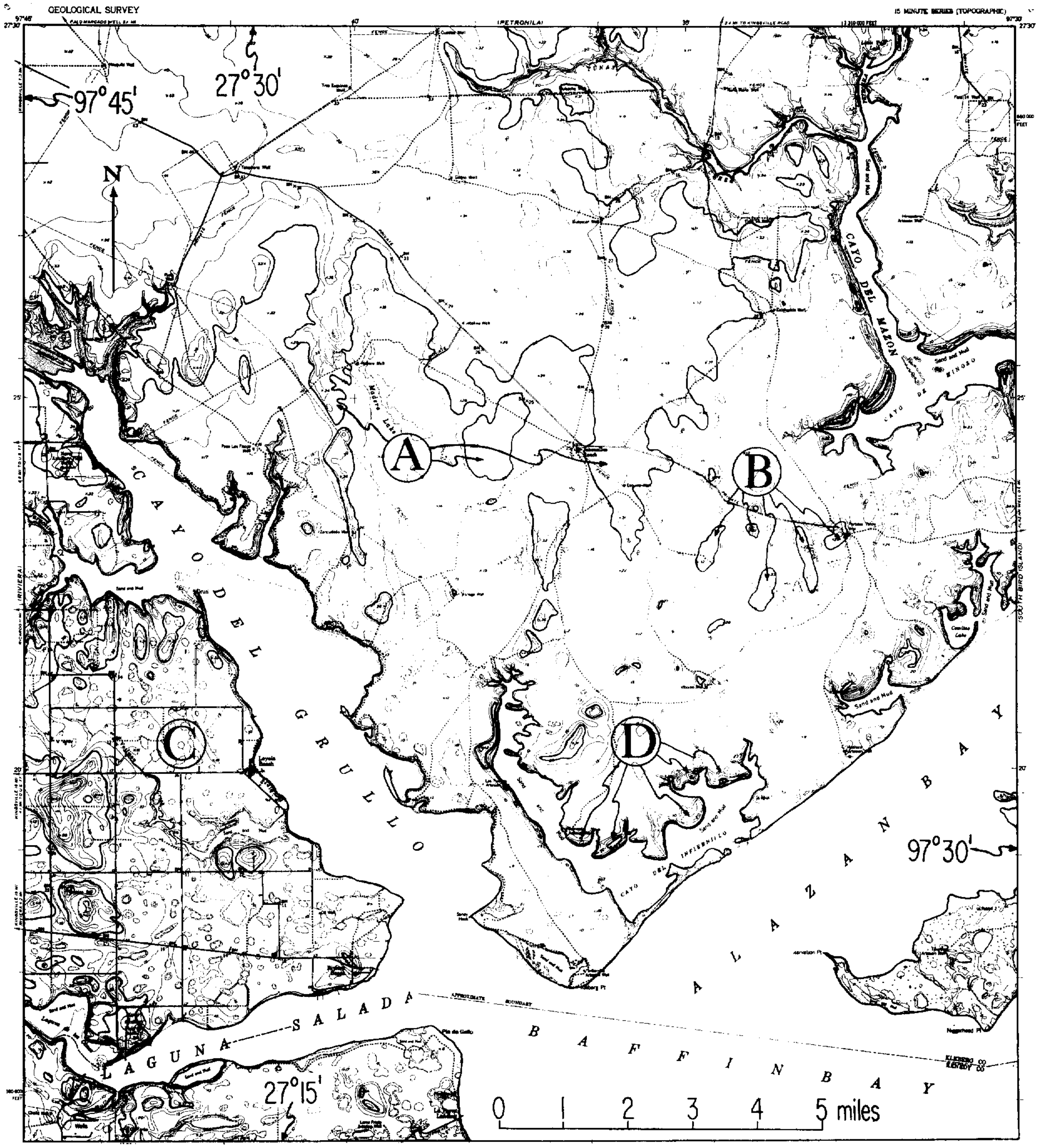
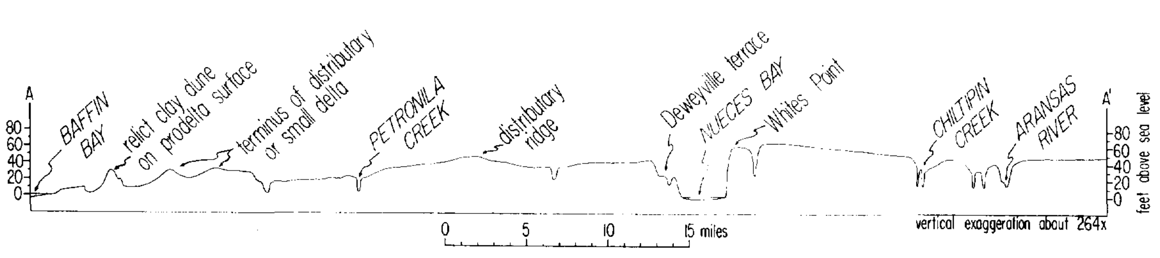


FIG. 4.—Topographic map (Riviera Beach 15-minute quadrangle) showing Beaumont-age delta front with small elongate deltas or distributary termini (*A*) and prodelta surface with relict clay dunes (*B*). South and west of Cayo del Grullo (*C*), relict clay dunes and deflation hollows on Montgomery-Bentley, undifferentiated, surface (see Fig. 2). Many Holocene active clay dunes in low-lying areas (*D*). CI = 5 ft; sea-level contour and 25-ft contour shown in heavy line.



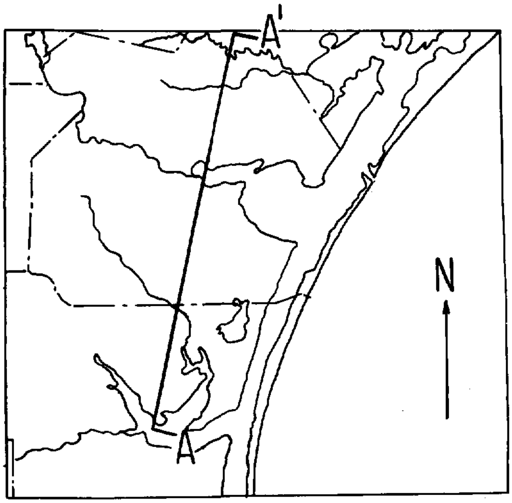


FIG. 5.—North-south topographic section through Corpus Christi region showing regional slope away from Holocene Nueces valley. Location map is area of Figure 2.

tilting or other distortion of the original depositional surface (*e.g.*, the terminal parts of 2B and 2C, Fig. 2).

Possibly the most interesting feature of the relict depositional topography is the preserved delta front in the northern part of Kleberg County (Fig. 4). Terminal parts of delta distributaries (levee ridges, submarine levee ridges, or bar fingers) or small individual elongate deltas seem to have been preserved as well as, at a lower altitude, the prodelta surface. The paleotopography was probably modified by clay dune formation, possibly shortly after uplift while saline water was intermittently available in undrained depressions (*cf.* Price, 1963, p. 766) close to sea level. A comparable development of a delta plain distal area can be seen in the near sea level parts of the Holocene Rio Grande delta in Cameron County on the south (Price, 1947, Fig. 5; also Los Fresnos and adjacent 15-minute quadrangles). Another generation of later Holocene clay dunes is accumulating peripheral to the low-lying, intermittently wet areas along the margins of Alazan Bay and Cayo del Grullo.

Doering (1956, Fig. 8) showed the exposed prodelta surface as an outcrop of his younger Eunice Formation, and the higher delta surface as part of his older Oberlin Formation, a view which I do not share.

The distributary pattern shown in Figure 2 is divisible into three fairly distinct segments or sublobes by the Holocene floodplain of the Nueces and by Petronila Creek and the Cayo del Mazon (Fig. 4), respectively. The distributaries of the two northern sublobes head upstream into the area of the present course of the Nueces, past the city of Mathis. The distributaries of the southernmost sublobe head upstream toward the Montgomery and Goliad outcrop areas on the west and north, respectively. In these directions the distributaries become less distinct, as seen on air photos (interpreted on Fig. 2) and the soils map (Fig. 3). Different soil series also appear (heavy dashed line on Fig. 3) and may indicate a Beaumont-age source for the sediments, as suggested by Franki *et al.* (1965, p. 46), rather than from the region of the present Nueces. This may revive the question of the possible diversion of

FIG. 6.—Air photo of part of distributary 2B (see Fig. 2). Light areas are underlain by loamy (sandy) soils. Dark circular and elliptical areas within lighter areas are shallow undrained depressions underlain by Banquete clay; dark area enclosing distributary, mainly Victoria clay. U.S. Dept. of Agriculture photo taken in 1969.

the Nueces from a more southerly terminus into the Gulf (through Baffin Bay) to its present one (*cf.* Deussen, 1924, p. 131; Bailey, 1926, p. 32–34; Sayre, 1937, p. 12–13). Although the problems of a possible twofold source of the Beaumont Formation and its relation to the diversion of the Nueces, and the significance of the soil series changes in the Beaumont Formation are interesting, they are not pursued in this paper. The simple, perhaps simplistic, assumption has been made here of an essentially unidirectional source of the sediments.

The areal relation of the delta distributaries and the Ingleside barrier strongly suggests that they developed synchronously and are not separated by an unconformity, as believed by most previous workers in this region (Fig. 1). The delta plain probably was built into a low area along the paleocoast in much the same manner that the Holocene Rio Grande built its delta into its embayed Pleistocene reentrant, depositing into the nearest low area and abandoning a course or distributary as a steeper, more efficient route to the sea opened. Distributaries 2A, 2B, and 2C in part fill the relict lagoon landward of the barrier (Fig. 2) and may record the successive "dodging" of an elongating barrier island. Distributary 3 lacks a clearly defined relict delta front and relict clay dune topography where it ends in Oso Bay. This distributary probably extended farther seaward and was eroded before development of the barrier in its present position, in a manner similar to the truncation of an early segment of the Holocene Rio Grande delta by Padre Island (Lohse, 1962, p. 41–42). The absence of a terminal topography and the abrupt ending of the distributaries of the northernmost sublobe along Chiltipin Creek and the Aransas River may be explained by their burial under deposits of the Pleistocene ancestors of these streams.

A conclusion and unequivocal answer to the contemporaneity problem of the barrier and the delta plain would be provided by radiometric dates on the barrier and the delta, or a well-defined soil or oxidized zone beneath the relict lagoonal and barrier sediments and co-extensive with the adjacent delta plain surface.

Preliminary View of Delta Sediments

The thickness of the Beaumont Formation—or the delta sediments herein assigned to it—is not known with any certainty. Subsurface data in the Corpus Christi region are insufficient to establish a lower contact for the formation, either on the basis of significant lithologic changes or some feature (*e.g.*, a weathered zone) indicating eustatic control of the base. Hayes and Kennedy (1903, p. 27–49) in their original description of the Beaumont clay suggested a thickness in the vicinity of Beaumont of about 400 ft. Later, Plummer (1932, p. 788) indicated a thickness for the whole Texas Gulf Coast ranging from about 450 to 900 ft, the average being about 700 ft. For the Houston area, Bernard *et al.* (1962, p. 208, 218) believed that the whole Pleistocene sequence is less than 500 ft thick. A reasonable subsurface projection of the exposed surface topography of the next oldest (stratigraphically lower) Montgomery Formation yields a thickness for the Beaumont Formation of less than 100 ft for both the Corpus Christi and Beaumont areas. Locally it may be thicker where the base of the Beaumont lies in channels incised in the Montgomery surface during a pre-Beaumont eustatic lowering of sea level.

As a first, rough approximation of the proportion of sediment types exposed on the delta plain, some soil acreage data can be used. The deltaic soils of the two principal counties in the area (Nueces and San Patricio) can be divided (Fig. 3) into a clayey group (mainly Victoria clay) and a loamy group. Probably the parent materials of the clayey group are largely backswamp (floodbasin) and lagoonal in origin; of the loamy group, they are largely point bar, levee, channel, *etc.* Detailed acreage data are given in Franki *et al.* (1965, Table 1) for Nueces County, in which the relative areas are about 75.3 percent clay and about 24.7 percent loam. Whether these have any volumetric significance depends on whether the exposed surface provides a representative slice of the delta. This division between loamy and clayey materials serves as a framework for the ensuing discussion.

In addition to the generalized soil data, other sources of information include well logs collected in groundwater investigations and surface exposures in road and stream cuts, shoreline bluffs, and pits.

In Nueces and San Patricio Counties (Shafer, 1968) 11 wells, logged by drillers, fall within the distributary areas. In most of these wells, the top of a sandstone bed is reported between 12 and 26 ft below the surface; sandstone thicknesses range from 14 to 166 ft. The material over the sandstone is variously described as soil, clay, or caliche. In Kleberg County (Livingston and Bridges, 1936) no logged wells are in distributary areas.[4]

South of the Nueces River in Kleberg and Nueces Counties, the many accessible stream and road cuts in the deltaic sediments exhibit largely clayey and silty materials up to 15 ft thick, including those in distributary areas and in distributary "fingers" or deltas of the delta front. Predominantly sandy sediments were not found.

North of the river, in San Patricio County, sandy deposits were found, particularly in stream valleys draining into Nueces Bay as well as in wave-cut bluffs and pits along the bay. The best exposures are at Whites Point, a prominent bluff about 50 ft high, and in the Centex Cement Co. clay pit (Fig. 2). Other localities are given by Price (1934, p. 950–951).

At Whites Point, which is within the area of the proximal ends of distributaries 7 and 8 (Fig. 2), under a cover of as much as 20 ft of clay, are mainly horizontally laminated and some cross-laminated, silty, very fine to fine sandstones interbedded with siltstone and clay. All materials are calcareous and, locally, well cemented by calcite. Some blocks of calcite-cemented sandstone were eroded out of the bluff and were lying at the base at about water level, simulating calcified beach rock. This kind of well-cemented sand is probably some of the "caliche" of drillers logs.

The Centex Cement Co. clay pit, east of Whites Point, has the best and most continuous exposures. The pit, excavated into a shoreline bluff, lies in an interdistributary area between distributaries 6 and 7 (Fig. 2). The surface materials are largely the calcareous, clayey parent materials of the Victoria clay soil. Borings by the Centex Cement Co. on 300-ft centers in and west of the pit suggest a north-south-trending sandstone body, 1,200–1,800 ft wide and at least 1,500 ft long terminating on the south in Nueces Bay. Exposures in the pit show essentially the western third and edge of the sandstone body. The borings show the sandstone to be more than 35 ft thick in places.

The sandstones are mostly very fine to fine grained, silty to clayey. They have great lateral continuity so that individual units can be traced in the walls of the pit for many tens of feet. They are almost all laminated or thin bedded (Figs. 7, 8); in a few places, tabular cross-laminae are developed (Fig. 9).

Horizontal lamination in modern fluvial sand similar to that shown in Figures 7 and 8 is described and illustrated by Harms *et al.* (1963, p. 576–577, Pl. 4C) from the Red River of Louisiana and by Harms and Fahnestock (1965, p. 97, Pl. 6) from the Rio Grande of Texas. In both papers the great lateral extent of these deposits is noted.

These horizontal laminae (assuming they were fluvially deposited) can be placed in the upper flow regime of plane beds of Simons *et al.* (1965, p. 35–37, Fig. 21) and Allen (1968, Figs. 6.8, 6.14). As shown in those figures, the sandstones in this pit are too fine grained to be placed in the plane beds of the lower flow regimes: mean fall diameters from two representative samples, as determined in an Emery tube, lie between 0.07 and 0.09 mm (within the fine sand range). The tabular cross-lamination can be interpreted as belonging to the lower flow regime (dune phase) of Simons *et al.* (1965, Fig. 21) or the large-scale ripples of Allen (1968, Figs. 6.9, 6.14).

The great thickness of horizontal laminae in the pit (over 16 ft exposed) is unusual in view of their limited occurrence in the Red River deposits, and the comment by Harms and Fahnestock on the Rio Grande (1965, p. 105–106) that "Preservation of horizontal stratification is limited to thin beds on point bar surfaces." They generally are preserved here because of the shallow scour depth during ripple migration at a lower flow regime. In narrow reaches of the Rio Grande, however, the subsequent deep scour by dune formation at lower flow regimes commonly destroys the laminations. A possible reason for their preservation may be their sub-

[4] The tables in Shafer's (1968) report show no wells in the area of the Beaumont Formation completed in sandstone or other aquifer materials associated with distributaries. Almost all wells less than 100 ft deep and outside the area of the Holocene barrier islands are completed either in alluvial or terrace deposits (Deweyville) of the Nueces River, or in the Ingleside barrier and its subsurface precursors (see data in Bernard and LeBlanc, 1965, Fig. 4, section B-B′; Fisk, 1959, Figs. 12, 13). Similarly in Kleberg County, almost all wells within the Beaumont Formation are over 750 ft deep or tap Ingleside barrier aquifers. Any potential aquifer materials associated with distributaries apparently have low transmissibilities or insufficient saturated thicknesses for economic use. Shallow aquifers may contain unusable saline water, as suggested by Ernest T. Baker, U.S. Geological Survey (personal commun.), and thus may be bypassed (*cf.* Price, 1935, p. 330). The lack or paucity of sandstone beds reported may be thus an artifact inherent in their inutility as aquifers.

sequent isolation from lower flow regimes which were confined to adjacent but topographically lower channels.

The thin bed of laminated, very silty and clayey, very fine sandstone along the edge of the sandstone body shown in Figure 10 may be identified tentatively as an extensive floodplain or crevasse splay (Happ *et al.*, 1940, p. 24, Pl. 4; Allen, 1965a, p. 122–123, 148) on the basis of the configuration.

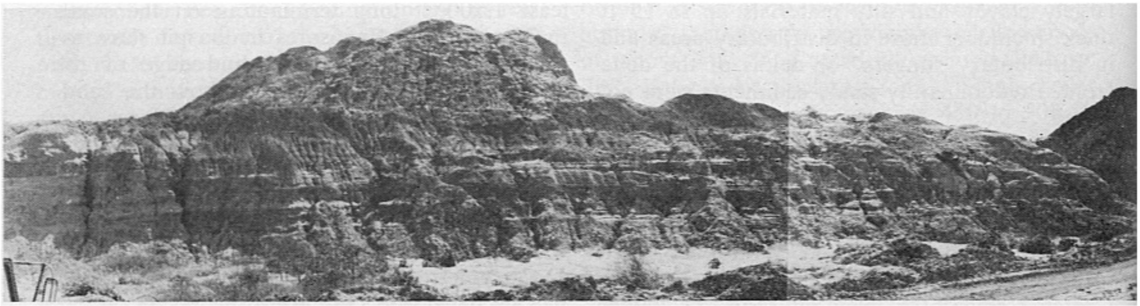


FIG. 7.—North-south cut in Centex Cement Co. clay pit (north at left); 5–6 ft of soil and clay over 11–15 ft of thin-bedded to laminated very fine- to fine-grained sandstone. "Peak" in left half of photo is spoil overlying disturbed soil and clay. Note great lateral continuity of bedding.

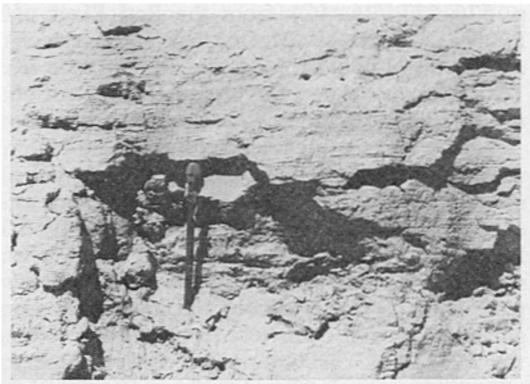


FIG. 8.—Close-up of laminated very fine- to fine-grained sandstone in Centex Cement Co. clay pit, thought to represent plane beds of upper flow regime. Exposed pencil length about 5.3 in.

FIG. 9.—Tabular cross-laminations in Centex Cement Co. clay pit thought to represent dune phase or large-scale ripples of lower flow regime. Pencil is about 6 in. long.

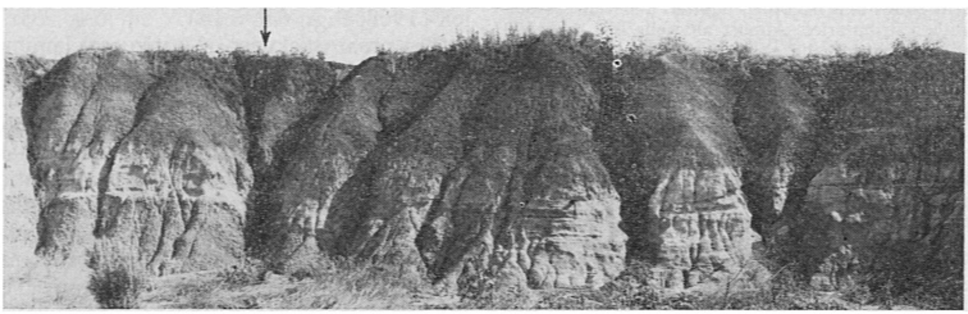


FIG. 10.—Exposure in northwest corner of Centex Cement Co. clay pit. Left of arrow, north-south wall; right of arrow, east-west wall. Uppermost layer, about 10 ft of soil and clay. Middle layer ranges in thickness from about 5 ft on left to over 15 ft on right; consists of laminated very fine- to fine-grained sandstone which becomes more clayey and silty at left. Underlain on left by about 7 ft of clay. Probably is western featheredge of channel deposit in form of crevasse splay.

Both tempting and risky is any interpretation of these limited exposures with respect to the meandering channel versus straight, multi-active distributary interpretations. However, Fisk (1961, p. 45–47) in the *locus classicus* of bar finger descriptions for the modern Mississippi delta stated:

> A striking feature of the entire section of bar-finger sands is the occurrence of thin cross-bedded layers, generally less than 2 inches thick. . . . Two types of cross-bedding are present. The more distinctive of these types is composed of thin laminae, which in a given bed, dip in a constant direction. . . . The other type . . . consists of minor festoons . . extremely thin curved laminae confined to beds less than 2 inches thick; some of the laminae are convex upward.

The predominantly clayey materials of the Beaumont Formation (the parent materials of the almost ubiquitous Victoria clay) have diverse origins: (1) lagoonal with probably minor deposits of mudflat, prodelta origin, and (2) backswamp of floodbasin, or, alternatively (should the large multi-active distributary concept be correct) the marsh and interdistributary trough facies of Fisk *et al.* (1954, p. 87–89) and Kolb and Van Lopik (1966, p. 37–38).

Mechanical analyses of the lowermost part (C horizon) of the Victoria soil profile show that these materials are over 60 percent clay in composition, as estimated from Franki *et al.* (1965, p. 38–39) and Kunze *et al.* (1963, p. 414).

The clayey materials, even in deep exposures, are massive or unlaminated, which may be the result of churning by organisms during and after deposition. Materials close to the surface also may be rendered massive by the self-mulching or "self-swallowing" activity of these deeply cracking, high shrink-swell clays (Soil Survey Staff, 1951, p. 158; 1960, p. 124).

The few logged wells in interdistributary areas (Shafer, 1968; Livingston and Bridges, 1936) show monotonously thick sections of clay, many over 100 ft. They are probably continuous with formations below the Beaumont.

My overall impression of the materials that underlie the delta surface is of their fine-grained character. Coarse sands and gravels seem to be lacking,[5] in marked contrast with the coarse sands and gravels found in the many pits opened in terraces of the Deweyville Formation, and in (or through) the Holocene alluvium of the Nueces. The coarser texture of these younger deposits is probably the result of greater rainfall and discharge than was available during the time of Beaumont deposition (Saucier and Fleetwood, 1970, p. 886–889).

[5] Price (1934, p. 951) noted the occurrence of gravelly sandstone outcrops which he suggests may be a Lissie inlier in the Beaumont. The location given suggests rather that they are coarse terrace materials of the Deweyville Formation and thus younger than the Beaumont.

Interpretation of Distributary Pattern as a Delta

The pattern and size of distributaries as shown in Figure 2 resemble the modern birdfoot delta of the Mississippi River and distributary patterns of other modern deltas, such as those of the Mekong and Irrawaddy (Fisher *et al.*, 1969, Figs. 48, 49, respectively), and the Niger (Allen, 1965b, Fig. 1). In the absence of any extensive subsurface data such as sandstone thicknesses, bedding characteristics, and three-dimensional geometry, I offer some speculative hypotheses concerning the significance of the pattern, which may be tested later by further detailed subsurface information.

The most obvious interpretation of the pattern is that the distributaries are those of a highly complex, multi-channel delta, similar in size to the present Mississippi birdfoot delta (Fig. 11), many times larger than the present Nueces delta (which covers about 34 sq mi). A similar comparison was made by Barton (1930, p. 372–373, Fig. 5) between the Beaumont-age delta plains of the Trinity and Brazos Rivers farther north.

> The ancient Brazos and Trinity deltas are fairly large, very much larger than the deltas of the present-day Brazos and Trinity rivers.... The ancient Trinity delta is of about the same size as the delta of the Mississippi River proper below New Orleans.... The ancient Brazos delta is perhaps slightly smaller.... The deltas of the present Brazos and Trinity rivers are microscopic in size compared to the deltas of their predecessors....
>
> The size of these ancient deltas and the amount of depositional activity they represent seem incompatible with the size of the present Brazos and Trinity rivers. The conclusion seems warranted that the ancient Brazos and Trinity were larger and carried more sediment than their successors. The further suggestion then follows that the rainfall was greater in the days of those old streams or that the drainage of those streams has been diverted to other river systems.

Barton's view of the Trinity delta plain has been widely, if uncritically, accepted both in print (*e.g.*, Henry, 1956, p. 3–5; Rehkemper, 1969, p. 14–15; Bernard and LeBlanc, 1965, p. 151) and in the oral tradition of the Gulf Coast Pleistocene, in which form it has been extended to the other delta plains. Price (1933,

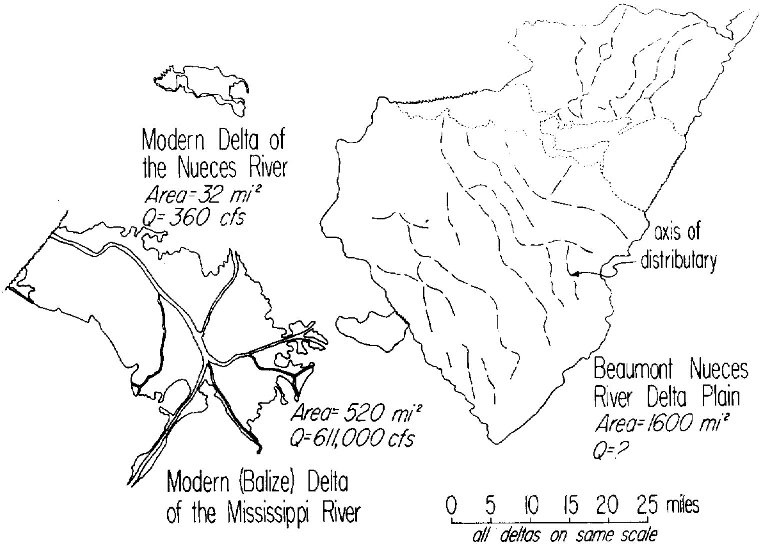


FIG. 11.—Comparison of exposed areas of Beaumont Nueces River delta plain, Holocene Nueces delta plain, and most recent Holocene delta of Mississippi River as designated by Kolb and Van Lopik (1966, Fig. 2). Mississippi delta outline from AMS 1:250,000 Breton Sound Sheet. Mississippi River discharge from Shirley and Ragsdale (1966, p. 234); Nueces River discharge estimated from data in Gilbert (1970, p. 11).

p. 922–924) seems to have adopted this view for the Beaumont Nueces River delta plain.

Barton's conclusions appear valid in the light of his assumptions, but I doubt these assumptions. A detailed study of the Beaumont Trinity delta plain (Aronow, 1970a; in press) suggests that it actually consists of many meandering courses of the Pleistocene Trinity, successively abandoned during a series of major channel changes or avulsions (Allen, 1965a, p. 119). Each meander belt or ridge crosses previous meander belts and terminates in a tiny delta similar in size to the present Trinity delta (*cf.* McEwen, 1969). The relict meander patterns are of the same order of magnitude as those of the present Trinity. On the assumption that meander size is roughly proportional to discharge, the paleoclimatic assumption of increased precipitation during Beaumont deposition seems unnecessary.

A comparison with the present birdfoot delta of the Mississippi is in order. An examination of maps of the present delta (*e.g.*, AMS 1:250,000 Breton Sound Sheet) and the several available topographic maps show that channel widths through the passes for the most part are between ⅓ and ¼ mi wide and surface levee and channel are about 1–2 mi wide. Subsurface bar-finger sandstones under the distributaries are 4–5 mi wide, as shown in maps and cross sections in Fisk *et al.* (1954, Figs. 11, 12); sandstone thicknesses are 250–300 ft. The available subsurface data for the Beaumont-age delta suggest that any contained sandstone bodies are considerably smaller than those of the Holocene Mississippi delta. The distributary areas of the Pleistocene Nueces delta are mostly less than 1 mi wide, a width comparable to that of the Holocene meander belt of the Nueces River. The intricate soil pattern of Figure 3 for the Pleistocene delta, I believe, was developed upon a complex of point bar, levee, oxbow lake, and channel deposits similar to those of the present Nueces floodplain and later modified (Aronow, 1970b). The overall distributary pattern is more likely the result of a series of avulsions similar to those of the contemporaneous Trinity delta plain, rather than the pattern developed on a large multi-channel delta plain. The ridges of the delta edge in Kleberg County (Fig. 5), in the direction of which many of the distributaries trend, are probably a series of small elongate deltas similar to those of the most recent Holocene Colorado River (of Texas) delta, but greatly modified by wind and water erosion. The Colorado delta also is in a lagoon protected by a barrier island (Matagorda Island).

The multi-active and meandering distributary pattern on the late Pleistocene and Holocene Niger delta (Allen, 1965b, Fig. 1) provides a plausible analogue for Barton's conception, in view of the relict meandering patterns preserved on the Pleistocene Trinity, Brazos, and Colorado delta plains (Aronow, 1970a; Aronow, in press; Bernard and LeBlanc, 1965, Fig. 5; LeBlanc and Hodgson, 1959, Fig. 11; Van Siclen and Harlan, 1965, Pls. 1, 3). The criss-crossings, truncations, and abandonments of channels on the several Beaumont-age deltas, as well as on their Holocene successors (excluding the Trinity), suggest that Barton's model, even if interpreted as a Niger-type delta, is inadequate. The Holocene Rio Grande delta plain (Lohse, 1962, p. 41–43; LeBlanc and Hodgson, 1959, Fig. 8) shows a pattern similar to the upper Gulf Coast Pleistocene and Holocene delta plains. None of these has a large terminal deltaic area in the sense of flow through synchronously active channels.

In common with others concerned with Gulf Coast geology, I have referred to the various segments of the Beaumont Formation surface as "delta plains," mainly to avoid cumbersome circumlocutions like "alluvial-deltaic" or "river deltaic" (Bernard and LeBlanc, 1965, Fig. 3). Perhaps the term "alluvial plain" would be preferable. Likewise, my use of the term "distributary" has its genetic implications. "Meander ridge" or "meander belt" would be more appropriate if my concept of the "alluvial plain" is valid.

The small size of the terminal deltas in the several ancient and modern plains with respect to the use of the term "delta plain" leads to an examination of the concepts of the term "delta."

1. Bates (1953, p. 2125) has the most highly restrictive definition: "... a deposit built by jet flow into or within a permanent body of water." Clearly the alluvial plains under discussion and the deltas of the Niger type would be excluded.

2. An early definition by Barrell (1912, p. 381) is broadly encompassing: "... a deposit partly subaerial built by a river into or against a body of permanent water." The alluvial plains and the Niger delta would fit here.

3. Guilcher (1963, p. 629) offers a compromise: "... a complex of distributary channels" and associated deposits. The Niger delta would be covered but not the alluvial plains.

Most other definitions and informal or undefined working concepts are close to the last two points of view. Scott and Fisher (1969, p. 10), mainly concerned with the three-dimensional aspects of stacked and imbricate deltas, defined a delta "as a river-fed depositional system that results in an irregular progradation of the shoreline ... The complex of delta lobes and their constituent facies comprise a delta system." The term "lobe" is used here in the sense of a distributary system. This would largely exclude the alluvial plains in both the two- and three-dimensional sense because of the meager development of lobes, as seen especially in the Holocene Rio Grande and Brazos-Colorado plains.

The 24 Holocene deltas illustrated in Shirley and Ragsdale (1966, p. 234–251) include those of the Rio Grande and the Brazos-Colorado. These deltas, and several others, obviously were not laid down in association with a large distributary framework. Actually shown on these maps are the Holocene areally wedge- or fan-shaped sedimentary fillings of the notches that were cut in the edges of the continents during the last glacial eustatic lowering of sea level. These illustrations fit the broad Barrellian concept of a delta (Barrell, 1912, p. 387) better than the more restrictive definition of Guilcher.

The alluvial plains also have no place in Allen's (1965a, Figs. 35, 36, p. 119) models of common alluvial facies, although the avulsed (in his special sense) character of the Rio Grande and other streams is noted.

With reference to the Texas Gulf Coast, Fisher (1969), in his detailed comparison of some Tertiary (largely subsurface) and Holocene delta systems, found that all the ancient ones can be interpreted in terms of the distributary framework of his high-constructive versus high-destructive models. Apparently the alluvial-plain model does not apply to the several streams ancestral to those discussed in this paper. Nanz (1954, p. 103, 105, 117), however, offers the Holocene alluvial plain of the Rio Grande as a possible analogue for the probably Oligocene ancestor to the Rio Grande in his study of "Sand 19B" of the Seeligson field of south Texas. Similarly, the Jurassic "Jackpile sandstone" of southern New Mexico is suggested by Schlee and Moench (1961, p. 144, 146, 150) as a possible deposit of a Rio Grande-like alluvial plain.

To accommodate these notch-filling alluvial plains as deltas, it would be necessary to return to the earlier, less restrictive concepts of Barrell. Figure 12 was constructed, *not* as a new classification, but as a means of summarizing the several points of view and helping focus possible differences of opinion regarding the genesis of these particular alluvial plains.

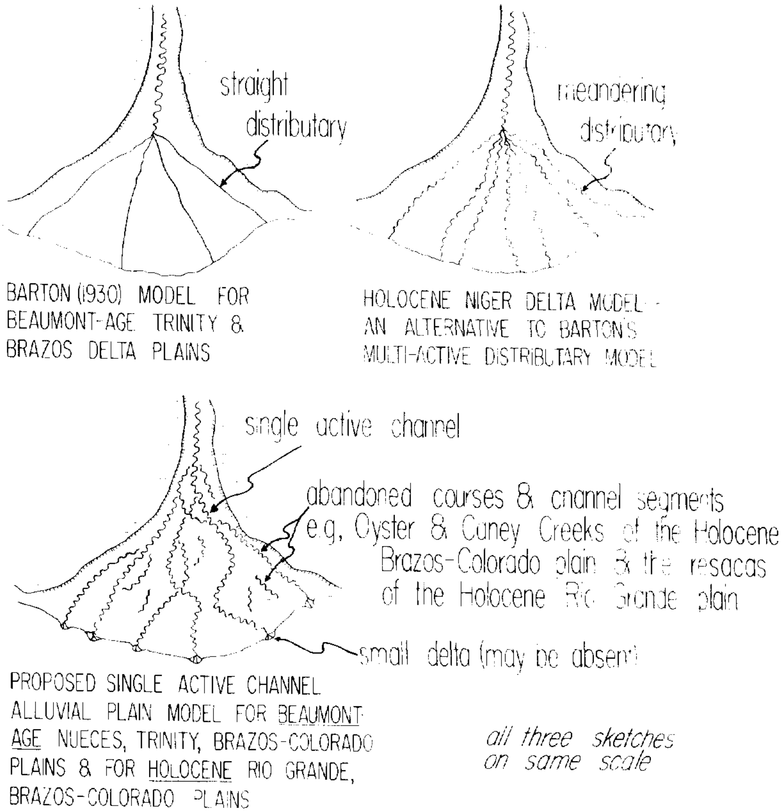


Fig. 12.—Suggested interpretations of several Pleistocene Beaumont-age and Holocene deltas in Texas Gulf Coast region.

Beaumont Formation: Depositional and Geomorphic Unit Versus Slope and Lithologic Unit

Fundamental to much of the previous discussion is the prior assumption that the delta plain can be isolated as a unit from, yet within, the Beaumont Formation. Many different maps of the whole outcrop area of the formation are available. The Corpus Christi segment shown in Figure 2 differs from the later maps by W. A. Price, the principal authority on the Pleistocene of that area, and from that of the widely cited and comprehensive scheme of J. A. Doering (see references in Fig. 1). The published map most similar to mine is the Geologic Map of Texas (Darton *et al.*, 1937).

Of the many criteria used in correlating and mapping the Beaumont Formation, four seem to be conspicuous: (a) distributary patterns and other relict depositional topography, in general, air photo patterns (this paper); (b) diagnostic soils (Darton *et al.*, 1937); (c) diagnostic regional topographic slopes or gradients (Doering, 1956; and this paper); and (d) presence of bounding erosional or tectonic scarps separating the Beaumont from older and from younger formations or deposits (Doering, 1956; Price, 1958, 1962; and this paper). With these explicit criteria in mind, the boundaries of the Beaumont Formation shown in Figure 2 are discussed and considered in relation to the earlier mapping by Doering, Price, and Darton *et al.*

The distributary pattern shown in Figure 2 covers most of the Beaumont Formation outcrop area and is absent elsewhere. The pattern crosses one of Doering's critical slope changes which establishes two of his formation contacts (1956, Figs. 7, 8).[6] In general, my Beaumont/Montgomery contact follows a well-developed

[6] A discrepancy exists between Doering's Figures 7 and 8: his Eunice/Oberlin contact is omitted from Figure 7.

to poorly developed scarp which encloses the distributary pattern. The lack of a clear-cut pattern on the Beaumont surface in the west-central part of the area is puzzling and may be related to a change in sediment source. The Beaumont/Montgomery contact is, in places, a compromise between a poorly developed scarp and a gradient change.

Beyond the limits of the Beaumont Formation there are significant lithologic and topographic changes (other than the absence of the distributary pattern) almost everywhere except across the Beaumont/Montgomery contact. In the Goliad outcrop area, thick, massive to nodular caliche is widely exposed in pits and road cuts. This type of caliche probably is absent from the Beaumont Formation, though calcite-cemented fine to very fine sandstones and calcareous nodule accumulations are common. Southwest, in the undifferentiated Montgomery/Bentley outcrop, in contrast to the smooth flat topography of the Beaumont Formation, the topography is characterized by isolated round to elongate hills. Though superficially like sand dunes in appearance, these hills, I believe, are relict clay dunes, for numerous exposures disclose them to be made of clay, silt, and sand. At any rate, this is the reasoning behind the choice of formational limits for the Beaumont Formation in Figure 2.

As far as I can discern from Doering's paper (1956), the major reason for not correlating the surface unit in the Beaumont Formation type locality (his Eunice Formation) with the surface unit in the vicinity of Corpus Christi (his Oberlin Formation) is the lack of similarity of regional slope. His Eunice Formation in the Beaumont area has a slope ranging from 1 to 1.7 ft/mi; his Oberlin Formation in the Corpus Christi area from 2.6 to 2.8 ft/mi (as computed from his Figs. 5, 7, 8). Most of my Beaumont Formation in the Corpus Christi area has a slope of between 3 and 4 ft/mi, with local extremes of 2 and 6 ft/mi; this difference is due to the larger area I map as Beaumont Formation.

Dependence on similarities of slope extending over the whole of the Beaumont outcrop area presupposes a uniformity of original depositional dip, a lack of local postdepositional tectonic distortion, and a uniformity of gulfward tilting after deposition. Such assumptions should follow identification of the outcrop area rather than serve as the bases for mapping the formation.

What I do consider as significant under the Fiskian scheme for the Gulf Coast Pleistocene are local differences in slope across the strike of the Beaumont and older adjacent formations, particularly if marked by scarps and accompanied by changes in soils, lithology, topographic expression, and air photo patterns.

Probably the most important topographic and air photo features of the Beaumont Formation surface are the relict fluvial patterns. In general, everywhere along the Gulf Coast of Texas these patterns occur in some form or other on the youngest extensive coastwise formation, regardless of the name given it. There is, however, a difference between the relict patterns in the Corpus Christi area and those of the Trinity and Brazos River Pleistocene delta plains. For example, clearly defined and easily recognizable relict levee ridges, abandoned channel segments, and oxbows are not found in the Corpus Christi area as they are farther northeast. I believe, as indicated previously, that this is due to a difference in the mode of postdepositional weathering, mass wasting, erosion, and wind modification of the surface. The fact that a depositional pattern is preserved there seems sufficient to warrant the correlation.

If the Beaumont Formation is largely absent from the Corpus Christi region, this would be virtually the only area in the Texas Gulf Coast in which a distinct, clearly defined, surface depositional pattern has persisted on a pre-Beaumont surface. Though this reasoning may not be particularly compelling, such a situation would be anomalous and would require some explanation.

In his most recent published works W. A. Price has tended to accept Doering's terminology and correlations, and thus may share his apparent belief in the correlative value of regional slopes. More specifically, however, Price (1958, p. 41–42; 1962, p. 22–23) has identified the landward edge of the relict lagoon behind the Ingleside barrier as an erosional scarp (which indeed it probably is in places) indicative of a eustatic cycle. I have not found anything in the pattern of the distributaries and topography of the area to support this conclusion, and thus question the significance of the scarp as a formational boundary. Should this be his main argument for the absence of a Beaumont-age delta plain, it does not seem valid.

Figure 2 resembles the old Geologic Map of Texas (Darton *et al.*, 1937) in asserting the extensive presence of the Beaumont Formation in the Corpus Christi area, though the actual area shown is considerably less than on Darton *et al.*'s map.

A comparison of the outcrop area of the Beaumont Formation (or clay) on Darton *et al.*'s map with the areas of the Victoria clay on early soils maps for this part of the Gulf Coast region (Mangum and Westover, 1911; Coffey, 1912; Carter, 1912; Smith and Marshall, 1938, which may have been available to Darton *et al.*) shows many striking similarities. A major exception is the area of relict clay dunes southwest of Baffin Bay and mapped on Figure 2 as Montgomery-Bentley, undifferentiated. Darton *et al.* were no doubt puzzled by the similarity of the delta-front clay-dune topography northeast of the Bay to that west of the Bay (Fig. 5).

The Victoria clay soil is the principal type found within the Victoria series. The series in the older soil classification was placed in the Grumosol Great Soil Group (Kunze *et al.*, 1963); in the new soil classification, in the Vertisol Order (U.S. Geol. Survey, 1969; Soil Survey Staff, 1960, p. 124, 131). These soils generally have almost no textural profile differences: in a given soil profile all the horizons, for example, may be clay. Generally high in montmorillonite, they undergo considerable volume changes upon wetting and drying, and develop slickensides, deep cracks, and gilgai microrelief. Franki *et al.* (1965, p. 6) described the Victoria clay in Nueces County as having a "surface layer of dark-gray, calcareous heavy clay . . . about 3 feet thick and . . . underlain by a layer of light-gray and dark-gray clay 18 inches thick. The substratum is pale-brown, calcareous clay containing a few lumps of lime." The clay (p. 55) persists in places to depths of over 4 ft. Almost all the Victoria clay (over 90 percent) is found on slopes of less than 1 percent—"the average slope about 4 feet in a mile, or is about 0.1 of 1 percent" (p. 17). My observations outside of Nueces County, in Bee, Jim Wells, and San Patricio Counties, indicate that most of areas mapped as Victoria clay on the older soil maps generally fit this description. It is virtually the only upland soil that is calcareous to the surface, has a clay A horizon, and underlies principally flat surfaces. These characteristics have made this soil type readily obvious to geologists and soil scientists from the time of the earliest reports. Independently of the soil maps, or using the soil maps as a guide, the compilers of the Geologic Map of Texas must have used the soil type as a lithologic unit to identify the Beaumont Formation. Farther north along the Gulf Coast, the Victoria clay and its related vertisols, the Beaumont and Lake Charles clays (Kunze *et al.*, 1963), are probably the most areally extensive soil series on the Beaumont Formation outcrop. Their occurrence was undoubtedly the principal reason for the wide acceptance of the lithologic designation in the older name, "Beaumont Clay." The soils are characteristic of the Beaumont Formation, but not diagnostic. In the Corpus Christi region, I believe that the Victoria clay transgresses geologic units from the Pleistocene Beaumont Formation to the Pliocene Goliad Formation.

Summary and Conclusions

1. The several deltaic-alluvial plain units of the Beaumont Formation are accessible on land for detailed geomorphic and sedimentologic investigation. In a search for analogies with subsurface deposits, these units potentially rival in utility similar Holocene deposits. A further study of the Nueces deltaic-alluvial plain part of the formation might generate some criteria for resolving differences in the interpretation of both the Beaumont-age deposits and older subsurface deposits.

2. The deposits of the Beaumont-age Nueces and other contemporaneous deltaic-alluvial plains of the Texas Gulf Coast are similar in origin to their several Holocene successors. Their overall morphology consists of meander belts containing sand, silt, and, in places, gravel of point bar, channel, and levee origin which are set in a matrix of clayey backswamp (flood basin) deposits. The meander belts criss-cross and truncate one another; at any one time most of the stream discharge is confined to one meandering channel ending in a small delta. In the contrasting Barton (1930) model, the meander belts are interpreted as distributaries of a multi-channel delta on the order of magnitude of the last Holocene Mississippi delta. In this model most of the sand would be of barfinger origin (topped with channel and levee deposits) and enclosed in a clayey matrix of interdistributary trough and related marsh and lacustrine origin. I do not believe the Barton model is applicable either to the Beaumont-age Nueces River and other contemporaneous deposits, or to the Holocene coastwise alluvial deposits.

3. Though the thickness of the Beaumont Formation in the Corpus Christi region is not known with certainty, the areal distribution of soil series, the available exposures, and the subsurface data suggest that the sediments of the Beaumont-age Nueces delta are largely fine

grained—about 75 percent clay and 25 percent very fine to fine sand.

4. The outcrop area of the Beaumont Formation (or its equivalents as the youngest extensive coastwise Pleistocene formation of the Texas Gulf Coast) has been shown in many different ways. Explicit criteria for recognizing or differentiating the formation have rarely been stated in the literature. I have attempted to reconstruct or interpret the criteria for the Beaumont Formation in several of the more important versions of its outcrop area. Regional gradients, the interpretation of scarps as interformational unconformities, and pedologic and lithologic criteria are probably not valid where used separately. Consideration of the Beaumont Formation as a series of adjacent depositional units of mainly alluvial-deltaic origin with a preserved relict depositional topography, together with the other criteria, seems the best way to map the formation.

5. The large-scale extension of the Beaumont Formation into the Corpus Christi region has eliminated the necessity of an interformational unconformity between the Ingleside barrier and the adjacent landward Pleistocene deltaic-alluvial plain.

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