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The Late Quaternary Rio Grande Delta—A Distinctive, Underappreciated Geologic System

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ABSTRACT

The delta of the Rio Grande/Rio Bravo in southernmost Texas and northern Tamaulipas is one of the major deltas of North America. Over 600,000 people live on the Holocene delta and river plain, and a million more on its Pleistocene ancestors, yet geologic knowledge is limited. Combining available geologic information with global satellite photography gives a balanced view of an important delta.

The Holocene delta begins at a point west of San Benito, Texas, forming a classic eastward-opening delta. Over half of the delta lies south of the present Rio Grande drainage. The delta passes westward into a floodplain that becomes entrenched into older rocks westward to Roma. In this delta, distributary channels or *resacas* are extremely sinuous and show a pronounced levee rise. A yazoo stream in the floodplain cuts northward across Pleistocene deposits to form a displaced delta. The delta plain is extensively modified by eolian processes. Erosion of clay-rich algal mats from exposed *esteros* (large, shallow ephemeral lakes) create complex 'clay dune' deposits that form 6 m (20 ft) high hills (*lomitas*) on the flat plain. Dominant SE to SSE winds affect sand movement along the transgressive shorelines. Longshore movement is particularly effective on the north side of the delta, less so on the south side.

The delta appears to have formed between 8000 and 3000 years BP by a robust, sediment-loaded Rio Grande. This period occurs during the Holocene Climatic Optimum, which was a dry time (altithermal) on the High Plains. Since 3000 years BP, the delta has been much less active and has been transgressed by barrier systems. The delta today is inactive, because of upstream reservoirs built since the 1940s. Before then, the river had irregular high discharge due to tropical systems and contributions from the upper Rio Grande system. The Pleistocene deltas that form the Beaumont surface underlying McAllen, Edinburg, and Harlingen probably exhibit similar landforms.

INTRODUCTION

This article serves as a short introduction to the Rio Grande Delta and the lower Valley of the Rio Grande (called the Rio Bravo in Mexico). A fuller treatment can be found in the guidebook for the field trip held in conjunction with the 2016 Gulf Coast Association of Geological Societies meeting (Ewing and Gonzalez, 2016). We hope that this will be the 'first edition' of many to come in describing and explaining the geologic and human history of the Rio Grande Delta and 'El Valle.'

Little geological research has taken place in the study area, despite the economic significance of the delta and its numerous features of interest. This is mostly due to distance from research centers and difficulties of working across borders on an international stream. Initial geologic work was conducted by Trowbridge (1932) and by Weeks (1937, 1945). Lohse (1952), in a mostly unpublished Ph.D. dissertation, was the first to work on the delta proper. Fulton (1976) has conducted the most recent geological investigation of the delta; this work

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likewise was published only in dissertation form. The area was mapped for the Geologic Atlas of Texas by Barnes (1976), and for the Environmental Geologic Atlas of the Texas Coastal Zone by Brown et al. (1980).

This is an appropriate time to reexamine what we know and need to find out about this delta. The availability of high-quality global imaging (Google Earth) gives us an excellent platform to look at the entire delta. The fact of over a million people living and working on the delta and its immediate ancestor give us an important social reason to work here; and the distinct and unique landforms and processes of the delta are worth studying in their own right.

DEFINITION OF THE DELTA AND VALLEY

The Rio Grande Basin is a complex drainage basin covering over 360,000 km^2 (140,000 mi^2) (Fig. 1). The headwaters of the Rio Grande lie at Stony Pass, elevation 3838 m (12,591 ft) in the San Juan Mountains of southwestern Colorado. The river runs south through New Mexico, picking up additional waters from the Sangre de Cristo Mountains on the east and highlands to the west. South of Fort Quitman, the river leaves a fertile floodplain and passes through wild, mostly unpopulated country. At Presidio/Ojinaga, the major Rio Conchos drainage rejuvenates the stream; its headwaters are in the Sierra Madre Occidental to the southwest. After passing through Big Bend and miles of deep gorges, the Pecos River joins from the north; its drainage heads in the Sangre de Cristo Mountains and receives additional runoff from the Sacramento Mountains area in south-central New Mexico. Shortly thereafter, the smaller Devils River and several short streams add to the flow. Much farther downstream, the Rio Salado enters, followed by the Rio San Juan, which drains much of the northeastern side of the Sierra Madre Oriental near Monterrey and Montemorelos.

Thus the river derives its water flow from mountains in the north, in the west, and in the southwest. The northern mountains have substantial snowpack in the winter, which melts in the spring, and significant summer rains. The Mexican mountains also have summer rains, but are more influenced by tropical systems in the late summer and early fall. The lower valleys are generally arid and contribute little flow.

In the 'natural state' (i.e., pre–1850), river flow into the delta region was derived from all of the above sources. Flow was irregular but had a spring and summer rising that was sufficient to support riverboat navigation from Brownsville to Roma. However, in the 1880s and thereafter, irrigation projects in New Mexico and Colorado appropriated the base flow of the upper river; only occasional flood waters now pass Fort Quitman into the lower river. At present, some 70% of water reaching the Rio Grande Delta comes from Mexican sources. Large reservoirs have been created by two dams on the lower Rio Grande/Rio Bravo (Amistad in 1969, elevation 360 m (1181 ft) and Falcon in 1953, elevation 92 m [302 ft]), as well as dams on major tributaries which have reduced severe flood flows from upstream sources. However, major tropical systems can flood the valley and delta—Hurricane Beulah in 1967 dropped more than 75 cm (30 in) of rain over most of the valley and delta.

At Roma, the river turns east and makes its way 193 km (120 mi) east (418 river km [260 mi]!) to the Gulf of Mexico, crossing Eocene through Pliocene outcrop belts (Fig. 2). From Roma to the east, there is a wide recent floodplain under irrigation. East of Peñitas (on the U.S. side) and Reynosa (on the Mexican side), the valley walls (now in Pleistocene sediments) widen, lower and disappear. From this point on, the river occupies the highest part of the delta, and loses water to distributaries and through flooding. A significant 'Yazoo stream' or flood drain on the north side, the Arroyo Colorado, carries water eastward from the lower parts of the Holocene valley. The Rio Grande is highly meandering with numerous oxbow lakes. Active channel migration in historic times led to hundreds of *bancos* or orphaned parts of one or the other country left on the other side. By an agreement in 1905, these areas became part of the contiguous country and the landowners could choose their country of residence.

At the longitude of Harlingen, the Holocene plain widens and numerous inactive distributaries (or old river channels, known as *resacas*) mark the landscape; this is the transitional zone to the Rio Grande Delta (Brown et al., 1980). To the east, delta plain deposits occur for some 110 km (70 mi) in a north-south direction and 55 km (35 mi) east-west. The highly meandering *resacas* are bordered by sand-rich levees, and lie 3–5 m (10–15 ft) above the surrounding interchannel areas. At the eastern side of the delta plain, a continuous shoreline and dune system marks the edge of the Gulf of Mexico. Strong, nearly continuous, south-southeast winds move sand from south to north around the protruding delta towards the convergence zone in central Padre Island to the north of the area. Growth of the shoreline along barrier island systems has left broad, shallow lagoons flanking the delta to the north and south—the Laguna Madre of Texas and the Laguna Madre of Tamaulipas.

To the north and south of the Holocene delta is a broad area underlain by upper Quaternary deposits of the Beaumont Formation. These surfaces also show the remains of distributary patterns similar to those of the Holocene, indicating that the Rio Grande Delta was active during previous times of sea-level highstand in the late Pleistocene.

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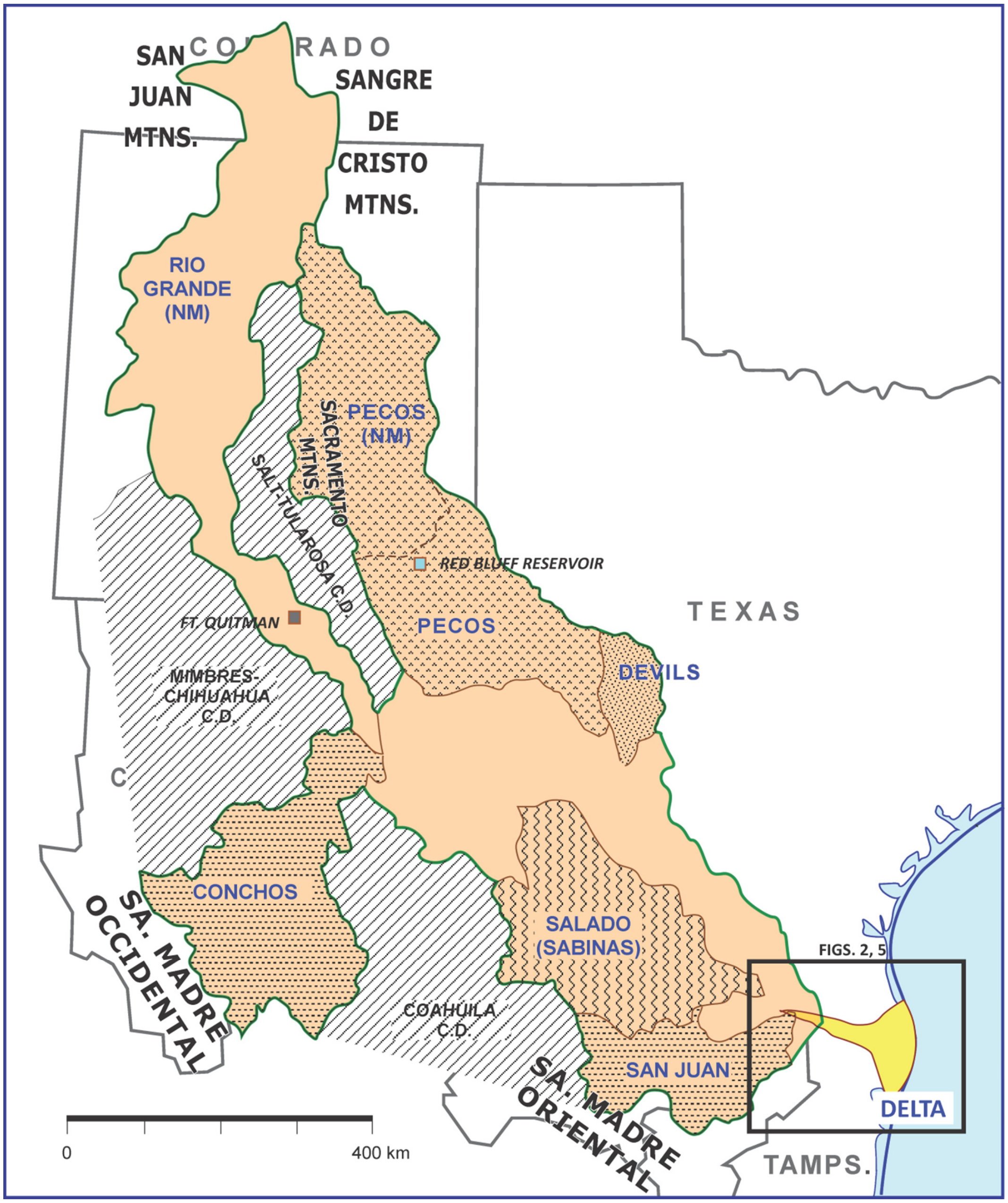

Figure 1. Drainage areas of the Rio Grande/Rio Bravo. In modern times, base flow ceases below Fort Quitman and flood flows are limited. Some 70% of water flows in the lower Rio Grande/Rio Bravo originate in Mexico. Mountainous areas (sources of runoff) are indicated; SA., Sierra.

Offshore, the Rio Grande Delta continues as a distinct feature to the shelf edge. Sparker seismic data show a late Pleistocene lowstand delta at the shelf margin, as well as earlier falling-stage deltas and a small delta formed during transgression in the earliest Holocene (Banfield and Anderson, 2004).

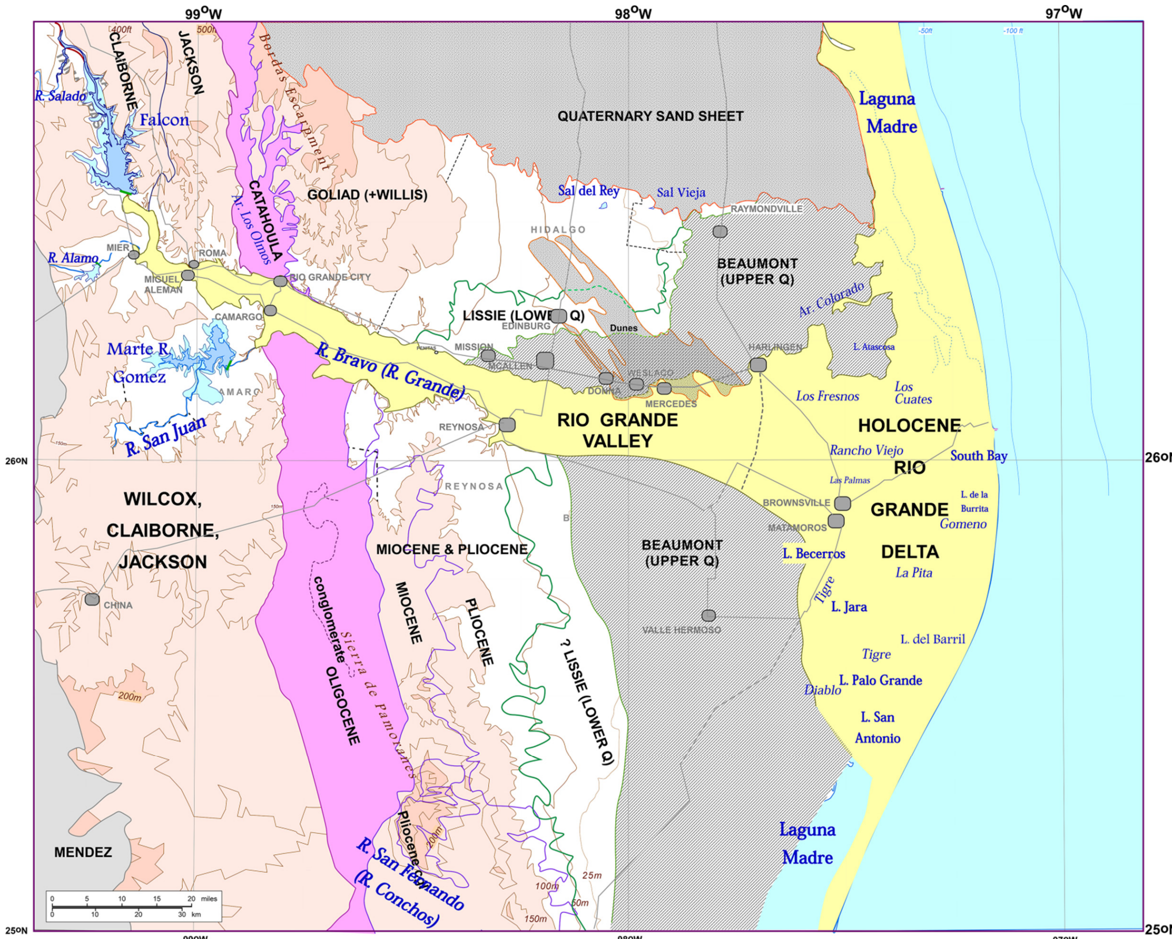

Figure 2. Physiography and geologic systems of the Rio Grande Delta and the Lower Rio Grande Valley (Valle del Rio Bravo). Geology from Barnes (1976), Brown et al. (1980), and Page et al. (2005).

DELTA GEOMORPHOLOGY AND PROCESSES

Looking at the delta from the air (Fig. 3A), we can divide it into an upper and lower delta plain. The upper plain is an extension of the valley floodplain, but marked by the presence of numerous *resacas* of various ages (Fig. 3B). These channels are the most distinctive part of the delta; highly sinuous meandering channels (like the present Rio Grande) sitting on a high sand-rich meanderbelt levee. It is unclear if some of these were true distributaries, receiving part of the river flow, or are ancestral Rio Grande channels formed by channel avulsion during flood events. In the upper plain, the interchannel areas are prairies that form shallow lakes during major events, but these dried rapidly due to the arid conditions and thus prevented flood basin organic rich deposits typical of most major deltas. Saltwater influence is minor, although salt is blown in from the surf zone and inhibits conversion to farmland.

The lower delta plain is geomorphically similar (Fig. 4A), but the general land level is lower. The interchannel areas are occupied by large shallow ephemeral lakes known as *esteros*. Many or most of the lakes are saline or brackish, experiencing saltwater intrusion as well as flood inputs. When the lakes dry out, they form expansive mudflats. The shores of the mudflats have thick mats of algae that shrink to expose the clay substrate (Fig. 4B). This zone contains numerous clay hills or clay dunes, that give the delta a remarkably hilly appearance (Fig. 4C). Some of the clay dunes are closely associated with the downwind (north and northwest) shores of major

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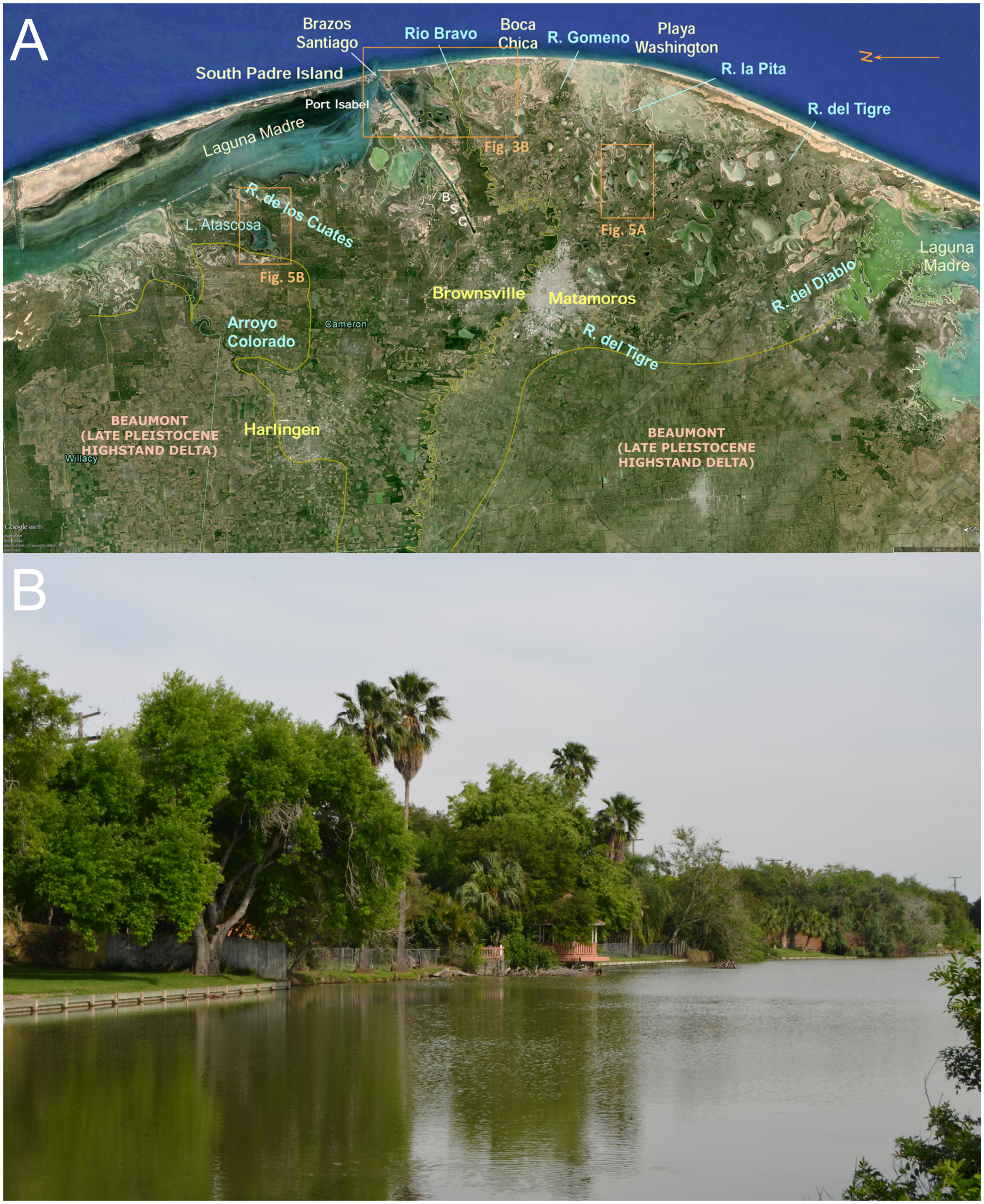

Figure 3. (A) Overview of the Rio Grande Delta (north to left); a point-source, digitate delta with flanking lagoons and reshaped to a lobate form by transgressive beaches. (B) Resaca de la Palmas, a distributary channel or ancestral river channel near Brownsville.

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(FACING PAGE and ABOVE) Figure 4. Views of the outer delta plain. (A) Closer view of the outer delta from Port Isabel (left) southward into Mexico. The current mouth of the Rio Bravo is nearly sealed by longshore sand transport. (B) Dessicated and deformed algal mats in mudflats flanking an estero; a possible source for clay dune material? (C) The hilly delta, view north from the Palmito Hill viewpoint on Texas 4.

esteros, but others are not obviously connected (as the high hills near Palmito on the road to Boca Chica). A few islands with striking ribbed patterns are found, notably Mesa Gavilan on the Boca Chica road. The ribs strike at a high angle to present shoreline and probably are eolian features related to old watercourses, but their formation is not understood. A clay dune on the north shore of El Hormigo in Mexico has overrun and swamped a nearby *resaca* (Fig. 5A), showing the power of eolian modification in this area. At the north end of the delta, Laguna Atascosa, a delta-margin freshwater lake, has expanded eastward and eroded into the Resaca de los Cuates just north of the wildlife refuge headquarters (Fig. 5B).

The present shoreline cuts across all older delta-plain features. It consists of a continuous sandy shoreline and dune ridge, only interrupted by the mouth of the Rio Grande (and that not always) and by the pass of Brazos Santiago, which connects to the Texas Laguna Madre. The dune line is narrow at the head of the delta from Playa Washington north to South Padre Island (Fig. 6A), but becomes wider and more complex to the north and south, with back-island dunes and washover fans developed. In Mexico, the back-island dunes form transverse dune complexes (Fig. 6B), as the prevailing wind is at a higher angle to the shoreline there.

There is very little information on the timing and stages of delta development. An early analysis by Lohse (1952) suggested an early Holocene delta lobe in the north along the resacas de los Fresnos and los Cuates; a middle Holocene lobe to the south along Resaca del Tigre; and a late Holocene-Modern lobe extending to Boca Chica along the present Rio Grande. Fulton (1976) obtained two radiocarbon dates from the northern area of 7000 and 4000 years before present (YBP), neither of these from the youngest feature in the area (Cuates). It has been proposed that the delta reached a maximum extent about 3000 YBP, and has been transgressed for the last 2000 years or more. However, if the los Cuates was active to 3000 YBP or so, it is reputed to be the oldest lobe! Morton and McGowen (1980) reported unpublished C–14 data as indicating that the lagoonal environments developed around 2500 YBP, and the youngest distributary channel sampled was about 2600 YBP. They suggest the present delta began to be constructed when sea level was about 9 m (30 ft) below present; this could have

Figure 5. Reshaping the delta by lake and clay dune growth. (A) Laguna El Hormigo; the clay dune formed downwind to the north is filling the Resaca de la Pita. (B) Laguna Atascosa, a delta-flank lake, has expanded eastward to consume part of the Resaca de los Cuates.

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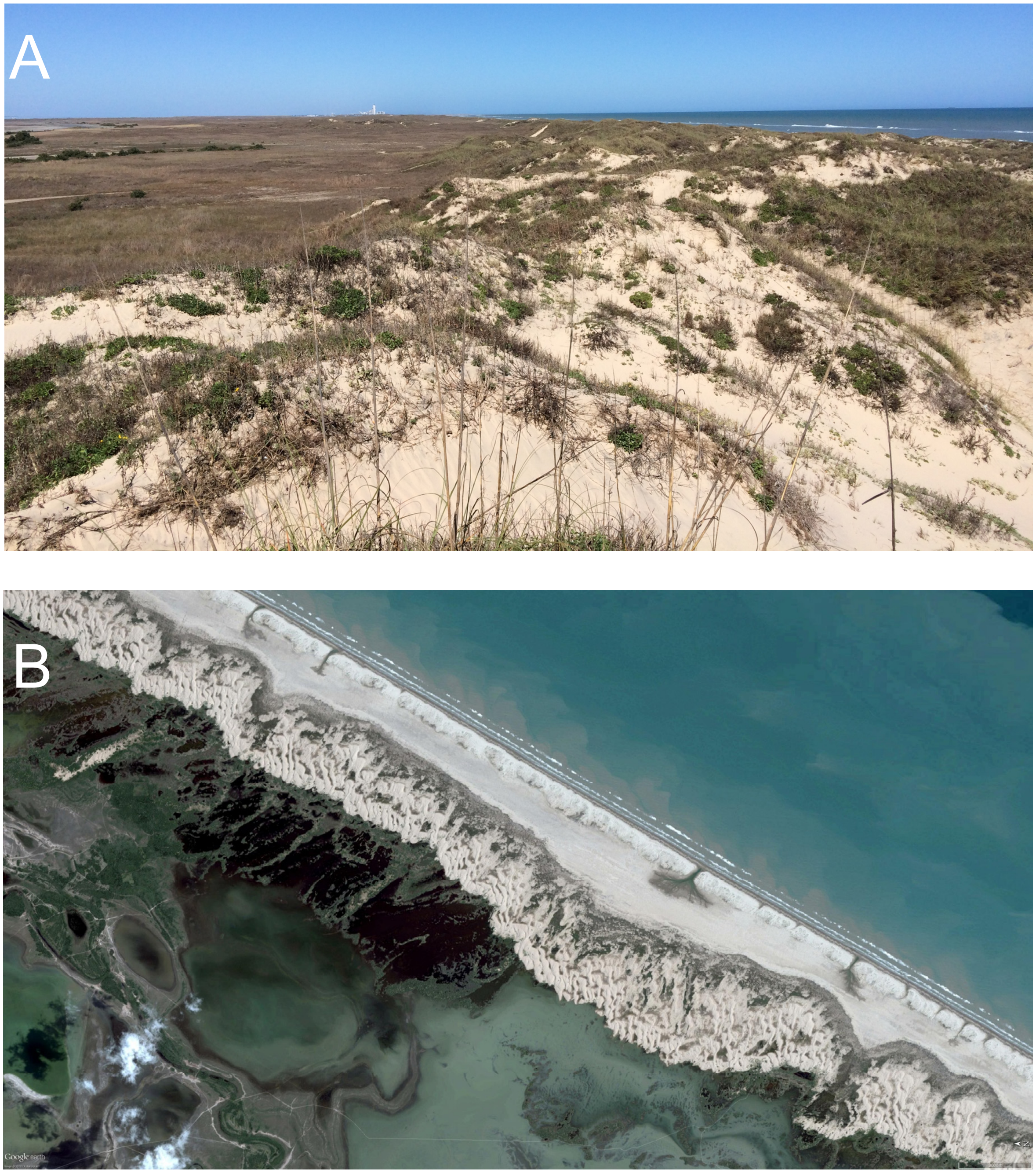

Figure 6. Modern beaches. (A) Dune ridge at Boca Chica, view to north (towers of South Padre Island in the background). (B) Transverse back-island dune complexes along present shoreline south of Playa Washington; Resaca del Tigre in lower left. North to left.

been about 9000 YBP. The lack of organic material has prevented recent efforts by one of the authors (JLG) to develop a radiocarbon based absolute chronology for the *resacas* on the Texas side of the delta. A great deal more work is essential to put our delta history on a sound footing.

HUMAN IMPACTS—IRRIGATION AND FLOODING

Original settlement by Europeans began in in 1749 with the establishment of Reynosa, Camargo, and Mier by Jose de Escandon. These small communities survived on small farming and ranching; large ranches were founded on the north bank as well. An eastern ranching station and mission (Refugio) began the city of Matamoros (renamed in 1826). This city grew rapidly as the main port for northeastern Mexico.

When Texas declared independence, she claimed the Rio Grande as a natural frontier (although the area had been within the boundaries of Nuevo Santander which became the state of Tamaulipas). This claim was inherited when the United States annexed northern Mexico in 1846. When the U.S. set up a fort opposite Matamoros, a Mexican army besieged it; a U.S. army under General Zachary Taylor moved up from Port Isabel and fought two battles (Palo Alto and Resaca de la Palma), defeating General Arista and relieving the siege of what became known as Fort Brown. Brownsville soon grew up as the main American town and port. Regular riverboat traffic ran from Brownsville and Matamoros upriver to Reynosa, Camargo, Rio Grande City, and Roma. But the land was still mostly used for ranching, with just small acreage of crops and sugar cane.

This changed in 1904, when the St. Louis, Brownsville, and Mexico Railroad reached Brownsville from the north. Almost immediately, a spur was laid west to Mission, and towns and irrigation companies sprouted along the tracks. (A Mexican railroad was built from Matamoros to Monterrey in 1905.) Texas companies built steam-operated pumphouses to lift water from the river and send it along miles-long canals to water their chosen acreage, often 30–50 km (20–30 mi) away. Farmers were recruited from the Midwest and all over to come to the sunbelt. Most of the land and irrigation companies came into financial difficulties, and most became mutually-owned irrigation districts by the 1920s. Some 27 districts exist today (Fig. 7). Some 315,600 ha (780,000 ac) were under cultivation by the 1960s; today many of these acres are covered by homes and urban development.

Mexican irrigation was delayed by the revolution and its aftermath. But in the 1930s, the Secretario de Recursos Hydraulicos began construction of two immense irrigation districts; one using water from the Rio San Juan, and the other using water from the Rio Bravo. Both districts used traditional gravity-fed channels, the Rode Canal and the Anzalduas Canal, to move water from a river takepoint to downstream users. The Bajo Rio Bravo district is now the largest in Mexico (240,000 ha or 612,800 ac).

Flooding from the erratic and powerful streams was always a major concern. Major floods could put essentially the entire irrigated valley under water. In 1924–1931, a system of floodways was designed and built. On the Texas side, the floodways used the Arroyo Colorado as a natural drain, but added a 'North Floodway' from Mercedes to Raymondville then east. On the Mexican side, a large set of dams was built to trap floodwaters, and a floodway designed to release them safely. Still, flooding was a problem second only to water supply, particularly for the downstream cities of Brownsville and Matamoros.

In 1936, a deep-water ship channel was built inland from the pass at Brazos Santiago towards Brownsville. This 27 km (17 mi) long channel has been steadily deepened, and is now at 13 m (42 ft) navigation depth. This construction and its spoil piles severed connections from Laguna Madre to the *esteros* of the Texas portion of the delta, causing a number of them to become nearly dry. Some of these connections have recently been restored under the supervision of the Lower Rio Grande Wildlife Refuge.

Finally, when the U.S. and Mexico signed a Water Treaty in 1944, the International Boundary and Water Commission was charged to construct a mainstream dam to regulate floods and water supply. Falcon Dam and Reservoir was constructed, opening in 1953. Combined with the Presa Marte Gomez (El Azucar) on the Rio San Juan (constructed in 1946) and other lesser reservoirs, flood risks were much reduced—at least from upstream sources. An unintended result of lesser stream flooding is that the downstream Rio Grande/Rio Bravo channel has greatly narrowed, as vegetation tries to heal over the stream scour. Channel widths near Brownsville are only a tenth of what they were in the 19th century—and therefore, the river cannot handle even the reduced flood flows that it now receives. The mouth of the river has been closed several times by sand bars transported south to north during times of low streamflow.

Major irrigation in a semiarid to arid environment always creates problems by raising the ground-water table and promoting salinization of the soils. To counter salinization and water-quality problems, a system of drains has had to be constructed on both sides of the border, to lower water tables and take saline water away safely. These low-level ditches also help to channel floodwaters from tropical events.

Thus the delta area has been extensively modified by human activity, disrupting natural stream flow and ecosystems. And water supply and management will continue to be a major focus of life in the Valley, even in the era of *maquilas* (factories in Mexico run by U.S. companies).

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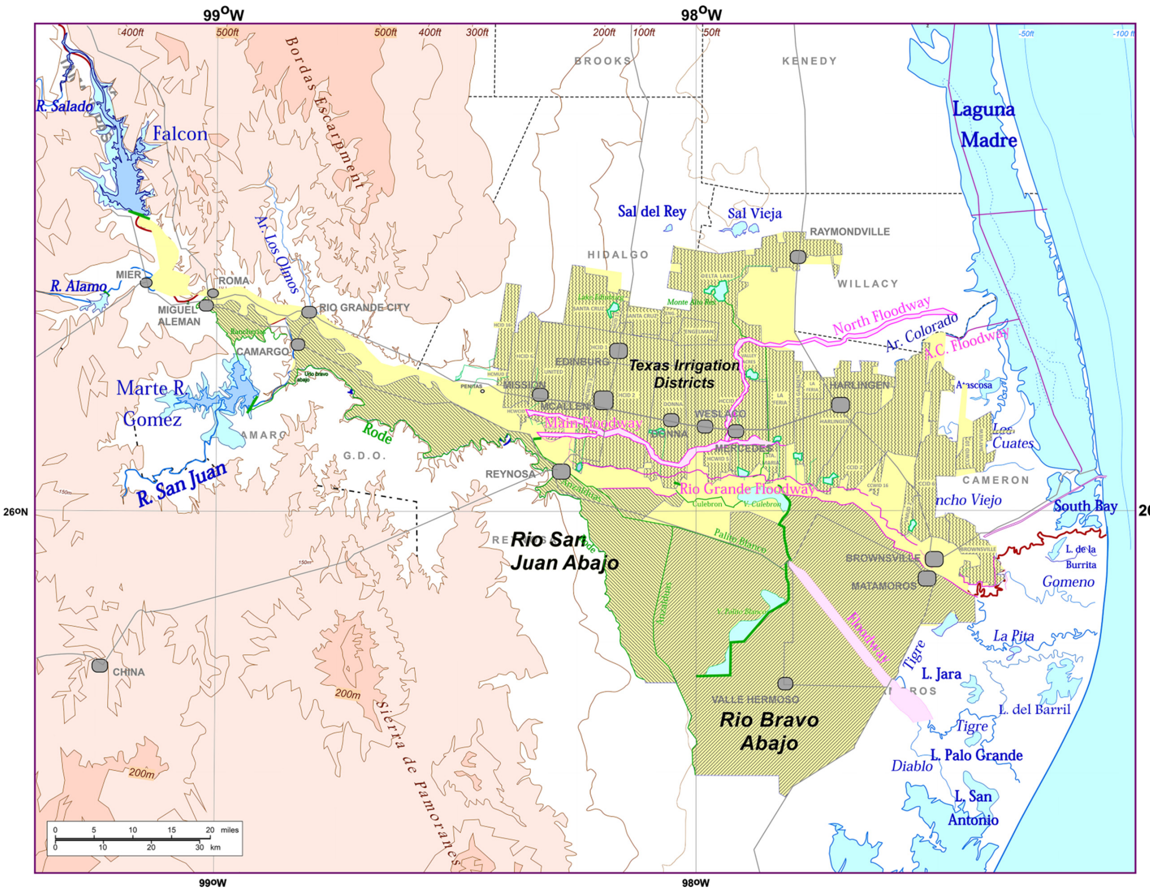

Figure 7. Irrigation and flood-control systems of the Rio Grande Valley/Valle del Rio Bravo. Mexican irrigation is mostly included in two large, government-run irrigation districts (shaded); it features large gravity-fed channels and large, shallow reservoirs that catch river flood flows. Texas irrigation, by contrast, is run by 28 irrigation districts (shaded), each with its own pump station that pulls water up from the river into canals and pipelines. Floodways (in purple) leave the river to the northeast and southeast, as well as the levee systems along the Rio Grande and Arroyo Colorado. They were built in the 1930s before upstream reservoirs were constructed. Total irrigated area shown in yellow.

REFERENCES CITED

Banfield, L. A., and J. B. Anderson, 2004, Late Quaternary evolution of the Rio Grande Delta: Complex response to eustasy and climate change, *in* J. B. Anderson and R. H. Fillon, eds., Late Quaternary stratigraphic evolution of the northern Gulf of Mexico margin: Society of Economic Paleontologists and Mineralogists Special Publication 79, Tulsa, Oklahoma, p. 289–306.

Barnes, V. E., ed., 1976, Geologic atlas of Texas, McAllen-Brownsville sheet: Texas Bureau of Economic Geology, Austin, scale 1:250,000.

Brown, L. F., Jr., J. L. Brewton, T. J. Evans, J. H. McGowen, W. A. White, C. G. Groat, and W. L. Fisher, 1980, Environmental geologic atlas of the Texas Coastal Zone—Brownsville-Harlingen area: Texas Bureau of Economic Geology, Austin, 140 p.

Ewing, T. E., and J. L. Gonzalez, 2016, Geologic and human systems of the Rio Grande Delta and the Valley of the Lower Rio Grande: Field Trip Guidebook, in preparation, ca. 80 p.

Fulton, K. J., 1976, Subsurface stratigraphy, depositional environments, and aspects of reservoir continuity—Rio Grande Delta, Texas: University of Cincinnati, Ohio, 314 p.

Knight, L., 2009, A field guide to irrigation in the Lower Rio Grande Valley: Texas Department of Transportation Historical Studies Report 2009–01, Austin, 285 p.

Lohse, E. A., 1952, Shallow marine sediments of the Rio Grande Delta: Ph.D. Dissertation, University of Texas–Austin, 113 p.

Lohse, E. A., and T. D. Cook, 1958, Development of the recent Rio Grande deltaic plain, *in* Sedimentology of South Texas: Gulf Coast Association of Geological Societies Field Trip Guidebook, p. 55–60.

Morton, R. A., and J. H. McGowen, 1980, Modern depositional environments of the Texas Coast: Texas Bureau of Economic Geology Guidebook 20, Austin, 167 p.

Page, W. R., D. P. VanSistine, and K. J. Turner, 2005, Preliminary geologic map of southernmost Texas, United States, and parts of Tamaulipas and Nuevo Leon, Mexico: Environmental health investigations in the United States–Mexico border region: U.S. Geological Survey Open-File Report 2005–1409, 11 p.

Price, W. A., 1958, Sedimentology and Quaternary geomorphology of South Texas: Gulf Coast Association of Geological Societies Transactions, v. 8, p. 41–75.

Trowbridge, A. C., 1932, Tertiary and Quaternary geology of the lower Rio Grande region, Texas: U.S. Geological Survey Bulletin 837, 260 p.

Weeks, A. W., 1937, Miocene, Pliocene and Pleistocene formations in Rio Grande region, Starr and Hidalgo counties, Texas: American Association of Petroleum Geologists Bulletin, v. 21, p. 491–499.

Weeks, A. W., 1945, Quaternary deposits of Texas Coastal Plain between Brazos River and Rio Grande: American Association of Petroleum Geologists Bulletin, v. 29, p. 1693–1720.