Matagorda Formation—A New Holocene Coastal Stratigraphic Unit, Texas

By Jeffrey G. Paine, Edward W. Collins, and Tiffany L. Caudle

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Randall C. Orndorff, Nancy R. Stamm, and David R. Soller

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square inch (in^2)	6.452	square centimeter (cm^2)
section (640 acres or 1 square mile)	259.0	square hectometer (hm^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square hectometer (hm^2)	2.471	acre
square kilometer (km^2)	247.1	acre
square centimeter (cm^2)	0.001076	square foot (ft^2)
square meter (m^2)	10.76	square foot (ft^2)
square centimeter (cm^2)	0.1550	square inch (in^2)
square hectometer (hm^2)	0.003861	section (640 acres or 1 square mile)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Datums

Vertical coordinate information is referenced to North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

MIS	marine oxygen isotope stages

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Chapter E

Matagorda Formation—A New Holocene Coastal Stratigraphic Unit, Texas

By Jeffrey G. Paine,[1] Edward W. Collins,[1] and Tiffany L. Caudle[1]

Abstract

We propose and describe the Matagorda Formation, a new stratigraphic unit comprising Holocene coastal (sea-level influenced) deposits on the Texas coastal plain. This formation consists of sediments deposited in fluvial-deltaic, bay and bay-margin, and gulf-margin paralic environments since the last glacial maximum (marine oxygen isotope stage 2, or MIS 2) within and at the margins of stream valleys incised into the coastal plain since the last Pleistocene sea-level highstand during MIS 5. The Matagorda Formation includes informal coastal facies that are influenced by sea level and grouped into fluvial-deltaic deposits (Lavaca Member), bay and bay-margin deposits (Carancahua Member), and paralic gulf-margin deposits (Saluria Member). Other coastal facies, such as eolian sand or silt sheets and clay dunes, are included in the Matagorda Formation but are not included within the members. The type area is herein defined as the Matagorda Bay system on the central Texas coast, where many examples of facies within the proposed formation are exposed along and near the shoreline. The upper boundary of the Matagorda Formation is the active depositional or erosional surface either on land or at the water bottom beneath coastal streams, tidal channels, and bays. The lower boundary is a composite unconformity that may be marked by (1) a mature soil or erosional surface at the top of the Pleistocene Beaumont Formation (a sharp boundary with or without soil development below the unconformity), (2) the top of alluvial terrace deposits above the Beaumont Formation (Deweyville Formation or broad equivalent) within the incised valley (sharp boundary with or without soil development below the unconformity), or (3) fluvial deposits above the Beaumont Formation at the base of the incised valley that predate the Holocene transgression (possibly a gradational boundary where active deposition was occurring as sea level rose and base level reached the incised valley).

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Introduction

New geologic mapping on the Texas coastal plain began in 2011 under the cooperative STATEMAP program (fig. 1). The goal of the new mapping was to use the latest high-resolution aerial imagery, lidar-derived digital elevation models, and near-surface geophysical methods (Paine and others, 2018) to map Quaternary strata in greater detail (1:24,000 scale or better) along the central and northeastern Texas coast of the Gulf of America. These tools facilitated a depositional facies-based approach to surficial geologic mapping on the coastal plain. Previous mapping efforts named Pleistocene formations that include the Lissie Formation (Deussen, 1914; Plummer, 1932; Brown and others, 1975b) and the Beaumont Formation (Hayes and Kennedy, 1903; Deussen, 1924; Plummer, 1932; Aronow, 1971; Brown and others, 1975b). These formations were distinguished from overlying Holocene deposits, which were generally undifferentiated and lumped into various categories, including "Recent" or Port Hudson clays (Hayes and Kennedy, 1903), "Recent deposits or series" (Deussen, 1914), stream deposits and wind-blown sands (Plummer, 1932), and Quaternary alluvium (map unit symbol Qal) and Quaternary beach-ridge and barrier-flat deposits (map unit symbol Qbr) (Brown and others, 1975b). Based on our mapping to date of thirty-four 7.5-minute quadrangles extending from Corpus Christi Bay to Matagorda Bay on the central Texas coast and surrounding the East Bay area on the upper Texas coast (fig. 1), we propose to (1) name the coastal (sea-level influenced) Holocene deposits the Matagorda Formation and (2) subdivide major parts of the Matagorda Formation into three members. These members contain assemblages of informally named sedimentary facies that were deposited in (1) fluvial-deltaic, (2) bay and bay-margin, and (3) gulf-margin paralic environments during the Holocene. Although our recent mapping focused on deposits exposed at the ground surface, the Matagorda Formation can be extended to include fluvial-deltaic, bay and bay-margin, and gulf-margin deposits that have partly or completely filled

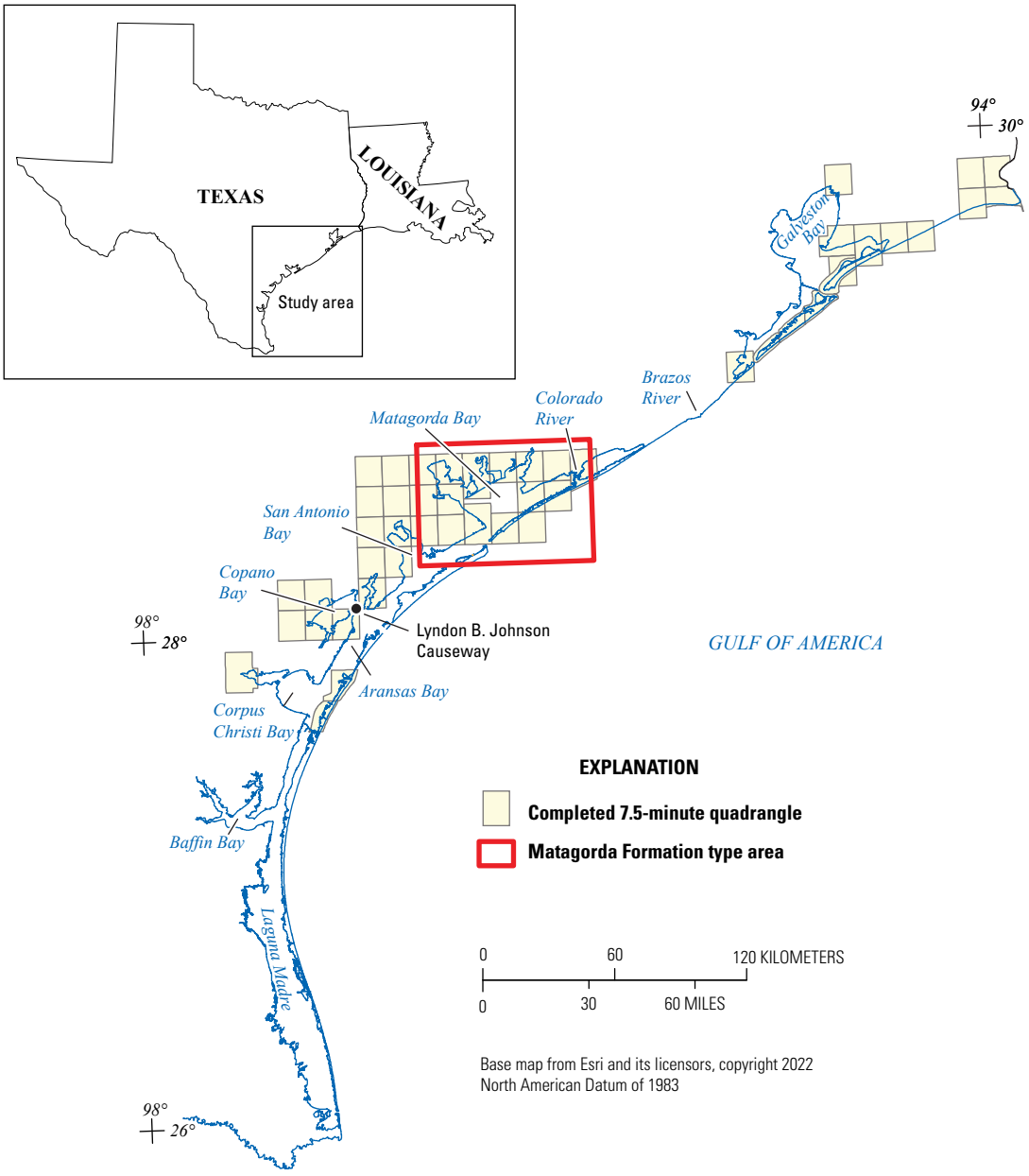


Figure 1. Location of the Matagorda Formation type area and STATEMAP geologic mapping project areas on the central and northeast Texas coast.

the valleys incised on the Texas coast since the global sea-level lowstand about 120 to 134 meters (m) below current sea level associated with the last glacial maximum (fig. 2; Yokoyama and others, 2000, 2001; Peltier and Fairbanks, 2006; Clark and others, 2009; Lambeck and others, 2014; Spratt and Lisiecki, 2016). These valley-fill deposits underlie the present-day bays, coastal rivers, and streams and are predominantly Holocene (Anderson and others, 2022). Within the incised valleys, Matagorda Formation coastal deposits may overlie basal fluvial deposits (Fagg, 1957; Shepard and Moore, 1960; Anderson and others, 2022) that are younger than the Pleistocene erosional surface on top of the Beaumont Formation but may be older than the time of postglacial sea-level rise into the incised valleys.

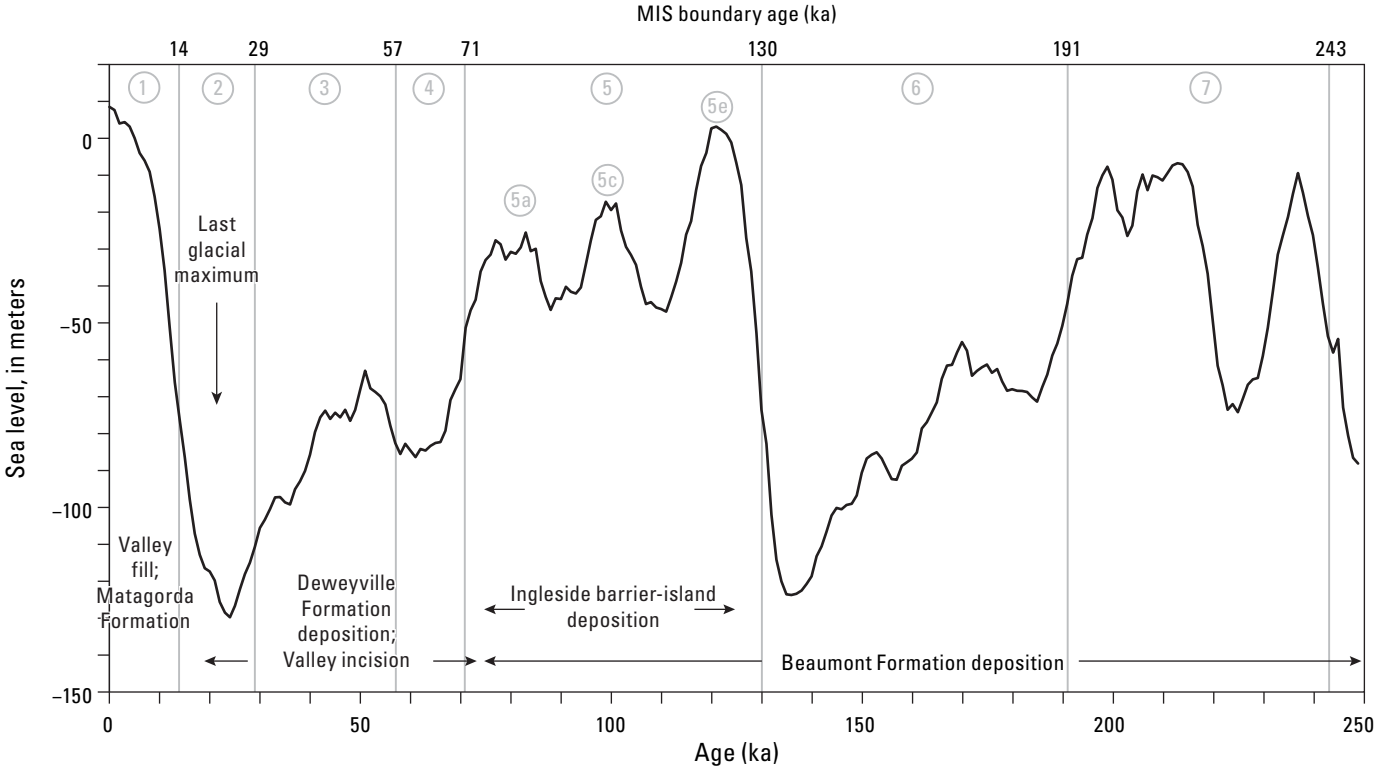


Figure 2. Approximate sea level, marine oxygen isotope stages (MIS; gray labels in upper part of figure) and ages, and timing of depositional and erosional episodes during the last 250 thousand years (ka). Sea level data from Spratt and Lisiecki (2016). MIS boundary ages from Lisiecki and Raymo (2005).

Rationale

Recent advances in achievable spatial resolution for aerial imagery (1 m or better) and airborne lidar-derived elevation models (1 m or better laterally and a few centimeters vertically) reveal distinct stratal units that have characteristic and consistent elevation ranges, image signatures, lithologic properties, and topographic patterns that are mappable at 1:24,000 scale. Previous geologic maps of the Texas coast, including the 1:250,000-scale Geologic Atlas of Texas series, were compiled from earlier maps and 1:24,000-scale aerial imagery acquired in the 1950s. These earlier maps combine Holocene strata into a single Quaternary alluvium unit (unit Qal), except for separately mapped beach and barrier-flat units (fig. 3*A*). Newer imagery and high-resolution surface elevation models permit many facies to be identified within units that were formerly undifferentiated in the Quaternary alluvium unit (unit Qal). These deposits are Quaternary in age, but they occupy only the most recent Quaternary epoch (Holocene) and can be readily distinguished from older Quaternary coastal-plain units by their unconsolidated nature, association with observed Holocene depositional environments, weak soil development, and stratigraphic position above an unconformity between Pleistocene and Holocene strata, which is marked by a mature soil developed on semiconsolidated Pleistocene strata and is accompanied by a significant increase in material stiffness documented in numerous borings and cores.

Formation and Member Names and Type Area

We propose to name the new Holocene stratigraphic unit the Matagorda Formation (map unit symbol Qm), named after Matagorda Bay along the central Texas coast. This bay occupies an incised valley that was downcut during marine isotope stages (MIS) 4 through 2 (at about 71 to 14 thousand years ago [ka]; Lisiecki and Raymo, 2005) and flooded during the final stages of MIS 2 and the early part of the MIS 1 transgression that followed the sea-level lowstand of the last glacial maximum

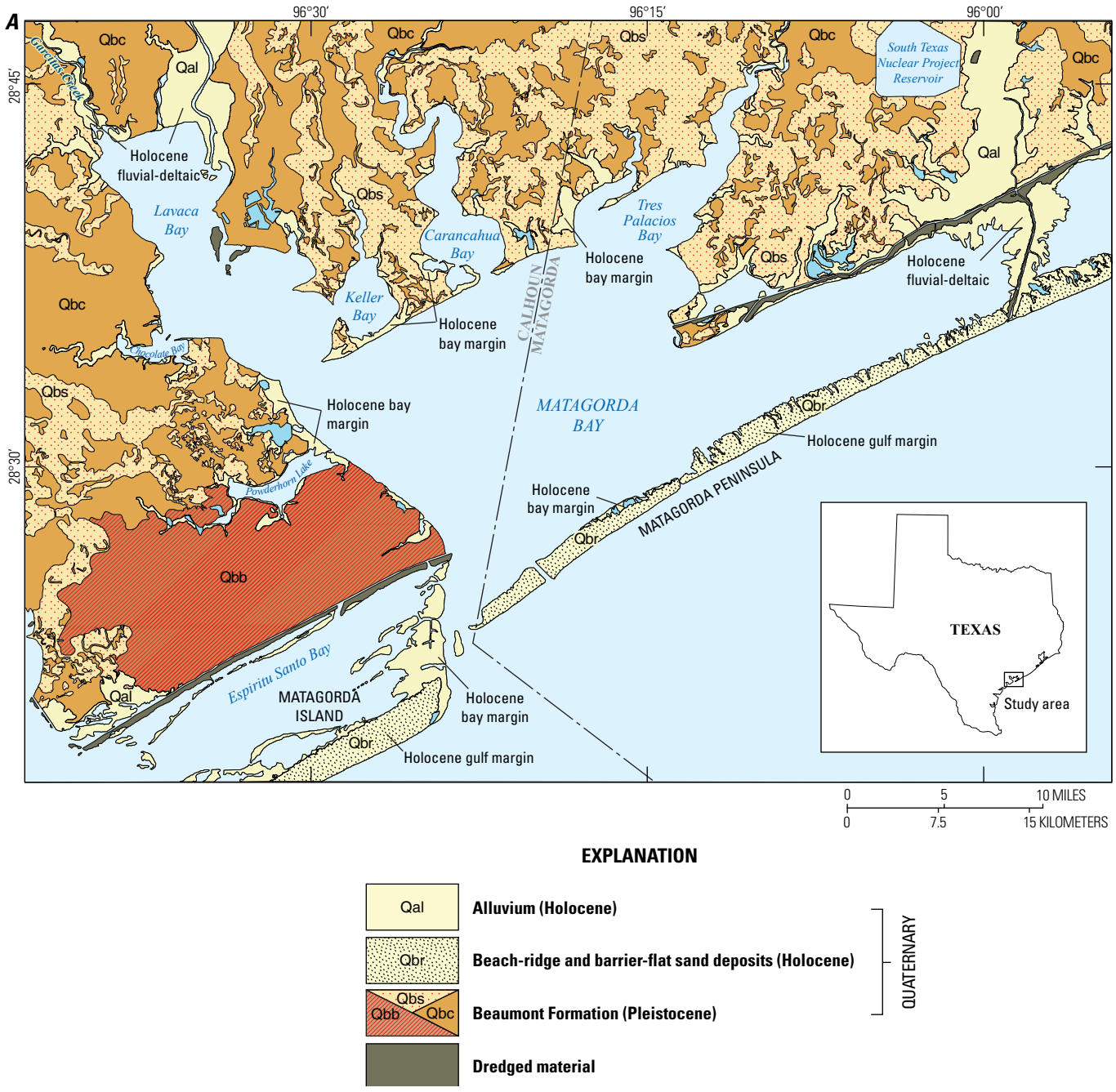
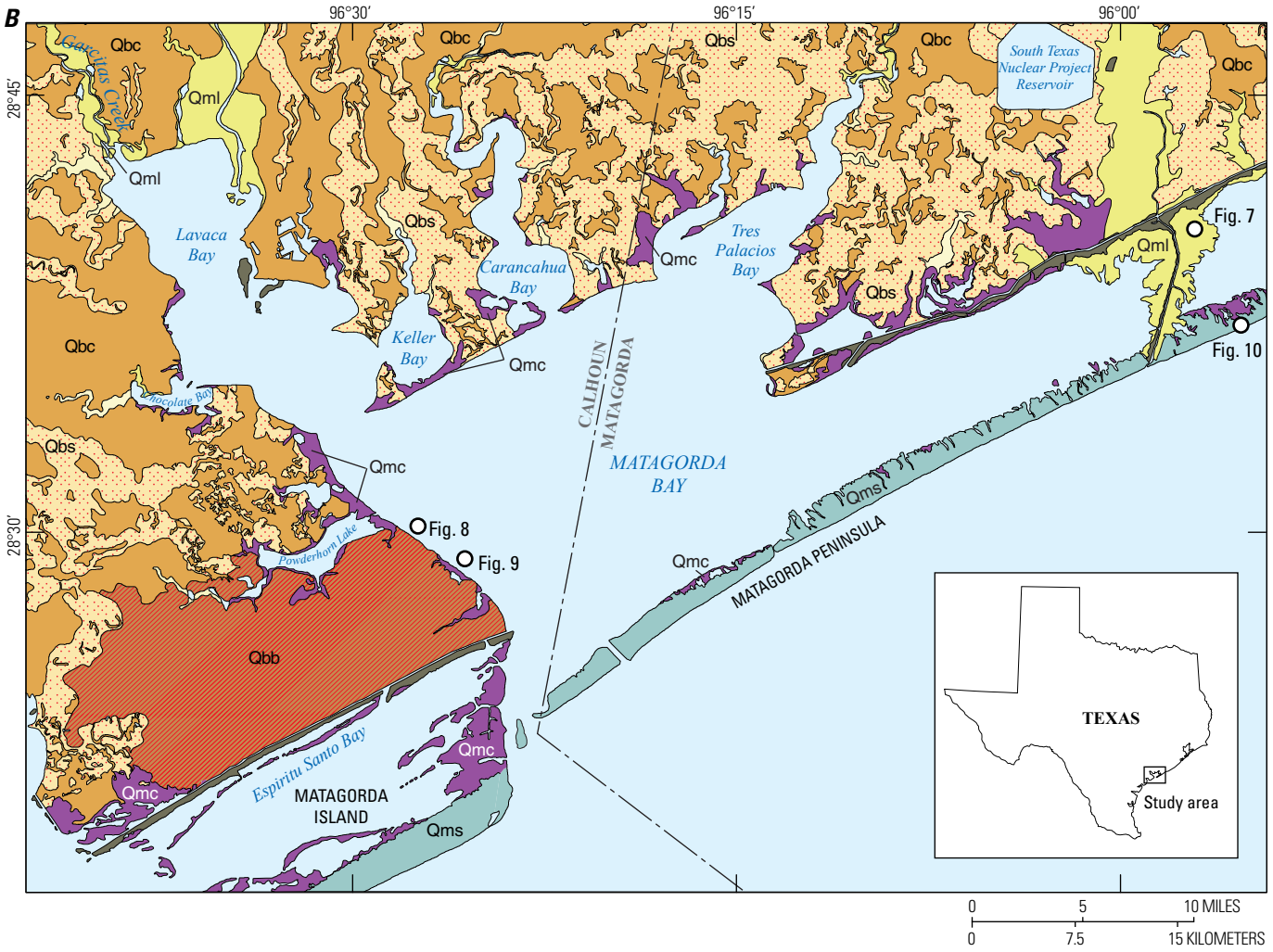


Figure 3. Comparison of geologic maps of the Matagorda Bay type section area (fig. 1) as mapped (*A*) on the Beeville–Bay City sheet of the 1:250,000-scale Geologic Atlas of Texas (Brown and others, 1975b) and (*B*) using the Matagorda Formation (unit Qm) nomenclature. Also shown are representative locations of areas mapped on the Beeville–Bay City sheet as Quaternary alluvium (unit Qal) or beach-ridge and barrier-flat sand deposits (unit Qbr) that are now proposed as Matagorda Formation, including fluvial-deltaic facies of the Lavaca Member (unit Qml), bay-margin facies of the Carancahua Member (unit Qmc), and Gulf-margin paralic facies of the Saluria Member (unit Qms).



EXPLANATION

Qml	**Matagorda Formation, Lavaca Member (Holocene)**—Fluvial-deltaic deposits
Qmc	**Matagorda Formation, Carancahua Member (Holocene)**—Bay-margin deposits
Qms	**Matagorda Formation, Saluria Member (Holocene)**—Gulf-margin deposits
Qal	**Alluvium (Holocene or Pleistocene)**
Qbs / Qbb / Qbc	**Beaumont Formation (Pleistocene)**
	Dredged material
○	**Photograph location**—Labeled with report figure number

QUATERNARY

Figure 3.—Continued

(fig. 2) from about 26.5 to 19 ka (Yokoyama and others, 2000, 2001; Mix and others, 2001; Peltier and Fairbanks, 2006; Carlson and others, 2008; Clark and others, 2009). Matagorda Bay is surrounded, and its underlying incised valley partly filled, by deposits associated with fluvial-deltaic, bay and bay-margin, and gulf-margin paralic facies that comprise the Holocene coastal sedimentary record in Texas (fig. 3*A*).

The type area of the Matagorda Formation is the geographic extent of the Matagorda Bay depositional system where the majority of the recent STATEMAP mapping has been completed, including Matagorda Bay and its subsidiaries Lavaca Bay, Keller Bay, Carancahua Bay, and Tres Palacios Bay (fig. 3*B*). The applicability of the formation extends beyond the Matagorda Bay area to similar deposits of similar age along the entire Texas coast (fig. 1). The informal facies that constitute the formation vary and may need to be augmented or modified for each geographic area. The general mapping criteria to identify facies and facies groups within the Matagorda Formation can apply to other low-relief, siliciclastic coastal margins worldwide.

Further partial subdivision of the Matagorda Formation into members is useful in portraying the relationships among, and evolution of, Matagorda Formation depositional environments. Facies associated with fluvial-deltaic environments are included in the Lavaca Member (map unit symbol Qml), named for deposits along the Lavaca River that flows into Lavaca Bay (fig. 3*B*). The Carancahua Member (map unit symbol Qmc), named after Carancahua Bay on the northwestern margin of Matagorda Bay, comprises bay and bay-margin facies. The Saluria Member (map unit symbol Qms), named after the historic townsite near the lighthouse on the eastern end of Matagorda Island, comprises gulf-margin paralic facies. Individual facies within the Matagorda Formation and its members are informal, vary laterally along the coastline, and are intended to be adaptable as mapping proceeds to areas unmapped at the current mapping scale (1:24,000). Many of the facies grade laterally and vertically into other facies within the same member or another member, but a composite unconformity forms the boundary with underlying Pleistocene strata.

Age, Boundaries, Thickness, and Lithology

The Matagorda Formation postdates the last glacial maximum centered at about 21 ka (fig. 2) and is dominantly Holocene. Most of the land areas mapped as Matagorda Formation are younger than about 4 ka when sea level was within a few meters of its present level following the end of the MIS 2 glacial maximum (Shepard, 1960; Nelson and Bray, 1970; Frazier, 1974; Milliken and others, 2008; Livsey and Simms, 2013; Anderson and others, 2022) and the rapid, punctuated rise in sea level during the transgression that followed the last glacial maximum (Anderson and others, 2022). Static or slowly rising relative sea level (the combined effect of sea level change and land subsidence) in the northwestern Gulf of America during the last few thousand years permitted the formation of subaerial depositional features such as barrier islands and peninsulas, flood-tidal deltas, storm washover fans, bay-margin beaches and spits, bayhead deltas, and coastal marshes and allowed them to persist to the present as active or abandoned systems.

At the margin of the bays, the base of the formation is defined as the unconformity at the top of the Pleistocene (fig. 4). This boundary is marked by a mature oxidized paleosol on Pleistocene Beaumont Formation strata that may be partly or wholly truncated by late Pleistocene to early Holocene stream and river valley incision. In areas submerged under bay waters, valleys incised into the Beaumont Formation are partly filled with fluvial-deltaic, bay, and marine-influenced strata. In many bays, bayhead delta deposits dated at about 10 ka and younger mark the entrance of Gulf of America waters into the incised valleys (Anderson and others, 2022). These deposits overlie, or are adjacent to (fig. 4), upper Pleistocene Deweyville Formation-equivalent fluvial strata (Bernard, 1950; Brown and others, 1975b; Blum and others, 1995; Blum and Price, 1998) that were deposited in times of generally lower sea level (fig. 2) during MIS 4 and 3 when sea level was 30 to 80 m below modern levels, and MIS 2, when sea level reached 120 m or more below modern levels (Lambeck and Chappell, 2001; Spratt and Lisiecki, 2016). These uppermost Pleistocene deposits in turn overlie the Pleistocene Beaumont Formation erosional unconformity.

The upper boundary of the Matagorda Formation is the modern ground surface on land and the base of the water column in the bays, tidal channels, and streams. Hence, the Matagorda Formation is being actively deposited and eroded.

Thickness of the Matagorda Formation ranges from less than 1 m to a few tens of meters. It is thinnest on top of mature soils developed on Pleistocene Beaumont Formation uplands at elevations as high as a few meters above sea level. It is thickest within the valleys incised into Pleistocene strata where Matagorda Formation deposits overlie the eroded Pleistocene surface or latest Pleistocene to early Holocene fluvial deposits. Deposits can be a single facies or vertical successions of facies that reflect migration of depositional environments as the incised valleys were transgressed by rising seas, barrier islands formed, bays were established, and bayhead deltas retreated or prograded into the upper parts of many bays. Bridge foundation borings (fig. 5) and cores into strata underlying Texas bays clearly indicate the boundary between stiff, semiconsolidated sandy muds and muddy sands with pedogenic overprints (representing the eroded surface of the Beaumont Formation) and the overlying unconsolidated sands, muddy sands, sandy muds, and muds that dominate the Holocene valley-fill deposits (Shepard and Moore, 1960; Wright, 1980; Paine, 1991; Morton and others, 1996; Anderson and others, 2022). Estimated maximum valley incision depths beneath major Texas bays, relative to current sea level, are about 24 to 43 m for Matagorda Bay, 24 to 29 m for Baffin Bay, about 30 to 42 m for Nueces and Corpus Christi bays, 31 m for Copano and Aransas

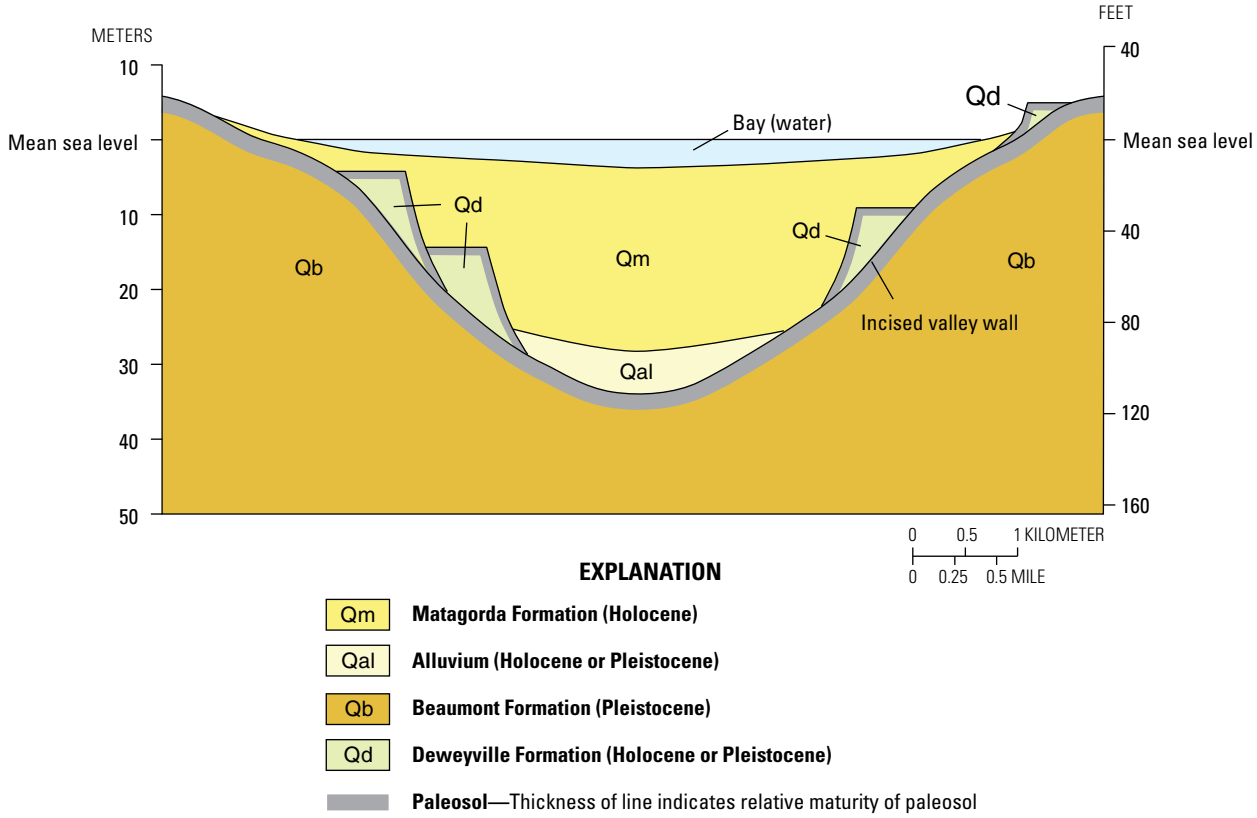


Figure 4. Schematic cross section across a Texas bay showing the effects of late Quaternary depositional and erosional episodes. The basal Beaumont Formation (unit symbol Qb) was incised during marine isotope stages 4, 3, and 2 (fig. 2). Depending on the location in the incised valley, the Beaumont Formation is overlain unconformably by (1) fluvial sediments that are interpreted to be equivalent to the Deweyville Formation (unit symbol Qd) deposited within the incised valley during downcutting, (2) undifferentiated fluvial sediments (unit symbol Qal) that were deposited at the base of the incised valley during the late Pleistocene or early Holocene before sea level reached the valley, or (3) Matagorda Formation (unit symbol Qm) coastal sediments that were deposited in fluvial-deltaic, bay and bay-margin, and Gulf-margin environments once sea level reached the incised valley. The contact between the Matagorda Formation and valley-floor fluvial deposits (unit symbol Qal) may be gradational.

bays, 23 to 27 m for San Antonio Bay, and 35 to 50 m for the Galveston Bay system (Fagg, 1957; Shepard and Moore, 1960; Behrens, 1963; Rehkemper, 1969a, b; Byrne, 1975; Wright, 1980; Smyth and others, 1988; Paine, 1991; Maddox and others, 2008; Simms and others, 2008; Simms and others, 2010; Anderson and others, 2022).

Previous Mapping

The Geologic Atlas of Texas is a series of thirty-eight 1×2 degree sheets that cover the entire state of Texas at a 1:250,000 scale. Two of these, the Beeville–Bay City (Brown and others, 1975b) and Houston (Aronow and others, 1982) sheets, cover the areas of new 1:24,000-scale mapping on the Texas coastal plain. Two others, the Corpus Christi (Brown and others, 1975a) and the McAllen–Brownsville (Brown and others, 1976b) sheets, cover most of the remaining areas of extensive Holocene deposition on the Texas coastal plain. These maps served as a starting point for new geologic mapping on the Texas coast. Holocene coastal deposits are lumped into Quaternary alluvium (unit Qal) and beach-ridge and barrier-flat deposits (unit Qbr) on the Beeville–Bay City sheet, and Quaternary alluvium (unit Qal) and barrier-island deposits (unit Qbi) on the Houston sheet. The Qal unit on these maps also includes Pleistocene alluvium, particularly in areas of the map that lie along streams upstream from the bay margins. The Holocene deposits lumped into Qal, Qbr, and Qbi units on these maps are being subdivided into the members and facies of the Matagorda Formation.

The Environmental Geologic Atlas of the Texas Coastal Zone series consists of seven volumes that cover the entire Texas coastal zone at the 1:125,000 scale. These efforts took a genetic approach to mapping coastal deposits that emphasized depositional environments based on interpretation of 1950s black-and-white aerial photomosaics, topographic maps, soil survey maps, and field investigations. Maps covering the area of new geologic mapping include the Galveston–Houston area (Fisher and others, 1972),

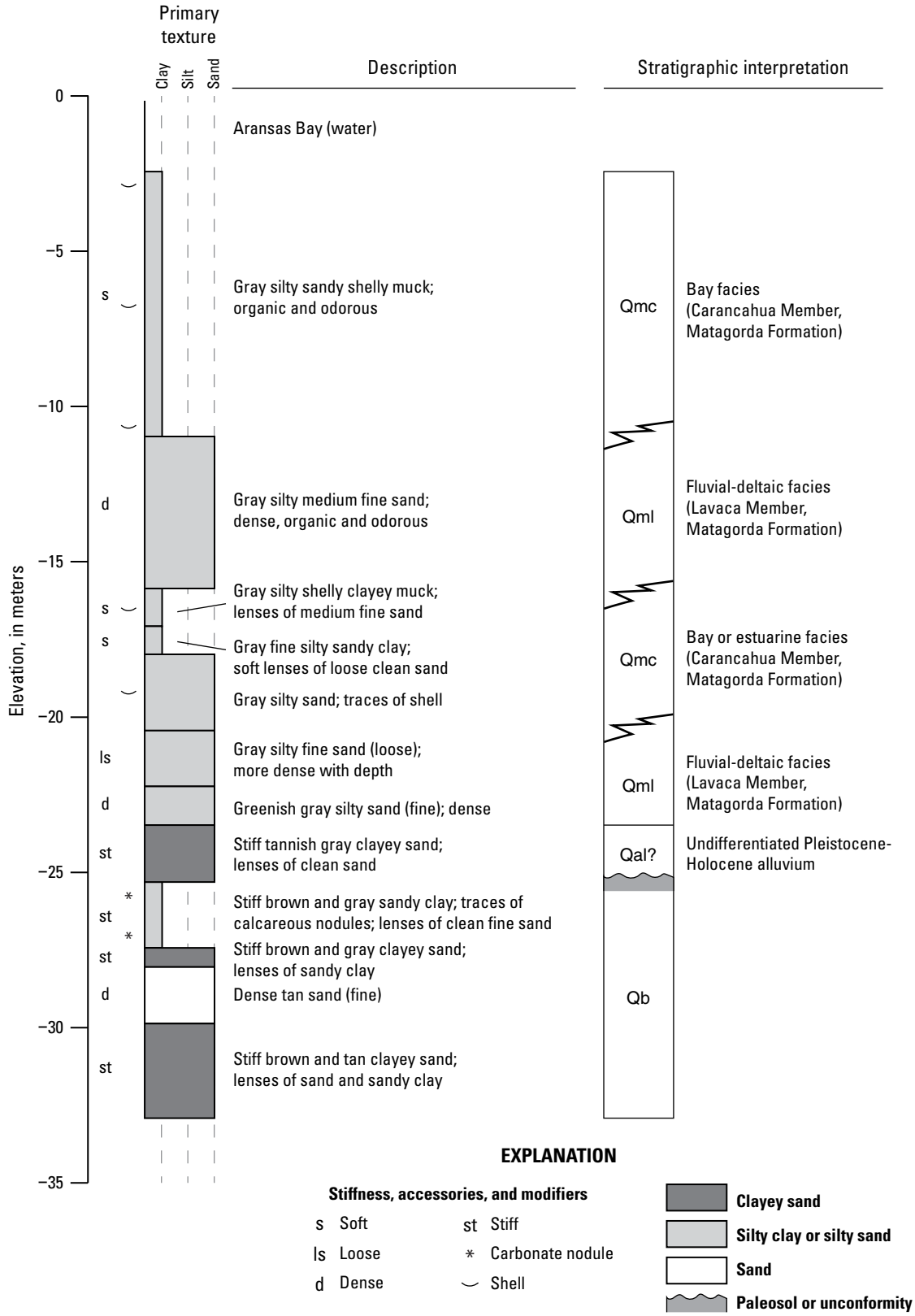


Figure 5. Representative stratigraphic section of the Matagorda Formation constructed from geotechnical boring descriptions of test hole no. 17 beneath Copano Bay along the Lyndon B. Johnson Causeway, Aransas County, Texas (fig. 1). The Matagorda Formation records the Holocene transgression through a sequence of laterally migrating fluvial-deltaic deposits of the Lavaca Member and bay or estuarine deposits of the Carancahua Member. Boring data from the archives of the Bridge Division of the Texas Department of Transportation, Austin, Texas. This and other similar boring descriptions are included in Paine (1991).

the Corpus Christi area (Brown and others, 1976a), the Bay City–Freeport area (McGowen and others, 1976a), and the Port Lavaca area (McGowen and others, 1976b). Environmental geologic map units were divided into Pleistocene and Holocene systems. Pleistocene units were subdivided into a dozen or more fluvial-deltaic depositional units and several barrier-strandplain units. Holocene systems included dozens of depositional units within fluvial-deltaic, barrier-strandplain, marsh-swamp, and bay-estuary-lagoon settings. Some geologic environments were mapped in more than one depositional system and both Pleistocene and Holocene time periods. The approach we are following in designating and describing the Matagorda Formation is a hybrid of the two approaches. We use the depositional environment approach of the Environmental Geologic Atlas maps to enhance the chronologic, stratigraphic, and lithologic value of the Geologic Atlas of Texas maps at greatly improved spatial resolution and locational accuracy.

Members, Facies, and Symbology

The Matagorda Formation (unit Qm) is intended to comprise all coastal (sea-level influenced) facies deposited during the Holocene sea-level transgression and highstand (fig. 6). The Matagorda Formation is partly subdivided into the Lavaca Member (unit Qml) that includes fluvial-deltaic facies, the Carancahua Member (unit Qmc) that includes bay and bay-margin facies, and the Saluria Member (unit Qms) that includes Gulf-margin paralic facies. Where further subdivision into individual facies is needed, our approach is to follow the member unit symbol (fig. 6) with a hyphen and a suffix of one or more letters denoting the facies being mapped (tables 1, 2, and 3). Example facies within the Lavaca Member (unit Qml; table 1) include flood plain, delta plain (fig. 7), point bar, levee, channel fill, crevasse splay, and fan or fan-delta deposits. Examples of facies within the Carancahua Member (unit Qmc; table 2) include beach or berm (figs. 8 and 9), marsh (fig. 9), washover (fig. 9), spit, tidal flat, tidal delta, and reef deposits. Examples of facies within the Saluria Member (unit Qms; table 3) include beach (fig. 10), dune (fig. 10), barrier flat (fig. 10), washover, and beach ridge and swale deposits. Unit symbols are used herein to differentiate the facies within Matagorda Formation as well as constituent members of these formations in the text, figures, and tables. Only a few Matagorda Formation facies are illustrated in the field examples (figs. 7, 8, 9, and 10).

Each facies is mapped using stratal characteristics evident from high-resolution imagery, topographic expression, and field relationships. All deposits are unconsolidated to a greater or lesser degree, are composed of fractions of sand, silt, clay, and

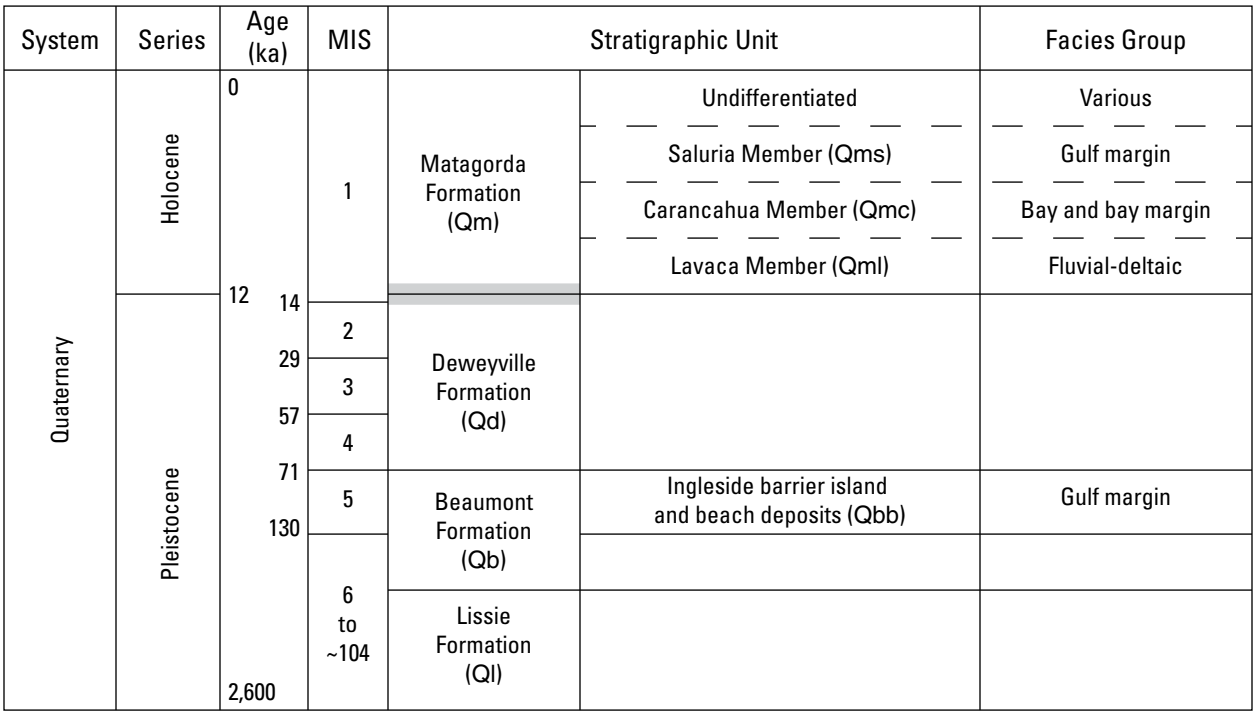


Figure 6. Stratigraphic chart showing the position of the Matagorda Formation relative to the older Lissie, Beaumont, and Deweyville Formations and marine oxygen isotope stages (MIS). MIS ages from Lisiecki and Raymo (2005). Ages in thousands of years (ka). Multiple interfingering facies populate the Lavaca, Carancahua, and Saluria Members of the Matagorda Formation (tables 1, 2, and 3, respectively). Other possible coastal Holocene facies, including clay dunes and eolian sand or silt sheets, are not shown as separate members owing to limited numbers of component facies, but are included in the Matagorda Formation as undifferentiated. The upper boundary of the Deweyville Formation and equivalent deposits may extend into the Holocene (gray line).

Table 1. Examples of informal fluvial-deltaic facies within the Lavaca Member (unit symbol Qml) of the Matagorda Formation.

[Lateral and vertical contacts between facies may be sharp or gradational.]

Unit symbol	Facies	Description
Qml-c	Channel and channel fill	Unconsolidated sand and mud filling fluvial channels.
Qml-cb	Channel bar	Unconsolidated sand deposited as bedload apron on levee and floodplain deposits during major floods, commonly on the downstream side of low-flow-stage meandering channels.
Qml-l	Levee	Unconsolidated sand and mud in low, narrow areas subparallel and adjacent to active and abandoned stream channels.
Qml-cl	Channel and levee, undivided	Unconsolidated sand and mud deposited in stream or river channel or levee.
Qml-pb	Point bar	Unconsolidated sand, silt, and clay deposited at the inside bank of sinuous, laterally migrating channel.
Qml-cs	Crevasse splay	Unconsolidated sand and mud deposited in fans adjacent to stream channels and levees.
Qml-lc	Levee and crevasse splay, undivided	Unconsolidated sand and mud deposited in levee and crevasse-splay setting.
Qml-fp	Flood plain	Unconsolidated mud and sand deposited on a low-relief valley floor during floods. Includes some minor levees, crevasse splays, and active and abandoned stream channels. Coastal prairie or wetland vegetation.
Qml-fd	Fan or fan delta	Unconsolidated sand and mud deposited in small, lobate deltas by streams flowing into bays and lakes. Coastal prairie, woodland, and brackish- to fresh-water marsh vegetation.
Qml-dp	Delta plain	Unconsolidated mud and sand deposited in bay-margin delta. May include some minor fluvial levees, crevasse splays, tidal-channel levees, and active and abandoned stream and tidal channels. Brackish- or fresh-water marsh vegetation.

Table 2. Examples of informal bay or bay-margin facies within the Carancahua Member (unit symbol Qmc) of the Matagorda Formation.

[Lateral and vertical contacts between facies may be sharp or gradational.]

Unit symbol	Facies	Description
Qmc-b	Beach or berm	Unconsolidated sand, shell, and mud deposited along bay shoreline from wave action. Beach is unvegetated; berm may be sparsely vegetated.
Qmc-ba	Beach or berm; abandoned	Unconsolidated sand, shell, and mud deposited in low berm along former bay shorelines from wave action. Commonly vegetated.
Qmc-m	Marsh	Unconsolidated mud and sand deposited in low-relief areas adjacent to bay shoreline. Common tidal channels. Salt- or brackish-water marsh vegetation.
Qmc-w	Washover	Unconsolidated sand and shell deposited adjacent to bay shoreline by high water level and wave activity during tropical cyclone passage. Commonly unvegetated.
Qmc-sp	Spit	Unconsolidated sand, shell, and mud deposited across bay and valley mouths from erosion of adjacent shoreline and lateral sediment migration.
Qmc-rf	Reef	Shelly (oyster) subaqueous framework covered with loose shell, sand, and mud modified by wave action.
Qmc-tf	Tidal flat	Unconsolidated sand and mud deposited in areas periodically inundated by astronomical tides or wind-driven water at the margins of bays or tributary valleys. May include barren or vegetated areas and algal mats.
Qmc-td	Tidal delta	Emergent, unconsolidated sand and mud deposited landward of the bay shoreline at a tidal pass. Common salt- or brackish-water marsh vegetation.

Table 3. Examples of informal Gulf-margin paralic facies within the Saluria Member (unit symbol Qms) of the Matagorda Formation.

[Lateral and vertical contacts between facies may be sharp or gradational.]

Unit symbol	Facies	Description
Qms-b	Beach	Unconsolidated sand deposited in forebeach or backbeach environment. Forebeach is unvegetated. Backbeach may have sparse vegetation.
Qms-d	Dune	Unconsolidated sand deposited by wind adjacent to the beach. Includes foredunes and former foredunes. May be active or stabilized by vegetation.
Qms-r	Ridge	Unconsolidated sand deposited in generally coast-parallel topographic high landward of the dune system showing barrier-island progradation. Common coastal prairie vegetation.
Qms-s	Swale	Unconsolidated sand and mud deposited in generally coast-parallel topographic troughs. Common fresh- to brackish-water marsh vegetation.
Qms-rs	Ridge and swale, undivided	Barrier island, peninsula, or strandplain ridge and swale deposits. Common coastal prairie vegetation on ridges and fresh- or brackish-water marsh vegetation in swales.
Qms-m	Marsh	Unconsolidated mud and sand deposited in low-relief marsh areas adjacent to the Gulf shoreline. Salt- or brackish-water marsh vegetation.
Qms-bf	Barrier flat	Unconsolidated sand deposited in low-relief barrier-island environment landward of the beach and dune system. May include washover deposits.
Qms-w	Washover	Unconsolidated sand and shell deposited in sheets, fans, or bars landward of the beach by high water level and wave activity during tropical cyclone passage. May be barren or vegetated.
Qms-wc	Washover channel	Unconsolidated sand, shell, and mud deposited in washover channels active during high water level associated with tropical cyclone passage. May be barren or vegetated.

Figure 7. Delta-plain facies (unit symbol Qml-dp; table 1) of the Lavaca Member of the Matagorda Formation. Location is on the Colorado River delta (fig. 3*B*). Photograph by J. Paine, Bureau of Economic Geology, The University of Texas at Austin.

Figure 8. Mature paleosol marking an unconformity on the Pleistocene Ingleside barrier-island unit (unit symbol Qbb) of the Beaumont Formation. Matagorda Formation facies include an eolian sand-silt sheet (unit symbol Qm-ss) directly on the unconformity and beach deposits of the Carancahua Member (unit symbol Qmc-b; table 2). Location is on the southern shore of Matagorda Bay (fig. 3*B*). Photograph by J. Paine, Bureau of Economic Geology, The University of Texas at Austin.

Figure 9. Examples of bay-margin facies of the Carancahua Member of the Matagorda Formation, including bay beach (unit symbol Qmc-b; table 2), washover (unit symbol Qmc-w; table 2), and marsh (unit symbol Qmc-m; table 2) deposits. Location is on the southern shore of Matagorda Bay (fig. 3*B*). Photograph by J. Paine, Bureau of Economic Geology, The University of Texas at Austin.

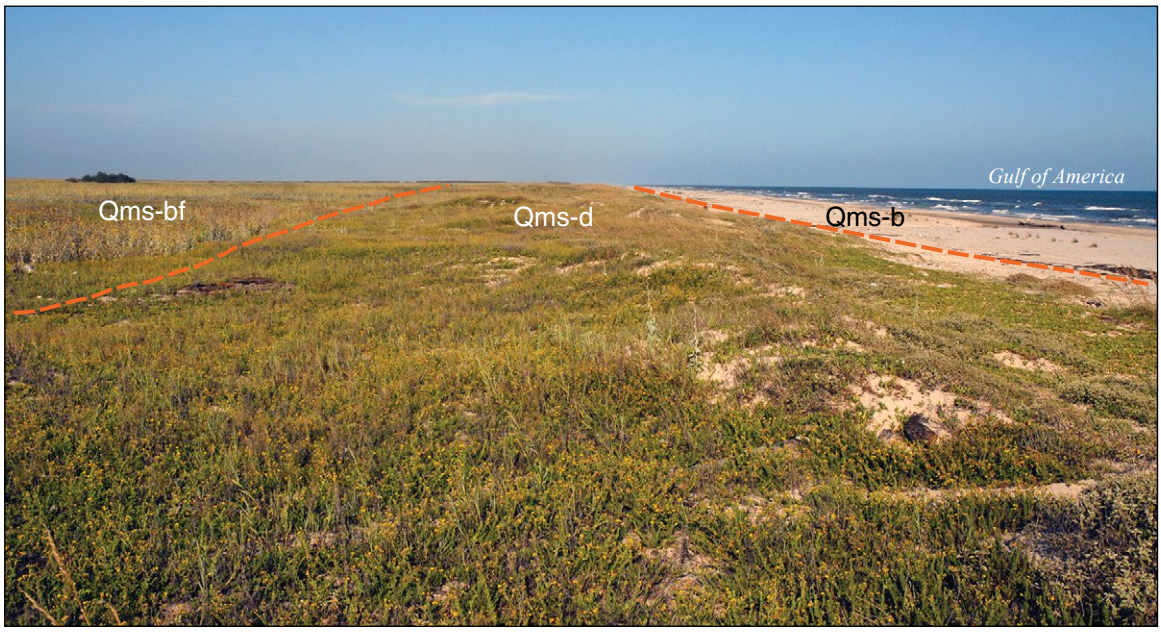


Figure 10. Examples of gulf-margin paralic facies of the Saluria Member of the Matagorda Formation, including beach (unit symbol Qms-b; table 3), foredune (unit symbol Qms-d; table 3), and barrier flat (unit symbol Qms-bf; table 3) deposits. Location is on Matagorda Peninsula (fig. 3*B*). Photograph by J. Paine, Bureau of Economic Geology, The University of Texas at Austin.

organic matter that vary depending on the facies, and have weak to moderate pedogenic development consistent with middle to late Holocene age. Additional facies belonging to the Matagorda Formation that do not fall within the named members may be needed locally to map contemporaneous coastal strata, including eolian facies associated with clay dunes (Price, 1963) and eolian sand or silt sheets (unit Qm-ss; fig. 8) that blanket Pleistocene and Holocene strata on the middle and lower coastal plain.

Conclusions

We propose a new Matagorda Formation (unit symbol Qm) and component members for use in Texas comprising unconsolidated Holocene coastal deposits. A similar stratigraphic unit derived from the results of this work could be useful for low-relief coastal settings with siliciclastic deposits worldwide. The Matagorda Formation is partly subdivided into three members that each contain groups of facies deposited in fluvial-deltaic (Lavaca Member, unit Qml), bay and bay-margin (Carancahua Member, unit Qmc), and gulf-margin paralic environments (Saluria Member, unit Qms). The lower boundary of the Matagorda Formation is a composite unconformity at the top of the semiconsolidated Pleistocene Beaumont Formation that coincides with the top of a well-developed paleosol in upland areas and a truncated paleosol within valleys incised by rivers and streams during the last glacial period (approximately marine isotope stages 4 to 2). Within these incised valleys, deposits of the Matagorda Formation may overlie fluvial sediments (including those broadly equivalent to the Deweyville Formation) deposited during the late Pleistocene to early Holocene when sea level was lower than present. The upper boundary of the Matagorda Formation is the modern depositional or erosional land surface or the base of the water column beneath streams, tidal channels, bays, and lagoons. The thickness of the Matagorda Formation ranges from less than 1 meter on upland surfaces and along the bay margins to tens of meters within the incised valleys beneath the bays. With the proposed usage of the Matagorda Formation as a repository for Holocene coastal strata, we recommend that Quaternary alluvium (unit Qal) usage on the Texas coastal plain be limited to undifferentiated noncoastal alluvium upstream from the coastal-influenced strata or at the base of the incised valley fill, recognizing that these sediments may be of Pleistocene or Holocene age and not directly influenced by sea level.

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