

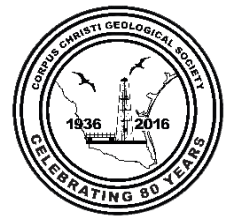
# GEOLOGY AND PALEONTOLOGY OF THE LOWER NUECES RIVER VALLEY

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A September 17 Field Trip for the  
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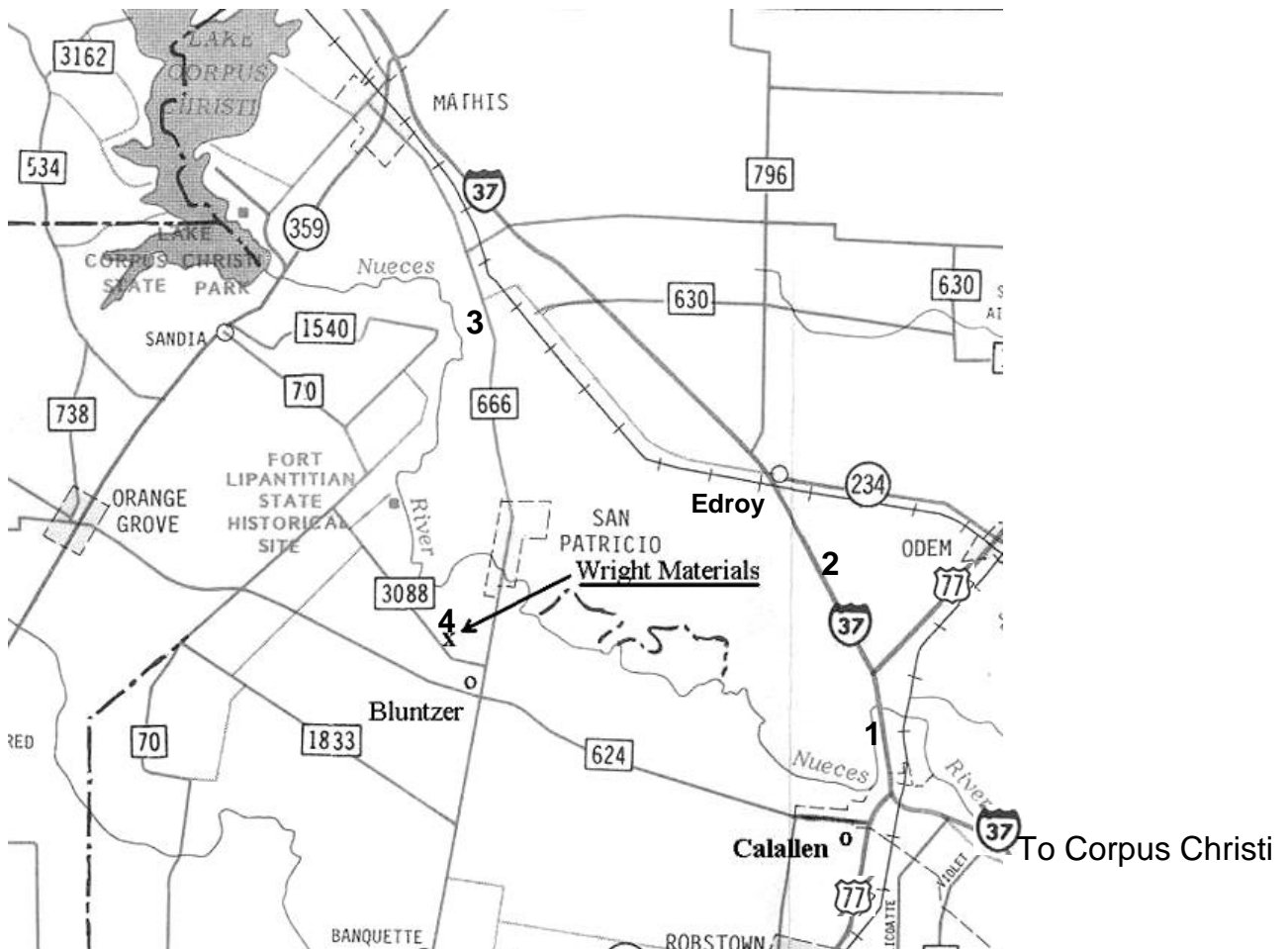


Figure 1b. Detailed map of field trip area showing stops.

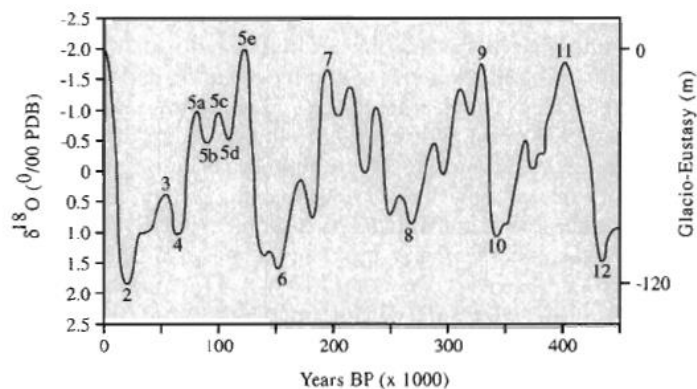
## INTRODUCTION

This field trip will examine the geologic and paleontological history of the Nueces River Valley in South Texas. The Nueces River valley and its sediments were formed at the end of the latest period of geologic history, the Quaternary. The Quaternary Period is subdivided into the Pleistocene and Holocene. The Pleistocene or "Ice Age" includes the events from 2.6 million to about 10,000 years ago. The Holocene (or Recent) includes the past 10,000 years. Vertebrate paleontologists designate the late Pleistocene in North America as the Rancholabrean Land Mammal Age (240,000-10,000 years ago). During the Pleistocene, major episodes of continental glaciation occurred at 100,000 year intervals. The last 120,000 years of the Pleistocene are the Sangamonian interglacial and Wisconsinan glacial ages. Wisconsinan glaciers reached their maximum extent 18,000 years ago, a time when continental glaciers extended to central Illinois, Indiana, and Ohio. Although glacial ice was several 1000 kilometers north, the advances and retreats of glaciers during the latest Pleistocene had dramatic effects on the biota, climate, and geomorphology of South Texas. The Nueces River carved out its present valley, which is over 30 meters deep and 10 kilometers wide, in this time period. Interglacial and Glacial periods were not times of uniformly rising and falling sea level, with uniform deposition and erosion respectively. Stadials and interstadials represent minor times of cooling and warming that are associated with Marine Isotope Stages (MIS). During stadials there was erosion of river valleys; during interstadials, there were minor rises in sea level and the rivers filled in their valleys with terrace deposits. [Blum and Aslan](#) (2006) present a more detailed explanation of these processes.

The Beaumont Formation, which underlies the coastal region of Texas was deposited approximately 120,000 to perhaps 50,000 years ago, during the Sangamonian Interglacial (MIS 5). Sea level rose to its highest level in the past several hundred thousand years and river and coastal deposition occurred along the Gulf Coast.

During the Sangamonian and Wisconsinan interstadials (Oxygen Isotope Stages 3, 5a, 5c), the five alluvial units that fill the Nueces River Valley formed at progressively lower elevations. These incised terrace and valley fill deposits range in age from perhaps 50,000 to 12,000 years ago ([Cornish and Baskin](#), 1995). They are capped by Holocene stream deposits of the Recent flood plain.

During the Wisconsinan, sea level fell, to as much as 120 meters 18,000 years ago, and exposed the continental shelf. Rivers carved out their valleys and carried sediment to the shoreline which was at the edge of the continental shelf. Mammoth, mastodon, and bison bones and teeth have been recovered from the Seven and One-half Fathom reef in the Gulf of Mexico off of Padre Island ([Thayer and others](#), 1974).



# ROAD LOG

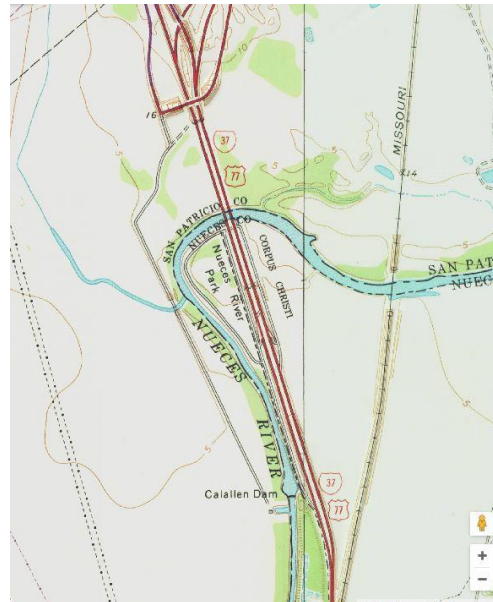
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Taken in part from: J. L. Russell and J. A. Baskin. 1981. Road Log - Day 2, p. 35-38, In Modern depositional environments of sands in South Texas. Corpus Christi Geological Society, Field Trip for 1981 Meeting of Gulf Coast Association of Geological Societies; with additions by R. Thomas.

[Figure 1b](#) is a map of Nueces County, showing the field trip stops.

Total Mileage from  
 Mileage last reading

- |   |   |
|---|---|
| <p>0.0 0.0 Junction of Shoreline Boulevard and I-37 and US-181</p> <p>1.1 1.1 Continue on I-37 toward San Antonio. Grain elevators and petrochemical industries along the Corpus Christi Ship Channel are visible to the right.</p> <p>4.8 3.7 Continue in the right-hand lanes toward San Antonio on I-37 at the junction with Padre Island Drive.</p> <p>5.1 0.3 Site of the former ASARCO Inc. zinc production facility is visible to the right. It was active from 1942 until 1985. In 1988, Encycle, an ASARCO subsidiary, converted the plant into a hazardous waste management facility. Encycle ceased operations in 2003 and shut down in 2005. There continues to be concern about lead and cadmium pollution in the soil.</p> <p>5.9 0.8 Continue on I-37 at junction with road to the International Airport.</p> <p>8.9 3.0 The Clarkwood fault, a down-the-coast growth fault that is still active, crosses the highway.</p> <p>11.0 2.1 Possible STOP. McKinzie Road exit to the <a href="#">Owen R. Hopkins Public Library</a> (3202 McKinzie Rd). Mammoth front leg and 3 meter long tusk and other fossils from the Wright sand and gravel pits are on exhibit.</p> <p>13.4 2.5 Good view of the Nueces River Delta to the right. The river is near the southern edge of the valley. The Nueces River eroded its valley into the Beaumont (Pleistocene) deltaic plain. Alluvial terrace deposits are commonly present on the margin of the valley.</p> | <p>15.5 2.0 JCT I-37 and US-77, continue on I-37 towards San Antonio</p> <p>17.4 1.9 Exit Right on Exit 16 to Labonte Park continue on the frontage road turn around.</p> |
|---|---|

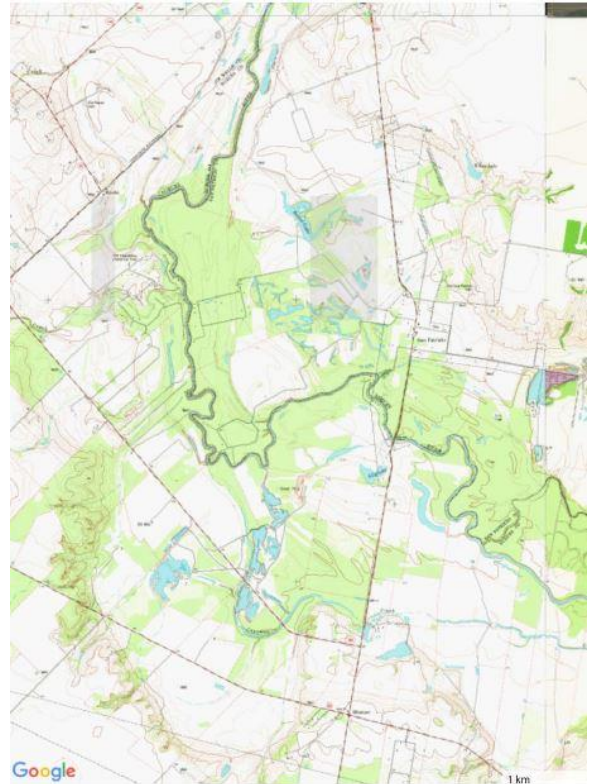


- 18.1 0.7 STOP 1. Labonte Park, Nueces County. Named in honor of NASCAR race drivers [Terry](#) and [Bobby](#) Labonte. Restrooms are available. View of the present day Lower Nueces River Valley. A low water dam prevents salt water encroachment from Nueces Bay moving upstream to the pumping station that supplies some of the drinking water for Robstown and Corpus Christi.
- 18.4 0.3 Turn right (south) on frontage road at Labonte Park offices.
- 19.4 1.0 Turn left on U turn loop under I-37.

- 20.0 0.6 Access road to I-37 North to San Antonio
- 23.6 3.6 Exit to I-37 Parking Area
- 23.8 0.2 STOP 2. Lower Nueces River Valley near its confluence with Nueces Bay. View of the present day floodplain, meander belts, terraces, and other features.
- 24.0 0.2 Access I-37 North toward San Antonio.
- 26.2 2.2 Exit Right at Exit 22, Edroy exit.
- 26.8 0.6 Turn left on County Road 50 (234).
- 27.2 0.4 Four way stop sign at Edroy, Texas, named for Ed and Roy Heuermann. Continue through Edroy on CR 50. CR 50 parallels the railroad. This portion of the trip is on the Beaumont Formation deltaic plain which represents the last major interglacial highstand.
- 34.0 Stop to observe Goliad and Lissie Fms in the distance (features 1-6 from STOP 3)
- 34.7 7.5 Railroad Crossing
- 35.4 0.7 Turn Left on FM 666(South)
- 35.7 0.3 STOP 3. Roadside stop. View of the upper portion of the Lower Nueces River Valley. CAUTION: BE CAREFUL WHILE GETTING IN AND OUT OF CARS NEXT TO THE HIGHWAY. Major features at this stop include views of
1. Mathis, Texas, to the north is at an elevation of  $\pm 150$  feet.
  2. The Goliad Formation crops out just north of Mathis. Although, frequently referred to the Pliocene, only the caliche caprock, visible in the Mathis area, is early Pliocene in age. The rest is late Miocene.
  3. The Plio-Pleistocene Lissie Formation outcrops as a surface just west of Mathis and on the western flank of the river valley at an elevation of  $\pm 135$  feet. The Lissie Formation has been interpreted as a strand-line beach sand. Regional outcrops of the Lissie Formation are prevalent to the North.
  4. The Pleistocene Beaumont Formation deltaic plain on-laps the Plio-Pleistocene Lissie and Mio-Pliocene Goliad formations in this area.
  5. 135' surface on the Lissie Formation outcrops between Mathis and Lake Mathis Dam.
  6. 95' terrace on the immediate north side of the highway.
  7. 85' terrace on the immediate south side of the

highway.

Continue south on FM 666. Traveling south on FM 666 the stair-step drops in elevation reflect progressively younger terraces until you reach the present Nueces River flood plain.



40.9 5.2 San Patricio (Historical Markers)

As you leave Old San Patricio, notice the abandoned stream channel on the left.

At least three alluvial terraces are present in the Nueces River Valley in this area. The terrace levels are approximately 15, 35, and 45 feet above the modern floodplain.

41.9 1.0 Nueces River Bridge

43.8 1.9 Wright's Rookery on the left. Snowy Egrets, Great Egrets, Cattle Egrets, Green Herons, Roseate Spoonbills, Neotropic Cormorants, and Wood Storks have nested here.

44.0 0.2 Turn Right on FM 3088

44.5 0.5 Road goes down the interior scarp of a terrace, across a meander loop of Cayamon Creek, a yazoo stream, and onto modern floodplain of the Nueces River.

45.3 0.8 STOP 4: [WRIGHT MATERIALS CO. SAND AND GRAVEL PITS](#). Stockpiles of sand and gravel are visible from the road. The material is obtained by drag-lines from pits on both sides of the road. The surface elevation of the quarries is approximately 10 meters above sea level, the level of the flood plain. The drag lines mine a total of 13 to 16 meters from the surface. A pump is used to lower the water level. The lower one to two meters of the pit are under water even during pumping.

After visiting the gravel pits turn east on FM 3088 and return to Corpus Christi.

46.6 1.3 Road goes along modern floodplain of the Nueces River, across a yazoo stream and up the interior scarp of the Bluntzer Terrace. At stop sign, turn right (south) on FM 666.

47.4 0.8 Stop at light at the old Bluntzer School. The road is now on the Corpus Christi Terrace. Turn left (east) on FM 624 toward Corpus Christi.

50.6 3.2 A small increase in elevation marks the point where the road begins traversing the late Pleistocene, Beaumont Formation deltaic plain.

56.7 6.1 STOP if time allows. Turn left into [Hazel Bazemore Park](#).



57.3 0.6 Ranger Station at Hazel Bazemore Park.

57.4 0.1 A deep gully to the left dissects alluvial terrace materials on the steep southern margin of the Nueces River Valley. A good view of the valley is present as we descend the valley wall.

57.7 0.3 Nueces River in Hazel Bazemore Park. Modern fluvial sediments deposited in channel, natural levee, and overbank environments occur in the lower Nueces River Valley at the Hazel Bazemore Park near Calallen. The Nueces River is a high suspended-load stream that is aggrading the flood plain in the park area. Although flooding occurs at least several times each year, the frequency of flooding and the quantity of sediment load available for deposition has been decreased by the construction of Wesley Scale Dam (Lake Corpus Christi) approximately 32 km (20 mi) upstream from the park. The Holocene meander belt is approximately 6.4 km (4 mi) wide and occurs in the valley that is entrenched into Holocene-late Pleistocene terrace sediments and the Pleistocene fluvial-deltaic plain (Beaumont Formation). Pleistocene terrace-sediments are well-exposed in an undercut bank of the river immediately south of the park; the exposure is near a pumping station that supplies river water to local municipalities.

Modern meander-belt sands deposited during point bar migration have accretionary features marked by variations in vegetation and minor relief. They occur east of the river and are visible from the bluffs overlooking the entrenched valley. Meander-belt sands are not present in Hazel Bazemore Park. Natural levees are well-developed marginal to the present channel. Deltaic natural-levees with poorly developed crevasse splays occur between the modern levees and flood basin marshes near the valley walls. Floodbasins and freshwater marshes contain muds that are extensively bioturbated. The natural levees and poorly developed crevasse splays contain fine sand and silt which is also commonly bioturbated causing obliteration of bedding structures.

58.7 1.0 Turn left (east) on FM 624

60.5 0.8 Intersection of FM 624 and US 77. Continue straight ahead on Up River Road.

70.0 0.5 Enter I 37 and return to Corpus Christi.

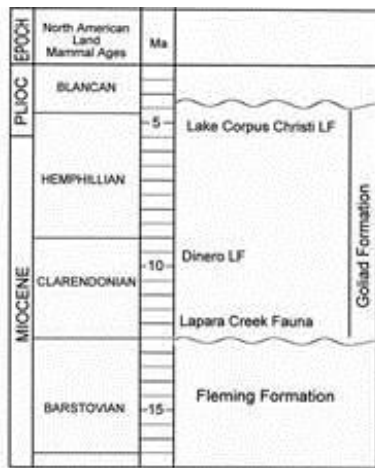
# REGIONAL GEOLOGY

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Adapted from: [Baskin \(1991\)](#), [Baskin and Hulbert \(2008\)](#)

South Texas is part of the northwestern Gulf Coast geologic province, which consists of mainly clastic, late Cretaceous and Cenozoic sediments and sedimentary rocks that dip gently coastward into the Gulf of Mexico basin. On the present-day, low-relief surface, the rocks and sediments become increasingly younger as the coast is approached. Figure 2 shows the general geology in the study area. This map is based on the Geologic Atlas of Texas (Barnes, 1975a, 1975b, 1976a, 1976b). [Aronow \(1971\)](#) presented an alternative (but similar) interpretation.



In South Texas, the fluvial Goliad Fm unconformably underlies Pleistocene deposits. It crops out in a belt 16-32 km wide and dips toward the Gulf at 2.9-3.8 m per km (Solis, 1981). Goliad sands, clays, and gravels are capped by a thick layer of caliche. In the 1950s-60s, the Lapara Creek Fauna (Quinn, 1955; [Wilson, 1956](#)), from low in the section and including virtually all the then known Goliad fossils, was assigned to the early Clarendonian (12 Ma) North American Land Mammal Age (NALMA). A Labahia Mission Fauna, based only on an undescribed tooth and leg bone, was placed in the succeeding early to middle Hemphillian NALMA. At that time the Miocene-Pliocene boundary was placed at about 13 Ma, which meant the Goliad was Pliocene, a correlation still followed by some. In the 1970s, the Mio-Pliocene boundary was set at about 5.5 Ma, and the

Goliad was reassigned to the middle to late Miocene. Baskin and Hulbert 2008, 2012) documented a late Clarendonian (10 Ma) Dinero Local Fauna (LF) and a latest Hemphillian (early Pliocene) (5 Ma), Lake Corpus Christi LF, for the caliche cap of the Goliad.

In the north-central to northeastern Gulf Coastal Plain, deposits of the latest Miocene to Pliocene Citronelle Formation and the late Pliocene or early Pleistocene Willis Formation have been recognized above the Goliad. These have not been mapped in South Texas, although they may be equivalent to the upper Goliad (Solis, 1981).

Sands and clays overlying the Goliad in South Texas have been referred to the Lissie or Montgomery Fm. Bernard and LeBlanc (1965) suggested that the Bentley (lower Lissie) and Montgomery (upper Lissie) are middle Pleistocene in age.

The late Pleistocene Beaumont Fm represents mainly stream, floodplain, delta, and coastal deposits (Aronow, 1971). The Ingleside sand, which forms the Encinal Peninsula and Live Oak Ridge, has been interpreted as the coastal margin of the Beaumont Formation (Aronow, 1971) or as a sand body deposited on top of the Beaumont during a following high stand (Wilkinson et al., 1975). The Ingleside Fauna (Lundelius, 1972), excavated from the Beaumont Formation on the backside of the Ingleside sand in San Patricio County, is one of the most abundant and diverse Rancholabrean (latest Pleistocene) faunas known from Texas. According to Shideler (1986), the upper part of the Beaumont Formation, including the Ingleside, was deposited 25,000-35,000 BP during a highstand of sea level in the mid-Wisconsinan. Suter (1989), however, interpreted the age of the Beaumont to be Sangamonian, forming during the major highstand of sea level preceding that of today (oxygen isotope stage 5, approximately 110,000 BP), in order to account for the geomorphic position of the Ingleside sand. The Nueces River terraces formed during highstands that occurred in the time interval following deposition of the Ingleside sand to the lowstand in sea level at the end of the Wisconsinan.

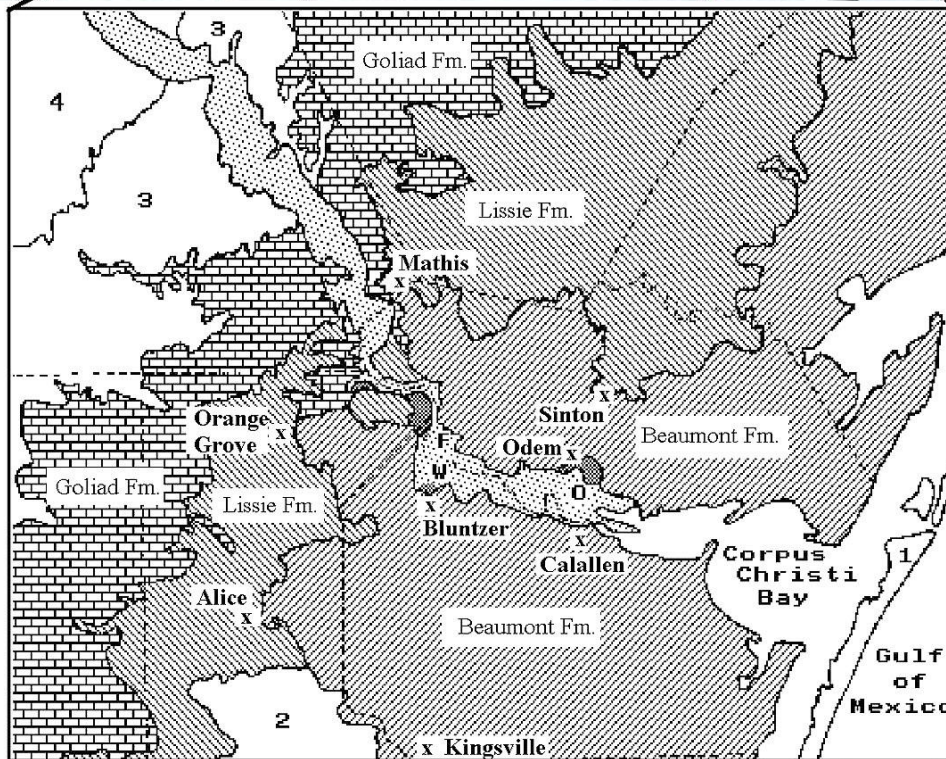
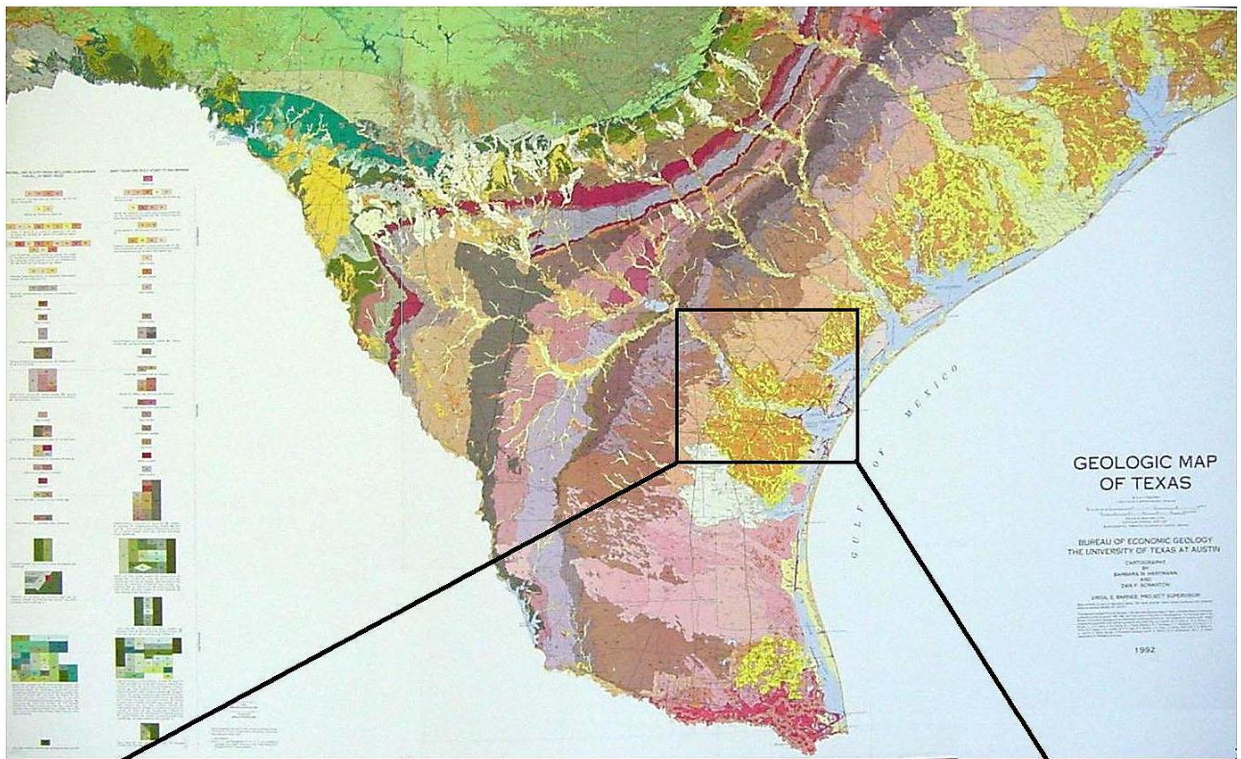


Figure 2. Regional geology of South Texas.

# TERRACE STRATIGRAPHY OF THE LOWER NUECES RIVER VALLEY

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<sup>2</sup>Department of Biology, Texas A&M University-Kingsville

Taken from: [Baskin \(1991\)](#) and [Cornish and Baskin \(1995\)](#)

River valleys and their alluvial sediments of the lower Gulf Coastal Plain, including those of the Nueces River, are the products of changing climate and sea level during the Quaternary (past 2 million years). The best studied late Pleistocene and Holocene river deposits of the Texas Coastal Plain are associated with the Colorado River (see Blum and Valastro, 1994, for a summary of this work). The Nueces River drains an area of 16,950 square miles (43,900 square km), a little more than 40% of the 39,900 square miles (103,000 square km) drained by the Texas Colorado River.

The lower Nueces River valley and its terrace and valley fill deposits are a testament to the effects of changing sea level on the lower Texas coast. At the western edge of the city of Corpus Christi, where IH 37 crosses the Nueces River, the valley floor is more than 25 m below the top of the valley wall of the Beaumont Formation and there is at least another 10 m of latest Pleistocene valley fill below that. This approximately 35 m of erosion is quite remarkable in coastal South Texas, where the land surface slopes gently gulfward at a rate of 2.5 ft per mile (0.5 m per km) (Weeks, 1945). This valley contains a complex variety of sedimentary fill. Three valley fill and four alluvial terrace units are recognized from Holocene and Late Pleistocene sediments in the lower Nueces River valley, Nueces and San Patricio Counties, Texas, between Odem and San Patricio, where the Nueces River is entrenched in the late Pleistocene (oxygen isotope stage 5) Beaumont Formation.

Terraces are geomorphic features that are recognized on the basis of landscape

position. Deussen (1924) was the first to map the terraces of the Nueces River. In the vicinity of Calallen (south of Odem), he recognized two terrace levels. Both are present in the region between San Patricio/Bluntzer and Odem. Price (1933) described these two terraces in greater detail. He named the upper unit the Corpus Christi Terrace and designated its type area as occurring approximately one mile (1.6 km) southeast of Odem, at an elevation of 50 ft (15 m). He showed only this upper terrace continuing to the east of Odem to Corpus Christi Bay.

The Geologic Atlas of Texas (Barnes, 1975b) classified exposed terrace deposits 5-20, 20-30, and 40-55 feet above the Recent Nueces floodplain as Deweyville formation (Bernard and LeBlanc, 1965). The Geologic Atlas maps only the upper terrace as Deweyville, and shows the younger terraces as part of the Quaternary alluvium. Because the type locality of the Deweyville is in the Sabine River Valley, this name should not be used for the Nueces River terraces.

Cornish and Baskin (1995) determined that there are four late Pleistocene terraces in the Nueces River Valley in this region (Fig. 3). They occur at elevations of 1) 0-19 ft (0-5.7 m), 2) 28-30 ft (8.4-9 m), 3) 36-45 ft (10.8-13.5 m), and 4) 48-55 (14.4-16.5 m) ft above the present day flood plain. The four terraces (from oldest to youngest) are the Corpus Christi, Fort Lipantitlan, Bluntzer, and Angelita

The sand and gravel pits in the Angelita terrace in San Patricio County are in these latest Pleistocene Deweyville-equivalent terrace deposits. The Angelita Terrace pre-dates the late Wisconsinan maximum drop

and is probably equivalent in age to the Eagle Lake Alloformation of the lower Colorado River (Blum and Valastro, 1994), where the river is cut into the alluvial plain of the Beaumont Formation. Blum and Valastro (1994) correlated the Eagle Lake Alloformation with the Sixth Street Terrace in the Austin area and stated that deposition of this unit took place from 20,000 to 14,000 BP.

By late Wisconsinan, approximately 15-20,000 BP (oxygen isotope stage 2), sea level in the Gulf of Mexico had fallen 120-160 m below its present level. During this time, the channel of the ancestral Nueces River was most deeply incised into the Beaumont Formation and Ingleside sand as a result of the increased gradient caused by the major drop in sea level. Seismic studies in the southeastern part of Corpus Christi Bay showed that the channel had at least 35 m of relief (Shideler, 1986). Similar relief is present in the study area (Baskin and Cornish, 1989, fig. 3).

Following the late Wisconsinan low stand, sea level began to rise (oxygen isotope stage 1), continuing on into the Holocene, reaching its present level about 5,000 BP. During this time of rising sea level, valley-fill deposits accumulated in the Nueces River valley beneath the present flood plain deposits. These are the sands and gravels being excavated in the Wright Materials, Inc. quarries in Nueces County. The three valley fill units are included in the Cayamon Creek Alloformation and are designated (from oldest to youngest) Cayamon Creek allomembers 1, 2, and 3. Allomember 1 consists mainly of coarse sands and gravels. A log from this unit has been dated at  $13,230 \pm 110$  BP. All of the fossils recovered are likely from this unit. This is unconformably overlain by the muddy sand of allomember 2. Gastropod shells from this unit were radiocarbon dated at  $965 \pm 95$  BP. The unconformably overlying Allomember 3 consists of late Holocene floodplain or channel sands.



Figure 3. Cayamon Creek allomembers exposed in working pit. Right shows cross bedded sands and gravel of the lower part of Cayamon Creek allomember 1 (CA1a).

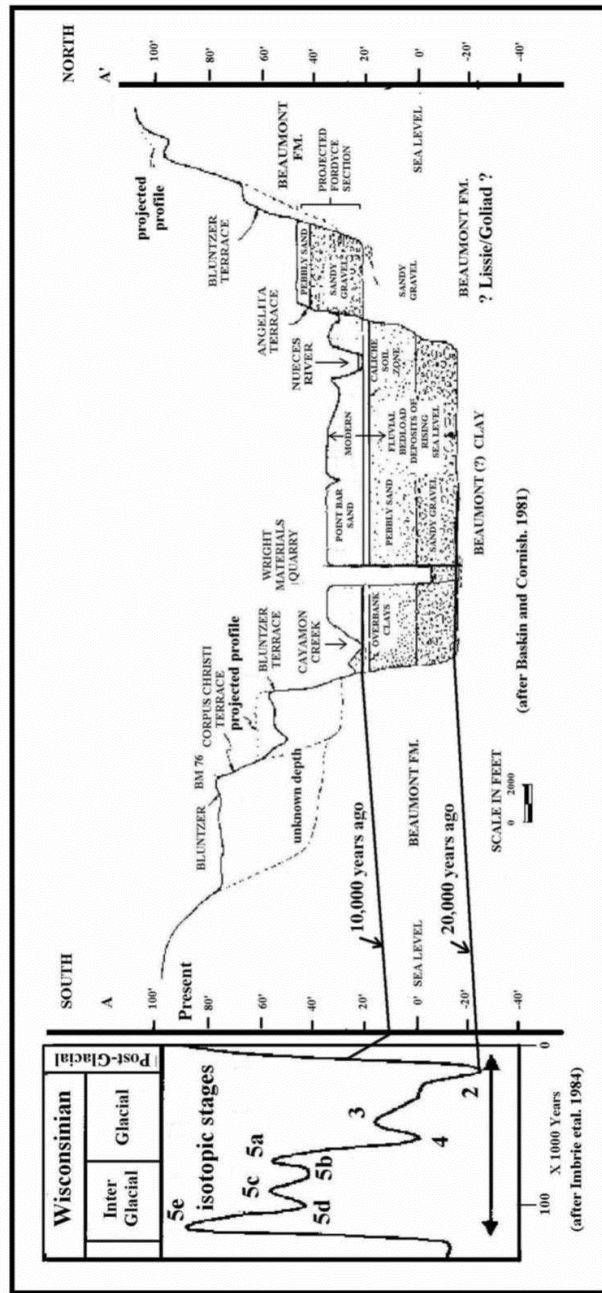
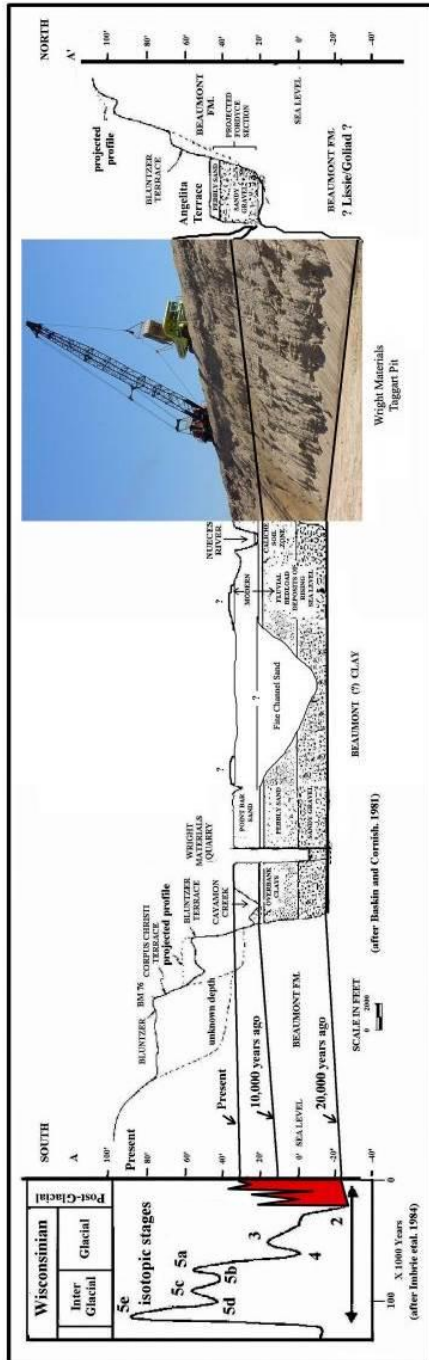


Figure 4. Cross section of the Nueces River Valley showing terrace and valley fill deposits, and correlation with oxygen isotope stages and sea level changes.

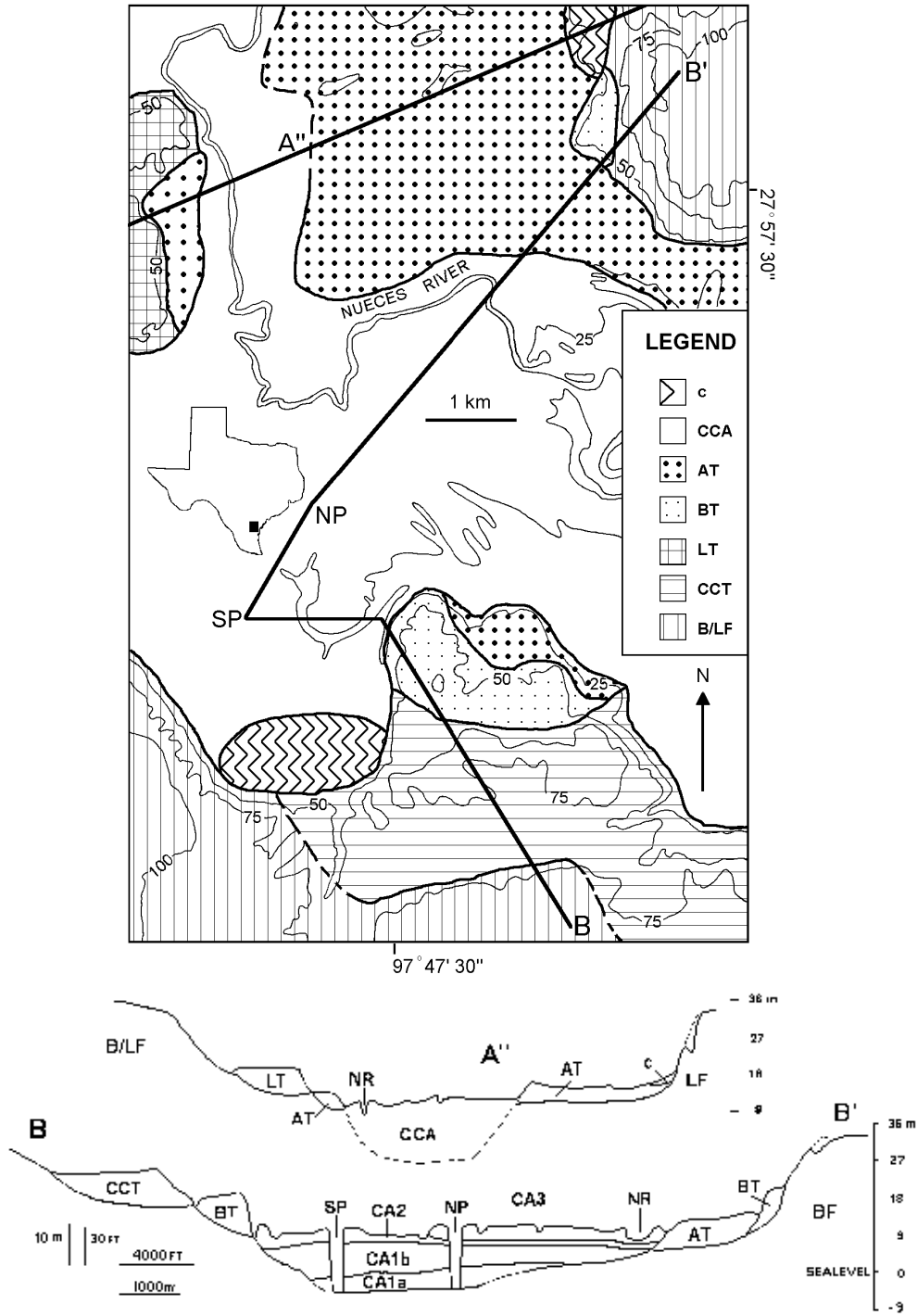


Figure 5. Cross sections of the Nueces River valley. A. cross section from south of Fort Lipantitan to near Willow Lake. B. cross section from Bluntzer through the gravel pits to San Patricio. Locations of sections are shown in Figure 2. Abbreviations: AT, Angelita Terrace; BF, Beaumont Formation; B/LF, Beaumont and/or Lissie Formation; BT, Bluntzer Terrace; c, colluvium; CA1a, Cayamon Creek Allomember 1, sandy gravel unit; CCA, Cayamon Creek Alloformation; CA1b, Cayamon Creek allomember 1, sand and muddy sand units; CA2, Cayamon Creek allomember 2; CA3, Cayamon Creek allomember 3; CCT, Corpus Christi Terrace; LF, Lissie Formation; LT, Fort Lipantitan Terrace; NP, north pit, Wright Materials, Inc.; NR, Nueces River; and SP, south pit, Wright Materials, Inc.

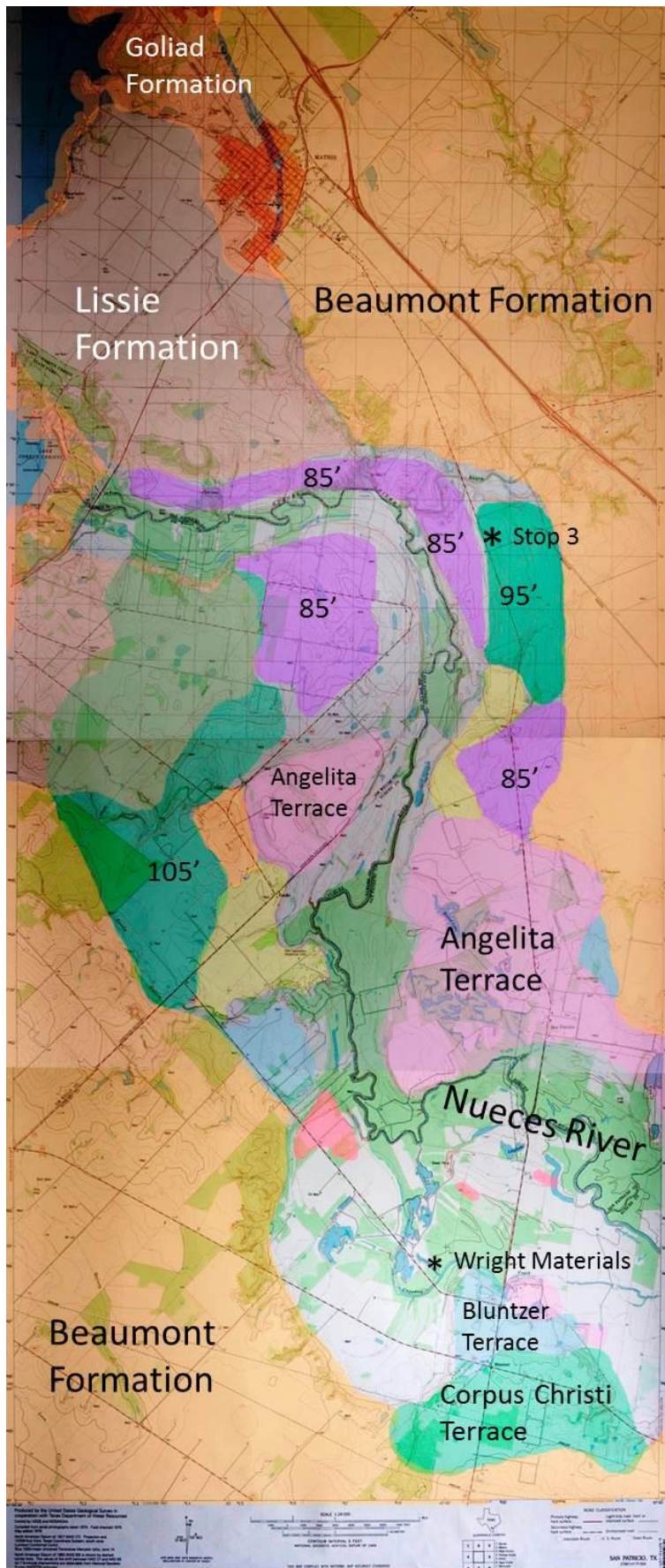


Figure 5a. Terraces in the gravel pit vicinity. Figure by Ronny Thomas

## **“CREEKOLOGY” of the LOWER NUECES RIVER GRAVELS**

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**“Creekology”** is the study of creek and stream deposits, to determine their history and origin. For centuries, prospectors followed trails of evidence, grain by grain, pebble by pebble, upstream to the source (“The Mother Lode”) of major deposits of gold, silver, diamonds and other minerals.

“Creekology” enables you to reconstruct the geologic history of the Southwestern United States from gravels found in the Lower Nueces River Valley. Over the last 65 million years the whole Texas Gulf Coastal Plain was developed by the repeated processes of erosion, transportation, and deposition of sediments derived from areas of uplift in the Western United States. Simply stated “Streams and rivers transported sediments eastward to the Texas Gulf Coastal Plain, where they were redistributed by shoreline processes of the Gulf of Mexico”. This combination of geologic processes has resulted in the accumulation of exotic gravels in the Lower Nueces River Valley of South Texas. Uplifted western mountains in Arizona, Colorado, New Mexico and Mexico provided the gravel source areas for the ancestral Nueces, Rio Grande, Rio Concho (in Mexico), Rio Salado (in Mexico), Pecos, Colorado and Brazos rivers flowing into the South Texas Gulf of Mexico.

The **GRAVELS** listed below are derived from outcrops of Tertiary and Cretaceous units within the present Nueces River Basin.

**BASALT, RHYOLITE, AND ANDESITE**, are volcanic igneous rocks from the Eocene, Oligocene and Miocene of Mexico, Arizona, New Mexico, and west Texas.

**VARIETY OF METAMORPHIC ROCKS** are from uplifted areas in Mexico.

**CHERTS** (flint used to make Indian bullets) are from the Cretaceous Glenrose and Edwards formations in the Texas Hill Country and from the Ordovician Maravillas Formation and the Devonian Caballos Novaculite Formation of West Texas. Silicified marine fossils are representative of these age rocks. Graptolites and crinoids are indicative of the Paleozoic units. The Cretaceous gravels have an abundance of pelecypods and gastropods.

**PRECAMBRIAN QUARTZITES** are from Arizona, western Colorado, New Mexico, and no longer existent terranes in Mexico.

**PETRIFIED WOOD** is predominately from the Eocene Yegua, the Miocene Catahoula and Oakville, and the Pliocene Goliad of South Texas. Other silicified, agatized, and fossilized woods are derived from outcrops of the Upper Cretaceous Aquia and Javelina, the Lower Tertiary Black Peak, Hannold Hill and Chisos formations of the Big Bend Region, the Lower Cretaceous Trinity Group and the Paluxy Formation of the Fredricksburg Group of the Hill Country of West Central Texas.

**GEODES** are quite common and occur in several varieties and sizes. Geodes are usually less than 2 inches in diameter, but some as large as 4 inches in diameter have been found.

The large majority consist of clear to dull botryoidal or drusy quartz filling in a rind of cream to buff colored chalcedony. The botryoidal variety also occurs in dirty orange, light blue, and black. Geodes with terminal quartz crystals are not as common; however a few really nice ones have been recovered. Combinations of terminal crystals and botryoidal and also occur.

**AGATE** is quite common and usually occurs in petrified wood and geodes.

**CALICHE** from the nearby Pliocene Goliad Formation is abundant. Caliche, a calcium carbonate arid land soil deposit, is relatively easy to breakup and is soluble. **Several spectacular early Pliocene fossils have been found in caliche boulders.**

**BONES AND TEETH** of Ice Age and Pliocene animals are found in pea-gravel to boulder-sized river gravels.



# THE PLEISTOCENE FAUNA OF SOUTH TEXAS

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## INTRODUCTION

South Texas has excellent record of late Pleistocene fossils. Fossils occur mainly in the river channel and floodplain deposits of the Beaumont Formation and in the terrace deposits cut into the Beaumont Formation. Rancholabrean fossils from South Texas were first described by E. D. Cope over 100 years ago. The majority of fossil mammals from South Texas are grazers, such as horses and mammoths. Grazers live in savannas and grasslands and feed mainly on grasses. They often have high-crowned cheek teeth, in which the enamel extends below the gum line and the roots are frequently open. Browsers are less common. Browsers are typically forest-dwelling animals that feed mainly on stems, twigs, and leaves. Browsers can be recognized by their low-crowned cheek teeth in which the enamel extends to the gum line and the roots are closed. During the Pleistocene, South Texas was a mosaic of grassland and woodland environments, which supported a much greater diversity of mammals than at present. There were probably extensive woodlands along the rivers. Time travelers to the Pleistocene of this region might at first glance think they were on the Serengeti Plain of Africa. Extinct fossil species identified from South Texas are listed below.

The Pleistocene was a time of extensive migration between North America and Eurasia and between North and South America. The Isthmus of Panama formed and connected North and South America in the late Pliocene, approximately 2.5 million years ago. During Pleistocene glacial episodes when sea level fell over 100 meters a land bridge formed in what today is the Bering Sea. The Pleistocene fauna of North America is distinct in containing South American immigrants (ground sloths, armadillos, glyptodonts, porcupines, capybaras, and opossums) and Old World immigrants (lions, hyenas, elephants, bison). Some mammals that evolved in North America became extinct on this continent, but survived in South America (llamas and tapirs) and the Old World (cheetahs, camels,

horses [including zebras and wild asses], and tapirs).

## PLEISTOCENE EXTINCTIONS

The extinction of large animals (the mega-fauna) in North America at the end of the Pleistocene has been related to climatic changes and human influences. [Lundelius](#) implicates a reduction in habitat diversity caused by a general warming and drying trend, as well as more seasonal conditions (warmer summers, colder winters). [Paul Martin](#) attributed the extinction to the arrival of big game hunters (the Clovis and Folsom cultures) across the Bering land bridge 11,500 years ago. This is known as the overkill hypothesis.

## FOSSIL LOCALITIES

- 1 = Nueces River
- 2 = Ingleside
- 3 = Aransas River
- 4 = Bee County
- 5 = Petronila Creek

The field trip today will visit the Nueces River Valley gravel pits near Bluntzer, Texas. The stratigraphy of this area has been described by Baskin and Cornish (1985) and Cornish and Baskin (1995). Only a few of the Pleistocene fossils have been described in detail (Baskin, 2016; Baskin and Mosqueda, 2002). Further information is provided at the [web site](#).

The Ingleside locality was excavated by the Works Progress Administration during 1939-1941. The fossils were described by [Lundelius \(1972\)](#). The site is no longer accessible.

## FAUNAL LIST

### SYMBOLS

- ††† = extinct genus  
†† = extinct species  
† = extinct subspecies

### CLASS REPTILIA

#### Order TESTUDINES

Turtles and tortoises.

#### †††*Hesperotestudo crassiscutata* (1, 2, 3)

These giant tortoises were previously considered closely related to the Galapagos tortoises. A recent study suggests *Hesperotestudo* is most closely related to gopher tortoises. Presence of this and other large tortoises indicates relatively mild winters.

#### †††*Hesperotestudo wilsoni* (4)

A smaller species with a sculptured carapace

#### ††*Gopherus hexagonatus* (1, 2)

Gopher tortoises today live in dry areas of the southeastern and southwestern United States. Westgate (1989) reported a mass occurrence of this giant species from Willacy County that indicated it was capable of burrowing

#### †*Trachemys scripta bisornata* (1, 2, 3, 4)

The common slider, a wide-spread turtle species that lives in ponds and slow moving streams. This extinct subspecies is considerably larger than recent forms.

#### *Terrapene carolina* (1, 2, 4)

The common box turtle.

#### *Kinosternum flavescens* (4)

The yellow mud turtle.

#### *Apalone spinifera* (1, 2)

The spiny softshell turtle.

### Order CROCODILIA

#### *Alligator mississippiensis* (1, 2)

The American alligator.

## CLASS AVES

#### *Haliaeetus leucocephalus* (1)

Robert Chandler identified a left distal tarsometatarsus as best fitting a large female bald eagle, or possibly a small male golden eagle (*Aquila chrysaetos*).

Feduccia (1973) identified the following birds from the Ingleside Fauna (2)

*Podilymbus podiceps*. Pied-billed Grebe.

†† *Ciconia maltha*. Asphalt Stork

*Branta canadensis*. Canada Goose.

Duck (Genus and species?)

*Anas* sp. Teal.

*Meleagris gallopavo*. Turkey.

*Colinus virginianus*. Bobwhite.

*Limnodromus* sp.? Dowitcher.

*Corvus brachyrhynchos*. Common Crow.

## CLASS MAMMALIA

### Order XENARTHRA

The xenarthrans, better known as edentates, are South American mammals that emigrated to North America in the late Cenozoic, especially after the completion of the Panamanian land bridge, approximately 2.5 million years ago.

#### Suborder Folivora

Sloths are browsers. There are two species of living sloths. Both are relatively small, and spend most of their lives hanging upside down from trees. Most of the extinct sloths were large ground dwellers.

#### Family Megatheriidae

#### †††*Eremotherium laurillardi* (?1, 3)

The megatheres include the largest of all the ground sloths. This genus, which ranged from Brazil to South Carolina, was the size of an elephant, with adult males over 6 meters long and weighing more than 3 tons. This species has been associated with savanna habitats.

#### Family Mylodontidae

#### †††*Paramylodon harlani* (2)

This giant ground sloth (sometimes referred to the genus *Glossotherium*) was a large browser the size an ox and weighed at least one ton.

#### Family Megalonychidae

#### †††*Megalonyx jeffersonii* (1, 2)

This ground sloth is the size of a large bear. This species is associated with forest and woodland habitats. The genus was named in 1796 by our third president Thomas Jefferson who thought its "great claw" (*megalo-onyx*) indicated the fossil was from a giant lion.

#### Suborder Cingulata

##### Family Pamphathiidae

†††*Holmesina septrionalis* (1, 2, 3, 4)

Although pamphathes are sometimes referred to as giant armadillos, it is unclear whether they are more closely related to armadillos or to glyptodonts. Pamphathes are larger and more specialized than members of the armadillo family. A nearly complete specimen, approximately 2 meters long, that was collected in Houston was on display at the Houston Museum of Natural History.

##### Family Glyptodontidae

†††*Glyptotherium floridanum* (1, 2, 3, 4)

Glyptodonts were large, slow moving browsers that grew to over 2 meters in length and weighed about a ton. They had a huge turtle-like carapace made up of thick polygonal plates. Analysis of ancient DNA of a Pleistocene glyptodont from South America and living armadillos indicates that glyptodonts (subfamily Glyptodontinae) are most closely related to hairy armadillos (Chlamyphorinae), and thus they really are "giant armadillos", in the family Chlamyphoridae.

#### Order CARNIVORA

##### Family Canidae

††*Canis dirus* (2, 4)

The dire wolf, a very large Pleistocene wolf.

*Canis cf. lupus* (1)

The extant grey wolf, not known historically from South Texas.

*Canis latrans* (2, 5)

The coyote.

##### Family Mustelidae

*Mephitis mephitis* (2)

The striped skunk.

##### Family Ursidae

††*Tremarctos floridanus* (?1, 2)

The extinct Florida cave bear is a relative of the South American spectacled bear.

†††*Arctodus simus* (?1)

The giant short-faced bear, a bear up to twice the size of the brown bear, is tentatively represented by a distal humerus.

##### Family Felidae

†††*Smilodon fatalis* (1, 2, 4)

The well-known Pleistocene saber-toothed cat. Both it and the dire wolf are extremely abundant in the tar pits of Rancho la Brea. They are both extremely rare in South Texas.

†*Panthera leo atrox* (1,2)

The American lion is a large subspecies that grew up to 2.5 m long.

*Puma concolor* (1, ?2)

The mountain lion or puma has been found in numerous Rancholabrean localities.

*Lynx rufus* (2)

The bobcat.

#### Order RODENTIA

##### Family Sciuridae

*Cynomys ludovicianus* (1, 2, 5)

The black-tailed prairie dog is no longer present in South Texas.

##### Family Geomyidae

*Geomys* sp. (2, 5)

Two gophers, *G. cf. attwateri* and *G. cf. personatus* are recognized from Petronila Creek.

##### Family Hydrochoeridae

†††*Nechoerus pinckneyi* (3)

This species is 40% larger than the living capybaras, the largest living rodents (which weigh up to 50 kg). This genus, a South American immigrant, was named from material discovered on the Aransas River.

Order PROBOSCIDEA  
Elephants and their close relatives.

Family Mammutidae

†††*Mammut americanum* (1, 2, 3)

The American Mastodon, a browsing form with low crowned teeth distantly related to elephants, is rare in South Texas. Mastodons stood about 2.7 m high at the shoulder.

Family Gomphotheriidae

†††*Cuvieronius* sp. (1, 2, 3)

Gomphotheres are browsing forms, related to elephants. These are also very rare in South Texas.

Family Elephantidae

†††*Mammuthus columbi* (1, 2, 3, 4)

The Columbian mammoth is closely related to the Indian elephant. Mammoths are grazers and they are among the most common fossils in South Texas. A full grown, male Columbian mammoth stood nearly 4 meters tall at the shoulder. The Columbian mammoth was larger than its northern relative, the woolly mammoth (*Mammuthus primigenius*), whose maximum size was about 3 meters.

Order ARTIODACTYLA

Family Tayassuidae

Although closely related to the Old World swine (Family Suidae), peccaries (or javelina) are easily distinguished from pigs by anyone who cares to tell the difference.

†††*Platygonus compressus* (1, 2, 4)

The flat-headed peccary was much larger than its living relatives, such as the collared peccary (*Pecari tajacu*), the official mascot of Texas A&M-Kingsville.

Family Camelidae

Camels and llamas initially evolved in North America in the late Eocene. In the Pleistocene they emigrated to Asia and Africa (camels) and to South America (llamas) and went extinct in North America.

†††*Camelops hesternus* (1)

This large "camel" is known from many Rancholabrean localities, including South Texas in South Texas ([Baskin and Thomas. 2016](#)). As

indicated by its high crowned, but rooted, teeth, it was mainly a grazer, although it probably browsed occasionally.

†††*Camelops* sp. (2, 3, 4)

The *Camelops* from Ingleside represents a new species. The material from the other localities is too incomplete to identify to species.

†††*Palaeolama mirifica* (?1, 2)

This short-legged llama was a browser.

†††*Hemiauchenia macrocephala* (1)

This llama had slender deer-like legs and was a cursorial grazer.

Family Cervidae

*Odocoileus virginianus* (1)

The white-tailed deer is the only species of large mammal known from the Pleistocene that is still extant in Texas. It is a browser.

Family Antilocapridae

The pronghorn "antelopes" belong to a family that is only known from North America.

†††*Capromeryx furcifer* (1, 2)

A diminutive species that weighed about 10 kg, with paired horn cores, a small anterior one, a larger posterior.

†††*Tetrameryx shuleri* (1, 2)

This genus includes large four-horned antilocaprids, which have a long posterior horn-core and a shorter anterior horn-core.

†††*Stockoceras onusrosagris* (?1)

A genus the size of the living pronghorn, but with 4 equal sized horns, two above each eye.

Family Bovidae

Bovids such as the bison (popularly referred to as buffalo) are mainly grazers.

††*Bison latifrons* (1)

The giant bison had horn cores that spanned up to 2.1 meters.

††*Bison antiquus* (1, 2, 5)

These bison have horn cores that are larger than the extant *B. bison*, and can span almost 0.9 meters in an adult male.

*Bison* sp. (3, 4)

Known only from dentitions. Horn cores are necessary to identify the different species of *Bison*.

#### Order PERISSODACTYLA

##### Family Tapiridae

††*Tapirus veroensis* (1, 2)

Tapirs are primitive browsers that occur today in the tropical and subtropical forests of South and Central America (as well as the East Indies), after emigrating from North America during the Pleistocene. They are poorly represented in South Texas.

##### Family Equidae (1, 2, 3, 4)

At least 3 species of *Equus* (which includes horses, zebras, and asses) are present in South Texas in the late Pleistocene and are probably the most common fossil. These grazers are well adapted for living in open country. It is probably impossible to identify species of *Equus* without relatively complete skulls and skeletons.

Three species of *Equus* were determined to be present from the Wright Material sand and gravel pits, using discriminant functions and bivariate and multivariate plots of measurements of metapodials (Baskin and Mosqueda, 2002). *Equus* cf. *conversidens*, the most abundant species, is a small- to average-sized horse with normal length metapodials. It is similar to members of the *E. alaskae* group, which probably includes living wild horses. The second species, represented by 24 metapodials, is assigned to *E.* cf. *scotti*. These are larger horses with robust limbs. The third, represented by six specimens, is a stilt-legged horse of the *E. francisci* group, which may resemble Asiatic wild asses.

## PLIOCENE FAUNA

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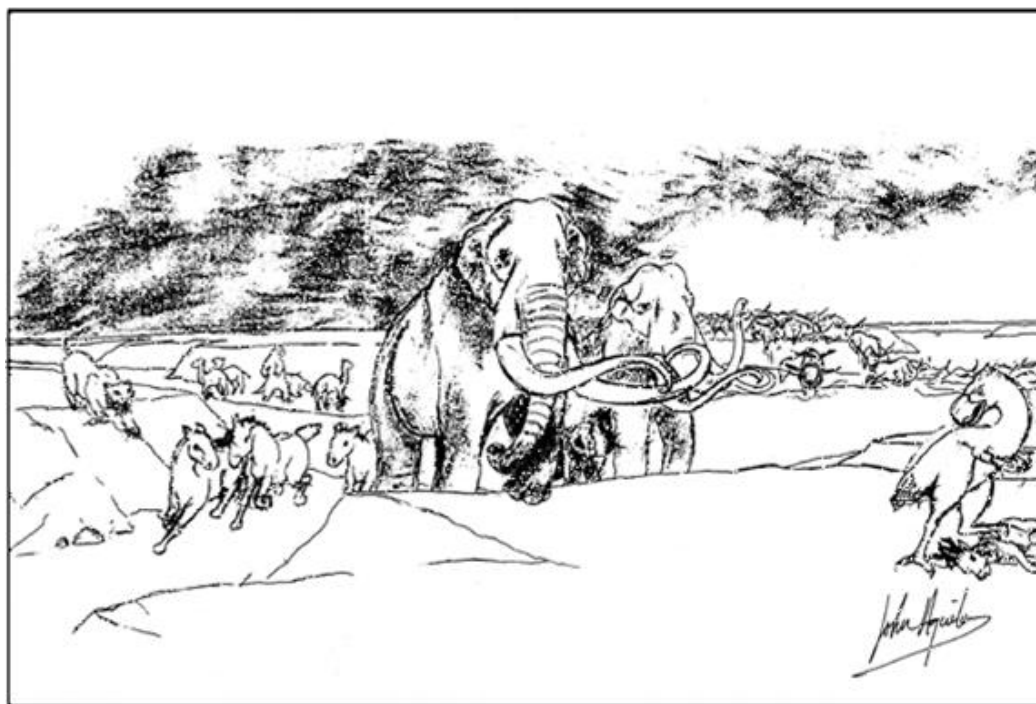
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[Baskin \(1991\)](#) described early Pliocene (about 5 million years old) horses from the Nueces River gravel pits. These horses are reworked from older deposits, presumed to be the upper Goliad Formation. The nearest exposures of the Goliad are approximately 10 km upriver from the sand and gravel pits near Bluntzer, Texas and 25 km from the gravel pit near Odem. Pliocene horses from the gravel pits are *Dinohippus mexicanus*, *Astrohippus stockii*, *Nannippus aztecus*, *Pseudhipparion simpsoni*, and *Neohipparion eurystyle*. Other evidence of a latest Hemphillian age of the reworked specimens are rhinoceros tooth fragments and parts of an edentulous *Rhynchotherium* mandible and palate. *Rhynchotherium* is a four-tusked gomphothere known from the late Clarendonian (late Miocene) through the late Blancan (late Pliocene). The terror bird *Titanis* is also part of this reworked, early Pliocene fauna.

†††*Titanis walleri* (1)

[A two meter tall, cursorial, flightless, predator.](#) It is distantly related to cranes. A Pliocene immigrant from South America. *Titanis* is fairly-well known from the late Pliocene (about two million years ago) of Florida. *Titanis* from Texas is known from a single proximal phalanx. Baskin (1995) considered that it might be late Pleistocene in age, since there is no evidence of two million year old mammals in the fauna and five million years is well before the main pulse of faunal interchange between the Americas. However, Rare Earth Element dating shows that the Texas *Titanis* is an early Pliocene migrant ([MacFadden and others, 2007](#)).

## SELECTED BIBLIOGRAPHY



[John Aguilar](#): Design for a mural at the John E. Conner Museum, TAMUK

- Aronow, S. 1971. [Nueces River delta plain of Pleistocene Beaumont Formation, Corpus Christi, Texas](#). American Association of Petroleum Geologists Bulletin, 58:1231-1248.
- Barnes, V. E, project director, 1975a. Geologic Atlas of Texas; Scale 1:250,000; Beeville-Bay City Sheet. Bureau of Economic Geology, University of Texas.
- Barnes, V. E, project director. 1975b. Geologic Atlas of Texas; Scale 1:250,000; Corpus Christi Sheet. Bureau of Economic Geology, University of Texas.
- Barnes, V. E, project director. 1976a. Geologic Atlas of Texas; Scale 1:250,000; Crystal City-Eagle Pass Sheet. Bureau of Economic Geology, University of Texas.
- Barnes, V. E, project director. 1976b. Geologic Atlas of Texas; Scale 1:250,000; Laredo Sheet. Bureau of Economic Geology, University of Texas.
- Baskin, J. A. 1991. [Early Pliocene horses from late Pleistocene fluvial deposits, Gulf Coastal Plain, South Texas](#). Journal of Paleontology, 65:995-1006.
- Baskin, J. A. 1995. [The giant flightless bird \*Titanis walleri\* \(Aves: Phorusrhacidae\) from the Pleistocene coastal plain of South Texas](#). Journal of Vertebrate Paleontology, 15:842-844.
- Baskin, J. A. and F. G. Cornish. 1989. Late Quaternary fluvial deposits and vertebrate paleontology, Nueces River Valley, Gulf Coastal Plain, South Texas. In Baskin, J. A. and Prouty, J. S. (eds.), South Texas clastic depositional systems. GCAGS 1989 Convention field trip, Corpus Christi Geological Society. pp. 23-30.
- Baskin, J. A. and R. C. Hulbert, Jr. 2008. [Revised biostratigraphy of the middle Miocene to earliest Pliocene Goliad Formation of South Texas](#). Gulf Coast Association of Geological Societies Transactions, 58:93-101
- Baskin, J. A. and R. C. Hulbert, Jr. 2012. [A Late Clarendonian Local Fauna from the Goliad Formation of South Texas](#). Paludicola, 8:1-7.
- Baskin, J. A. and A. E. Mosqueda. 2002. [Analysis of horse \(\*Equus\*\) metapodials from the Late Pleistocene of the Lower Nueces Valley, South Texas](#). Texas Journal of Science, 54: 17-26.
- Baskin, J. A. and R. G. Thomas. 2007. [South Texas and the Great American Interchange](#). Gulf Coast Association of Geological Societies Transactions, 57:37-45.

- Baskin, J. A. and R. G. Thomas. 2016. A review of Camelops (Mammalia, Artiodactyla, Camelidae), a giant llama from the Middle and Late Pleistocene (Irvingtonian and Rancholabrean) of North America. *Historical Biology* 28:119-126.
- Bernard, H. A., and R. J. Leblanc. 1965. Resume of the Quaternary geology of the northwestern Gulf of Mexico province, p. 137-185. In H. E. Wright and D. G. Frey (eds.). *The Quaternary of the United States*. Princeton University Press, Princeton.
- Blum, M. D., and A. Aslan. 2006. [Signatures of climate vs. sea-level change within incised valley-fill successions](#). *Sedimentary Geology*, 190:177-211
- Blum, M. D. and S. Valastro, Jr. 1994. Late Quaternary sedimentation, lower Colorado River, Gulf Coastal Plain of Texas. *Geological Society of America Bulletin*, 106:1002-1016.
- Blum, M. D., Morton, R. A., Durbin, J. M., 1995. "Deweyville" terraces and deposits of the Texas Gulf Coastal Plain. *Transactions of the Gulf Coast Association of Geological Societies*, 45:53-60.
- Conkin, J. E., and B. M. Conkin. 1962. Pleistocene Berclair terrace of Medio Creek, Bee County, Texas. *American Association of Petroleum Geologists Bulletin*, 46:344-353.
- Brown, K. M. 2006. [The Bench Deposits at Berger Bluff](#): Early Holocene-Late Pleistocene Depositional and Climatic History. Unpublished PhD dissertation (Anthropology), University of Texas at Austin.
- Conkin, J. E., B. M. Conkin, and W. T. Mason, Jr. 1962. Pleistocene snails from San Patricio County, Texas. *Transactions of the Kentucky Academy of Science*, 23, 25-50.
- Cope, E. D. 1885. Pliocene horses of southwestern Texas. *American Naturalist*, 19, 1208-1209.
- Cope, E. D. 1891. On a skull of *Equus excelsus* Leidy, from the *Equus* bed of Texas. *American Naturalist*, 25, 912-913.
- Cornish F. G. and J. A. Baskin. 1995. Late Quaternary sedimentation, lower Nueces River, South Texas. *Texas Journal of Science*, 47:191-202.
- Dalquest, W. W. and G. E. Schultz. 1992. Ice age mammals of northwestern Texas. *Midwestern State University Press*. 309 pp.
- Durbin, J. M., M. D. Blum, and D. M. Price. 1997. Late Pleistocene stratigraphy of the Lower Nueces River, Corpus Christi, Texas: Glacio-eustatic influences on valley-fill architecture. *Transactions of the Gulf Coast Associations of Geological Societies*, 47:119-129.
- Feduccia, A. 1973. [Fossil Birds from the Late Pleistocene Ingleside Fauna, San Patricio County, Texas](#). *The Condor*, 75:243-244.
- Garrison Jr, J. R., and McCoy, B. 2007. The Nueces Incised Valley Revisited: A Reinterpretation of the Sedimentology and Depositional Sequence Stratigraphy of Preserved Pleistocene and Holocene Valley-Fill Sediments. *Transactions of the Gulf Coast Associations of Geological Societies*, 57:291-304.
- Hay, O. P. 1926. A collection of Pleistocene vertebrates from southwestern Texas. *Proceedings of the U. S. National Museum*, 68(24):1-18.
- Hester, T. M. 1995. [The Prehistory of South Texas](#). *Bulletin of the Texas Archeological Society*, 66:427-459.
- Holman, A. H. 1995. Pleistocene amphibians and reptiles in North America. Oxford University Press. 243 pp.
- Johnson, E. 1993. A late Pleistocene small mammal fauna from south Texas. *Current Research in the Pleistocene*, 10: 105-107.
- Kurtén, B. and E. Anderson. 1980. Pleistocene mammals of North America. Columbia University Press. 443 pp.
- Lewis, C. R. 1994. Pleistocene and Holocene *Bison* with associated artifacts from the Petronila Creek site in South Texas. *La Tiera, Journal of the Southern Texas Archeological Association*, 21:6-16.
- Lewis, C.R. 2009. An 18,000 year old occupation along Petronila Creek in Texas. *Bulletin of the Texas Archeological Society*, 80:15-50.
- [Lundelius, E. L. 1972](#). Fossil vertebrates from the late Pleistocene Ingleside Fauna, San Patricio County, Texas. Bureau of Economic Geology, University of Texas, Reports of Investigations, 77:1-74.
- Lundelius, E. L. 1988. What happened to the mammoth? The climatic model. p.75-82 in (R. C. Carlisle, ed.) *Americans before Columbus: Ice Age Origins*. *Ethnology Monographs* 12, University of Pittsburgh.
- Lundelius, E. L. and M. S. Stevens. 1970. *Equus francisi* Hay, a small stilt-legged horse middle Pleistocene of Texas. *Journal of Paleontology* 44:148-153.

- MacFadden, B. J., Labs-Hochstein, R. Hulbert, Jr., and J. Baskin. 2007. [Revised age of the late Neogene terror bird \(\*Titanis\*\) in North America during the Great American Interchange](#). *Geology* 35:123-126
- Mandryk, C. A. S., J. A. Baskin, E. O. Matthews, and R. G. Thomas. 2005. Possibly human-modified mammoth tusk and bone from the Pleistocene of South Texas. *Bulletin of the Florida Museum of Natural History*, 45:531-539
- Martin, P. S. and R. G. Klein. 1984. *Quaternary Extinctions: A prehistoric revolution*. University of Arizona Press.
- McDaniel, G. E., Jr., and G. T. Jefferson, 2006, Dental variation in the molars of *Mammuthus columbi* var. *M. imperator* (Proboscidea, Elephantidae) from a Mathis gravel quarry, southern Texas. *Quaternary International*, 142-143:166-177
- Neck, R. W. 1983. Paleoenvironmental significance of a nonmarine Pleistocene molluscan fauna from southern Texas. *Texas Journal of Science*. 35:147-154.
- Otvos, E. G., and W. E. Howat, 1996, South Texas Ingleside barrier; coastal sediment cycles and vertebrate fauna: *Transactions of the Gulf Coast Association of Geological Societies*, 46:333-344
- Price, W. A. 1933. Role of diastrophism in topography of Corpus Christi area, South Texas. *American Association of Petroleum Geologists Bulletin*, 17:907-962.
- Price, W.A., 1958, *Sedimentology and Quaternary geomorphology of South Texas: Supplementary to Field Trip Manual, Corpus Christi Geological Society Spring Field Trip, Transactions, Gulf Coast Association of Geological Societies*, 8:41-75.
- Quinn, J. H. 1955. Miocene Equidae of the Texas Gulf Coastal Plain. Bureau of Economic Geology, University of Texas, Publication, 5516: 1-102.
- Quinn, J. H. 1957. Pleistocene Equidae of Texas. Bureau of Economic Geology, University of Texas, Reports of Investigations, 33:1-51.
- Sellards, E. H., Adkins, W. S., Plummer, F. B. 1932. *The Geology of Texas*, vol. 1, Stratigraphy. University of Texas Bulletin 3232:1-1007.
- Sellards, E. H. 1940. Pleistocene artifacts and associated fossils from Bee County, Texas. *Geological Society of America Bulletin*, 51:1627-1658.
- Shideler, G. L. 1986. Seismic and physical stratigraphy of late Quaternary deposits, South Texas coastal complex, p. 9-31. In G. L. Shideler (ed.), *Stratigraphic Studies of a Late Quaternary Barrier Type Coastal Complex, Mustang Island-Corpus Christi Bay Area, South Texas Gulf Coast*. U.S. Geological Survey Professional Paper, 1328.
- Solis, R. F. 1981. Upper Tertiary and Quaternary depositional systems, central Coastal Plain, Texas. The University of Texas at Austin, Bureau of Economic Geology Report of Investigations, 108: 1-89.
- [Suhm, R. W. 1980](#). The La Paloma Mammoth Site, Kenedy County, Texas (with notes on the archaeology by T. R. Hester). In *Papers on the Archaeology of the Texas Coast*, edited by L. Highley and T. R. Hester, pp.79-104. Special Report 11. Center for Archaeological Research, The University of Texas at San Antonio
- Suter, J. R. 1989. South Texas Coast: Mustang and North Padre Islands, p. 51-76. In J. A. Baskin and J. S. Prouty (eds.). *South Texas Clastic Depositional Systems. Gulf Coast Association of Geological Societies 1989 Convention Field Trip, Corpus Christi Geological Society*.
- Swift, C. 1968. Pleistocene freshwater fishes from Ingleside Pit, San Patricio County, Texas. *Copeia* 1968:63-69.
- Thayer, P. A., A. La Rocque, and J. W. Tunnell, Jr. 1974. Relict lacustrine sediments on the inner continental shelf, southeast Texas. *Transactions of the Gulf Coast Association of Geological Societies* 24: 337-347.
- Weeks, A. W. 1945. Quaternary deposits of Texas Coastal Plain between Brazos River and Rio Grande. *American Association of Petroleum Geologists Bulletin*, 29:1693-1720.
- Westgate, J. W. 1989. Mass occurrence of the giant gopher tortoise (*Gopherus hexagonatus*) in the late Pleistocene Beaumont Formation, Willacy County, Texas. *Journal of Vertebrate Paleontology*, 9 (supplement to number 3): 44A.
- Wilkinson, B. H., J. H. McGowen, and C. R. Lewis. 1975. Ingleside strandplain sand of Central Texas coast. *American Association of Petroleum Geologists Bulletin*, 59:347-352.
- Wilson, J. A. 1956. [Miocene formations and vertebrate biostratigraphic units, Texas coastal plain](#). *AAPG Bulletin*, 40:2233-2246.