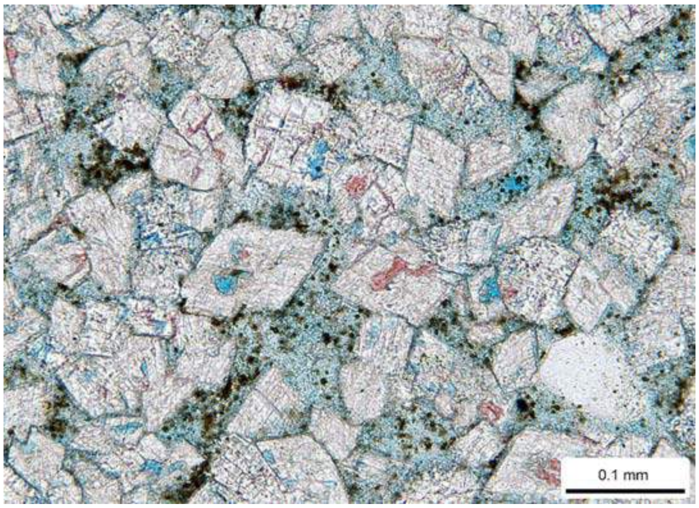
Boquillas Formation (Eagle Ford) and Associated Strata in Road Cuts along U.S. Highway 90, Northwest of Del Rio, Texas



FIELD TRIP
JUNE 14-16, 2018

Barry Wawak, Thomas Gentzis
editors

Field Trip Guidebook Sponsor
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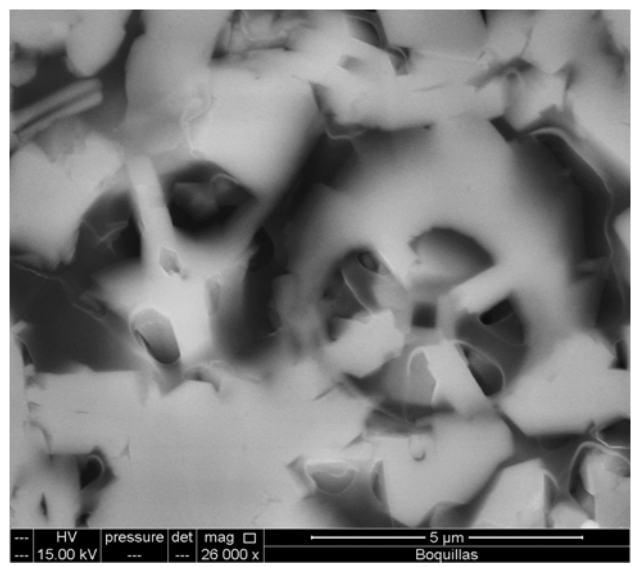

Rice University, Houston, Texas

The Edwin W. Roedder Conference

Pan-American Current Research On Fluid Inclusions

PACROFI 14

June 11-16, 2018

Boquillas Formation (Eagle Ford) and Associated Strata in Road Cuts along U.S. Highway 90, Northwest of Del Rio, Texas

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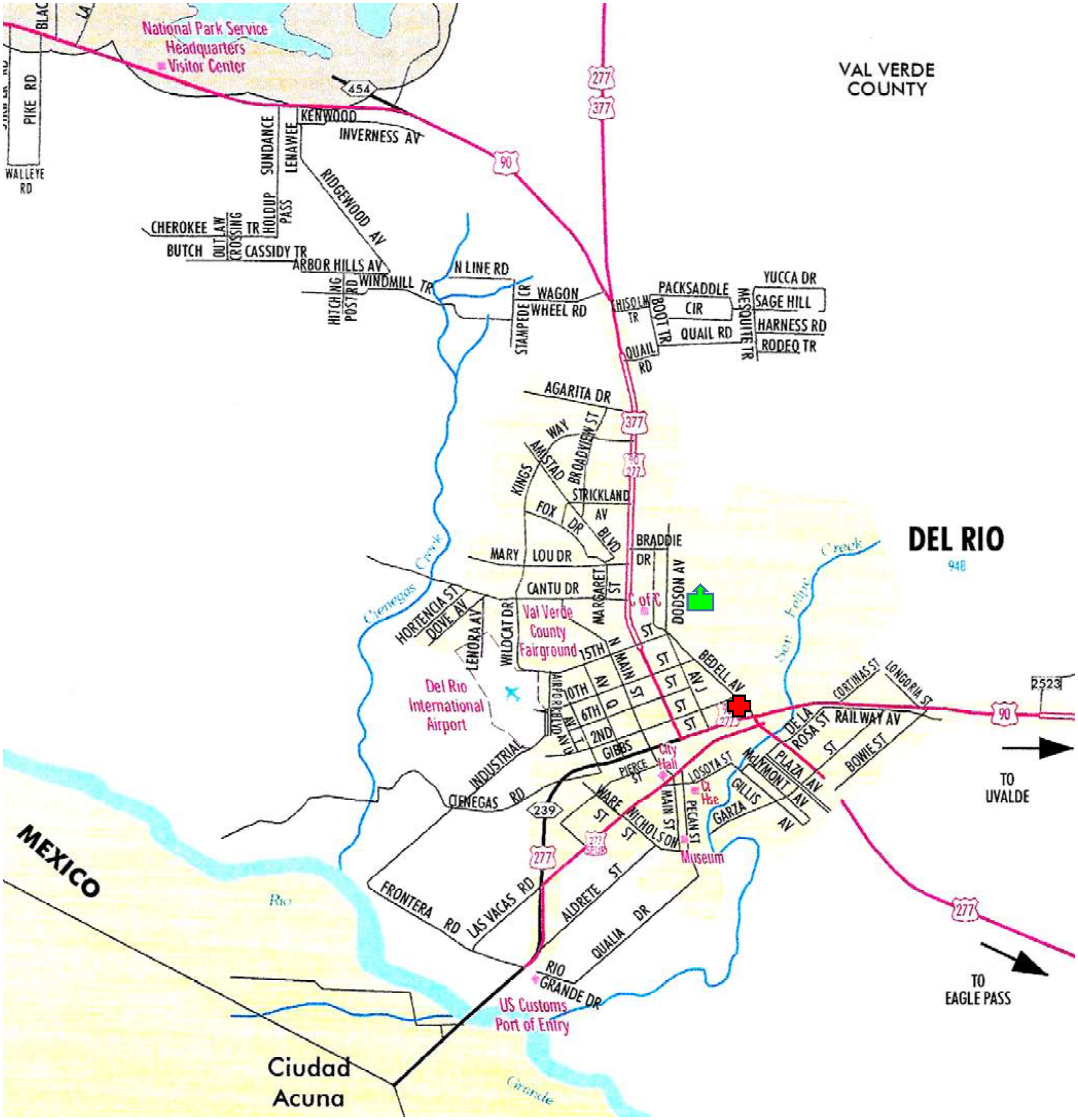


Map of Del Rio, showing location of hotel (green symbol) and location of nearest hospital (red symbol).

Hotel

Hampton Inn & Suites
2219 Bedell Ave.
Del Rio, Texas 78840
830-775-9700

Hospital Facilities

Val Verde Regional Medical Center
801 N. Bedell Ave
Del Rio TX 78840

Itinerary

Friday: Drive – Houston to Del Rio, Texas

Saturday: Drive Del Rio Texas to Langtry Texas, and return

Sunday: Drive – Del Rio Texas to Houston, Texas

Two nights (Thursday, Friday) at Del Rio

> **Hampton Inn & Suites**
> **2219 Bedell Ave.**
> **Del Rio, Texas 78840**
>
> **830-775-9700**

Safety

Weather this time of year in the field trip area should be pleasant (Low Temp ~70ºF) in the evenings to very warm/hot (Hi Temperature ~90-95ºF) during the day. This is a desert climate so expect the humidity to be very low. Drink lots of fluids and wear hat, sunglasses and cover exposed skin with sun screen to avoid dehydration and heat stress, up to and including heat stroke.

We will be looking at steep road cuts (falling rock hazard, falling person hazard), walking over rough ground (falling, tripping hazard), reducing the size of the outcrops with rock hammers (eye hazard), and avoiding cars (and trucks) along highway road cuts (multiple hazards – depending on how fast the vehicle is moving).

Additionally there is a possibility we may also encounter snakes, scorpions, spiders, and insects that can bite or sting, and depending upon your immune system can cause serious health problems. May sure you look before you put your hand into any shady spot or crevasse, spiders love to spin their webs in the area and black widow spiders have a highly toxic bite.

Be aware of where you are at all times – be aware of what is above you at all times. Be cautious when approaching the high road cuts – look for loose rock and avoid standing under overhangs.

Wear your orange hazard vests at all time during the day on Saturday.

Make sure to pay attention, not only to what you are doing, but what others around you are doing. Stay with the group and keep the trip as safe as possible.


BEWARE OF
SNAKES!


BE ALERT
DON'T GET HURT


WATCH
FOR
FALLING
ROCK

Table of Contents

Acknowledgments

This material is gathered from numerous books, periodicals and web sites, all of which are referenced in the body of the guidebook and listed in the Reference List. All of the photos were taken by B. Wawak, except where otherwise stated. Thanks also to my wife, Debbie who tolerates the inordinately long time it takes to drive anywhere, because of the innumerable stops at road cuts and outcrops (and the picture of the bug) and for the detailed notes she recorded as we field-checked various road-logs and field guides for this trip. Thanks also to Core Laboratories, Inc. who graciously agreed to sponsor the printing of the guidebook. Thanks also to Seare Ocubalidet and Ken Hunnicutt, members of the Reservoir Geology team at Core Laboratories, for compiling some of the information and collecting some of the data used in this guidebook.

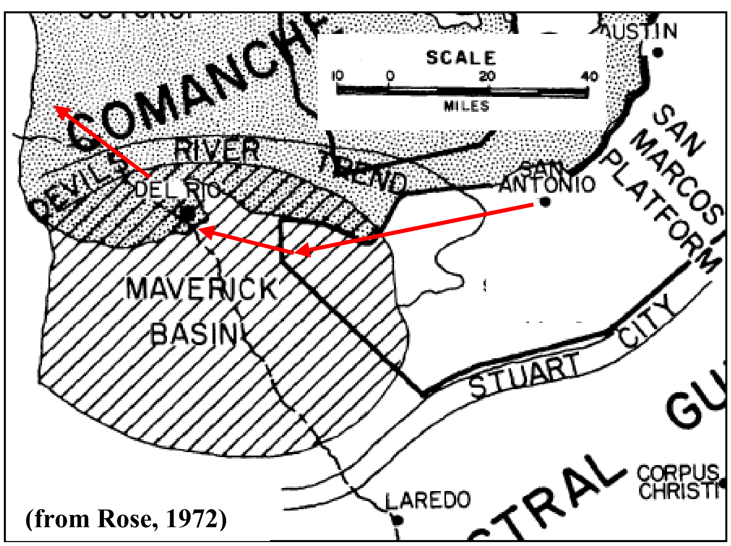
Boquillas Formation (Eagle Ford) and Associated Strata in Road Cuts along U.S. Highway 90, Northwest of Del Rio, Texas

Introduction

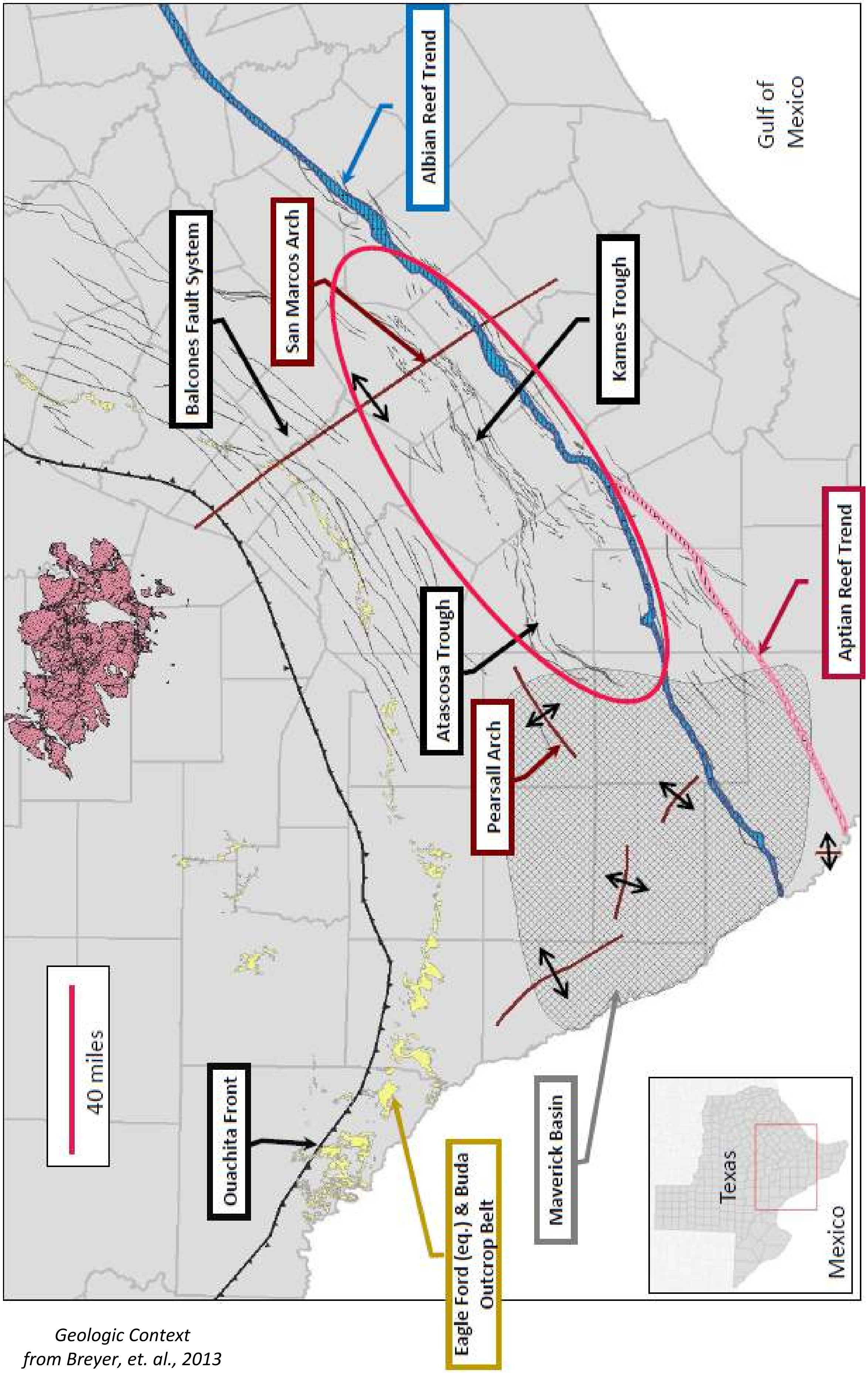
Welcome to our PACROFI 14 Field Trip. We will be traveling across a part of Texas that is geologically interesting and rich in cultural history. This guidebook is divided into several parts. Attached to this introduction are several figures and maps intended to provide a geological perspective for the trip. The first road log covers geological and historical highlights of our travel route along Highway 90 between San Antonio and Del Rio. We will be travelling along the Balcones Fault Zone, as far as Uvalde, and over significant hydrological features such as the Uvalde Pool portion of the Edwards Aquifer and the 'Knippa Constriction'. Near Uvalde, we will make a brief stop to see Cretaceous intrusive volcanic rocks at the Black Waterhole along the Frio River. Continuing our travel route will take us just south of the southern edge of the Edwards Plateau, through the Uvalde Volcanic Field, just north of the Southwest Texas Heavy Oil province and across the northeastern part of the Maverick Basin. Each of these geological features will be briefly described at the appropriate points along the road log. All of the geological material is taken from several older field guides that cover various parts of our travel route. I have cited specific figures and maps, but in lieu of referencing each written entry, I have listed all of these sources in the attached Reference List. Unattributed photos throughout the guidebook were taken by BW.

After the first road log is a summary paper describing the characteristics and occurrence of the Eagle Ford Formation (by TG). The outcrops of the Boquillas Formation that we will see along Highway 90 west of Del Rio are the outcrop equivalent to the subsurface Eagle Ford that occurs in south Texas. Following the summary paper are two additional road logs. The first road log covers the outbound portion of the field trip from Del Rio to Langtry and most of the stops will be at outcrops of the Boquillas Formation. The second part of this road log is the inbound portion of the trip from Langtry to Del Rio and stops will be primarily of Cretaceous strata associated with Boquillas Formation and structural features. The final part of the guidebook is an extensive reference list.

The history of the area extends back to Paleo-Amerindian times, several thousand years before present, and has been influenced subsequently by historic Amerindians, Spanish, French, Mexicans, Texans and Americans. Some of the earlier history of the area is discussed in the brief article about Seminole Canyon State Park. The history of the area reflects the interactions, sometimes violent, between these various groups of peoples. I have taken the liberty to quote directly the several historical markers that have been placed at various points along the highway by the Texas Historical Commission. Other historical data are from various articles in the Online Handbook of Texas, as well as a few other sources, which are also identified in the attached Reference List. Historical items that are mentioned are based strictly on the interest of the author and do not imply any particular significance.

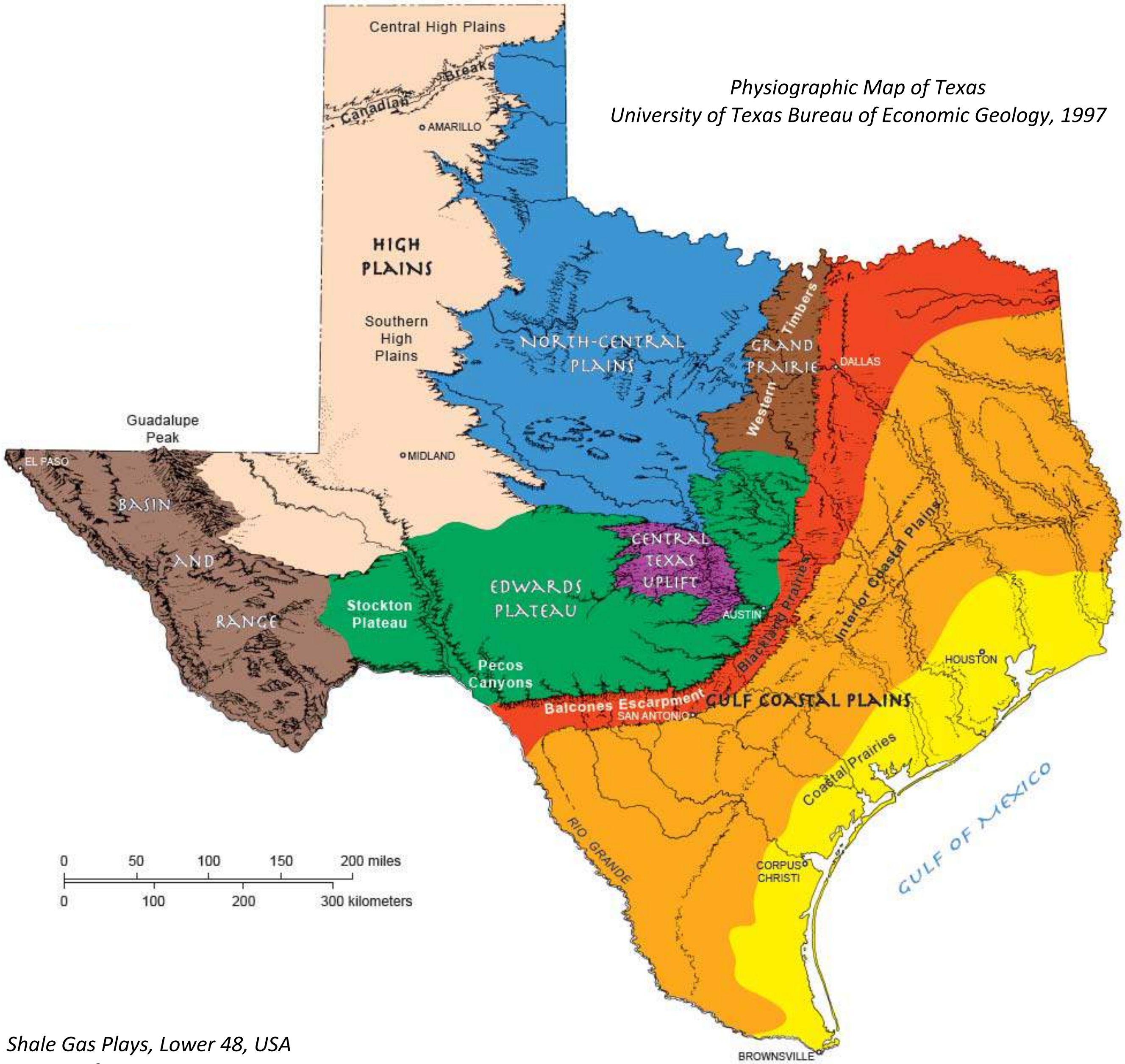


Field trip route (red) superimposed on map of major structural features along the travel route.

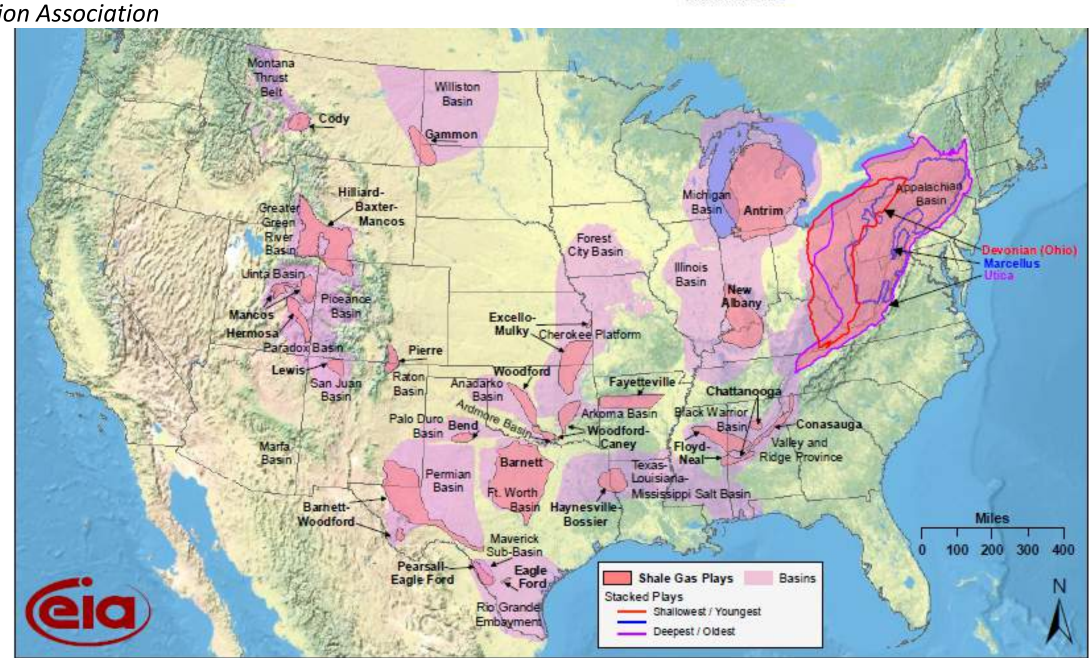


Geologic Context
from Breyer, et. al., 2013

Physiographic Map of Texas
University of Texas Bureau of Economic Geology, 1997



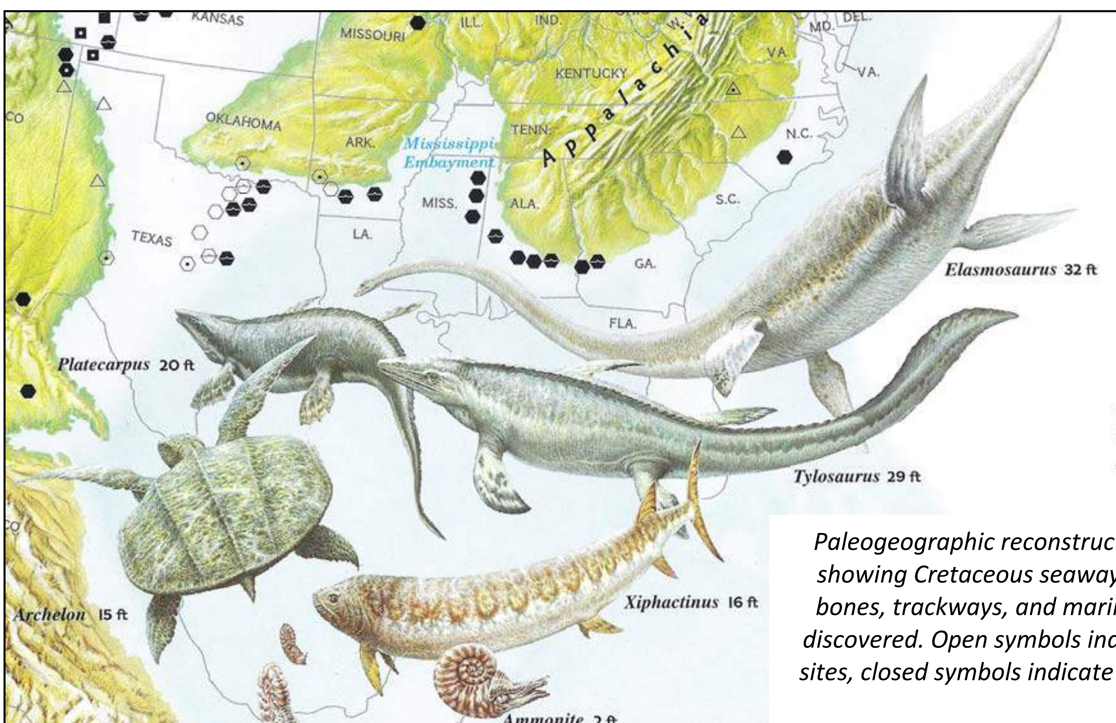
Shale Gas Plays, Lower 48, USA
Energy Information Association



Cretaceous Correlation Chart
(Kettenbrink, 1983)

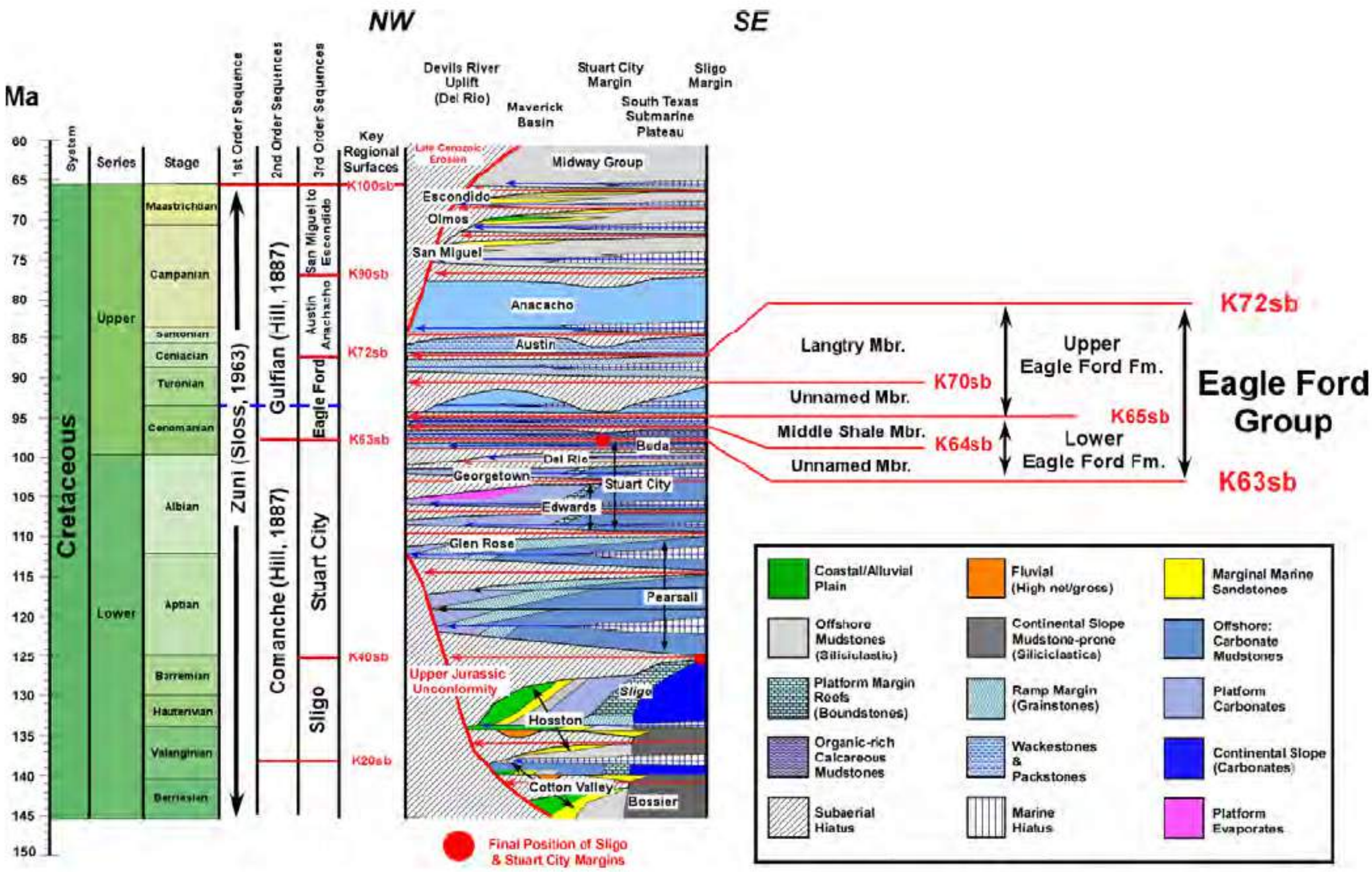
	European Stages		Gulf Coast Series	Gulf Coast Division or Group	Far West Texas Big Bend Area Surface	Southwest Texas Kinney Maverick and Edwards Co's Surface	Central Texas (Austin Area in Part) Surface
UPPER CRETACEOUS	SANTONIAN		GULF CRETACEOUS	AUSTIN	TERLINGUA CLAY (RESTRICTED) WITH EXOGYRA PONDEROSA ?	LOWER ANACACHO LS. MBR. (GOBER EQUIVALENT) UPSON CLAY BURDITT CHALK DESSAU CHALK WITH EXO. POND.	? CLAYS BURDITT CHALK "DESSAU CHALK" WITH EXO. POND. ?
	CONIACIAN				UNAMED CHALK MBR. WITHOUT EXO. PONDEROSA	UNAMED CHALK MBR. WITHOUT EXO. PONDEROSA	UNAMED CHALK MBR. WITHOUT EXO. PONDEROSA
	TURONIAN			EAGLEFORD	BOQUILLAS UPPER PART TURONIAN LOWER PART PROBABLY UPPER CENOMANIAN (ON BASIS OF AMMONITES)	EAGLEFORD UPPER PART CHALKY LS. & MARLS WITH TURONIAN AMMONITES LOWER PART CLAYS, SILTSTONES & SILTY LIMES (BOQUILLAS FACIES) WITH UPPER CENOMANIAN AMMONITES	EAGLEFORD CLAYS & LIMESTONES TURONIAN & UPPER CENOMANIAN AMMONITES PEPPER CLAYS LEWISVILLE EQUIVALENT ?
	CENOMANIAN	UPPER					
		MIDDLE		WOODBINE RESTRICTED	MISSING	MISSING	MISSING
		LOWER	COMANCHE CRETACEOUS	WASHITA	BUDA LS. DEL RIO CLAY (GRAYSON)	BUDA LS. DEL RIO CLAY	BUDA LS. GRAYSON MARL.
LOWER CRETACEOUS	ALBIAN	UPPER			GEORGETOWN LS. UNDIFFERENTIATED WITH BASAL DUCK CREEK AMMONITES	GEORGETOWN LS. UNDIFFERENTIATED WITH BASAL DUCK CREEK AMMONITES	GEORGETOWN LS. UNDIFFERENTIATED WITH BASAL DUCK CREEK AMMONITES ?
		MIDDLE		FREDERICKSBURG	KIAMICHI EDWARDS COMANCHE PEAK & WALNUT MAXON SAND	SUBSURFACE KINNEY, MAVERICK CO'S FREDERICKSBURG UNDIFF'D UPPER PART MC KNIGHT FM. WITH EVAPORITES. SUBSURFACE & SURFACE RELATIONSHIPS INDICATED POST EDWARDS IN AGE	SHELLY LS & CLAYS IN PART KIAMICHI GOODLAND LS (EDWARDS) COMANCHE PEAK PALUXY WALNUT (GATESVILLE AREA)
		LOWER		TRINITY	TRINITY UNDIFFERENTIATED GLEN ROSE EQUIVALENT WITH BASAL SDS. & GRAVEL LOWEST AMMONITES PROB. UPPER OR MIDDLE LOWER ALBIAN	TRINITY UNDIFFERENTIATED GLEN ROSE EQUIVALENT IN PART WITH BASAL SS.	GLEN ROSE UNDIFF'D HENSEL SD.

Paleogeographic map – North America, ca. 85 Ma
Ron Blakey, University of Northern Arizona

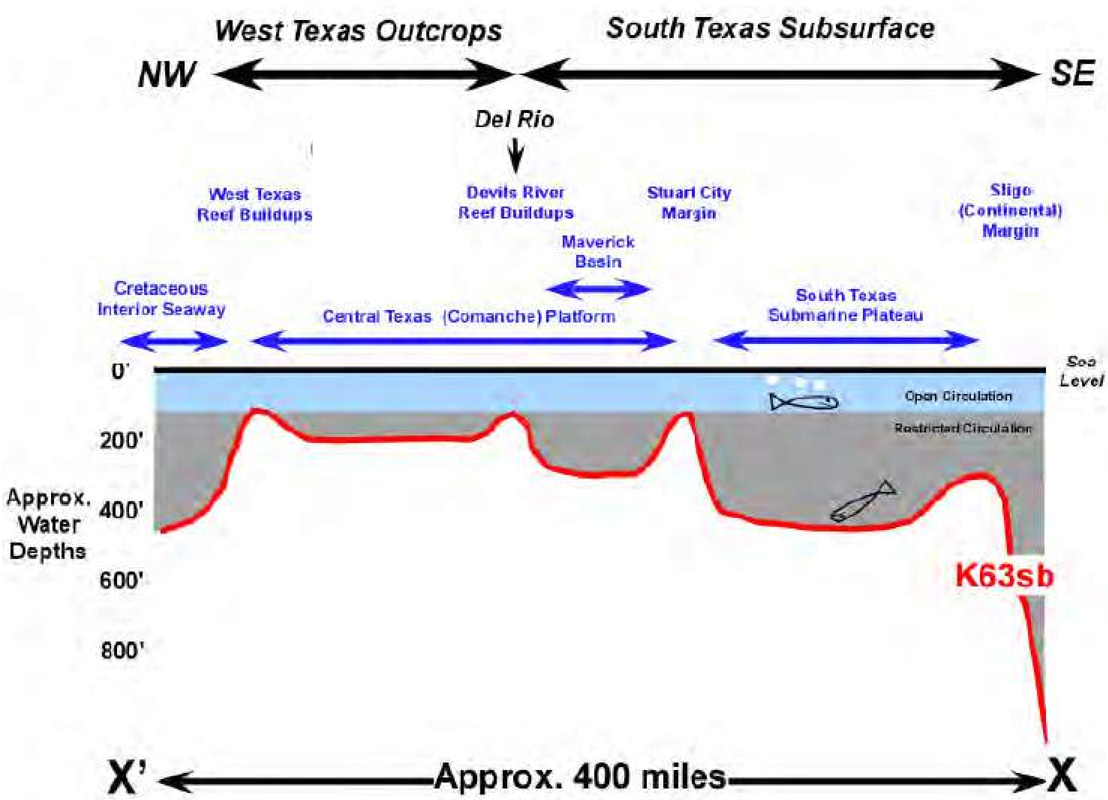


Paleogeographic reconstruction of North America showing Cretaceous seaway and locations where bones, trackways, and marine animals have been discovered. Open symbols indicate Early Cretaceous sites, closed symbols indicate Later Cretaceous sites.

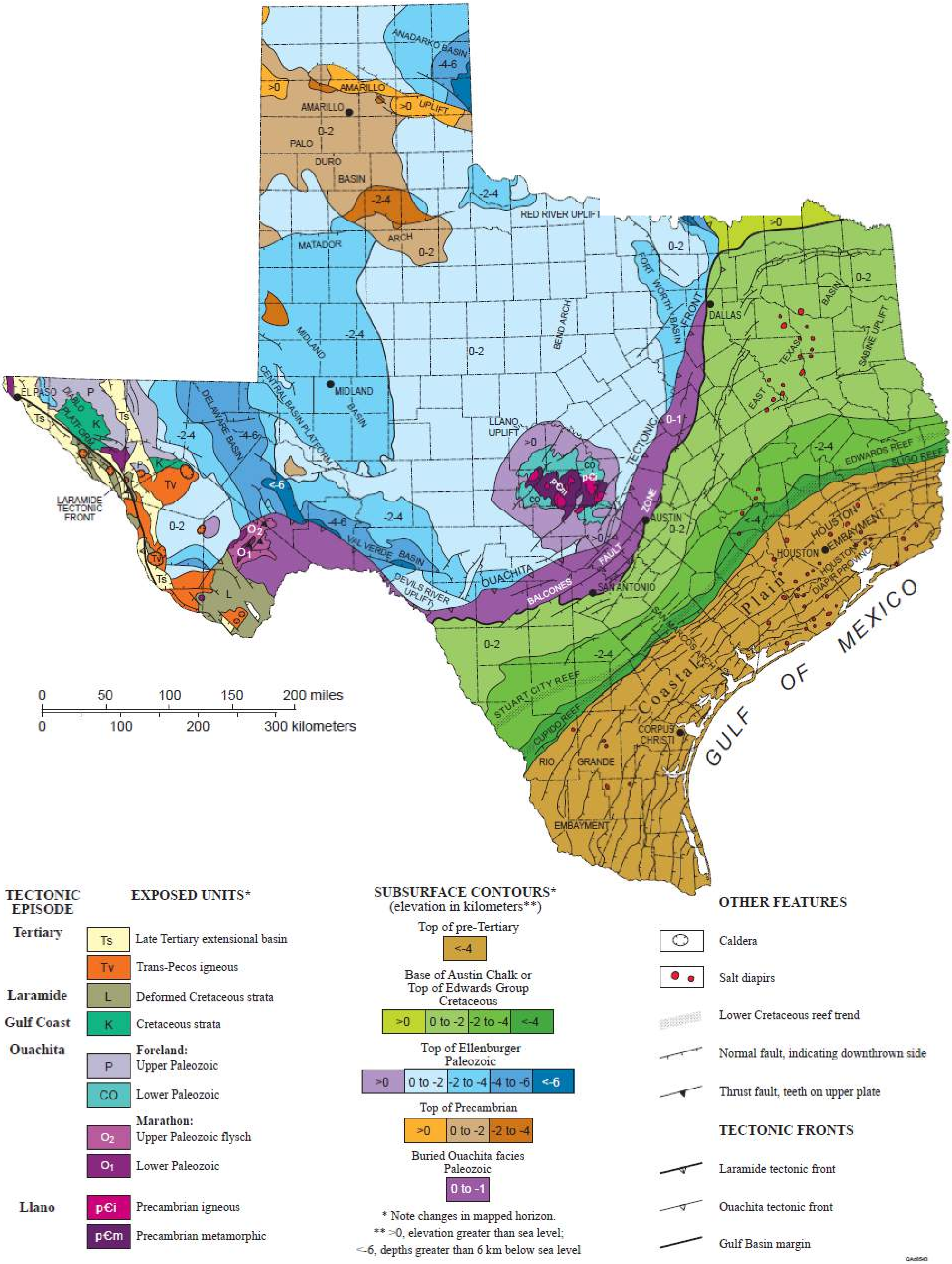
from: North America and the Age of Dinosaurs National Geographic poster



Cretaceous chronostratigraphy – South Texas
(Donovan, et.al., 2012a)

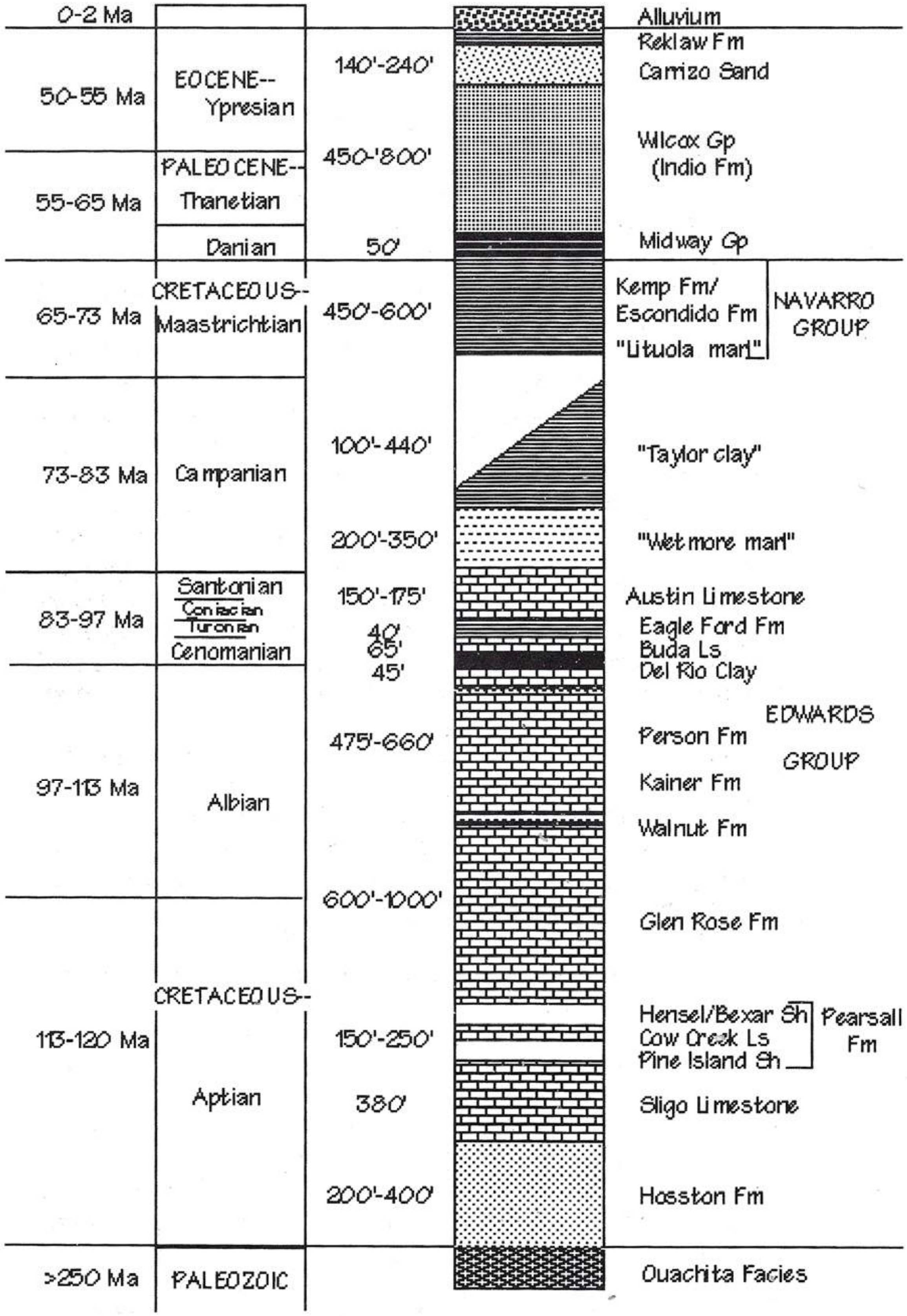


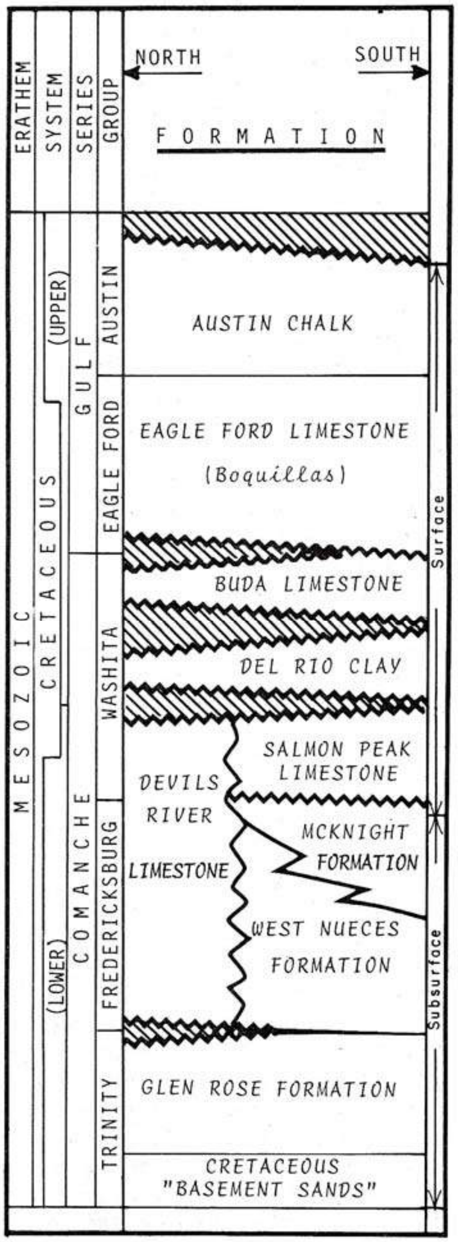
Reconstructed transect across the Late Cenomanian Comanche Platform
(Donovan, et. al., 2012a)



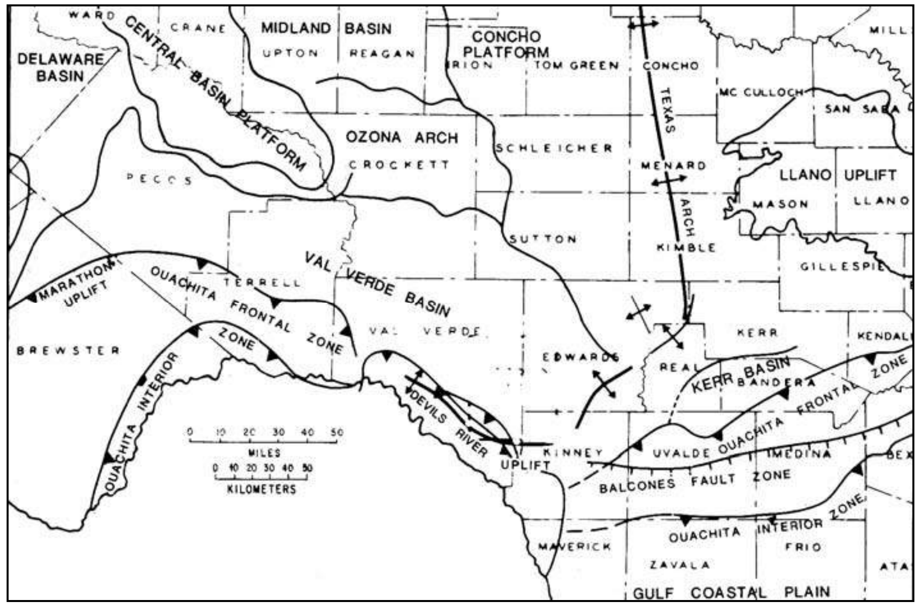
Tectonic Map of Texas
University of Texas Bureau of Economic Geology, 1997

Stratigraphic Column for the San Antonio Area
(Ewing, 1996)



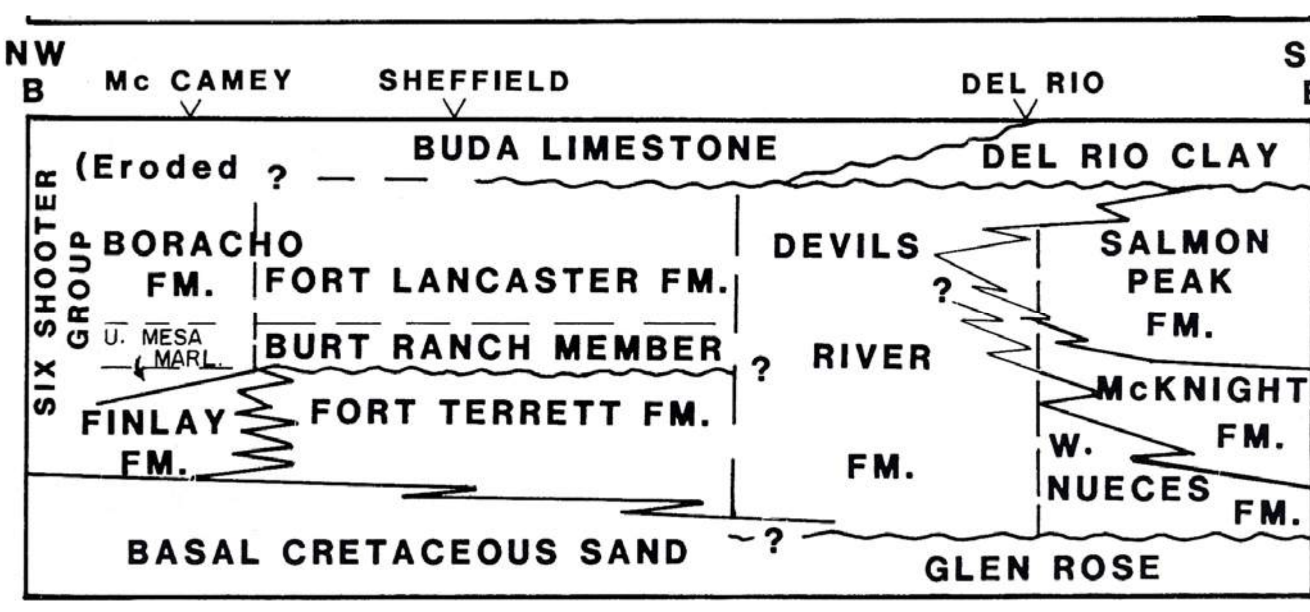


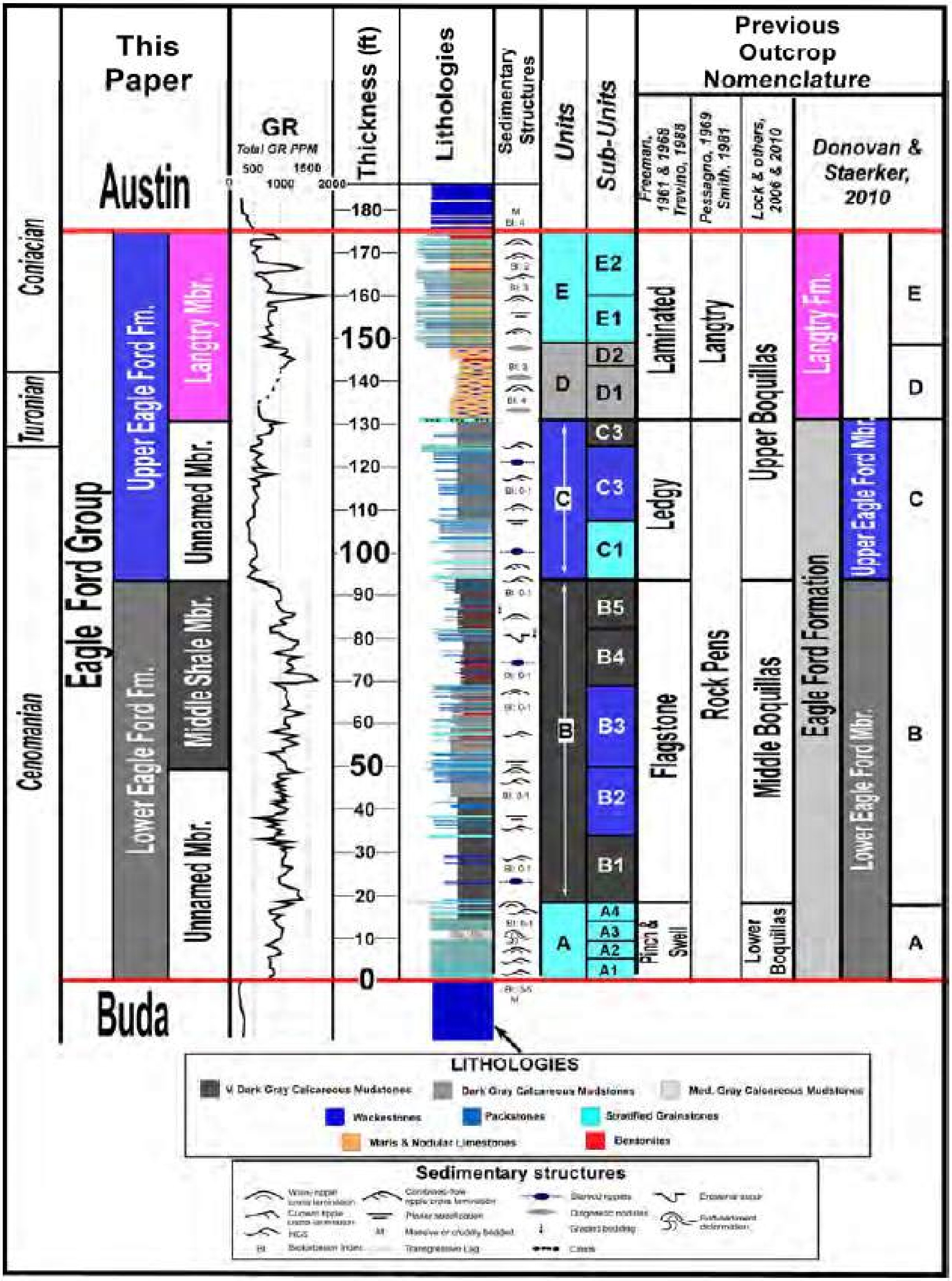
Composite Stratigraphic Column
Devils River Uplift
Val Verde and Kinney Counties, Texas
(Smith, 1984)



Major structural features SW Texas
(Kettenbrink, 1983)

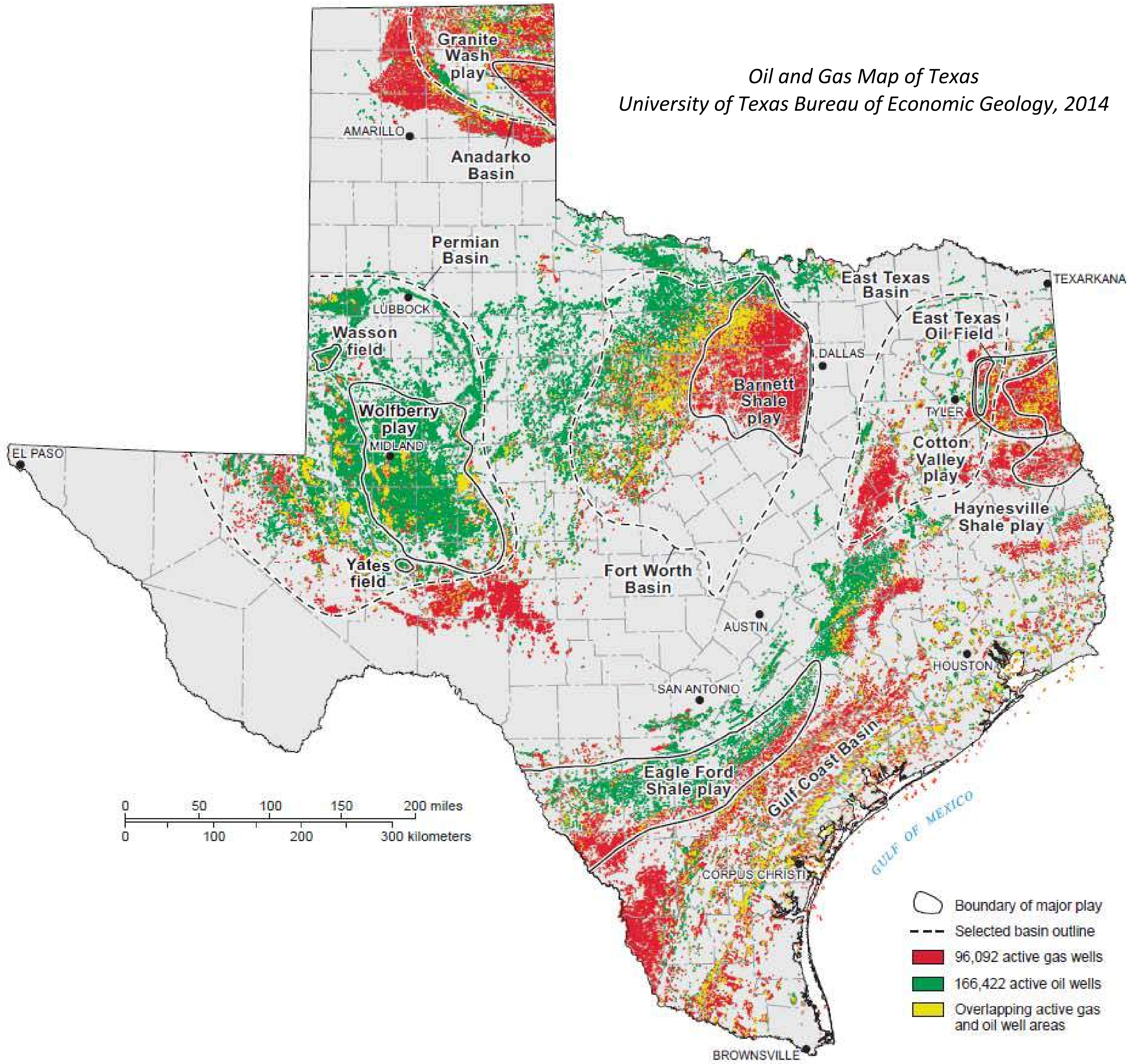
Generalized Stratigraphic Column
Fredericksburg-Lower Washita, West Texas
(Kettenbrink, 1983)

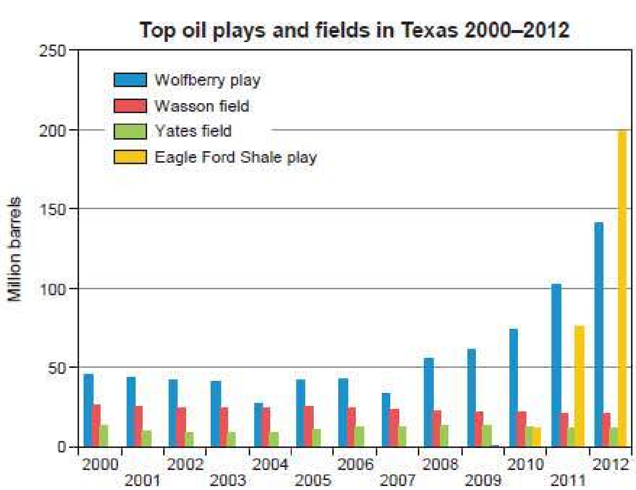


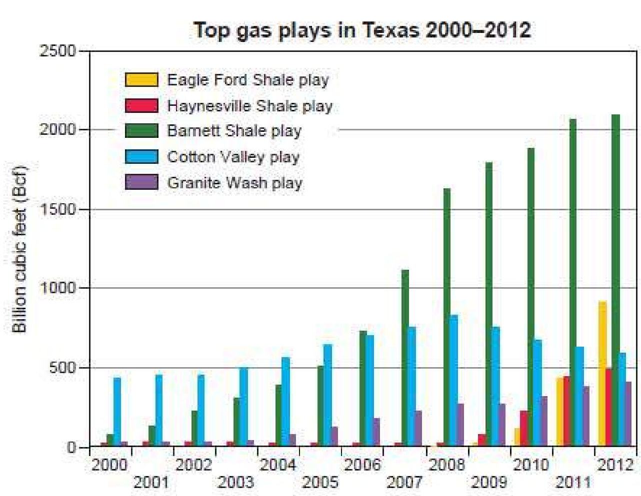


Stratigraphic nomenclature applied by various researchers to the outcrops in West Texas
(Donovan, et. al., 2012a

Oil and Gas Map of Texas
University of Texas Bureau of Economic Geology, 2014

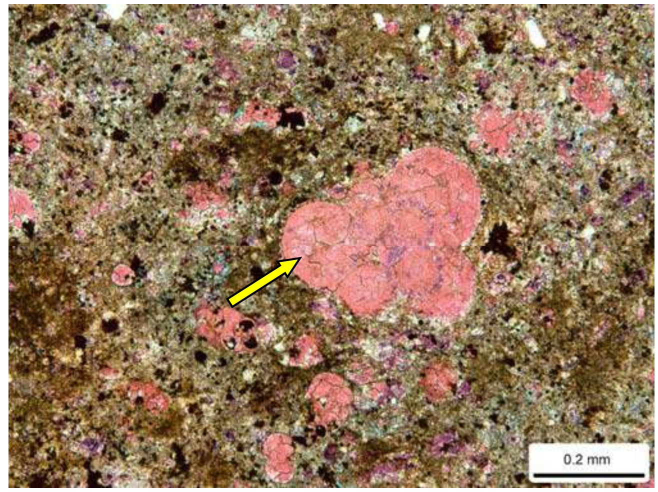






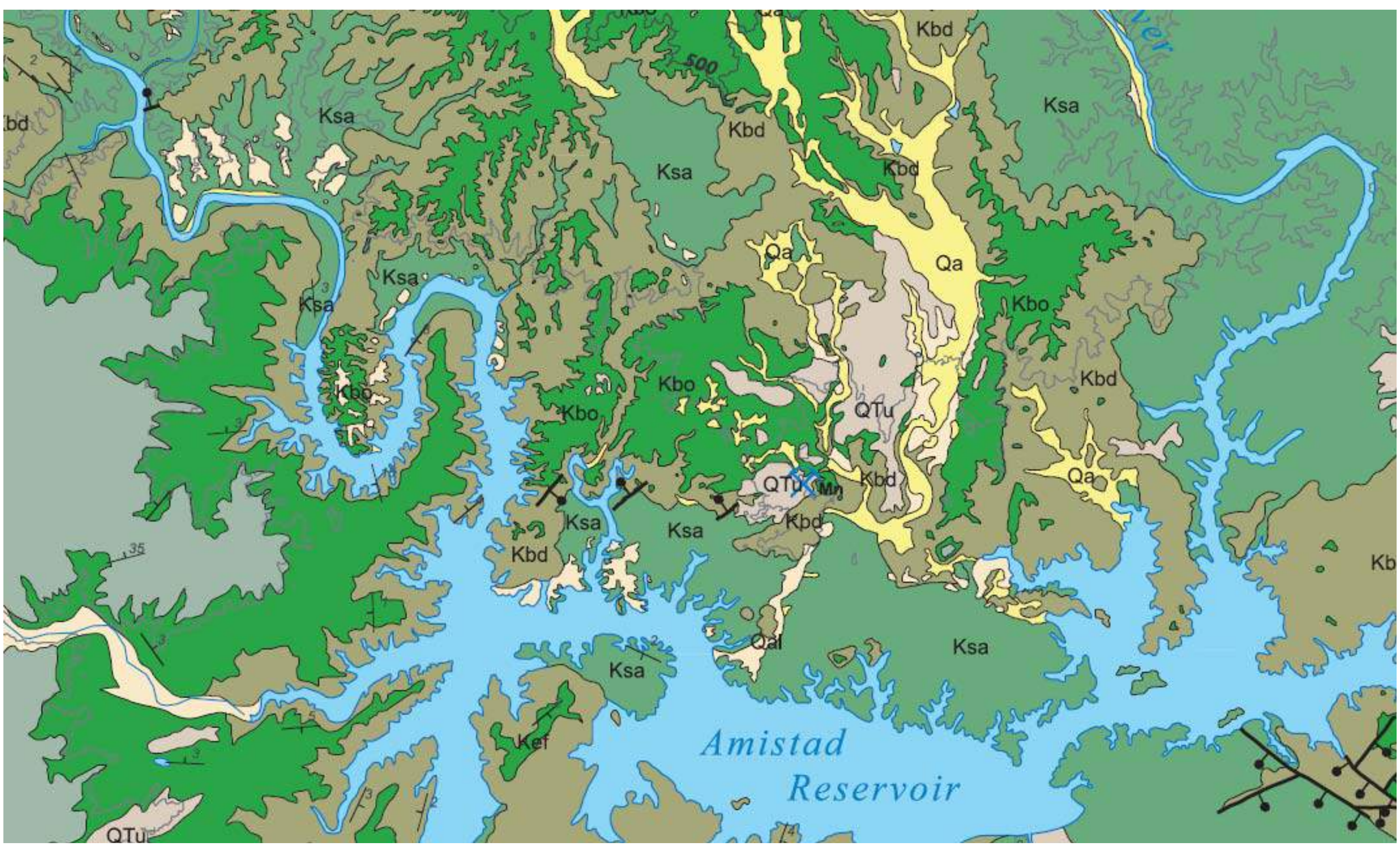
Key to Map Units (1)
Page, et. al., 2009

w	Water
Qa	Modern alluvium (Holocene)
Qcd	Clay to sand dunes (Holocene)
Qsd	Active dunes (Holocene)
Qds	Stabilized sand dunes (Holocene)
Qs	Sand sheet (Holocene)
Qsi	Silt sheet (Holocene)
Qla	Lacustrine deposits (Holocene)
Qal	Alluvium, undivided (Holocene and Pleistocene)
Qtr	Travertine deposits (Pleistocene)
Qbe	Beaumont Formation (Pleistocene)
Ql	Lissie Formation (Pleistocene)
QTg	Quaternary and Tertiary gravel, undivided (Holocene to Pliocene)
QTu	Uvalde Gravel (Pleistocene or Pliocene)



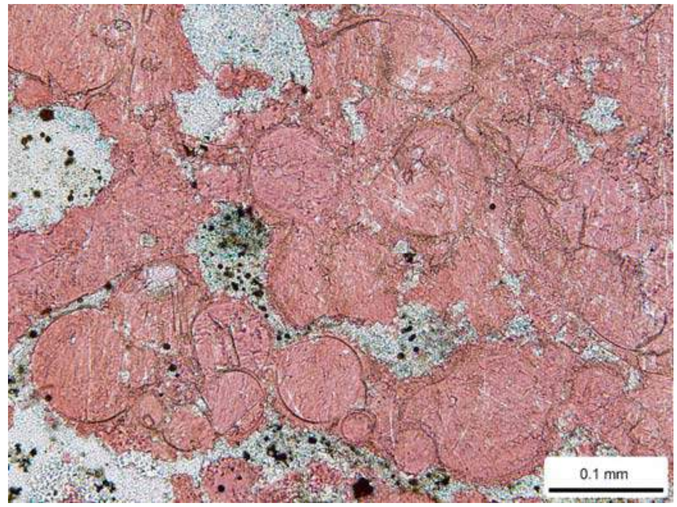
Calcareous mudstone, middle Boquillas, sample from lower part of road cuts at Stop 3. Note large foraminifer test (arrow) with chambers that are filled with spary calcite (pink). Brownish-colored clays are the other principal rock constituent seen in this image.

Detailed Geological Map of Field Trip Area
(eastern half)
Page, et. al., 2009



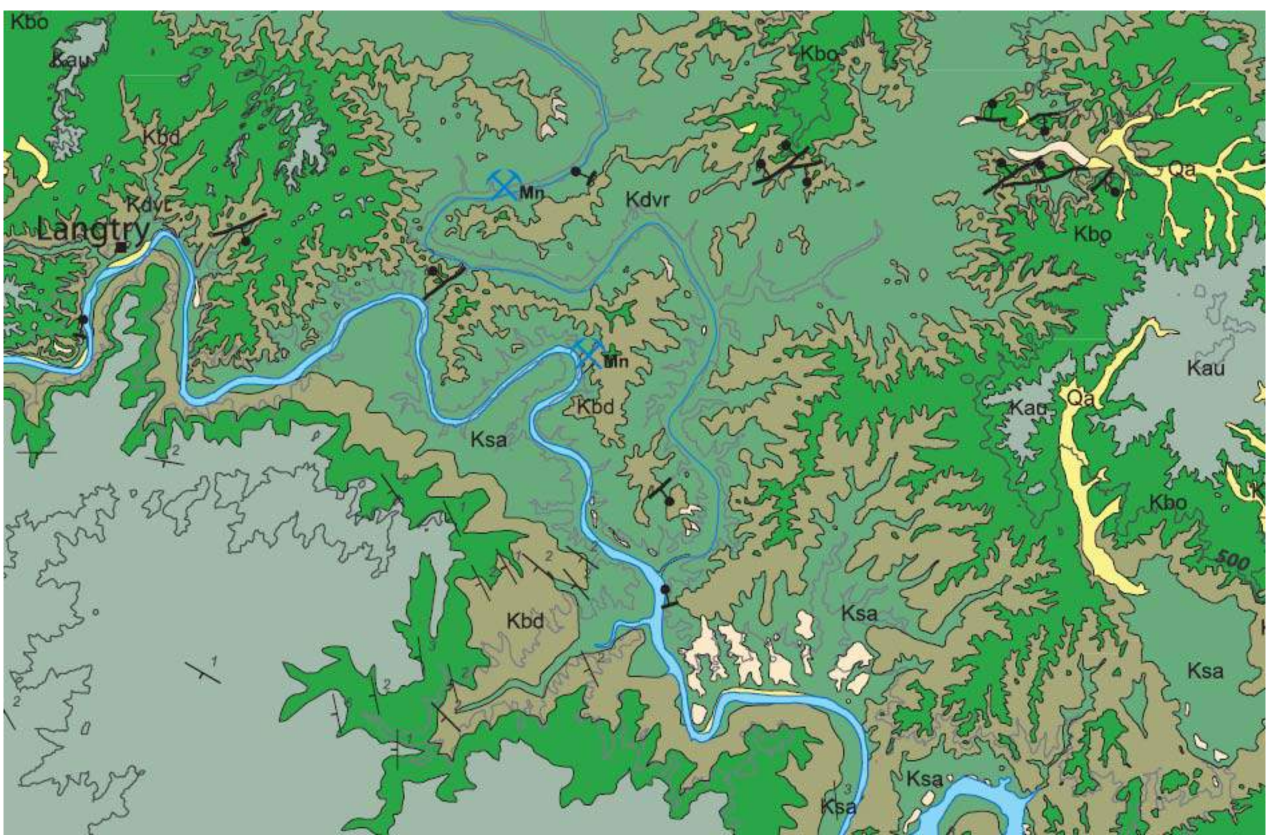
Key to Map Units (2)
Page, et. al., 2009

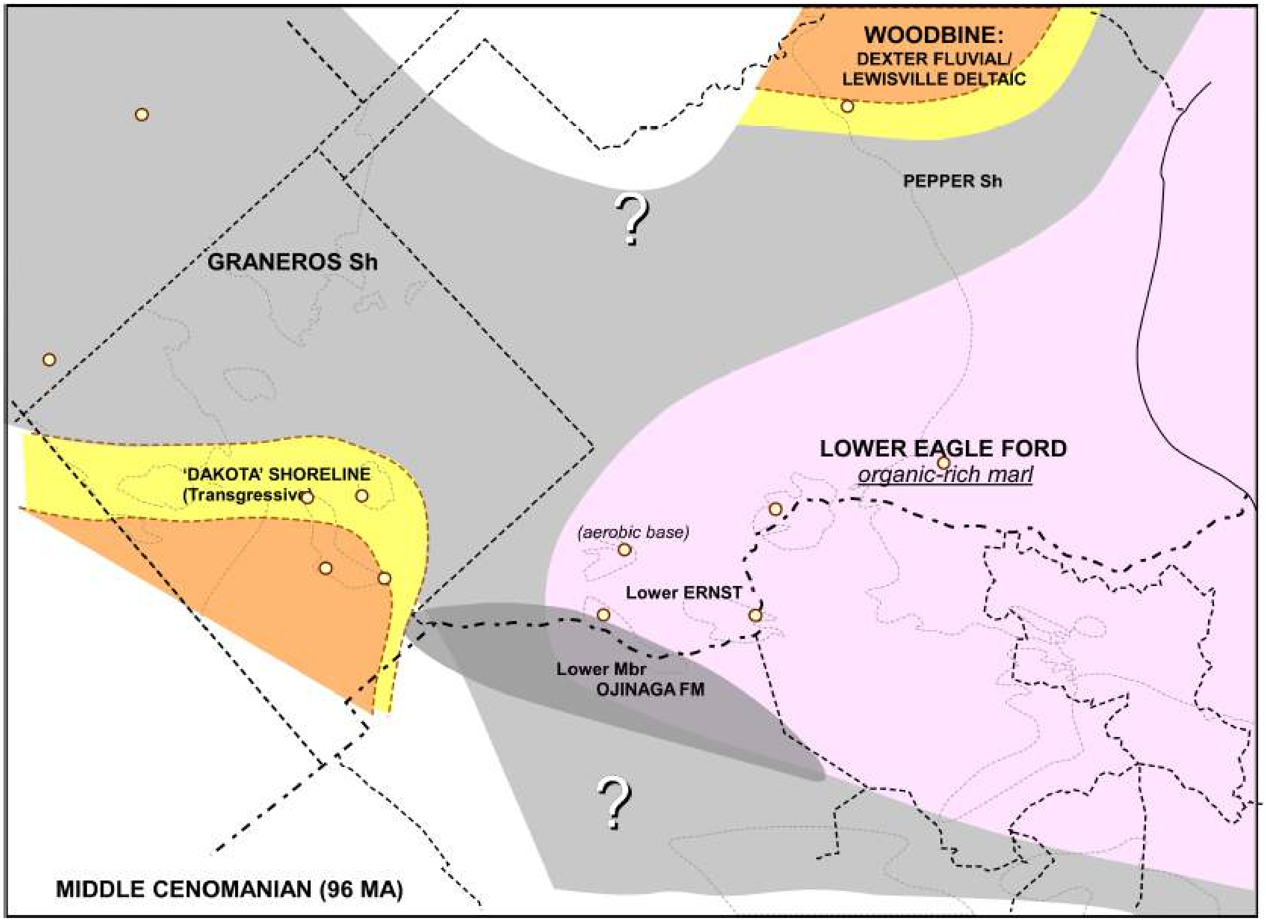
Kac	Anacacho Limestone (Upper Cretaceous)
Kpg	Pecan Gap Chalk (Upper Cretaceous)
Kau	Austin Chalk (Upper Cretaceous)
Kbo	Boquillas Formation (Upper Cretaceous)
Kef	Eagle Ford Group (Upper Cretaceous)
Kbd	Buda Limestone and Del Rio Clay, undivided (Upper Cretaceous)
Kwa	Washita Group, undivided (Upper and Lower Cretaceous)
Kdvr	Devils River Limestone (Lower Cretaceous)
Ksa	Salmon Peak Limestone (Lower Cretaceous)
Kmk	McKnight Formation (Lower Cretaceous)
Kwn	West Nueces Formation (Lower Cretaceous)
Ked	Edwards Limestone, undivided (Lower Cretaceous)



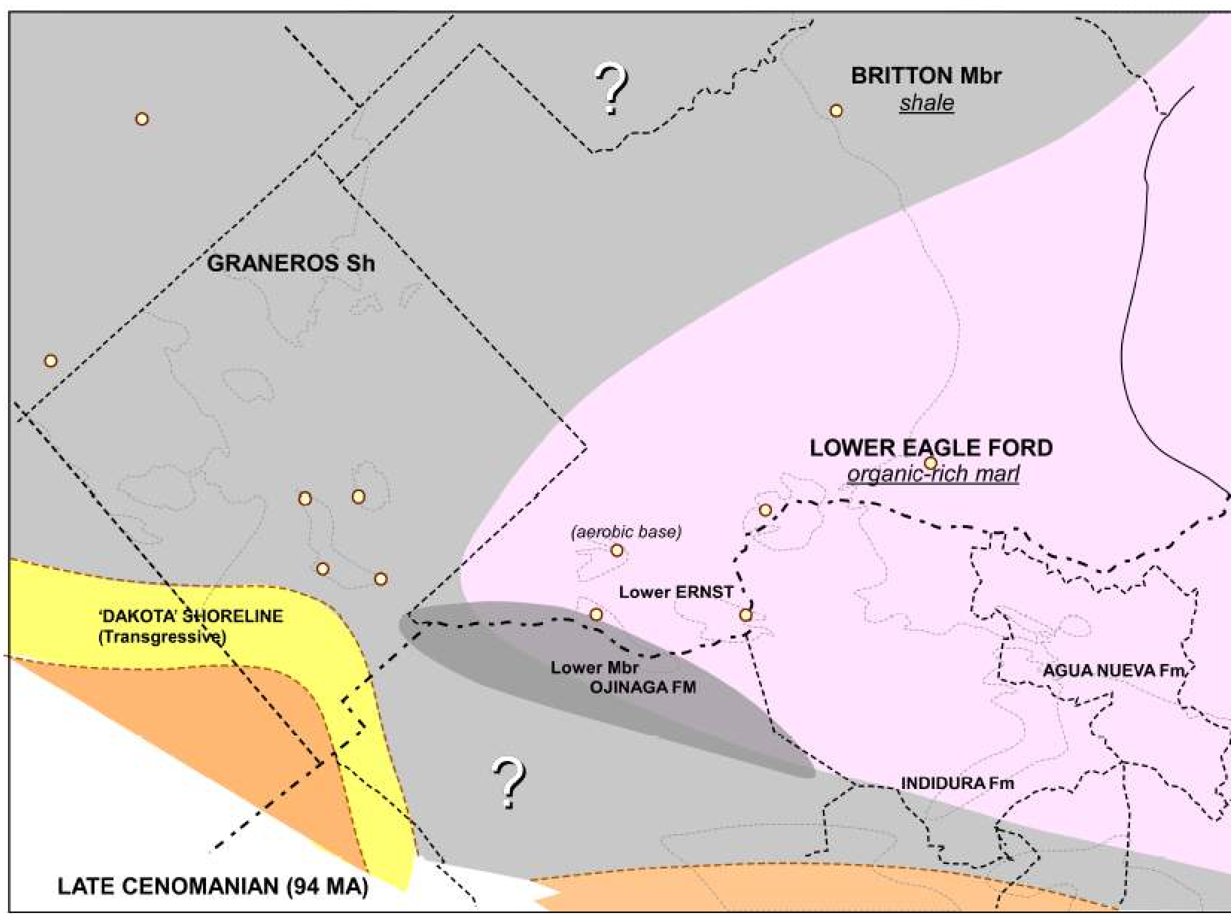
Recrystallized limestone (silicified), lower Boquillas, sample from bed immediately above turbidite bed in road cuts at Gazebo alternate stop. Sample is predominantly calcite cement, spary-calcite filled foraminifera tests and microcrystalline silica cement. Calcite is pink and quartz is gray in this image.

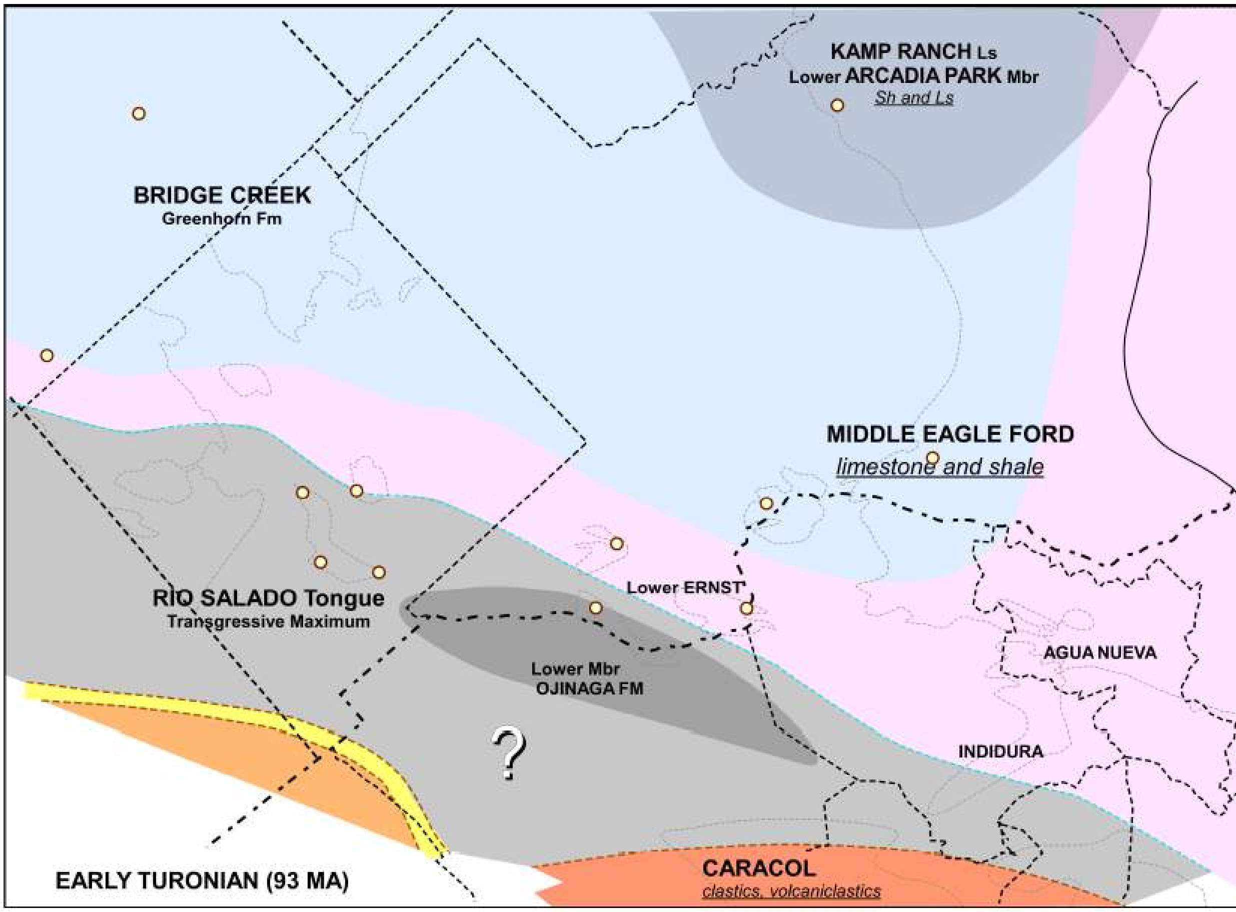
Detailed Geological Map of Field Trip Area (western half)
Page, et. al., 2009



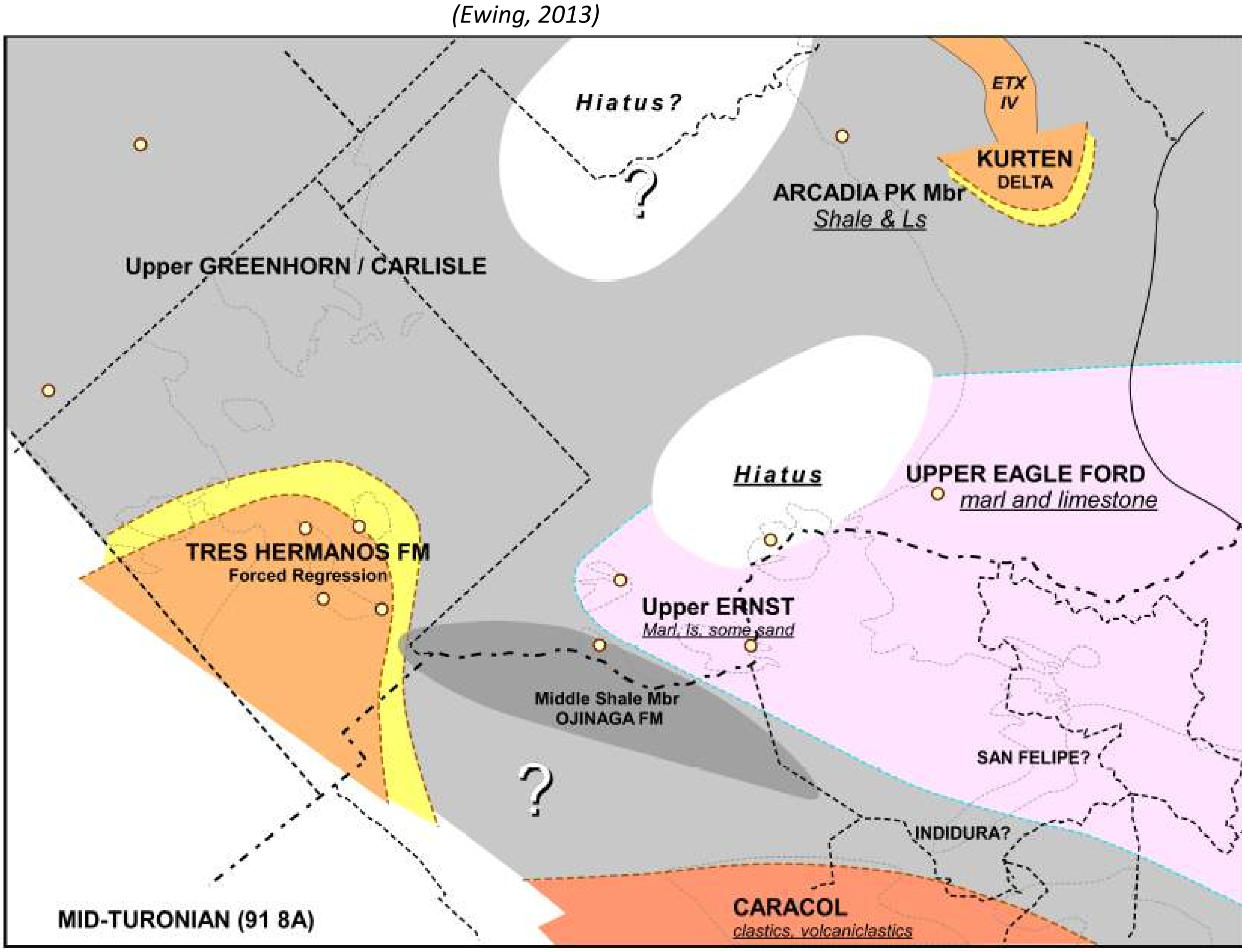


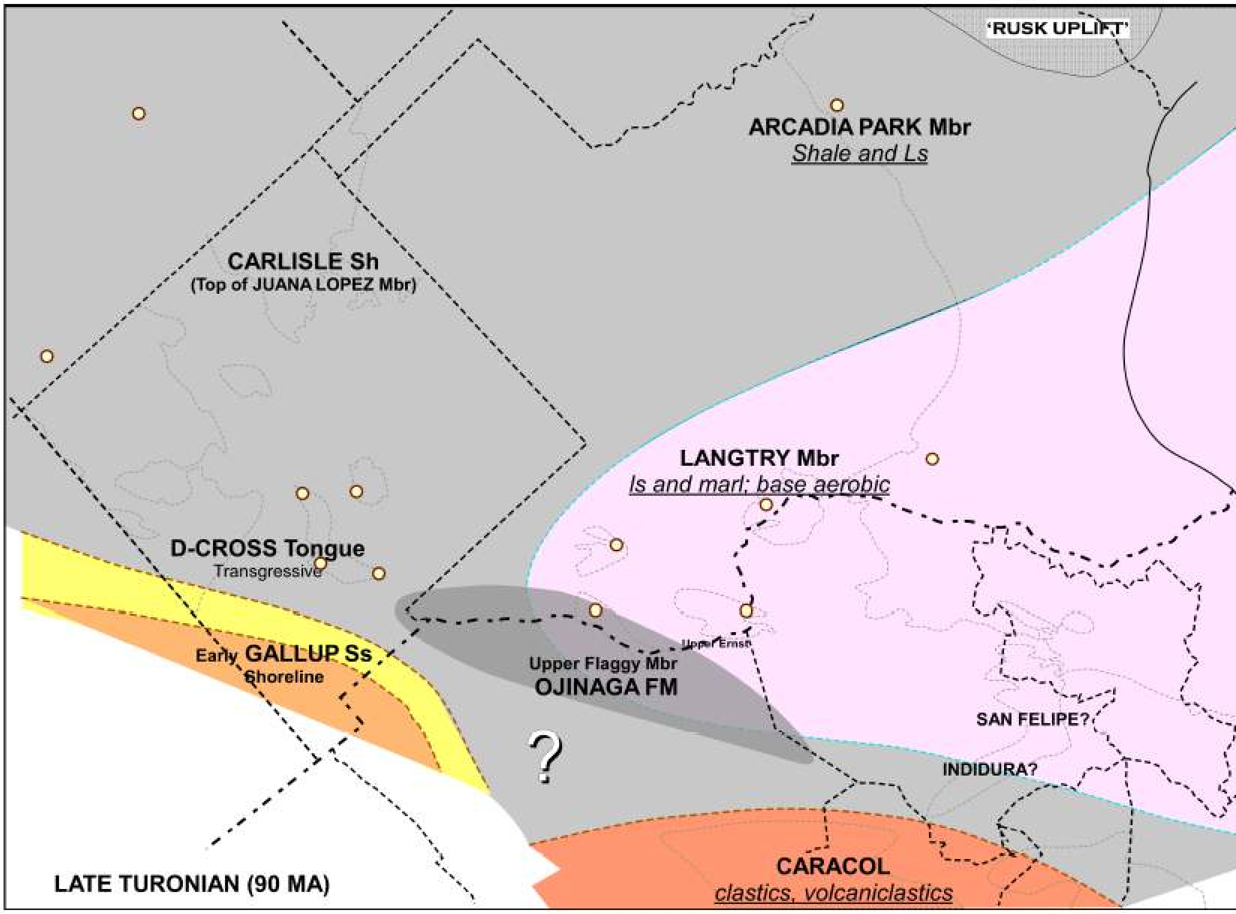
Paleogeographic Maps – Middle Cenomanian & Late Cenomanian
(Ewing, 2013)



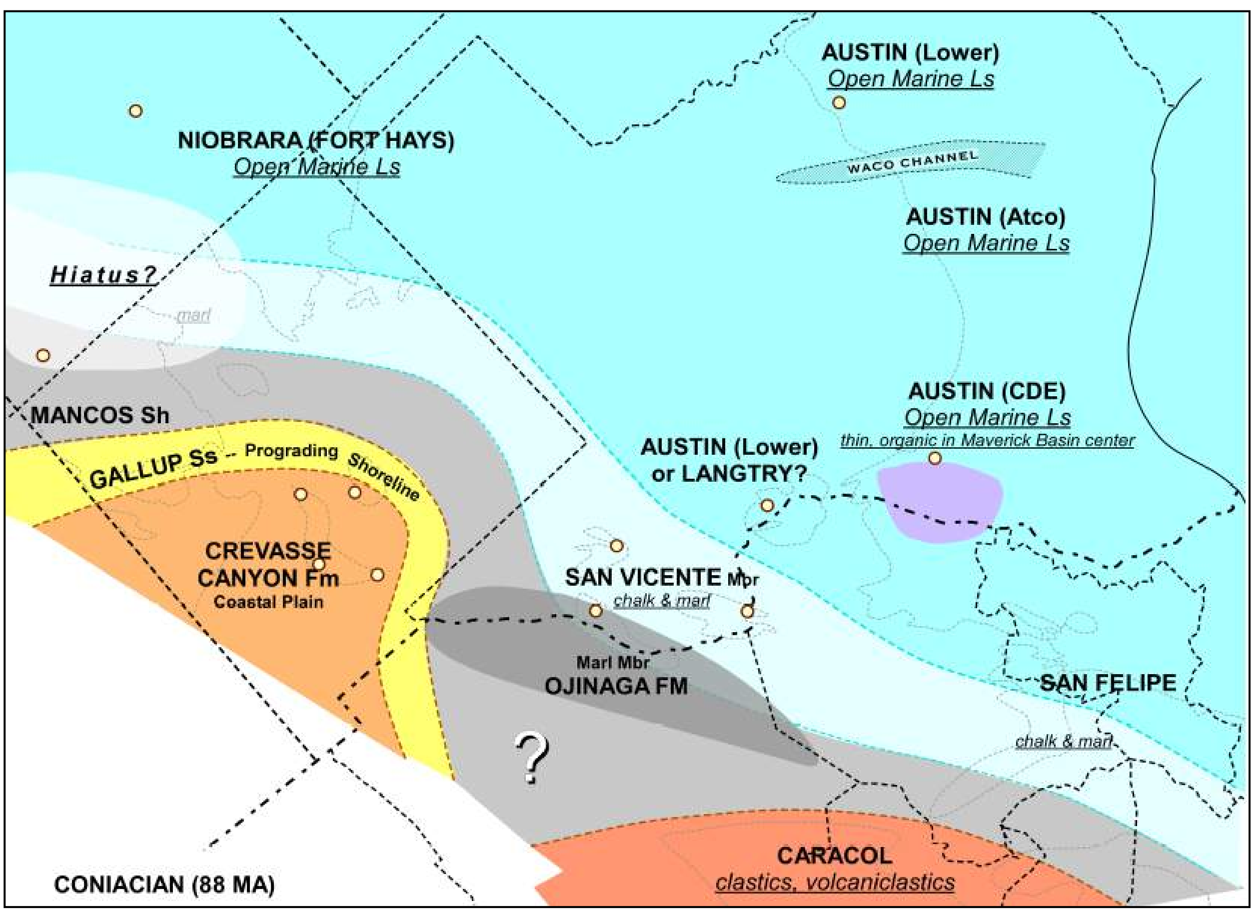


Paleogeographic Maps – Early Turonian & Middle Turonian
(Ewing, 2013)





Paleogeographic Maps – Late Turonian & Coniacian
(Ewing, 2013)



Road Log (1): U.S. Highway 90 - San Antonio to Del Rio

0.0 0.0 US-90/I-410; SW San Antonio.

Balcones Fault Zone

The dominant geological structures of the San Antonio area are formed by faults associated with the Balcones Fault zone, which extends from the Uvalde area east/northeast to at least Waco. The fault zone forms the southeastern outcrop limit of the resistant Lower Cretaceous limestone, also known as the Balcones Escarpment. The Balcones Escarpment is the boundary between the Edwards Plateau (Hill Country) and the Gulf Coastal Plain physiographic provinces. Strata north and west of the fault zone dip very gently (5-10' / mile) towards the Gulf, while strata to the south and east dip up to 100' / mile. The Balcones Fault zone defines the structural grain of the area between San Antonio and Uvalde. Internally the Balcones Fault zone consists of four to ten strike-parallel down-to-the-southeast normal faults of remarkable straightness, with several hundred-foot displacements. The larger faults are linked by complexes of small-scale faults. Down-to-the-northwest normal faults are not unknown, but tend to have lesser displacement. The major Balcones faults are generally linear, with a lateral extent of up to 40 miles and with 200-800’ displacement. Bexar County lies in a structurally complex part of the zone. Faults that extend for miles east or west of Bexar County die out and/or interact in a complex manner, in the San Antonio area. The major faults cut the entire Cretaceous section and root in or below the underlying Ouachita facies. The overlying Uvalde terraces are unfaulted. West of Uvalde the fault zone rapidly dies out. Faults that have their maximum displacement at the Uvalde/Medina county line cannot be identified at the Uvalde/Kinney county line. The most obvious structure west of the Nueces River is a south to southwest dipping homocline, with prominent cuestas of Salmon Peak, Austin, and Anacacho limestones.

Culebra Anticline (about 5 miles NW)

The Culebra Anticline extends from north-central Bexar County southwestward into Medina County. It is bounded on the NW by the Cliff fault and on the SE by the Castroville fault. The principal structure is a broad, asymmetrical fold, seven to nine miles wide, plunging to the southwest. The axis of the fold is some 6 miles south of the Balcones Escarpment and the southeast side has the steeper dip. Topographically, the anticline consists of a central hill of Austin Chalk surrounded successively by bands of Anacacho Limestone (“Austin-like”), Corsicana Marl, and the Escondido Formation. The Medina River flows around the nose of the anticline.

Balcones Escarpment

The Balcones escarpment parallels US-90 about 12 miles to the north. The escarpment marks the southern, highly dissected edge of the Edwards Plateau which is developed on resistant Lower Cretaceous limestone. The escarpment approximately locates the northern edge of the Balcones fault system along which Upper Cretaceous formations are faulted down to the south against Lower Cretaceous strata. If the atmosphere is not too hazy the southern edge of the Edwards Plateau can be seen to the north, especially between here and Sabinal.

3.2 3.2 FM 1604.

To the north, the Castroville fault on the south side of the Culebra Anticline places the Navarro / Escondido (which we are presently traveling on) against the Austin-‘Anacacho’ section.

6.3 3.1 Hard ledge near base of Navarro/Escondido with abundant large *Exogyra* sp. (bivalve-oyster) formerly exposed on the south side of the highway.

7.2 0.9 Tx-211.

10.2 3.0 Medina County Line.

Evidence of early man in Medina County has been discovered at a site known as Scorpion Cave on the Medina River in the northeastern part of the county. Archeologists believe that ancestors of either Coahuiltecan or Tonkawa Indians occupied this cave continuously for several thousand years before the arrival of the first Europeans. The first Spaniard to set foot in the region was probably Alonso De León, governor of Coahuila, who passed through the area in 1689 en route to East Texas, and named the Medina River, Hondo creek and Seco creek. Two years later Domingo Terán de los Ríos, the first provincial governor of Texas, tracked across southern Medina County, laying the foundation for El Camino Real (Old San Antonio Road). Throughout the 1700's the area was frequented by roving bands of Lipan Apaches and Comanches, whose seasonal raiding parties traveled south from the plains area of North and West Texas and New Mexico on their way to Mexico. From this vantage point the Apache-Comanche Indians would attack San Antonio with impunity. The Republic of Texas was convinced that if this large block of land were settled it would provide a protective zone against any invasion forces approaching San Antonio from the south and west. They negotiated an empresarial contract with Frenchman Henri Castro on February 15, 1842, to settle the area. One of Castro's land grants began four miles west of the Medina River. He purchased the sixteen leagues between his granted concessions and the river from John McMullen of San Antonio. Castro, with the assistance of German wine merchant Ludwig Huth and his son Louis August Ferdinand Huth, arranged the transport of German and French-speaking farmers from the Alsace region of northeastern France. Castro brought the settlers overland from the Texas coast to San Antonio, and on September 2, 1844, set out to locate a site for settlement. Castroville was founded on September 3, 1844, and was the westernmost settlement in Texas. In a relatively short time the settlements of Quihi (1845), Vandenburg (1846), New Fountain (1846), and Old D'Hanis (1848) were also established.

12.6 1.4 Castroville (sign).

Castroville is often called the "little Alsace" of Texas. The town was named for its founder, Henri Castro. Empresarios (Spanish, 'entrepreneur') were individuals who had been granted the right to settle on Mexican land in exchange for recruiting and taking responsibility for new settlers. The Spanish were the first to use this form of colonization, later Texas incorporated this idea as it expanded settlements through southwest Texas. On September 2, 1844, Castro set out from San Antonio with his colonists, accompanied by Texas Ranger John C. Hays and five of his rangers, to decide upon a site for settlement. The company chose a level, park-like area near a sharp bend of the Medina River covered with pecan trees. Castro recounts in his memoirs that after crossing the river members of his party killed two deer, three bears, and one alligator and caught numerous fish. Subsequently, the colonists endured raids by Comanches and Mexicans, droughts in 1848 and 1849, an invasion of locusts, and a cholera epidemic in 1849. Castroville became the first county seat of Medina County, but the county seat was later relocated to Hondo, after the railroad bypassed the town in 1880. The city of Castroville had refused to grant the railroad a bonus for building it tracks through town. Many of the old buildings remain (97 are officially recognized historic buildings).

Henri Castro (1786–1865)

Henri Castro, empresario and founder of Castro's colony, was born in the department of Landes, France, in July 1786. His family, descended from Portuguese Jews, had fled to France after the inception of the Spanish Inquisition, and occupied a position of wealth and status in southwestern France. At nineteen Castro was appointed by the governor of Landes to a committee to welcome Napoleon during a visit to the province, and in 1806 he served as a member of Napoleon's guard of honor when the emperor installed his brother Joseph as king of Spain. In 1813 Castro married a wealthy widow, Amelia Mathias, who brought him a dowry of 50,000 francs. After the fall of Napoleon, he immigrated to the United States and in 1827 became a naturalized citizen. He returned to France in 1838 and became a partner in the banking house of Lafitte and Company. While with that firm he was active in trying to negotiate a loan for the Republic of Texas and thus became interested in the young republic. Out of gratitude for his influence and kindness to Texas, President Sam Houston appointed him consul general for Texas at Paris. In 1842 Castro entered into a contract with the Texas government to settle a colony in Southwest Texas on the Medina River. After great expense, labor, and vexing delays, between 1843 and 1847 he succeeded in chartering twenty-seven ships, in which he brought to Texas 485 families and 457 single men. His task was made difficult because at this same time the French government was trying to colonize Algeria and because the Mexican War made Texas ports often unsafe harbors for the landing of immigrants. Castro was able, however, to settle his first shipload of families at Castroville in September 1844; in 1845 he established the village of Quihi; in

1846, the town of Vandenburg; the last village, D'Hanis, was founded in 1847. Castro was a learned, wise, humane man. In the management of his colony he is more comparable to Stephen F. Austin than is any other Texas empresario. He expended his own money freely-more than $200,000-for the welfare of his colonists, furnishing them cows, farm implements, seeds for planting, medicines, and whatever they really needed that he was able to procure for them. He had unbounded faith in the capacity of intelligent men for self-government. Among his duties Castro found the time to publish his memoirs. He made many maps of his colonial grant and of the area bordering on it and circulated them throughout the Rhine districts of France to induce colonists to join his settlements. These maps did much to advertise Texas in Europe. Despite his scholarship, his exceedingly great energy, and his rare aptitude for work, he was exceptionally modest and retiring. While on his way to France in 1865, he became severely ill at Monterrey, Nuevo León, and died there on November 31, 1865. He was buried in Monterrey at the foot of the Sierra Madre. His many interests were carried on by his son, Lorenzo. Castro County, in the Panhandle, was named in his honor.

13.3 0.7 FM-471 (south).

14.3 1.0 FM-471 (north).

14.5 0.2 Medina River.

The Medina River rises in north and west branches that originate in springs in the Edwards Plateau of northwest Bandera County and converge near Medina. The river then flows southeast for 116 miles to join the San Antonio River in south Bexar County. The first European to see the river was Alonso De León, governor of Coahuila, who led his expedition across Texas in 1689 in pursuit of the French. De León noted in his diary that he named the stream for Pedro Medina, the early Spanish engineer whose navigation tables he was using. For a time it was considered the official boundary between Texas and Coahuila. On August 18, 1813, bearers of the green flag of the Republican Army of the North, fighting to uphold the declared independence of Mexico from Spain, met defeat at the battle of Medina on the river southeast of San Antonio de Béxar. Hundreds of rebel troops were killed by forces under Spanish general Joaquín de Arredondo. At the same site on March 2, 1836, Gen. Antonio López de Santa Anna paused in his march from the Rio Grande in order to gather forces for the final approach to Bexar and the engagement with Texans in the Alamo. Diarist José Enrique de la Peña mentions resting at the river, the making of plans, and carrying out such tasks as assigning horses to dragoons. In the midst of the excitement over impending battle, Peña still took note of "the little stream whose banks were rich with pecan trees."

In 1852 John James, Charles Demontel, and John Herndon formed a partnership for the purpose of building a cypress-lumber mill and laying out a town "on the Medina above Castroville." The mill was a significant part of the regional economy until floods during the 1870s destroyed the mill and all other development at river level. The availability of water from the Medina and its many spring-fed small tributaries seems to have influenced the choice of Bandera as a staging area for cattle drives during the 1870's. The recurrence of the floods that had destroyed the lumber industry revived the idea of a major dam in the famous box canyon of the Medina. Alex Walton, who had visited the canyon in 1894, interested fellow engineers Frederick Stark Pearson and Clint Kearny in launching a project to build such a dam, with canals to carry irrigation water to highly promoted farm tracts in the lower Medina valley around Natalia. A company was formed, assisted by investment of British capital, and the scheme was brought slowly to fruition, despite drought and financial disaster. After construction of the concrete dam was finished in 1912, the proposed lake stood dry until rains a year later brought water down the river. The river and the lake suffered through record dry periods in the 1930s and the 1950s, which were followed by the usual floods. On August 2, 1978, what was widely termed a 500-year flood came down the Medina, an unofficial record rainfall of forty-eight inches having fallen on the North Prong in twenty-four-hours. Twenty-two lives were lost, millions of dollars of property loss or severe damage reported, and thousands of cypress and pecan trees downed.

16.2 1.7 FM-1343.

21.6 5.4 Dunlay (sign).

The Dunlay field was discovered in 1938 by the Ewing #1 E.G. Riff well, which pumped 50 BOPD of 17.5 API gravity from 'serpentine' at depths between 548-716 feet. The well produced 2,205 barrels of oil before abandonment in 1940.

22.5 1.1 RR crossing (overpass).

25.7 3.2 Hondo Creek.

29.4 3.7 Tx-173 (overpass). North to Bandera, South to Pearsall.

29.5 0.1 Hondo (sign).

Hondo was platted by the railroad in 1881, and because of the increase in population and influence of the city, Hondo displaced Castroville as the county seat in an election on August 27, 1892. During its heyday in the early 1900s most of the downtown business buildings were built, chiefly of D'Hanis brick. In 1942, became home to the Hondo Army Airfield which housed the Army Aviation Navigation School, the largest in the world at the time. The base was shut down in 1946, but civilian contract flight training and pilot screening programs for Air Force cadets continued operations for a while.

30.5 1.0 FM 4625 (south).

30.9 0.4 FM 4625 (north).

31.5 0.6 Bruce's Rock Shop (south side of highway).
Medina County Museum (north side of RR tracks – old RR station).

39.0 7.5 D'Hanis (sign).

The community is sometimes called New D'Hanis to distinguish it from the site of old D'Hanis ~1.5 miles to the east. The original D'Hanis was founded in 1847 and was the fourth settlement sponsored by Henri Castro, through his agent, Theodore Gentilz. It named for the Antwerp manager of the company, William D'Hanis. When established in the spring of 1847 by twenty-nine Alsatian families, D'Hanis was the frontier settlement on the Old San Antonio Road. When the railroad arrived in 1881, it bypassed the old town, and the town subsequently relocated at its present site. The building of nearby Fort Lincoln in 1849 afforded the settlers employment and much-needed protection from Indian raids. The D'Hanis Brick and Tile Company was founded in 1883 and was still in operation in the 1980s. A second brick factory, Seco Pressed Brick, opened in 1910.

39.4 0.4 FM 2200 (south).

D'Hanis Brick and Tile Company (founded in 1883) – to north. Brick was made with clay from pits in the Escondido Formation that are little over a mile to the northwest. As much as 54-feet of silty claystone and siltstone has been measured in these pits.

39.6 0.2 FM 1796 (north)

State Historical Marker – **D'Hanis** (north of RR tracks).

"In 1847 Henri Castro established D'Hanis, his fourth colony, 1.5 miles east of this site, named for a Castro company official. Alsatian immigrants endured great hardship to build a community that thrived for over 30 years. In 1881, when the railroad bypassed the town, D'Hanis moved with it. Aided by the railroad, new D'Hanis flourished, sending cattle, cotton, and brick to markets. From 1900, a strong Mexican-American community grew in the town, contributing to its fortune. The new area survived despite crop failures and the Great Depression, becoming known simply as D'Hanis." - 1997

40.6 1.0 Seco Creek.

Good exposures of the Anacacho Formation occur 1.6 miles upstream in Seco Creek. This locality includes ~50 feet of Lower and Upper Anacacho grainstone, wackestone, and packstone. The contact between the

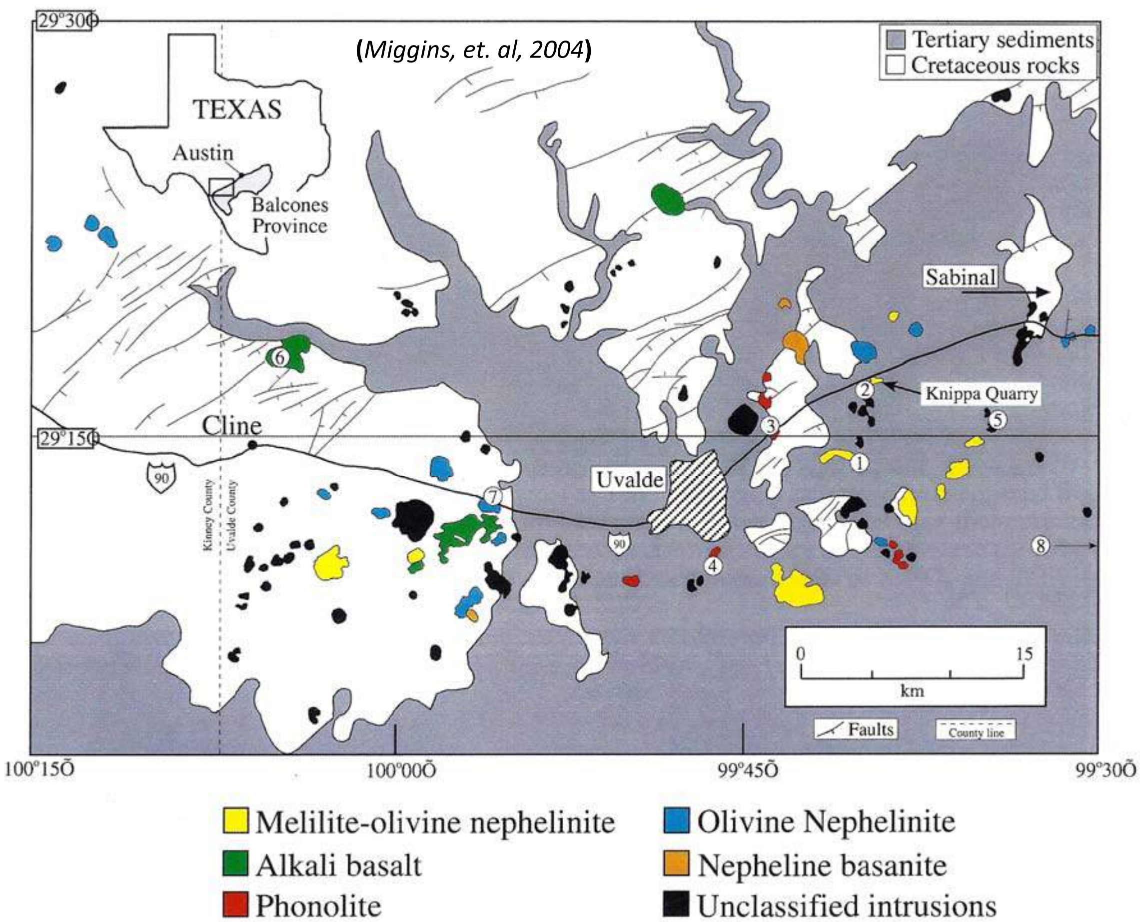
Anacacho and the overlying Escondido is exposed in a ~23-foot section on private land to the northwest, near the site of Ft. Lincoln (1849-1852).

44.6 4.0 West Squirrel Creek.

We are entering the main part of the Uvalde Volcanic Field. The Fina #1 Faust well was drilled in 1991, about 4 miles to the south. The well was drilled deep into the Paleozoic sequence, to a depth of 23,316'. Seismic and gravity data indicate a very large Paleozoic high in this area. Closer to the highway aeromagnetic data indicate a very large, complex igneous mass, completely covered by Uvalde gravels. A well 1.5 miles southeast penetrated 91 feet of 'basalt' at 358 feet, followed by 24 feet of 'serpentine'.

Uvalde Volcanic Field

The Uvalde Volcanic Field forms the southwestern half of the Balcones Igneous province. The Balcones Igneous Province roughly follows the trend of the Balcones Fault Zone, and in addition to the Uvalde Volcanic Field, includes volcanic rocks near Austin, in Wilson and Atascosa Counties, and small igneous dikes and plugs in lower Cretaceous strata as far north as Waco. Cretaceous igneous activity is concentrated in the Uvalde Volcanic Field which refers to an area that includes southern Uvalde and northern Zavala counties. Various data sets indicate the concentration of volcanic features (subaerial and subsurface) in this area may exceed 6 to 8 per square mile. The most recent radiometric dating (~2004) indicates the igneous activity occurred in two pulses at ~80-82 Ma and ~71-72 Ma. Stratigraphic relationships indicate most of the volcanic activity occurred during latest Austin, Anacacho, and San Miguel time. Uvalde igneous rocks occur both as volcanic flows, hypabyssal (near-surface) intrusions, and as fragmental tuffs. The igneous rocks are predominantly ultramafic and alkaline, forming a volcanic peridotite known as nephelinite. There are also local occurrences of more evolved phonolite.



45.7 1.1 Rest Area (left entrance).

47.8 2.1 Uvalde County Line.

Uvalde County was organized in 1852 and named for Spaniard Juan de Ugalde. The Edwards Plateau covers the northern third of the county. Elevations range from 2,000 feet above sea level to 700 feet above sea level. Low rolling hills and deep canyons cut across the county's midsection from southwest to northeast. The southern and eastern part of the county is in the South Texas coastal plain.

Artifacts discovered in various parts of the county indicate that people hunted and gathered in the future Uvalde County as early as 9000 years before present. The Edwards Plateau and the surrounding hills were the favorite hunting grounds of the Comanche, Tonkawa, and Lipan Apache Indians during historic Amerindian time. Either Álvar Núñez Cabeza de Vaca in 1535 or Andrés do Campo in the middle 1540s may have been the first European to set foot in Uvalde County. Evidence of a permanent Indian village on the Leona River, south of the Fort Inge site, is indicated in the written accounts of Fernando del Bosque's exploration in 1675. In 1762 Nuestra Señora de la Candelaria Mission was established near the site of present Montell and near the site of a prehistoric Indian village at Candelaria Springs. The mission was abandoned in 1767 due to Comanche attacks. On January 9, 1790, Juan de Ugalde, governor of Coahuila and commandant of the Provincias Internas, led 600 men to a decisive victory over the Apaches near the site of modern Utopia at a place known then as Arroyo de la Soledad. In honor of his victory, the canyon area was thereafter called Cañon de Ugalde.

Fort Inge, established in 1849, was one of many frontier forts commissioned to repress Indian depredations on the international border with Mexico. Located at the base of Mount Inge and served by the Overland Southern Mail, Fort Inge proved to be a focus for the early settlement of Uvalde County. Beginning with the Civil War and Reconstruction Uvalde County endured three decades of unrelenting lawlessness and frontier savagery. The abandonment of Fort Inge immediately after secession was followed by renewed Indian attacks. Many men in Uvalde County fought for the Confederacy, while such Unionists as Reading Black fled to Mexico to avoid persecution. The years immediately following the Civil War were marked by conflicts between Confederates and Unionists returning to live in Uvalde County. The region was home to smugglers, cattle and horse rustlers, and numerous other desperadoes. One of the county's most colorful and powerful characters during this period of lawlessness was its most notorious cattle rustler, J. King Fisher. Uvalde County gradually emerged from the chaos, and eventually King Fisher was appointed county deputy sheriff in 1881.

50.7 2.9 Sabinal (sign).

Sabinal, originally known as Hammer's Station, named after the first settler at the site, Thomas B. Hammer, who established a stage stop there on the east bank of the Sabinal River in 1854. In 1856 the Second United States Cavalry established Camp Sabinal on the riverbank opposite Hammer's Station, to protect people and commerce on the road from San Antonio to El Paso and to protect the settlers from hostile Indians and outlaws. Sabinal is built on Quaternary low terrace deposits. The name 'sabinal' is from the Spanish word for cypress. These trees line the Sabinal and other perennial streams in this region and were logged and milled for cypress shingles in the mid- to late 1800's. The Edwards surface is relatively depressed in this area, and is informally known as the Sabinal embayment. In the Sabinal city well, the top of the Edwards is 920’ subsurface.

State Historical Marker – Sabinal: *"Named by Spanish for Rio Sabina and cypress trees along river. Town founded in 1854 by Thomas B. Hammer who operated a stage stop and was first postmaster. Despite Indian depredations town thrived as settlers built homes and railroad reached here in 1881. In 1906 town was incorporated telephone service started. City waterworks and volunteer fire department organized. In 1907 Sabinal Christian. College was founded, closed in 1917. Cotton industry was foremost in early 1900's. Today farming and ranching flourish in community." - 1967*

51.1 0.4 Ranch Road 187 / Tx-127.

To the north, along Ranch Road-187 north of Vanderpool, in the southern part of the Edwards Plateau, there is a spectacular road cut (photos, top of next page) that exposes ~420 feet of the Ft. Terrett and lower Segovia Formations (Edwards Group). The two formations are separated by a thin, slightly nodular, marly unit, the Burt Ranch member of the Segovia Formation (arrow, left photo). The Burt Ranch has been mapped as far west as the Marathon-Ft. Stockton area. About five miles south the Burt Ranch changes to limestone and no longer is a mappable horizon. Past this line of facies change it is impractical to map the Ft. Terrett and Segovia as separate units, and the entire Edwards Group is then referred to the Devil’s River Formation.

51.2 0.5 Historical Marker

State Historical Marker - Methodist Church

"This church began in 1876 as part of the Sabinal circuit assigned to the Rev. Henry T. Hill. Circuit ministers served the fellowship until 1900, when it became an organized congregation. Services were held in the Christian and Baptist church buildings until the present structure was completed in 1907. For a time pastors at Sabinal Methodist also served new rural congregations in Frio and Knippa. As the membership grew and church programs expanded to meet the needs of the community, additions were made to the church facility." 1983

52.0 0.8 Sabinal River.

The Sabinal River rises in fissure springs that flow from slabs of limestone in the Lost Maples State Natural Area (right), seven miles north of Vanderpool in northwestern Bandera County. It flows southeast to the Balcones Escarpment, where its course changes to the east and then to the west, and then continues to the Frio River, ten miles south of Sabinal. The river is sixty miles long, and in several places it sinks underground to rise again downstream. Cañon Creek, in Uvalde County, is called the West Prong of the Sabinal. The river traverses flat to rolling terrain surfaced by sandy and clay loam that supports hardwoods and grasses. Along the course of the Sabinal was a well-known Indian trail marked on early Spanish maps as Comanche Trail. The river was originally called Arroyo de la Soledad, Spanish for "Stream of Solitude."

Sidebar – Black Waterhole

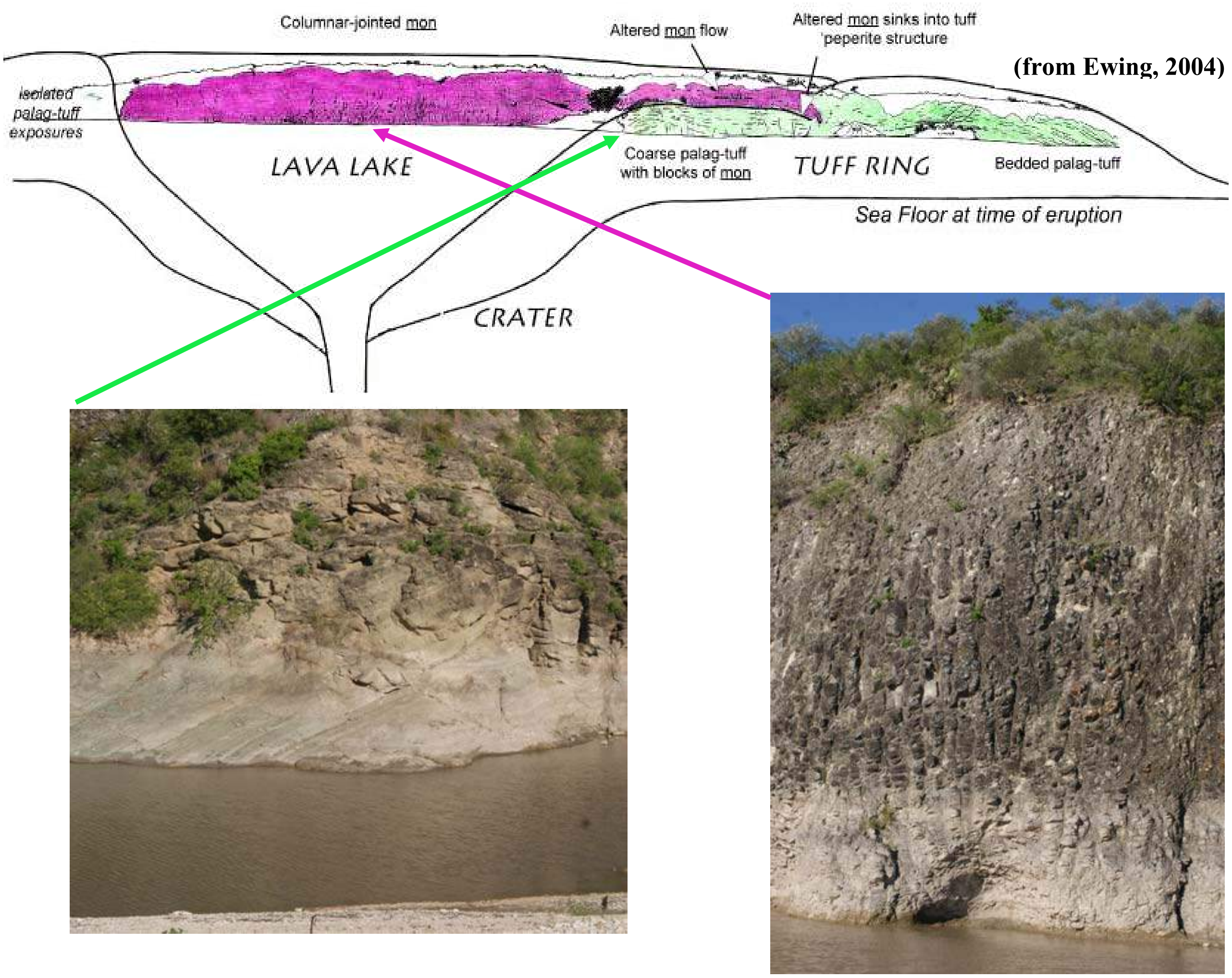
West bank of Frio River, where it cross FM 1023 – about 6 miles east-northeast of Uvalde.

Directions:

1.5 miles west of Sabinal River – turn left onto County Road 301; Travel south on County Road 301 to FM 1023. Turn right onto FM 1023. Travel 5.8 miles to low water crossing of the Frio River. Outcrop is just upstream from the road crossing. After visiting the outcrop we will return to US-90 the same way we came in and continue west toward Uvalde.

The Black Waterhole locality is a plug-like mass lying between two fragmental tuffs. This structure suggests that initial violent eruptions of pyroclastic material were followed by a flow phase that filled and covered the vent. The outcrop is a cross section of a small tuff ring filled with black, very-fine grained mafic igneous rock. The north rim is well exposed showing bedded tuff with dips both toward and away from the center of the volcano. Tuff that is proximal to the vent is much coarser grained, contains large blocks of hard igneous rock and chalk nodules and is only crudely bedded near the inferred vent. The outward-dipping tuffs are much finer grained and more regularly bedded with possible antidune features. On the southern margin of the vent area are small and difficult to reach exposures of iron-stained palagonite tuff that appears to be hydrothermally altered. The rock filling the core of the volcano is a mass of melilite-olivine nephelinite. Columnar jointing is subvertical but plunges steeply toward viewpoint on the east side of the river, suggesting that the mass filled a funnel-shaped opening. Some of the igneous rock appears to have flowed north over the tuff. The rock that flowed over the tuff is considerably more altered and is highly veined with calcite. Several rounded and drawn-out masses of nephelinite sank into the underlying tuff forming a peperite indicating that the lave flowed out over soft, water-saturated tuff. The rock here is melanephelinite – it contains no feldspar and mafic constituents (olivine, pyroxene) dominate felsic minerals (nepheline, melilite). This rock (thin section) is 42.1% clinopyroxene, 23.9% olivine, 13.1% nepheline, 11.9% melilite and 8.9% opaques.

(From, Ewing and Caran, 1982; Matthews, 1986; Ewing, 2004)



(end side trip – return to Hwy 90)

54.1 2.1 RR 4530 (north).

56.6 2.5 Blanco Creek.

57.2 0.6 Quaternary gravel in road cuts.

58.5 1.3 Quaternary gravel in road cuts.

61.8 3.3 Knippa (sign).

Knippa, originally known as Chatfield, was named for its founder George Knippa, who moved his family to the site in the 1880s. A period of abundant rainfall in the Frio River region ended with the drought of the early 1890s, dashing the hopes of many of the farming families who had followed Knippa to the area. Around 1900 the rains returned, and a new wave of settlers, mostly Germans, moved to Knippa. Most of the original settlers in the community were Lutherans. A Lutheran church was built on land donated by George Knippa in 1910. Church services, directed by Rev. Gottlieb Langer, were conducted in German. At the beginning of World War I, however, the Uvalde Council of Defense prohibited the use of German. The community responded by taking the council to court, and the prohibition was eventually rescinded by the United States Supreme Court.

62.0 0.2 FM 1049.

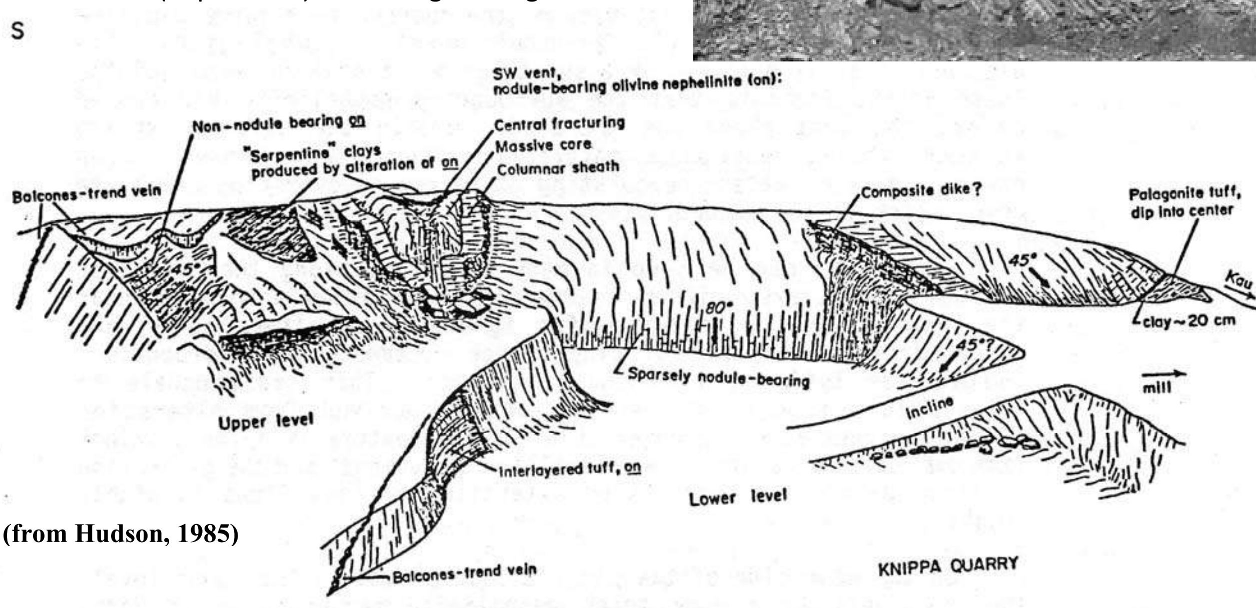
62.6 0.6 Frio River.

The Frio River rises from the juncture of the East, West, and Dry Frio rivers and flows southeast, across central Uvalde and Frio counties and continues southeast, for ~200 miles to the Nueces River. It is joined by the Leona River in southern Frio County, the Sabinal River in southeastern Uvalde County, and the Atascosa River in Live Oak County. *Frio* is Spanish for "cold." The river's drainage area is 7,310 square miles. The Frio River has been identified as the stream that Alonso De León called Rio Sarco in 1689. Frio County is named for the river.

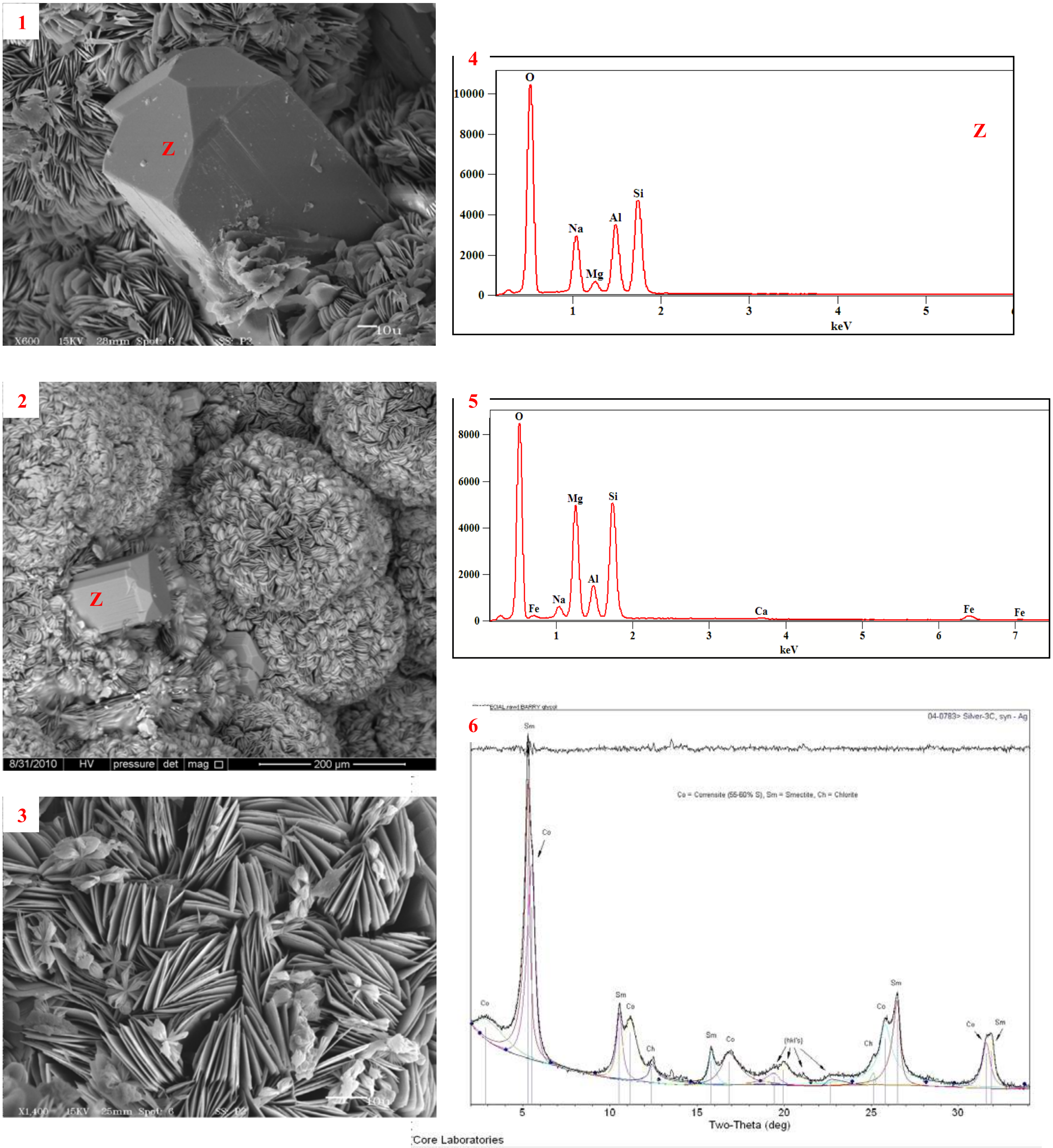
62.8 0.2 Vulcan Materials – Knippa Quarry (entrance).

The quarry opened around 1905 to provide railroad ballast for the Southern Pacific railroad and presently produces aggregate for a variety of uses. Photo (right) is a ca.1932 photo of quarry that shows the well developed columnar joints seen in part of the excavation, and drawing (below) is a sketch of how the quarry looked ca. 1985. The quarry material is a Late Cretaceous alkali ultramafic rock (nephelinite). Recent age dating indicates

(from Darton, 1933)



(from Hudson, 1985)



*Authigenic minerals found coating vugs in nephelinite from Knippa quarry. 'Z' (SEM Photomicrograph #1) indicates mineral that corresponds to EDX histogram shown in Figure 4. The presence of sodium (Na), aluminum (Al), silicon (Si), and oxygen (O) suggests this is a zeolite mineral, possibly natrolite (**$Na_2Al_2Si_3O_{10} \cdot 2H_2O$**). The EDX pattern for the bladed crystals (SEM photomicrograph, #3) that form the spherical aggregates (SEM photomicrograph, #2) is shown on the bottom EDX histogram (#5). An XRD pattern of this mineral is shown at bottom right (#6). XRD analysis indicates this mineral is a mixture of corrensite and smectite. The presence of sodium (Na), magnesium (Mg), aluminum (Al), silicon (Si), and oxygen (O), (EDX #5) is consistent with this mineralogy, but the crystal morphology is more characteristic of a chlorite-group (e.g. clinochlore) mineral. This suggests the corrensite/smectite is a pseudomorph after chlorite.*

the age of the igneous complex is ~81 Ma. The quarry is developed on a topographic high called Chatfield Hill, a domal hill about 125' high and 1250' in diameter. As of 2004, the quarry has removed about three fourths of the hill. The Dry Frio River flows along and is diverted by the eastern flank of the hill. The quarry provides an outstanding cross-section of a multiphase lava lake filling a volcanic crater. The contact with the lava lake and the outer tuff ring is exposed in the north wall. The outer ring is predominantly palagonite tuff. Well developed columnar jointing is exposed in the northern benches of the quarry (see photo, previous page). The lava lake is comprised of nephelinite and the plug-like vent phase consists of melilite-olivine nephelinite with large nodules of spinel lherzolite. Both of these are ultramafic rocks that contain no feldspar. Mantle xenoliths are caught up in the nephelinite providing a glimpse of the composition of the mantle beneath south-central Texas. The xenoliths include several varieties of peridotites, including dunite, harzburgite, and lherolite. The mineralogy of the xenoliths includes olivine, orthopyroxene, clinopyroxene, and spinel, indicating an origin at about ~43.5 miles depth.

63.1 0.3 Dry Frio River.

The Dry Frio River is an intermittent, spring-fed stream that rises just south of Farm Road 337, which connects Camp Wood and Leakey, in Real County and runs south-southeast for sixty miles to the main Frio, just below U.S. Highway 90 and southwest of Knippa. Its course runs roughly parallel to that of the main Frio, and in Uvalde County, Farm Road 1051 closely follows the stream. The surroundings of its upper reaches are typical of the heavily dissected canyonlands of the Balcones Escarpment on the southern edge of the Edwards Plateau, forested with open stands of live oak, mesquite, and Ashe juniper. A pavement exposure of the Austin Chalk is exposed in the river bed, just south of the highway bridge.

Uvalde Salient / Knippa Constriction / Edwards Aquifer

Unique to the Uvalde area is a regional uplift that exposes Lower Cretaceous rocks of the Salmon Peak Formation that projects approximately 10 miles southward into the Gulf Coastal Plain. This area of uplift contains numerous igneous features and is called the Uvalde Salient. The internal structure of the feature is poorly exposed and distorted by laccoliths and volcanic vents. The general high-standing nature of the area and its coincidence with the zone of maximum erosion on regional Late Cretaceous unconformities suggests a Late Cretaceous (or earlier) origin. The uplift may be the core of an igneous-related thermal dome around which the

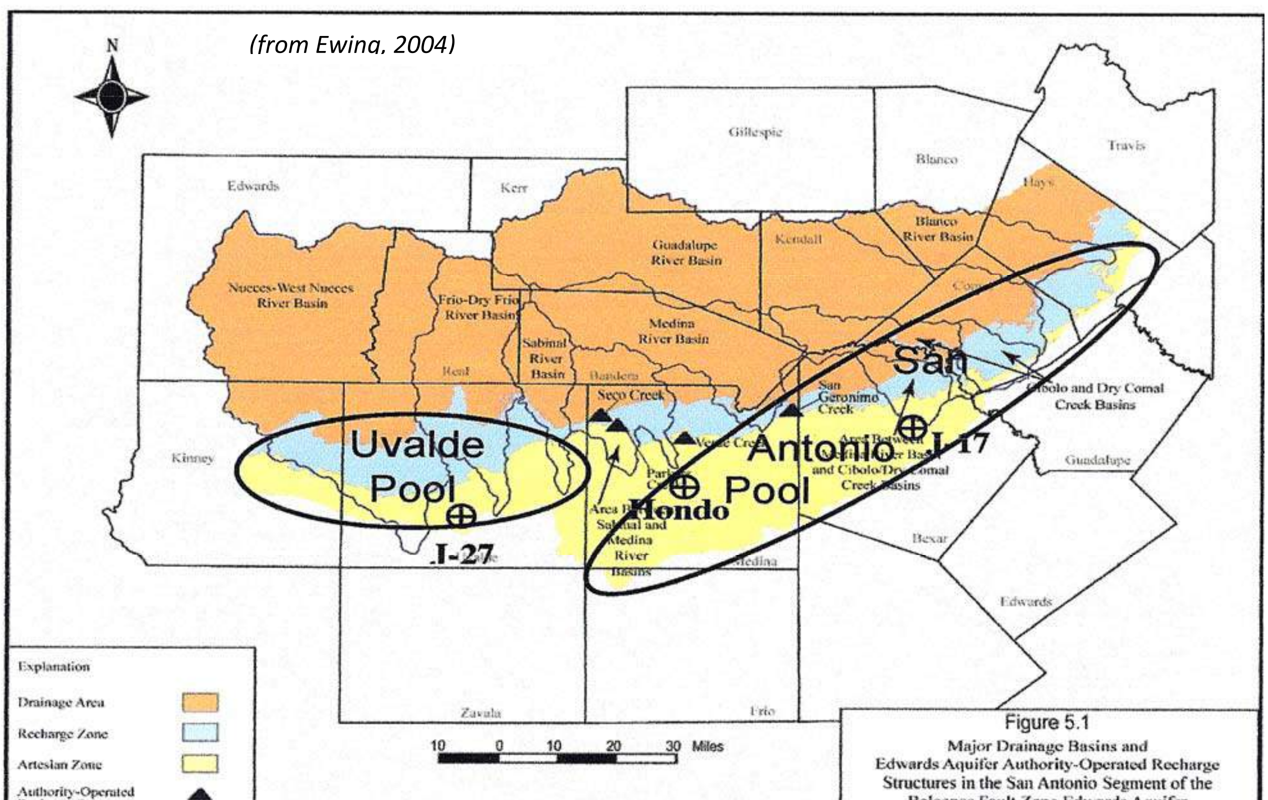


Figure 5.1
Major Drainage Basins and
Edwards Aquifer Authority-Operated Recharge
Structures in the San Antonio Segment of the
Balcones Fault Zone Edwards Aquifer

Anacacho shoals developed.

A significant portion of the recharge to the Edwards Aquifer is attributed to recharge in Uvalde County and surrounding areas. The Edwards Aquifer Authority currently divides the San Antonio segment of the Edwards Aquifer into two compartments, the Uvalde pool and the San Antonio pool (map, previous page). The hydrologic boundary of the western limit of the Uvalde pool is the groundwater divide located near Brackettville. The eastern hydrologic boundary is placed at the Knippa Constriction. The exact location and the nature of the hydrologic communication between the two pools is not well understood. The Knippa Constriction is a feature that is defined by a steep gradient in the potentiometric surfaces of the buried, confined Edwards aquifer, in the area just north of Knippa. The steep gradient implies a partial barrier to water flow, due to a combination of structure and stratigraphy, and is likely related in some manner to the Uvalde Salient which is to the southwest.

68.3 5.2 FM 2369 (to north). Ange Siding road cut on north side of highway, at FM 2369.

Low road cut on north side of highway exposes phonolite, a relatively uncommon igneous rock in the Uvalde Volcanic field that has an obscure relationship to the Buda Limestone that is exposed just to the southwest in the same road cut. The rock may be a hypabyssal intrusive. The phonolite has a trachytic texture, and the phenocrysts are green clinopyroxene (unrimmed) red amphiboles and equant opaque minerals. The amphiboles and opaque minerals are rimmed with clinopyroxene, nepheline and anorthoclase. The age of the intrusion is ~72.5 Ma.

70.0 1.7 Uvalde (sign).

Uvalde was founded by Reading W. Black, who settled here in 1853. Black hired Wilhelm C. A. Thielepape as surveyor in May 1855 to lay out a town which he called Encina. Seminole, Tonkawa, and Lipan-Apache Indian raids and temporary withdrawal of troops from nearby Fort Inge discouraged settlement during that first year. Later, in 1856 when the county was organized, the town was chosen as county seat and renamed Uvalde for Spanish governor Juan de Ugalde.

Juan de Ugalde (1729–1816).

Juan de Ugalde, Indian fighter, son of Brig. Gen. Miguel and Doña Catalina (González) de Ugalde, was born in Cádiz, Spain, on December 9, 1729. He joined the Spanish army in 1738 and first saw action as a captain against the Austrians in northern Italy in 1743. From 1749 to 1757 he fought against the Moors in North Africa and against the Portuguese (Seven Years' War, 1756–63). He was promoted to lieutenant colonel and dispatched to South America, in 1764, where he served as corregidor of Cochabamba, Bolivia, until 1772. He returned to Spain in 1774 and was promoted to colonel, and on March 26, 1776, King Charles III appointed him governor of the province of San Francisco de Coahuila in northern New Spain. Before leaving Spain, Ugalde was also appointed a knight in the Order of Santiago. He officially took office as governor on November 23, 1777. His primary charge was to protect Coahuila from Indian attacks, specifically from the Lipan and Mescalero Apaches. Between May 3, 1779, and March 9, 1783, Ugalde conducted four campaigns against the Mescaleros in northern Coahuila and the Big Bend and Pecos River regions of Texas. Although only nineteen Apaches were killed and sixty-seven taken prisoner, many others were forced to flee or make peace.

For leaving Coahuila's settlements inadequately protected while on campaign, however, Ugalde was relieved of all duties on April 17, 1783. He remained in Mexico City until August 26, 1786, when he was promoted to commander of arms of the Provincias Internas, with authority over Coahuila, Nuevo León, Nuevo Santander, and Texas. Again he took to the field in January of 1787 and combed his territory for Apaches, from the Bolsón de Mapimí in the south to the headwaters of the Colorado in the north, and from the Pecos River in the east to the Guadalupe Mountains in the west. He signed peace treaties whereby several Apache groups agreed to settle near his headquarters at Santa Rosa. Ugalde was promoted on December 3, 1787, to commanding general of the eastern internal provinces and now had total command of Coahuila, Nuevo León, Nuevo Santander, and Texas. On August 20, 1789, he launched a lengthy campaign against the Apaches in West Texas within an area bounded by San Antonio, San Saba, and El Paso. On January 9, 1790, he and his troops, with more than 100 Indian allies, surprised and *defeated 300 Lipan, Lipiyan, and Mescalero Apaches at the Arroyo de la Soledad, the present Sabinal River canyon. In commemoration of this victory, the battlefield was named the Cañón de Ugalde.*

After a change of viceroys, Ugalde was suspended in 1790. His service in the New World was characterized by rivalries, political maneuvering, and abrupt reversals of fortune. His aggressive military actions against the Indians were pursued in disregard of the conciliatory policy of the colonial administration, and it is debatable whether his campaigning pacified or merely antagonized the Apaches. After being ordered back to Spain, he continued in the service. He was promoted to field marshal in 1797 and to lieutenant general in 1810 and awarded the Gran Cruz de San Hermenegildo in 1815. Ugalde died in Cádiz in 1816 at the age of eighty-seven.

72.7 2.7 Leona River.

Leona Springs rise along the Leona River, both north and south of US-90. The springs flow from the Leona gravels, but the water comes from the Edwards aquifer. Leona (Mountain Lioness) Springs is actually four groups of springs, the first just southeast of Uvalde and the last seven miles southeast of the city. The springs rise under artesian pressure from the limestone of the Edwards aquifer, recharged by the Nueces River and streams to the northwest. The spring flow generally lags behind the rainfall by several months. The four main groups of springs once flowed from a higher level, but nearly all the springs are now beneath the surface of the river. The first group, just south of the Uvalde municipal golf course, powered a gristmill in 1858 and was a principal source of water for the city until a well was drilled in 1893. The second group is in a county park two miles southeast of Uvalde, the site of Fort Inge. The springs are beneath the waters of an old irrigation reservoir on the Leona River now used for recreation. The third group is 3½ miles southeast of Uvalde, in a travertine formation that forms a small waterfall just above a flow-measuring station. The combined yearly flow of these three groups of springs fluctuates, from a 'trickle' in the six-year period 1952–58 to 476 gallons per second in 1977. The fourth group of springs is seven miles southeast of Uvalde in Leona Estates. Its discharge emerges underwater just upstream from an old washed-out irrigation dam on the Leona River. The last measurement of its flow was thirty-eight gallons per second in 1947.

73.1 0.4 US-83; Town Square. Uvalde has an unusually large town square, actually four squares were originally surveyed in 1855.

The Janey Slaughter Briscoe Grand Opera House (north side of town square). Built in 1891, the Opera house is the oldest functioning theater in the state of Texas. It was added to the National Register of Historic Places on May 22, 1978.

State Historical Marker– Early Texas Wagon Yards (NW corner of intersection)

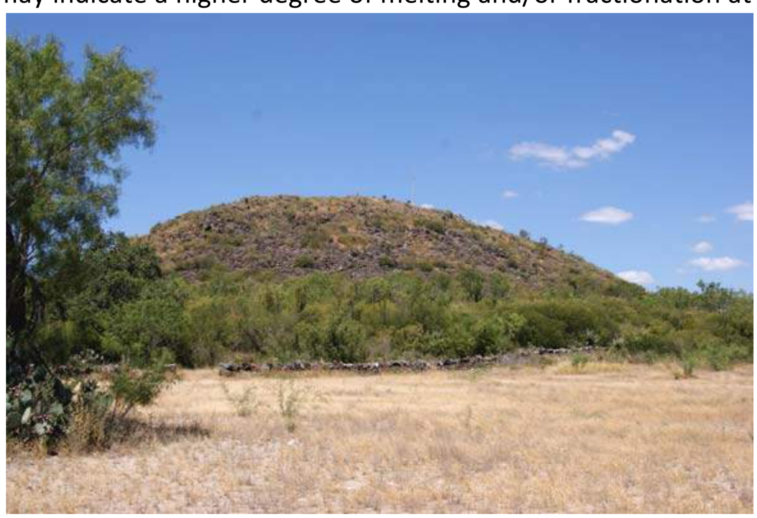
"Places of shelter for drivers, teams, and wagons. Here travelers could cook bacon, eggs, beans, coffee, talk with friends and strangers. For people from the country, a wagon yard was both a hotel and a social center. Usually it was an open area flanked by a sheds, stalls and feed rooms. It might cover a city block, and charges were 25 cts to $100 a day. Drivers pulled into yards, cared for teams, found cooking and sleeping space. Men or families might stay for weeks, await kin or goods coming by train or stage. Amusements were practical jokes, gossip, games, music by fiddle, guitar, harmonica. Young boys overcame bashfulness, learned to dance, roller skate, whip bullies. The yard was center for trading goods and horses, obtaining advice on travel, work, weather. Some yards were stops for stages and freighters. A block west of this site was a wagon yard of F.A. Piper Company (predecessor of Horner's Store). Like many Texas merchants, Piper built and ran the wagon yard to aid customers, who used it free of charge. Modern transportation has made the wagon yard a relic of the past, but it has a secure place in the history of pioneer days in Texas." 1983

Fort Inge

Fort Inge (Camp Leona) is on the east bank of the Leona River a mile south of Uvalde. The site is dominated by Mount Inge, a 140-foot volcanic plug. Archeological evidence indicates this area has been intermittently occupied since the Pre-Archaic period, about 6,000 years before common era. On March 13, 1849, frontier artist Capt. Seth Eastman and fifty-six soldiers of Companies D and I, First United States Infantry, established camp on the Leona, four miles above Woll's Crossing. In December 1849 the post was renamed Fort Inge in honor of Lt. Zebulon M. P. Inge, United States Second Dragoons, a West Point officer killed at the Mexican War battle of Resaca de la Palma. Fort Inge was established as a part of the first federal line of frontier forts in Texas. It was to serve as a base of operations for army troops and Texas militia. The missions of the soldiers included security patrols for the construction of the San Antonio-El Paso military road, escorts for supply trains and mail, protection for frontier settlements from bandits and Indian raiders, and guarding the international boundary with Mexico. The establishment of the post in 1849 immediately attracted a number of farmers to the area. In 1853 Reading Wood Black bought land a mile upstream and began the settlement of Encina in 1855. The community was renamed Uvalde in 1856. Fort Inge was closed for federal service on March 19, 1869, and the garrison transferred to Fort McKavett. In 1871 United States troops returned to tear down some of the buildings and recover the timber and stone to be used in construction at Fort Clark. The site was used as a camp by the Texas Rangers until 1884. It was farmland until 1961, when it became Fort Inge Historical Site County Park.

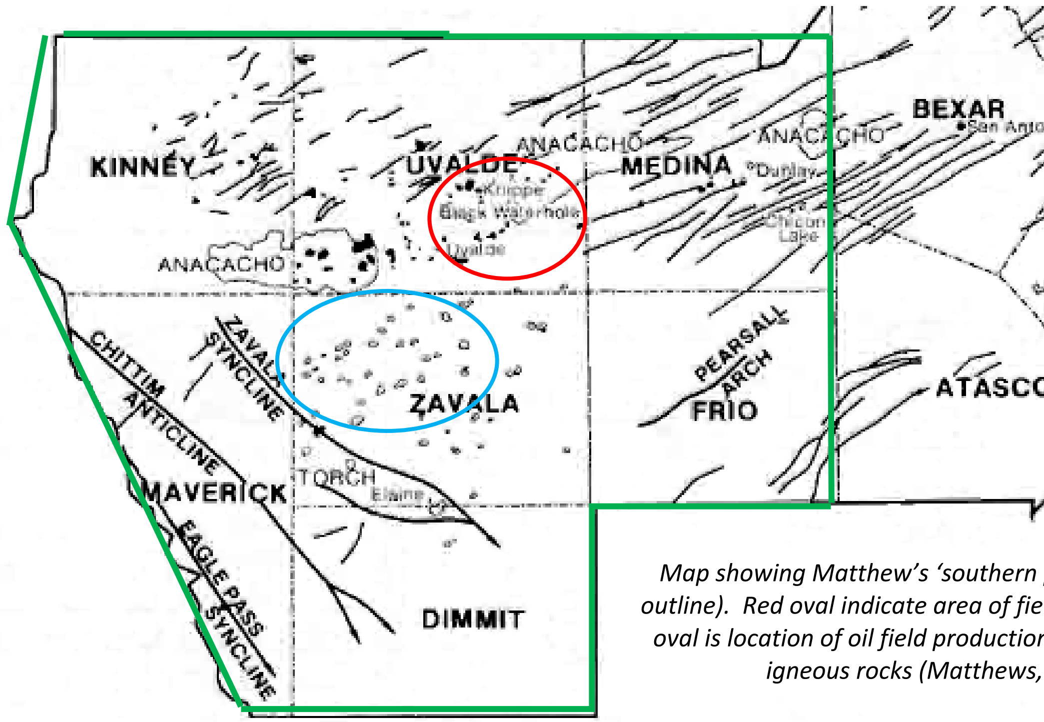
Mt. Inge

Mt. Inge is a plug of mafic phonolite (photo, below). A reported age of ~73.5 Ma, indicates the age of the rock formed during the younger phase of volcanism in the Uvalde Volcanic field. The rock contains a diverse assemblage of phenocrysts, including nepheline, anorthoclase, clinopyroxene, and red amphibole. Phonolite is not widely distributed in the Balcones Volcanic field, with the best examples here and at Ange Siding. The occurrence of phonolite in the Uvalde Salient area may indicate a higher degree of melting and/or fractionation at crustal depths, compared to the nephelinites. Excellent views of the surrounding area can be seen from the top of Mt. Inge. Adjacent to the mountain to the west and south is the site of Ft. Inge. Groups of springs, all called “Leona Springs”, occur both upstream and downstream of the fort. To the west and southwest are fertile lowlands along the Leona River. To the north and east are volcanic hills and laccolithic uplifts exposing Lower Cretaceous strata. Volcanic features continue for 40 miles to the south, but are ever more deeply buried. Drape folding over these volcanoes forms most of the oil and gas fields in Zavala County.



‘Serpentine Plug’ Reservoirs

Atypical oil reservoirs identified as ‘serpentine plugs’ were discovered in the early part of the 20th century along the southwestern Balcones Fault zone and subsequently identified in an arcuate belt extending about 250-miles from Maverick County northeast to Milam County, running roughly parallel to the trend of the Balcones / Luling fault zone. Since their discovery in 1915, hydrocarbon traps in and around these "serpentine plugs" have produced about 47 million barrels of oil (Ewing & Caran, 1982). Production is from isolated reservoirs within mounds of altered volcanic tuff and associated shoal-water carbonates. The plugs are largely tuff mounds formed by accumulation of volcanic ash (subsequently altered to palagonite) on the sea floor around submarine volcanic vents. Volcanic activity peaked during deposition of the upper Austin Chalk and lower Taylor Marl (about 80 my). After their eruption, the tuff mounds localized the deposition of shoal-water carbonates with good porosity and permeability. Low-permeability, organic-rich marine shale and marl of the Taylor Group capped the carbonates, serving as both a hydrocarbon source and a stratigraphic seal.

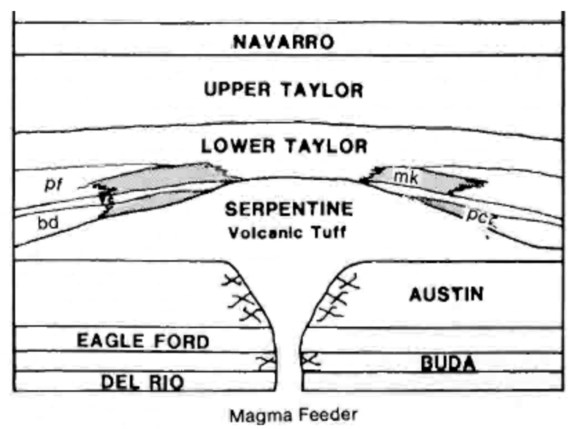


Map showing Matthew's 'southern province' (green outline). Red oval indicate area of field trip route. Blue oval is location of oil field production associated with igneous rocks (Matthews, 1986)

Matthews (1986) suggested there are three distinctive sub-provinces of plugs and the primary reservoir in each is a slightly different lithofacies: 1) In the northern subprovince (~70 features in 7-counties in and around the Austin area) the oil occurs in the altered tuff, 2) in the middle subprovince (primarily in Wilson County, but could include several counties in and around San Antonio area) where the oil occurs in grainstones and fractures associated with the underlying strata, and 3) in the southern subprovince (~150 surface and subsurface features – area outlined in green in above map) reservoirs are characterized by well-developed sands overlying the 'serpentinite plug'. This southern subprovince is roughly coincident with Ewing's (2004) Uvalde Igneous Field (see map on following page) where he indicates recent USGS investigations had identified over 200 igneous bodies at the surface and in the subsurface.

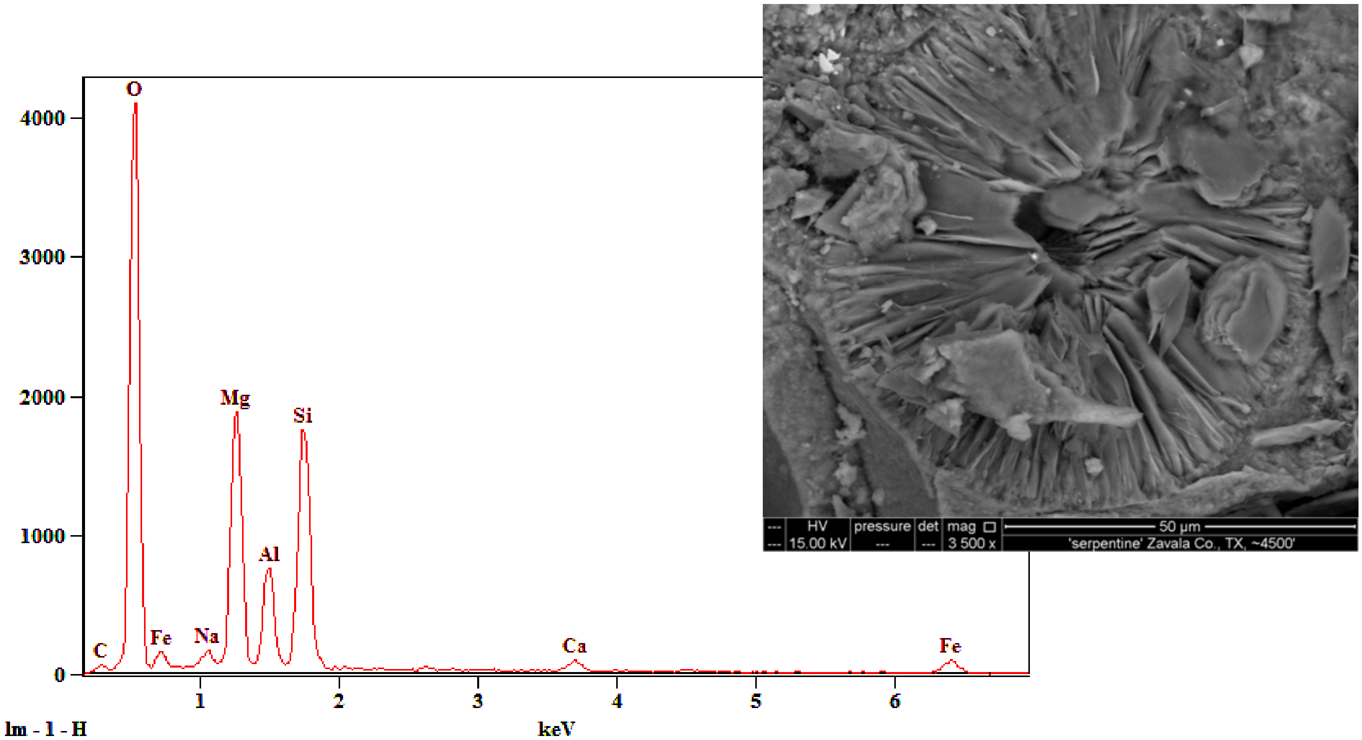
The earliest discovery of oil associated with igneous rocks was in the discovery well of the Thrall Field (1915) in the northern subprovince.

> "Quite early in the development of the field the senior author of this paper discovered that the oil in one of the wells came from a green igneous rock. In a thin slide made of some of the cuttings of the green rock that had been submitted by one of the early operators as the "pay rock," he saw outlines of crystals of augite, and noted that magnetite and pseudomorphs of olivine occurred in association with what appeared to be spherulitic structures." Udden and Bybee (1916)

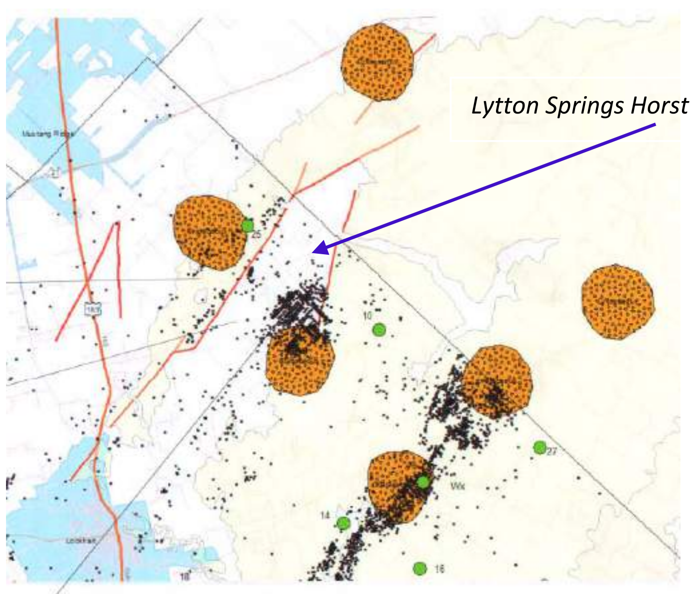


Diagrammatic section of a 'serpentine plug' and its associated facies in the northern subprovince (Matthews, 1986)

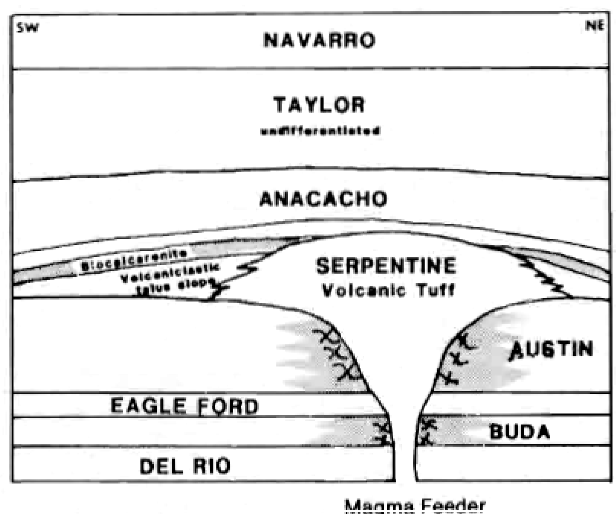
Investigation of a recently cored interval of 'green-breccia' in a well from Zavala County indicated this green material is a highly altered tuff and it contains spherulitic structures that appear to be similar to the ones mention in Udden and Bybee's report. A representative portion of the sample was extracted from the core and analyzed with SEM/EDS (images and spectrum on next page). EDX analysis of the speurulitic material indicated it is predominantly magnesium (Mg), aluminum, (Al), silicon (Si) and oxygen (O), with small amounts of iron (Fe) and calcium (Ca). This elemental composition is consistent with the mineral clinochlore ($Mg_5Al_2Si_3O_{10}(OH)_2$).



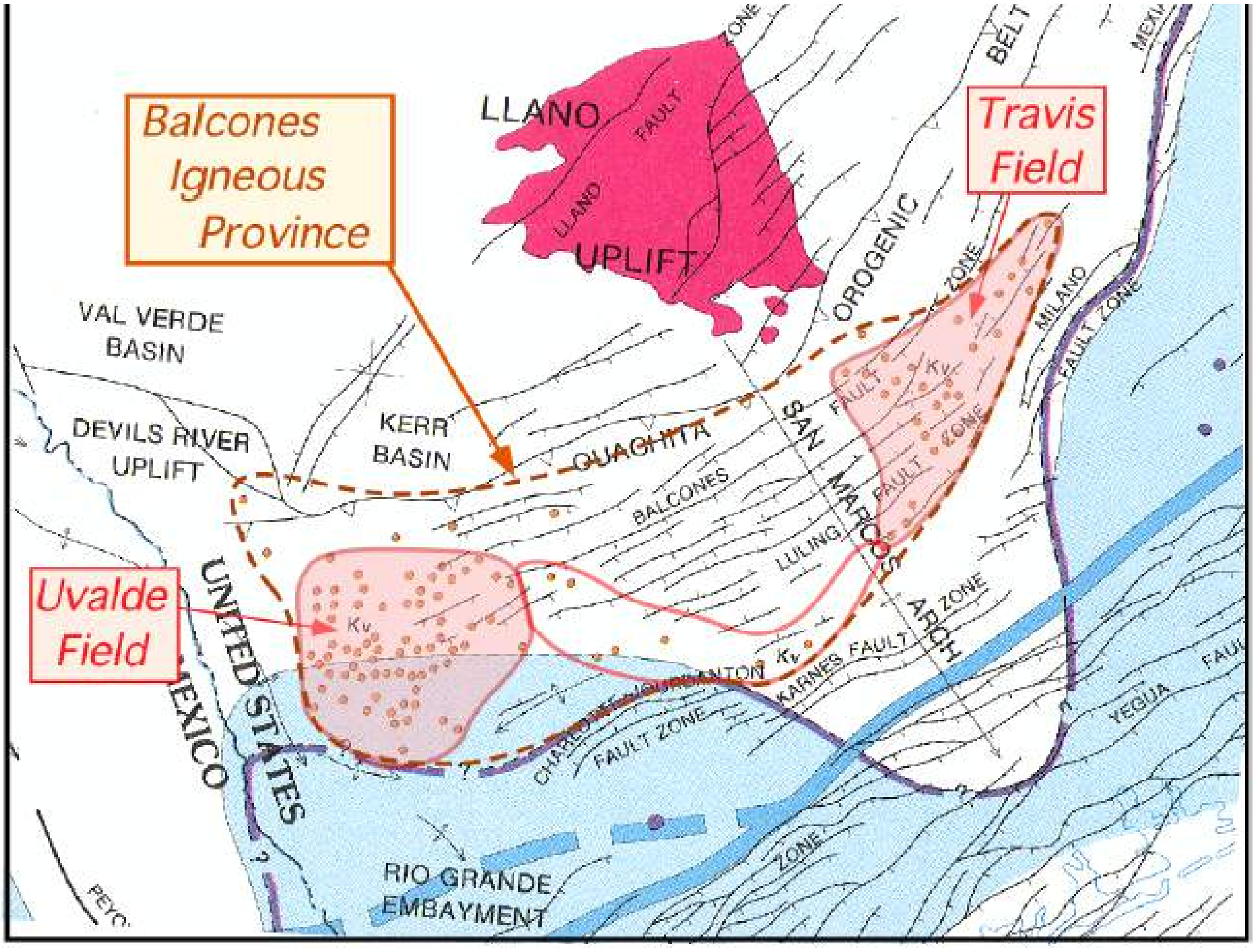
In the middle subprovince the known volcanic centers are clustered in the south central portion of Wilson County where the area of the plugs roughly coincides with the down to the northwest faulting associated with the Luling and Charlotte Fault Zones, and lies within the horst and graben area associated with these faults. As of 1986 the largest of the producing files was the Lytton Springs field. The Lytton Springs oil field was discovered by Gulf Oil Corporation in 1925. This field is associated with the Lytton Springs horst (see map below) is a structurally deformed feature associated with deep seated stike-slip faults and Upper Cretaceous igneous intrusions (after W.F. Wilson).



Surface Geology and Buried Igneous Intrusions



Diagrammatic section of a 'serpentine plug' and its associated facies in the middle subprovince (Matthews, 1986)



Map showing Ewing's (2004) Balcones Igneous Province. Ewing's Uvalde Field is roughly coincident with Matthews' (1986) 'southern' subprovince and the Travis Field is roughly coincident with Matthews' 'northern' subprovince.

73.4 0.3 John Nance Garner Museum (333 Park St.).

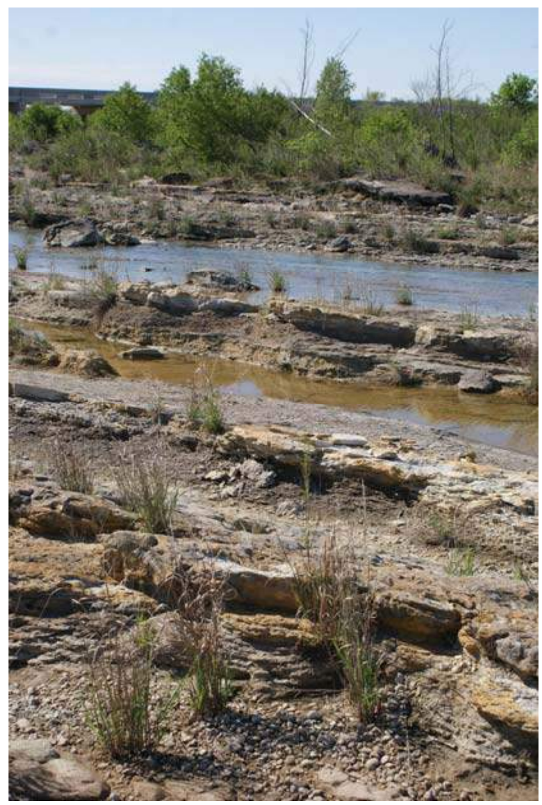
John Nance Garner (1868-1967) *John Nance (Cactus Jack) Garner, the thirty-second vice president of the United States, was the first of thirteen children of John Nance and Sarah (Guest) Garner. He was born on November 22, 1868, in a log cabin near Detroit, Texas. At eighteen he went to Vanderbilt University in Nashville, Tennessee, where he stayed only one semester, possibly because of ill health. He returned to Clarksville, Texas, read law, and was admitted to the bar in 1890. After an unsuccessful run for the office of city attorney he moved to Uvalde, where he began law practice. Broadening his political horizon, Garner was elected in 1898 to the state legislature, where he served until 1902. While in the Texas legislature he had the opportunity to establish a new Fifteenth Federal Congressional District and at thirty-four was elected its representative. He entered the Fifty-eighth Congress as a Democrat on November 9, 1903, and served continuously for fifteen terms. He served as minority floor leader in the Seventy-first Congress and when the Democrats organized the House in 1931 he became speaker. At the Democratic Party convention in 1932, he gave his votes to Franklin D. Roosevelt on the fourth ballot, and Garner was offered the vice-presidential nomination, which he reluctantly accepted. On November 8, 1932, he was simultaneously elected to the vice presidency and reelected to Congress. He resigned from Congress on March 4, 1933.*

Next to the president, Garner was the single most important man in the New Deal. When he became vice president he had thirty years' experience in the House, including two as speaker. Now his ability to make friends and his political knowledge combined to give him respect and great persuasive powers.

Moreover, he was talented in other areas tangential to politics, such as whiskey drinking and poker playing. Although Garner was not always in accord with administration programs, especially deficit spending, he continued to support the New Deal until the spring of 1937. It was inevitable that Garner would split with the president, for his view of the Democratic party differed considerably from Roosevelt's. As an old-line Democrat with Progressive Era background, Garner distrusted Wall Street, and so he championed New Deal legislation aimed at correcting the putative excesses of the financial markets. The event, however, that sealed the split between Garner and the president was the Court-Packing Plan of 1937, whereby the president was to receive unprecedented powers in the appointment of Supreme Court justices. As 1937 drew to a close Garner was recognized as the second most powerful man in Washington. He was the leader of a group of conservative Democrats and Republicans dedicated to retard, change, or scuttle various phases of the New Deal. Though Garner never openly acknowledged his split with Roosevelt, their mutual hostility continued, and the president grew to despise Jack. Garner reciprocated by transferring his dislike of the New Deal to the president himself. Because of their mutual distrust, during the last two years of Roosevelt's second administration Garner opposed virtually everything the president wanted. Opinions about Garner's vice presidency vary widely. John L. Lewis characterized him as a "labor-baiting, poker-playing, whiskey-drinking, evil old man," but the New York Times praised his "political miracles". After 1940, Garner returned to Uvalde and spent the rest of his years in relative seclusion. In the late 1940's his wife burned his public and private papers, leaving only his scrapbook collection, which is housed in the Barker Texas History Center at the University of Texas at Austin. John Nance Garner died on November 7, 1967, a few days before his ninety-ninth birthday, and is buried in Uvalde.

74.1 1.0 Cooks Slough

74.7 0.6 FM-481 (to Eagle Pass).

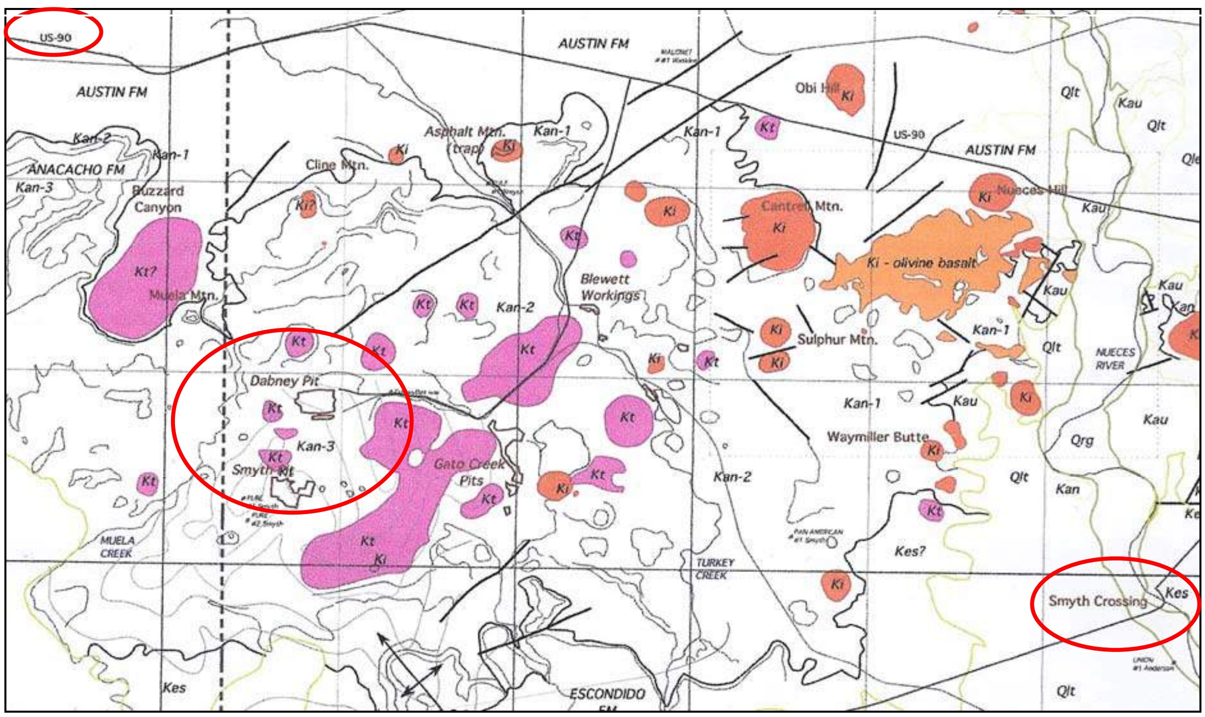


Smyth Crossing, Nueces River (~7.5 miles to SW). At Smyth Crossing the Nueces River flows over thin-bedded sandstone, limestone, siltstone and shale in the Escondido Formation (upper Cretaceous). At the road the beds strike N60^{o}W and dip 13^{o}SW (photo, above right). This locality occurs at the southern end of the Uvalde Salient according to subsurface mapping, so the steep dips may represent the edge of a Cretaceous dome, or alternatively, this could be near a Balcones fault. Regional mapping indicates the top of the Edwards is ~1100 feet subsurface. The drillers log from the Union #1 Anderson well (drilled less than one mile south) indicated the top of the Edwards at -675' and the top Paleozoic at -2322'. The sandstones are typically very fine to fine grained, bioturbated, fossilferous, and saturated with asphalt. The upper surfaces are bleached beige. Large boulders of limonitic, fine-grained sandstone are also present south of the road. Asphaltic sandstones are exposed along the Nueces River south to the Midway contact at Pulliam (Black Waxy) falls. They are part of the Southwest Texas Heavy Oil province which also includes the Anacacho Limestone-hosted asphalt and the asphalt and heavy oil hosted in the San Miguel Sandstone.

Southwest Texas Heavy Oil Province

The Uvalde area hosts a very large, 'unconventional' hydrocarbon resource of heavy oil and asphalt, called the Southwest Texas Heavy Oil Province. It covers a large area of southern Uvalde and Kinney Counties, northern Zavala County, and northeastern Maverick County. The best documented parts of this resource-province are 1) the 'Asphalt Belt', of southern Uvalde County where large reserves of asphalt are hosted in the Anacacho Limestone, and 2) the subsurface San Miguel 'D' sandstone in the Saner Ranch Field in NE Maverick County. Estimates made in the late 1980's suggested there is as much as 550 million barrels of oil in place under ~23,000 acres in the Anacacho Limestone. Estimates of strippable reserves made in the 1950's suggested there are 127-154 million barrels of 'strippable bitumen' in the Anacacho. The San Miguel 'D' sandstone is about 2000-feet subsurface beneath ~160 thousand acres of NE Maverick and NW Zavala counties. Oil in this reservoir is extraordinarily heavy (-2^{o} API) and viscous. It is a plastic solid at reservoir conditions. In the late 1970's and early 1980's Conoco used coal-fired combustion to generate steam and a patented 'fracture assisted steam technology' (FAST) to produce oil at the Saner Ranch Field. Estimates made during the 1980's suggest there are as much as ~3.2 billion barrels of oil in place in the San Miguel "D" sandstone in the Saner Ranch Field. There is a possibility that the amounts of hydrocarbon in the Southwest Texas Heavy Oil Province could be much greater that the ~4 billion barrels of the 'official' estimates, if undocumented and speculative amounts of hydrocarbon, based on known occurrences of asphalt in other areas and formations, are included in the total.

Geology Map of part of the Southwest Texas Heavy Oil Province (from Ewing, 2004)



74.9 0.2 Low road cuts in Salmon Peak limestone (K – Albian), both sides of road.

76.3 1.4 FM 2369. Low hills to north are Buda Formation overlying Del Rio Formation. The outcrops are segmented by small, closely-spaced normal faults of the Balcones Fault Zone. Near this point the Balcones Fault Zone dies out into numerous low-displacement normal faults, and the structure becomes a south dipping homocline.

Uvalde Meteorite Crater (Bee Bluff Structure)

The Uvalde Meteorite Crater (also known as the Bee Bluff structure) is located along the Nueces River, ~12.5 miles south of Uvalde in Zavala County. Except for locally disturbed geology there is little if any topographical evidence for a crater. On the Geologic Atlas of Texas the crater area is an isolated island of exposed Carrizo Sandstone with Quaternary Terrace deposits to the south and sparsely distributed exposures of the Indio Formation to the east. At the east edge of the impact-site the Nueces River has cut a bluff (Crater-Rim Bluff) that exposes about 3-foot thick cap of indurated Indio Formation that is underlain by a few-inches of nonmagnetic iron-rich mineral and then about 30-feet of soft, poorly indurated Indio Formation. A hard surface occurs at the base of the bluff and forms the bed of the river. A large assortment of sandstone breccias (suevite) have been collected from the Torres RediMix quarry south and east of the impact site. (A suevite breccia is a polymictic impact breccia with clastic matrix that contains shocked and unshocked clasts and cogenetic melt particles). Polydeformed quartz, presence of high-temperature/pressure ('shocked') quartz, and suevite breccia from this site suggests this was the location of a meteor impact.

80.3 4.0 Nueces River.

The Nueces River rises in two forks in north central Edwards County and northwestern Real County and follows a southerly and southeasterly course of 315 miles to Nueces Bay, on the Gulf of Mexico. It drains an area of 16,800 square miles. The Nueces River, although not explored in its entirety until the eighteenth century, was the first Texas river to be given a prominent place on European maps. It is identifiable as the Río Escondido ("Hidden River"), which first appeared on a 1527 map attributed to Diego Ribeiro, signifying the obscure location of the river mouth behind its barrier island. It was to this river that René Robert Cavalier, Sieur de La Salle, confused by the period's inadequate maps, sailed in 1685, believing that it was the Mississippi River. Four years later, in 1689, Alonso De León, marching from Coahuila to find La Salle's settlement, crossed the Nueces in what is now Dimmit or Zavala County and named it Río de las Nueces ("River of Nuts") for the pecan trees growing along its banks.

81.3 1.0 Road cuts – north side of highway.

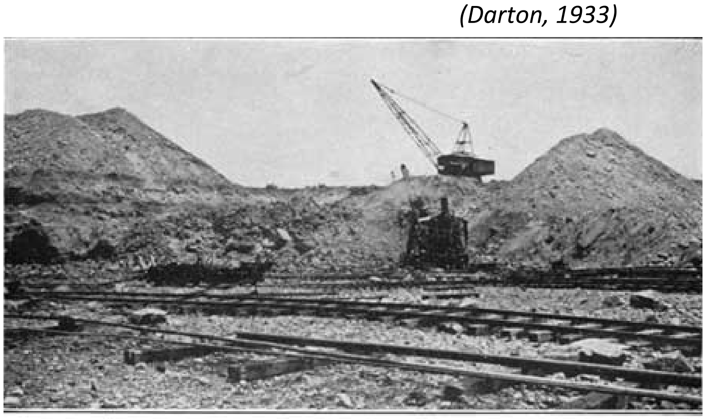
About 30' of open-marine, slightly to moderately bioturbated lime mudstone, with two 'ash beds' (clay/marl units) in the lower part of the Austin Chalk is exposed in this road cut. Small Balcones-trend normal faults and a gentle syncline occur at the eastern end of the road cut. The limestone below the two ash beds displays cyclic bedding, beds of harder and softer chalk, evenly spaced, with indistinct margins. This style of bedding has been related to climate cycles in basinal chalk-producing environments.

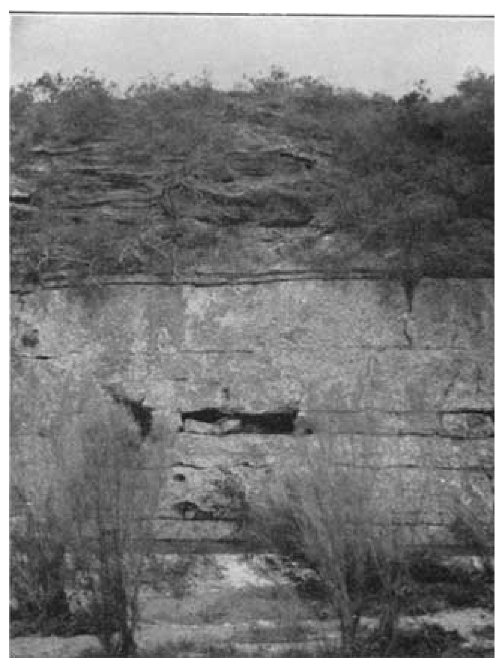
82.9 1.6 INS checkpoint (east bound lanes).

87.5 4.6 FM 1022.

Vulcan Materials – Uvalde Rock Asphalt Quarry is ~7.5 miles SW.

Photos of the Anacacho asphalt quarries ca. 1932 (Darton, 1933)





Vulcan Materials operates one of two presently active quarries (2004) in the Anacacho Limestone. Early mining of the asphalt dates to ca. 1894 when the Litho-Carbon Company opened a quarry to produce paving material and to extract asphalt gum, know as 'ichthyol', near the present townsite of Blewett, about 3 miles south of US-90. The early quarries were located along Turkey Creek and along Gato Creek, south of town. Production peaked at 376,000 tons in 1927. Presently, Blewett is a ghost town on private land. Mining activity in the vicinity of the Vulcan quarry began as early as 1888, by the Lathe Carbon Company. As of the early 80's the capacity of this quarry was about 1-million tons per year. The present quarry consists of two separate pits, the Dabney and the J.B. Smyth pits. The most recent mining activity is in the Smyth pit.

The Dabney pit exposes more than 150-feet of the Anacacho Formation. Three distinct units are recognized in the quarry walls of the Dabney Pit;

1) An upper unit of approximately 36-feet of cream-colored recrystallized lime mudstone and packstones, with no asphalt. This is in the near-surface, oxidized zone.

2) A middle unit of approximately 30-feet of fossilferous lime packstone and grainstone that contains asphalt. The middle unit is finer-grained than the underlying unit and contains planar crossbeds. The base of the unit is ~2-foot of gray-green volcanic ash that contains abundant pyrite. This ash-bed acts as a permeability barrier to the vertical movement of water, as indicated by the numerous seeps above this bed. The limestone just above the ash-bed contains extensive burrows and local accumulations of macrofossils. On of these accumulations consists of numerous molds of a turritellid gastropod. The molds are filled with asphalt and rimmed with pyrite.

3) A lower unit that is ~90-feet of coarse-grained, occasionally cross-bedded, fossilferous grainstone and associated limestone containing abundant asphalt. The shell fragments in the lower unit are markedly coarser than those in the upper unit, and the size of the shell fragments also appears to increase toward the southeast. The two asphalt bearing units contain an abundant and varied fauna including mollusks (gastropods, cephalopods, bivalves – rudists), echinoderms, benthic foraminifera, red algae, few planktonic foraminifera. Identifiable rudist bivalves include *Monopleura* sp., and *Toucasia* sp.

The J.B. Smyth Pit has been the active mining area since 2002. The main part of the quarry is a thick, relatively homogenous series of coarse-grained biosparites with a fairly uniform 8-9% bitumen. There are no ash beds or tight zones identified in this pit. Individual beds are 2-12' thick in the highwall section (~110'). One ~40-foot bed has very-good crossbedding that are emphasized by tighter zones and porous zones.

The origin of the asphalt is a long-unresolved question. The discussion tends to fall into two camps; 1) in situ formation, and 2) petroleum residuum formation. 'In-situ' advocates argue that heat from the adjacent igneous intrusion had driven oil from the nearby organic-rich sections to accumulate in the porous limestones. 'Residuum' advocates suggest hydrocarbons were entrapped beneath Claiborne marine shales during mid-Tertiary time. During later uplift, the shales were eroded away and the unconformity was exhumed, and the hydrocarbons degraded to asphalt. The quarry exposures exhibit evidence that seems to support both hypotheses. Plumes of asphalt cutting across bedding planes with barren zones of limestone in between and zones of uniform lithology saturated with asphalt next to barren zones of slightly differing lithology would seem to support migration, lending support to the 'residuum' hypothesis. But, there are zones that contain asphalt in moldic and secondary pores that have no apparent interconnecting pore space, lending support to the 'in situ' hypothesis.

8.1 0.6 Road cuts – both sides of road. Thin bedded micrite and wackestone in upper member ("Burditt"), Austin Chalk.

89.3 1.2 Road cuts – both sides of road.

91.7 2.4 Cline (sign); RR crossing.

91.8 0.1 Uvalde Co. Rd. 212;

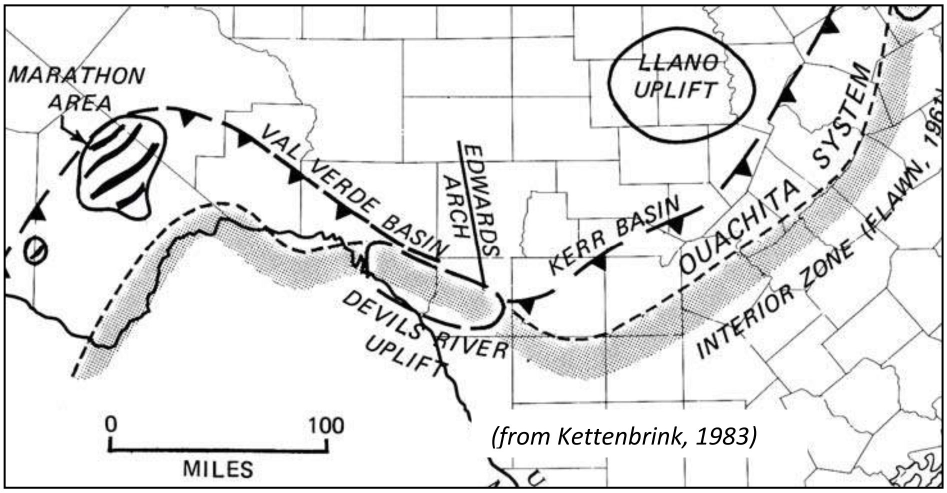
State Historical Marker – Cline Community (1/2 mile south)

"First settler, Celeste Pingenot came to this area in 1870. He built first house on south bank of Turkey Creek, 1871. Established stage coach stand, store, and Inn. Named it Wallace. He was first postmaster,

commissioned, 1878. Community protected from Indians by small detachment of soldiers billeted at "the spring", nearby. August Cline was employed by Pingenot to operate store and stagecoach stand, when railroad came in 1883. Built rockhouse and post office on north bank. Became postmaster. Renamed community Cline." 1967

As we continue traveling west, we will be traveling over the southeastern end of the Devils River Uplift and the northern edge of the Maverick Basin. When we 'turn the corner' at Del Rio, we will be traveling across the northwestern portion of the Devils River Uplift.

Devils River Uplift

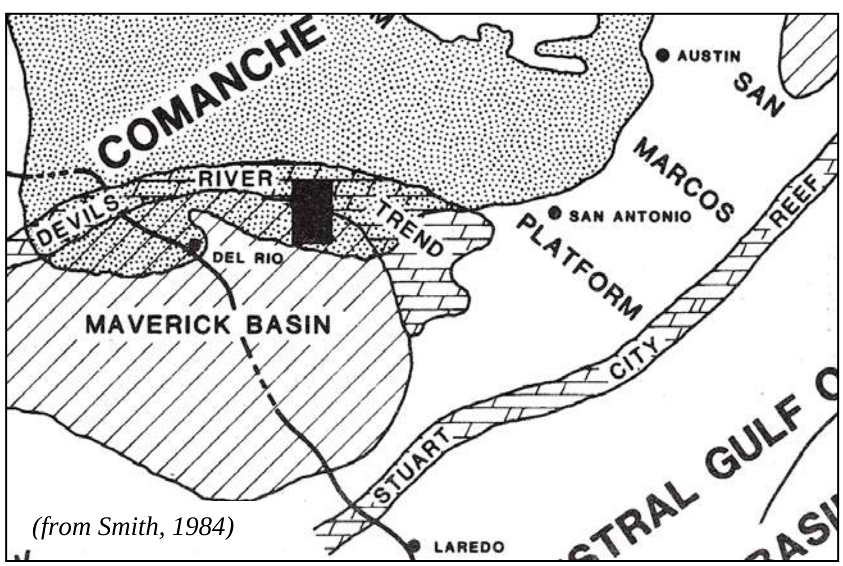


(from Kettenbrink, 1983)

The Devils River Uplift is located on the southeast flank of the Val Verde basin. The Val Verde is one of a chain (along with the Kerr and Strawn Basins) of asymmetric foredeep basins occurring on the edge of the Ouachita foldbelt. Precambrian basement and the mantle of lower and middle Paleozoic rocks have been uplifted in Kinney and southern Val Verde Counties along a major NW-SE trending fault system to form the Devils River Uplift. The location of the boundary between the Ouachita System and the foreland has not been mapped with any certainty.

Maverick Basin

The Maverick Basin is the northwestern part of the Rio Grande Embayment section of the Gulf Coast Basin, where Lower Cretaceous sedimentary rocks accumulated in a more rapidly subsiding basinal area south and west of shallow cratonic shelf deposits along the Central Texas Platform – San Marcos Arch axis and northward of the Stuart City barrier reef. Cretaceous formations thin generally to the north, across the area. The area has a complex tectonic history, beginning with the Texas Lineament as described by Muehlberger, which imposed a continuing pattern of NW trending right-lateral shear beginning in the Precambrian. During the late Paleozoic the northern part of the future Maverick basin was the site of Ouachita-Marathon folding, faulting, and associated metamorphism, including the development of the Devils River Uplift. During the Jurassic and Cretaceous the area appears to have to have been a relatively stable depositional basin, except for the emplacement of mafic igneous intrusives during the Late Cretaceous.



(from Smith, 1984)

93.4 1.6 Kinney County Line. Anacacho Mountain at 11:00.

The county embraces 1,359 square miles, partly on the Edwards Plateau and partly on the plain of the Rio Grande. The area has been the site of human habitation for several thousand years. Artifacts recovered in the region suggest that the earliest human inhabitants arrived around 6,000 to 10,000 years ago and settled in rock shelters in the river and creek valleys. Following these earliest inhabitants, Lipan Apaches, Coahuiltecans, Jumanos, Tamaulipans, and Tonkawas inhabited the region; later, Comanches and Mescaleros also drifted in. The first European explorers were the Spanish. It is possible that Álvar Núñez Cabeza de Vaca traversed the county from east to west in 1535. In 1665 Fernando de Azcué crossed the Rio Grande on a punitive expedition and cut across the southeast corner of the county as he advanced twenty-four leagues beyond the river. Brother Manuel de la Cruz explored the region of present Kinney, Maverick, and Val Verde counties in 1674, and the Bosque-Larios expedition crossed the Rio Grande river in May 1675 and traversed the region from south to north. The third expedition of Alonso De León in 1688 discovered Jean Henri among the Indians near the site of present Brackettville. During the latter eighteenth century several Franciscans established a settlement on Las Moras Creek near the center of the county, and a small village and mill were still in evidence in 1834, when English empresarios John Charles Beales and James Grant attempted to establish an English-speaking colony called Dolores at the site. Streets were laid off and fifty-nine colonists were brought in, but the project was abandoned, and no other American settlement was attempted for another twenty years. In June 1852 the United States Army established a fort on Las Moras Creek, which it named Fort Riley; the name was changed a month later to Fort Clark, after John B. Clark, who had died in the Mexican War. Brackett (now Brackettville) was established nearby the same year. In the early 1870s a number of Black Seminole Indians living along the border were organized into a company of scouts and brought to Fort Clark. Others joined them, and by the mid-1870s they numbered some 400 or 500. For the next quarter century they lived on a reservation along Las Moras Creek. In 1914 the Black Seminoles were removed from the Fort Clark reservation, but some of their descendants still live in the county.

99.0 5.6 RR 1572 (south).

104.2 5.2 Weather Radar on north side of highway.

107.0 2.8 Elm Creek – Picnic Area.

111.8 4.8 Brackettville (sign).

Brackettville is named after Oscar B. Brackett, who established the first general dry goods store near the site of Fort Clark in 1852. Brackett, as it was called originally, was established on the San Antonio-El Paso Road, and by 1857 its Sargent Hotel and small restaurant run by a Mr. Sheedy were a regular stop for the San Antonio to San Diego stage line. The settlement was six miles south of Las Moras Mountain near the prolific Las Moras Springs. Roving bands of Indians, who had historically hunted and camped at Las Moras Springs, harassed early settlers. The community was known as Brackett or Brackett City when it received a post office in 1873, but another Texas community was also named Brackett, so the postal service changed the community's name to Brackettville. It was designated the county seat of Kinney County when the county was established in 1876. Brackettville enjoyed a period of exceptional prosperity during the period between 1878 and 1882, as nearby Fort Clark swelled with thousands of soldiers. Devastating floods in 1880 and 1899 caused considerable damage and persuaded many of Brackettville's residents to move to higher elevations about the community. The Gulf, Harrisburg and San Antonio Railway originally planned to route its westward track through Brackettville but in 1882 followed an alternate path ten miles south of the community.

111.9 0.1 ***State Historical Marker – Military Roads in Texas***

"The routes that moved troops in early Texas often followed old Indian trails. Usually were little more than deep wagon ruts. This one, the Chihuahua Road – joining Ft. Clark with other southwest posts – was widely used, 1850-1880. The Comanche war trail, part of the Chihuahua road, carried women, children, and horses stolen by Indians from Mexico to the north. The Spanish era opened El Camino Real (the old San Antonio road in 1691 to join Louisiana to Mexico. After 1836, Republic of Texas settlers demanded forts for safety from Indians; A main 1840 supply road followed present Austin-Dallas highway. Central

national road, 1844, linked Trinity and Red Rivers. (Its rules required all trees to be cut 12 inches or less from the ground.) From 1848 to 1860, surveys by U.S. led to a network of military roads in west central Texas. In 1849, Capt. Randolph B. Marcy blazed a west Texas trail used by California gold hunters. Famed US 2nd Cavalry made Ft. Belknap-San Antonio road a military artery in 1850's. During Civil War, supplies moved from Mexico to Texas over the cotton road. The Indian campaigns of Capt. R.S. Mackenzie in 1870's opened trails across the staked plains; but by 1881, the railroad had begun to replace Texas' once-famous military routes." 1968

112.5 0.6 US-131 (south).

112.9 0.4 Entrance to Ft. Clark – Los Moras Springs.

Las Moras Springs, the ninth largest group of springs in Texas, is on the property of Fort Clark. The springs rise under artesian pressure from the Edwards limestone and travels along a fault in the overlying rock. Their average discharge from 1896 to 1978 was about 160 gallons a second. Las Moras Springs was used by prehistoric people and served as a stop on both the Old Spanish Trail from San Antonio to El Paso and the later military road from Eagle Pass. In 1840 a cavalry unit drove Comanches from their village at the springs. The mulberry trees for which the springs are named were first described by W. H. C. Whiting after a visit in 1849. The springs irrigated gardens and lands at Fort Clark and Brackettville by 1852 and later powered an ice plant. They temporarily quit flowing in the summer of 1964, and again in June 1971.

Fort Clark

Fort Clark was established on June 20, 1852, at Las Moras Springs by Companies C and E of the First Infantry under the command of Maj. Joseph H. LaMotte. The name Las Moras ("the mulberries") was given by Spanish explorers to the springs and the creek they feed. The site was long favored by Coahuiltecan Indians and later by the Comanches, Apaches, and other tribes. During the late eighteenth and early nineteenth centuries the big spring was a stopping place on the eastern branch of the Comanche Trail into Mexico. In 1849 Lt. W. H. C. Whiting, during his reconnaissance for a practical wagon route between San Antonio and El Paso, recognized its military potential and recommended the location as a site for a fort. The post was originally named Fort Riley in honor of the commanding officer of the First Infantry, but on July 15, 1852, at Riley's request, it was renamed in honor of Maj. John B. Clark, a deceased officer who had served in the Mexican War.

The fort was strategically located as anchor to the cordon of army posts that had been established along the southwest Texas border after the Mexican War. The fort's purpose was to guard the Mexican border, to protect the military road to El Paso, and to defend against Indian attacks arising from either side of the Rio Grande. By November 1852 Fort Clark had two companies of the First Infantry under the command of Capt. W. E. Prince. With the establishment of Fort Clark, a neighboring settlement of Las Moras came into existence when Oscar B. Brackett established a supply village for the fort. The town's name was changed to Brackett in 1856 and later to Brackettville. The stage from San Antonio to El Paso ran through the settlement and for almost a century the town and the fort remained closely identified. In the summer of 1854 the Indian menace in Texas prompted Gen. Persifor F. Smith, the department commander, to make a requisition to Governor Elisha M. Pease for six companies of Texas Rangers to conduct a campaign against the raiders. In 1856 one company of the First Artillery and two companies of Mounted Rifles under the command of Bvt. Lt. Col. J. B. ("Prince John") Magruder resided at Ft. Clark.

J.B. Magruder was a tall, handsome man with a penchant for the ladies and good whiskey, which helped him earn his nickname "Prince John". He was also had a bad habit of choosing the wrong side in his military endeavors. When Virginia seceded from the Union at the beginning of the War Between the States, he resigned his commission and joined the confederacy, where he served with the rank of general. After a poor showing at the battle of Malvern Hill, he was reassigned to the Texas, New Mexico and Arizona department of the western theater. His greatest wartime achievement was retaking Galveston from the Union early in 1863. After the war, Magruder fled to Mexico and entered the service of Emperor Maximilian I of Mexico as a major general in the Imperial Mexican Army. However, by May 1867, the emperor's forces had been defeated and the emperor had been executed. Magruder returned to the United States and settled in Houston, where he died in 1871. He is buried in the Episcopal Cemetery at Galveston.

In February 1861 Texas voted to secede from the Union, and on March 19, Capt. W. H. T. Brooks, with three companies of United States Third Infantry, surrendered Fort Clark to a small company of the Provisional Army of Texas. In June 1861, Fort Clark was garrisoned by Companies C and H, Second Regiment of Texas Mounted Rifles, with Capt. H. A. Hamner as post commander. In August 1862 all Confederate troops were withdrawn from Fort Clark, and subsequently the southwest Texas frontier was left relatively unprotected, and Indian attacks, particularly by Indians using Mexico as a sanctuary, were widespread and devastating. Especially significant during the Indian campaigns in the last half of the nineteenth century were the Black Seminole scouts, who served at Fort Clark from 1872 until 1914. The Black Seminoles had spent twenty years protecting the northern Mexican frontier state of Coahuila before being recruited by the United States Army to serve as scouts. Under Lt. John L. Bullis, who commanded them from 1873 to 1881, the scouts played a decisive role in the Indian campaigns. Among the roster of scouts are four who were awarded the Medal of Honor.

Mackenzie's raid on Remolino (northern Mexico) in 1873 had stopped Indian activity for almost three years, but, as the lesson of Remolino dimmed, violence once more came to the Rio Grande border area. In the first of a long succession of border violations, U.S. cavalrymen splashed across the Rio Grande and drove deep into the mountains of northern Coahuila chasing Indian raiders. For two years the U.S. Cavalry's determined thrusts into Mexico in pursuit of the marauding Indians and their chief, Washa Lobo aroused Mexican animosity and caused tensions between the United States and Mexican governments. Eventually, William R. (‘Pecos Bill’) Shafter's extensive campaign on the Texas frontier boldly implemented the army's aggressive policy toward hostile Indians, which was one of removal or extermination. By the end of the 1870's the Indian ‘problem’ along the border had finally been brought under control.

As the surrounding country became settled, the role of the fort was reduced to a routine of garrison duty and border patrol. In 1882 Gen. William T. Sherman, described Fort Clark as the "largest and most costly military post in Texas if not in the United States." Because of the new railroad being constructed nine miles south, he thought Fort Clark was obsolete and should be closed. The fort revived briefly during the Spanish-American War, when it was garrisoned by the Third Texas Infantry. With the United States’ entrance into World War I in 1917, a period of reconstruction and enlargement was begun that continued after the war ended. Many infantry regiments and practically all of the cavalry regiments were stationed at Fort Clark at various times. For twenty-one years, from 1920 to November 1941, Fort Clark was home of the Fifth Cavalry. The regiment, first organized in 1855 as the Second United States Cavalry, had been associated with the fort as early as 1856. Col. George S. Patton, Jr., served at Fort Clark in 1938 as regimental commander of the Fifth Cavalry.

At the outbreak of World War II the 112th Cavalry Regiment of the Texas National Guard, under command of Col. Julian Cunningham, was assigned to Fort Clark, where it trained until it was deployed for combat in the Pacific. On February 25, 1943, the Second Cavalry Division, the army's last horse-mounted unit, was activated under command of Maj. Gen. Harry H. Johnson. More than 12,000 troops were stationed there until their deployment in February 1944 to the European Theater of Operations. World War II added another feature to the history of Fort Clark, that of having a German prisoner of war camp on the 4,000-acre reservation. Finally, in June 1944, nearly three years after the beginning of World War II, and after full mechanization of the cavalry, the government ordered the closure of Fort Clark, one of the last horse-cavalry posts in the country. The fort was officially de-activated in early 1946.

In 1971 Fort Clark was purchased by North American Towns of Texas and developed into a private recreation and retirement community. In September 1979 Fort Clark was entered on the National Register of Historic Places. In 1990 Fort Clark encompassed about 2,700 acres. The large spring still fed Las Moras Creek, as well as the adjacent large swimming pool. The grove of ancient oak and pecan trees next to the spring is now a beautiful picnic area. Below the spring are seven miles of wooded creek front. The historic district of the fort remains much as it was planned and built in the 1870s, with the old parade ground now a well-groomed par-three golf course. Much of the fort's military history is on display in the Old Fort Clark Guardhouse Museum, which is maintained by the Fort Clark Historical Society.

113.0 0.1 US-334 (north).

114.7 1.7 Tx-693 (south).

121.4 6.7 Pinto Creek

State Historical Marker – Dolores Townsite (about 8 miles south)

"Only settlement founded in John Charles Beales' ill-fated Rio Grande colony of 1834-1836. Beales (1804-1878) – empresario of 70,000,000 acres in present southern and western Texas and New Mexico – was Texas' largest known land king. In 1833 he and a partner brought 59 settlers here to colonize a town – to be named for Beales' Mexican wife. Indian raids and drouth soon took their toll. But the death blow came in 1836, as the group fled the Mexican army during the Texas revolution, Comanches killed all but 7 on one party. This ended the town's existence." 1970

131.3 9.9 Val Verde County Line / Sycamore Creek.

Val Verde County is in southwestern Texas on the Mexican border. Part of the county extends west of the Pecos River and more than two-thirds of it is on the Edwards Plateau. Del Rio is the county seat. The first people to live in the area of Val Verde County settled into the rock shelters and caves of the Lower Pecos Canyon District near the site of Comstock as early as 6,000 to 10,000 years ago. Spaniards probably first passed through the area of future Val Verde County in 1535, when Álvar Núñez Cabeza de Vaca is thought to have crossed the Devils River. By that time Lipan Apaches, Coahuiltecans, Jumanos, and Tamaulipans lived there. Later, Comanches drifted into the area. In August 1590 Gaspar Castaño de Sosa brought European-descent people through the isolated canyonland of the county. Castaño led a mining expedition from Monclova, Mexico, to the northern New Mexico pueblo of Santo Domingo. The party of 170 men, women, and children traveled slowly and laboriously into Devils Draw with two brass cannon for protection and a train of two-wheeled carts for provisions. Although no Spanish mission or settlement was built in the area of Val Verde County, Juan Larios opened a mission school at a location between Del Rio and Eagle Pass in 1673 to teach agriculture to the natives. However, the school lasted only a short time. In 1675 Franciscan priests celebrated a Mass at San Felipe Springs as they traveled through northern Mexico. On January 1, 1736, Lt. Miguel de la Garza Falcón commanded a unit of 100 soldiers who traveled along the Devils River in pursuit of Apaches. The Marqués de Rubí came to the site of Del Rio as he made an inspection tour of Texas in 1767. A settlement was begun on San Felipe Creek in 1834 by James Grant and John Charles Beales, but Indian attacks and drought brought its end. A permanent community, San Felipe, was settled along San Felipe Creek in 1868. The community was sometimes called San Felipe Del Rio (for its proximity to the Rio Grande) to distinguish it from the San Felipe of Austin's colony.

131.9 0.6 Low outcrops along road. – upper part of the Salmon Peak Fm.

137.5 5.6 Entrance to Laughlin AFB. Four Historical Markers on north side of highway, just east of entrance road. Welcome to Del Rio

Laughlin Air Force Base

Laughlin Air Force Base is seven miles east of Del Rio. It was named Laughlin Army Air Field on March 3, 1943, Laughlin Field on November 11, 1943, and Laughlin Air Force Auxiliary Field on January 13, 1944. The base was closed in October 1945 and reopened as Laughlin Air Force Base on May 1, 1952. It is named for Lt. Jack T. Laughlin, the first casualty of World War II from Del Rio. The facility was opened on July 2, 1942, as a bombardment school, but its mission was changed in December. It was closed in October 1945 and the land was leased to local ranchers as sheep pasture. When the base was reopened in May 1952 its mission was to train F-84 fighter pilots. By 1957 the base had been assigned to the Strategic Air Command and provided a home for RB-57 and U-2 reconnaissance aircraft. Laughlin-based U-2's provided the first conclusive evidence of the Soviet missile build-up in Cuba. The Air Training Command returned to Laughlin in April 1952. The base continues to provide flight training for air force and foreign pilots.

State Historical Marker – Rudolf Anderson, Jr.

"U.S. Air Force pilot Rudolf Anderson, Jr. was the only American airman shot down during the Cuban Missile Crisis. Born in 1927 in South Carolina, Anderson joined the military in 1951 and soon began flying reconnaissance missions during the Korean conflict. Stationed at Laughlin Air Force Base by 1957, he was here when the Cuban Missile Crisis developed in October 1962. On October 27, while piloting a U-2 plane

over Cuber to provide surveillance of a medium range ballistic missile site under construction, antiaircraft fire hit his plane, killing him. The Air Force decorated Anderson posthumously and in 2001 renamed Laughlin's operation building Anderson Hall. He is buried in South Carolina". 2006

State Historical Marker – Military Aviation in Val Verde County.
"In 1911, eight years after the Wright brothers' historic flight at Kitty Hawk, North Carolina, Galbraith Perry Rodgers landed his plane at Del Rio while on the first transcontinental flight across the United States. The arrival of a plane in Del Rio was a major event then, but it became a common sight in later years. During World War I, the town was a center of aerial patrols along the United States-Mexico Border. In 1919 planes were dispatched to the area in reaction to Pacho Villa's border raids. One pilot stationed here to fly border patrols was Lt. James H. Doolittle, who later gained international attention in World War II. In the 1940's Del Rio was chosen as the site of an air base because of the flat terrain and the mild climate. Opened as the first B-26 bombardier school, Laughlin Air Force Base was named in honor of Lt. Jack T. Laughlin. The first pilot from Del Rio killed in action in World War II. Later a pilot training school, that was closed after the war. In 1952, through the efforts of local residents, it was reopened. Laughlin has been utilized for astronaut training, strategic air command U-2 reconnaissance missions, the development of air training commands' undergraduate pilot training mission, and other important innovations." 1981

State Historical Marker – Lt. Jack T. Laughlin
"Born in Del Rio on Sept. 17, 1914, Jack Thomas Laughlin graduated from Del Rio High School and earned a degree from the University of Texas. In 1940, he joined the Army Air Corps and the following year received his pilot's wings at Stockton, Ca. On Jan. 29, 1942, during World War II, his B-17 Flying Fortress was shot down over the Java Sea in the Indonesian Islands. The U.S. Army established an airfield in that year, and citizens and officials requested it be named for Laughlin, the first Del Rio-born pilot killed in the war. Despite the official policy for naming bases, the idea prevailed, and in March 1943 Laughlin Field was dedicated with the pilot's widow and daughter in attendance." 2006

State Historical Marker – Laughlin Army Air Field
"With the need to train more pilots for military service during World War II, the U.S. Army established an air field east of Del Rio in 1942. The region's year-round good weather and vast areas of open ground offered near ideal flight training conditions. On July 2 of that year, the army activated the field as what the local press called a "jaw shattering title": The Army Air Forces Transition Flying School, Medium Bombardment. Lt. Col. E.W. Suarez oversaw construction of the base, which was accessible by U.S. Highway 90 and by the Southern Pacific rail line. Col. George W. Mundy became the base's commanding officer on December 26, 1942. Earlier in 1942, Del Rio native and army pilot Lt. Jack Thomas Laughlin died in military action, becoming the first pilot from the community killed in World War II. He was shot down over the Java Sea while flying a B-17. Local citizens and U.S. Congressman Charles L. South petitioned the Army to name the base for Laughlin, which the army agreed to in 1943. Laughlin's widow and the young daughter he never met attended the field's dedication that year, and Maj. Gen. Gerald C. Brant delivered a dedicatory speech. Instructors at the field trained experienced pilots on the Martin B-26 medium bomber, which was also known as the Marauder, the Widow Maker, and the Flying Prostitute. Laughlin's pilots went on to fly missions in both the European and Pacific Theaters of war. The Army closed the base at the end of the war, but reopened it as Laughlin Air Force Base in 1952." 2006

Del Rio (sign)

The Spanish established a small presidial complex near the site of present Ciudad Acuña, the Mexican sister city of Del Rio, and some Spaniards settled on what became the United States side of the Rio Grande. In the vicinity of Del Rio the San Felipe Springs provided millions of gallons of water that could sustain a settlement. A number of developers acquired several thousand acres adjacent to San Felipe Creek and developed plans to sell small tracts of rich farmland to prospective buyers. These investors formed the San Felipe Agricultural, Manufacturing, and Irrigation Company in 1868. The organization soon constructed a network of irrigation canals (completed in 1871) to deliver water to its various customers. In 1885 Val Verde County was organized and Del

Rio became the county seat. Early development was dependent on the railroad, the military, ranching and agriculture, government-related employment, and retail business. Other major economic activities were focused on tourism and ties with Mexico. From the mid-nineteenth century to the present the military has played a leading role in the fortunes of Del Rio. As soon as the Mexican War was over, military expeditions into the area began with patrols and the establishment of frontier military camps at Del Rio and Camp Hudson, and to the west on the Devils River. Most military activities were controlled from Fort Clark, thirty miles east, near the present city of Brackettville. In the twentieth century the government continued to use the isolated Del Rio area for different types of military training. As World War II started, the army opened a base near Del Rio, Laughlin Field, for pilot training. Later the name was changed to Laughlin Air Force Base. Ranching and agriculture have always been an integral part of the economic scene of Del Rio. During the late nineteenth century sheep and goat raisers found the scrub terrain to be an ideal place for their livestock. For many years Del Rio served as a focal point for the wool and mohair industry.

140.3 2.8 FM 2523 (to Carta Valley).

142.6 2.3 San Felipe River. San Felipe Springs rise ~1/2 mile north of road, near the water treatment plant.

San Felipe Springs

San Felipe Springs, the third largest springs in Texas, is a group of springs that extends two miles along San Felipe Creek northeast of Del Rio. The water rises under artesian pressure through a fault in the overlying rock. In 1590 Gaspar Castaño de Sosa stopped here, and he was followed by other Spanish explorers in the seventeenth and early eighteenth centuries. A mission was established in 1808 and followed by the settlement of San Felipe del Rio (now Del Rio) in 1834. The springs were also used by cavalry and stagecoaches in the 1800s. The springs are the sole water supply for the city of Del Rio and Laughlin Air Force Base. In 1977 the average flow was over 63,200 gallons per minute. The average flow from 1889 to 1977 was 41,080 gallons per minute. The development of Amistad International Reservoir on the Rio Grande to the west has increased the flow of San Felipe Springs since its impoundment in 1968. It has provided additional recharge water and diverted part of the flow of Goodenough and other inundated springs to San Felipe Springs.

State Historical Marker – U. S. Army Camel Corps (south side of highway, in park).

"The proposal to use camels for commerce and transportation in the arid southwest came about in the 1830s, but it was under U. S. Secretary of War Jefferson Davis that the idea became a reality. The first shipment of camels arrived on the Texas Gulf Coast in 1856, and they were taken to Camp Verde (150 mi. NE of here) for training. Several expeditions made their way west through Del Rio, and this park was the site of one of their camps. Although the officers in charge wrote favorably of the camel corps, the Civil War brought the experiment to a close. Confederate troops stationed at nearby Fort Hudson found camels still in the area, and confirmed sightings of wild camels continued into the mid-20th century." 2002

142.8 0.2 US-277 (south); Bedell Street (north).

143.4 0.6 Spur 297 to downtown Del Rio; courthouse square; winery; US-90 turns right at this intersection.

State Historical Marker* – *Val Verde County (at Courthouse Square)

Organized in 1885 from sections of Crockett, Kinney, and Pecos Counties, Val Verde County was named for a Civil War battle in New Mexico which involved Texas Confederate forces. The growing railroad town of Del Rio was chosen as the seat of government and commissioners set up offices in a commercial building on Perry Street, now South Main. Soon after formation of the county, the limestone jail was built here on a corner of the public square. During construction of the courthouse, it provided additional office space. A three-story annex to the building was completed later. The limestone courthouse was constructed at this site in 1887. Architects were A.O. Watson and Jacob Larmour of Austin, designers of courthouses in Milam and Comanche Counties. Built by the contracting firm of Hood and McLeod, it features classical revival detailing and octagonal corner turrets. As the area population increased, the buildings were modified to provide for the expansion of services. A separate facility for the sheriff's office and county prisoners was completed in 1956 and the old jail was remodeled for use by other departments." 1980

State Historical Marker - John Taini (at courthouse square)

On November 1, 1854, John Taini was born in Rezzato, Italy (near Brescia) to Gerolamo and Lucia Pradelli Taini. John later became a stonemason there, and an American contractor recruited him and his partner, G.B. Cassinelli, to build structures in New York. Although those projects fell through, Taini and Cassinelli worked for the railroads and then for the US Army constructing stone buildings at Fort Clark, in Bracketteville, Texas. Like many hired to work at Fort Clark, Taini and Cassinelli later moved to Del Rio, where many other Italians immigrated in the 1880's. Family tradition holds that Taini returned to Italy in 1889 to wed Erminia Gerola (1874-1955). The couple reared two daughters, Annie and Lucy. Taini maintained his partnership with Cassinell, building several structures, as well as buying and selling real estate in the Del Rio area. As a stonemason, Taini worked as a sub-contractor on the Val Verde courthouse in 1885. Other projects at that time included Southern Pacific Railroad employee housing, Sacred Heart Catholic Church, Club Café, the 1904 Methodist Church building and numerous residences. Taini's partnership with Cassinelli dissolved by 1904, but he continued working on construction projects. He won multiple county and city contracts, including work on the county jail, bridges, canal and creek improvements and two dams across San Felipe Creek. Unfortunately, many of Taini's structures were damaged or razed as a result of the 1998 flood. In addition to Taini's architectural contributions, he was also a leader in the Del Rio community. He donated land for civic improvements and served as an election judge and on the board of directors of the Italian Catholic cemetery, now part of Sacred Heart cemetery, where he was buried in 1929." 2006

Border Radio

The term "border radio" refers to the American broadcasting industry that sprang up on Mexico's northern border in the early 1930s and flourished for half a century. High-powered radio transmitters on Mexican soil, beyond the reach of U.S. regulators, blanketed North America with unique programming. Border station power generally ranged from 50,000 to 500,000 watts. Some stations used combinations of two or three separate transmitters in close proximity, boosting the effective power of the signal up to possibly as much as a million watts. Sometimes listeners claimed to hear broadcasts without a radio, receiving the powerful signal on dental work, bedsprings, or barbed wire fencing. Claims were also made that birds fell out of the sky if they flew too close to the transmitters. American network programs were often lost in the ether when a Mexican border station was broadcasting near an American station's frequency. Mexico accommodated these "outlaw" media operators, some of whom had been denied broadcasting licenses in the United States, because Canada and the United States had divided the long-range radio frequencies between themselves, allotting none to Mexico.

Though the "border blaster" transmitters were always in Mexico, studios (especially in the early 1930s) were sometimes in the United States, and the stations were often identified by the American town across the border. The border stations played a significant role in popularizing country music during the genre's crucial growth years before and after World War II. Dr. John R. Brinkley, originator of the "goat gland transplant" as a sexual rejuvenation treatment, opened XER (later called XERA) in Villa Acuña, Coahuila, in 1931. Brinkley later bought XED, changing the name to XEAW. In 1939 he sold XEAW to Carr Collins, Dallas insurance magnate and owner of Crazy Crystals, a laxative product derived from the fabled Crazy Water from Mineral Wells. According to Collins's son Jim, Texas governor (and later U.S. senator) W. Lee "Pappy" O'Daniel was part-owner of the station. The Mexican government confiscated XERA in 1941 and tried to confiscate XEAW shortly thereafter, but Collins moved his equipment north of the border. Important postwar stations included XEG in Monterey and XERF in Ciudad Acuña. Webb Pierce, Jim Reeves, and other stars appeared live in the studio with XERF disc jockey Paul Kallinger, known from "coast to coast and border to border" as "Your Good Neighbor Along the Way." In a colorful exaggeration that could hold a nugget of truth, Pierce said that country music "might not have survived if it hadn't been for border radio." The Good Neighbor turned down an appearance on his show by the future King of Rock, Elvis Presley. But in the early 1960s, a young platter-spinner from Brooklyn named Bob Smith metamorphosed into XERF's late-night saint of radio naughtiness, Wolfman Jack. From his border lair the Wolfman tantalized American listeners with rock-and-roll, rhythm-and-blues, and blues. Austin-based musician Joe Ely recalled listening to the Wolfman while drinking beer in Lubbock cottonfields: "it was the first time any of us heard John Lee Hooker, Muddy Waters, Lightnin' Hopkins, Mance Lipscomb, all these guys." Delbert McClinton remembered the border airwave as a mysterious force. "With border radio," he explained, "you could hear race music and funky stuff, and it only existed through this secret channel you could pick up from across the border." Some border musicians played several roles, such as singing cowboy, evangelist, and pitchman. "Only three things will sell on the border," said Dallas "Nevada Slim" Turner: —"health, sex, and religion." Often, border radio programming combined all three. Some listeners even claim to have heard commercials for "autographed photos of Jesus Christ." In 1986 the Mexican government seized XERF, and all border stations were dealt a crippling blow by an international broadcasting agreement between the United States and Mexico that allowed both Mexican and American broadcasters to use the other country's clear-channel frequencies for low-powered stations in the evening. That meant that the signals of the border stations would be drowned out in many communities by local broadcasts. The agreement effectively ended the era of high-powered, far-ranging radio.

Val Verde Winery

The Val Verde Winery, a family-owned winery in Del Rio, Texas, has been in existence for over a century. It was established in 1883 by Frank Qualia and has been in continuous operation ever since, owned and operated by the descendants of the founder. Frank Qualia arrived in North America with a number of Italians who emigrated from northern Italy-especially the regions of Lombardy, the Tyrol, and Tuscany. Many of these came from an agricultural background. After a short stay in Mexico, Qualia traveled to Texas in the 1870s, where he heard of inexpensive land that was being developed near the Rio Grande. Traveling westward on the Galveston, Harrisburg and San Antonio Railway, Qualia reached the small community of San Felipe del Rio. He was able to acquire some fertile land and, most importantly in that arid region of Texas, plenty of abundant surface water that could be used for irrigation. Having acquired land in 1883, Qualia began to raise various truck crops and planted the Lenoir grapes from which his first wines would be made. Eventually his son, Louis Qualia, took over the operation of the Val Verde Winery. In 1919 the Eighteenth Amendment was ratified, making prohibition the law of the land. This brought an end to the fledgling wine operations of the Val Verde Winery and other similar operations in various parts of the state. Unlike other vintners, Qualia continued to tend his vines and was able to survive prohibition by selling table grapes. Although some of the vines were lost, most of them survived and became the nucleus for the expanded vineyard and winemaking operation that began soon after the repeal of prohibition. While some wines were produced in Texas after prohibition, eventually all of the wineries, except one, had ceased to exist by the late 1950s. The Val Verde Winery, under Louis Qualia's direction, was the only bonded winery that continued to operate in Texas until the 1970s. Because of Louis Qualia's contribution to the infant wine industry, and because he and his father bridged the gap between the old and the new in Texas viticulture, the Texas Grape Growers Association, formed in 1976, dedicated a posthumous plaque to him for his efforts. In 1982, the year after Louis Qualia died, the Texas Grape Growers Association presented this plaque to his son, Thomas Qualia, who has led the Val Verde Winery into the 1980s and 1990s. The Qualia winery remains a small operation concentrating on producing award-winning wines from locally grown grapes and from grapes purchased from other regional Texas vineyards and wineries.

144.9 1.5 Cantu Road (left to Sul Ross University Del Rio campus).

147.9 3.0 US 277/377 (traffic light).

150.5 2.6 Spur 454 to Amistad Reservoir.

152.5 2.0 Road cuts in Salmon Peak Fm. (photo at right)

152.8 0.3 Amistad National Recreation Area Visitors Center.

Amistad Reservoir

Amistad Reservoir is located in the Rio Grande valley in southern Val Verde County, Texas, and Coahuila, Mexico. Amistad dam is about twelve miles northwest of Del Rio. The idea of a flood control structure on the Rio Grande came about as a result of widespread and massive flooding associated with Hurricane Alice. Hurricane Alice formed during June, 1954 in the western Gulf of Mexico and moved directly up the Rio Grande valley resulting in heavy rain throughout the lower Pecos River and Devils River drainages. The Pecos River crested at over 96-feet, 5.5 miles above the Rio Grande confluence and the Devils River crested at over 34-feet, about 24 miles above the Rio Grande confluence. Three hundred residents of Del Rio lost their lives and the Highway 90 bridge over the Pecos River was totally destroyed. Construction on Amistad Dam began in 1963 and was completed in 1968, and was a co-operative effort between the United States and Mexican governments. Many limestone caves and rock shelters occur along the banks of the Rio Grande, Pecos, and Devils Rivers, and had been inhabited by prehistoric Indians, who left their art on the walls of the caves and numerous sites throughout the area. When Amistad Lake was filled after the fall of 1969, the paintings and many of the archaeological sites were inundated. Over 14 miles of Southern Pacific Railroad track, 16.3 miles of US Highway 90, and 2.7 miles of US Highway 277 were rerouted to make way for the reservoir. The dam is 6.06 miles long and the roadway across the top of the dam is 253 feet above the riverbed. At conservation level (1117 feet above sea level) the Rio Grande arm is 85 miles long, the Pecos River arm is 14 miles long, and the Devils River arm is 25 miles long. The length of the shoreline is over 850 miles. Today, Amistad Dam is operated and maintained jointly by the United States and Mexico Sections of the International Boundary and Water Commission, a branch of the U. S. State Department. The National Park Service began managing recreation at Amistad Reservoir in 1965. The lake surface covers 89,000 acres, and its capacity is 5,658,600 acre-feet. Amistad Lake was built for flood control, conservation, irrigation, power, and recreation. In honor of the cooperation and goodwill exhibited by both counties in the project, the dam and reservoir were named the Spanish word meaning "friendship".

153.2 0.4 Road cuts – Salmon Peak Fm.

153.5 0.3 Road (right) to Blackbrush recreation area.

155.0 1.5 Road (right) to Diablo East boat launch and marina – Amistad Reservoir.

155.5 0.5 Spur 249 to Amistad Dam and Mexico. Low outcrops in Salmon Peak Fm.

End road log.

Archaeology

It is estimated that there are more than 1,500 cultural resource sites adjacent to the more than 540 mile shoreline on the United States side of Amistad Reservoir. These resources span more than 10,000 years of Native American prehistory and include historic remains associated with the 19th century Southern Transcontinental Railroad and early 20th century ranching. Prehistoric archeological sites are the most common, with an estimated 900 sites within the immediate flood pool of the reservoir. Prior to the impoundment of waters behind Amistad Reservoir in 1969 over 300 major prehistoric sites had been documented. In the Spring of 1994, lake levels began dropping in response to what would become a multi-year, regional drought affecting most of southwest Texas and northeastern Mexico. By the summer of 1998, Amistad Reservoir had dropped 56 vertical feet and covered less than 20% of the area it did at normal operating levels. Since 1994, archeological surveys in drawdown zones have documented over 150 new archeological sites and re-documented nearly 50 sites identified by the pre-inundation research. Intermixed within the recently uncovered soils are small, modern Asiatic clam shells (*Corbicula fluminea*). Because of its widespread distribution throughout the reservoir, continuous burrowing behavior, and high population densities, the Asiatic clam is adversely affecting most submerged archeological sites throughout the entire reservoir basin. More than 1500 individual fire-cracked rock features have been documented since 1994, nearly all of which have been significantly affected by wave-action from high winds, passing boats, and fluctuations in reservoir levels. The modern ground slope of exposed terraces is a basic determinant of the severity of wave-action damage to all archeological sites or individual features. Typically, sites with ground slopes above eight degrees will have a series of individual cutbanks often resembling stair-steps with each step representing a different lake elevation. Sites with low ground slope angles usually have a parallel series of drift lines or windrows (similar to high-tide lines at the beach) composed of corbicula shells, chert flakes, and small fraction fire-cracked rocks. In either setting, horizontal relationships among artifacts or feature specific lithic associations are highly suspect given the number of times most sites have been subjected to the cycle of inundation, exposure, and reinundation.

Devil's Mouth Site

The Devil's Mouth Site is directly northwest of the spot where the Devils River flows into the Rio Grande, and is presently covered by the waters of Amistad Reservoir. The site is made up of many layers of prehistoric camping debris within an alluvial terrace of the Rio Grande that was fifty feet above water level before the river was impounded. The terrace extends 150 feet southward from a high limestone cliff toward the Rio Grande and runs 1,000 feet along the edge of the river. The Devil's Mouth Site is one of the first deep, well-stratified archeological sites to be excavated and reported in western Texas, as well as the first to yield a long record of vegetational and climatic change based on pollen studies. Golondrina and early tanged and barbed projectile points were first found in a good stratigraphic context at this site. The artifacts and site records are housed at the Texas Archeological Research Laboratory of the University of Texas at Austin.

The ancient vegetation and climate of the area were reconstructed by studies of fossil pollen and by analyses of alluvial sediments and buried erosional surfaces. At the end of Wisconsin Ice Age, around 10,000 years ago, the Devil's Mouth site was a gravel bar and bedrock exposure only a few feet above river level. Periodic flooding gradually deposited layers of silt and sand, slowly raising the site's surface. The climate during this epoch was cooler and wetter than today, and piñon and grasses were more common in the surrounding desert. Around 7000 B.C. the first prehistoric Indians camped at the site, leaving chert knives, scrapers, and long spear points of a type called Golondrina (left, photo from *lithicsnet.com*). The Golondrina point was named by Leroy Johnson Jr. in 1964 for examples found at the Devils

Mouth site, Amistad Reservoir, Val Verde County, Texas. A few points with a basal tang for attachment to the spear shaft were also made during this period. Lightweight spears with such points were propelled by throwing sticks (atlatls) rather than by hand and struck with great force. Deer, smaller animals, and some wild plants were apparently the main food items. From 7000 until around 2300 B.C. the terrace continued to build upwards, while the climate gradually became drier and warmer. Successive soil layers contained short, barbed spear points in the lower zones and points of the Pandale type (right) in the higher strata. The latter style is twisted longitudinally like an airplane propeller. A few milling stones (manos and metates) from these zones indicate that desert seeds were now being collected and ground into flour. Around 2300 B.C. heavy floods washed away part of the terrace on the southeast, nearest the junction of the two rivers. An arid climatic period with severe but infrequent rains and devastating runoff is thought to be responsible. From 2300 B.C. onward the terrace gradually increased in height, while the climate apparently became slightly less arid, although the local vegetation was still typical of a desert. A brief return to cooler and moister conditions around 500 B.C. was followed by the warming and drying trend that continues today. The people who camped at the site after 2300 B.C. left behind layers of fire-cracked limestone from hearths used to bake such desert plants as sotol and lechuguilla. They also left a succession of many dart-point styles, from barbed and tanged forms called Shumla and Langtry to such later styles as Montell, Ensor, and Frio (below). Seed-grinding stones, as well as chert knives and scrapers, continued in use. Small chert arrow points and rare fragments of earthenware pots, both from after the time of Christ, appear in the topmost strata of the terrace. The local artifact assemblage, with the possible exception of the early Golondrina material, belongs to the prehistoric desert cultures that stretched across the American Southwest, western Texas, and northern Mexico after the Ice Age. The Devil's Mouth Indians adapted their economy to hunting small game and gathering wild plants in an increasingly arid environment and lacked permanent housing or agriculture.

From: Projectile Point Types, Amistad National Recreation Area, Val Verde Co., Texas
National Park Service poster

Hurricane Alice and the Pecos River flood of 1954.

This Month in Climate History: Hurricane Alice, June 1954

While Hurricane Alice caused some damage due to its one-minute sustained winds of approximately 80 mph at landfall, the storm's unprecedented flooding along the Rio Grande Valley in June 1954 made Alice one for the record books. The tropical storm, which would strengthen into Hurricane Alice, formed over the Bay of Campeche in the Gulf of Mexico on June 24, 1954. While moving northwest, Alice reached Category 1 hurricane status before making landfall in extreme northern Mexico the morning of June 25. The hurricane maintained its intensity as it progressed inland between Texas and Mexico, approximately paralleling the Rio Grande. A weakened Alice passed over Laredo, Texas, late on the 25th and eventually dissipated over southern Texas the next day. Hurricane Alice's extreme rainfall over the inland areas of south Texas and northeastern Mexico caused the bulk of the damage. A three-year-long drought in the region worsened the flooding by causing the soil to be especially vulnerable to erosion. The June 1954 Texas Climatological Data Publication shows post-storm "bucket survey" results exceeding 27 inches in a few cases. However, the highest total occurring at an official reporting station was 24.07 inches near Pandale, Texas, of which 16.02 inches fell in a 24-hour period. The peak rainfall took place in a small area centered near the Pecos River, with some areas receiving more rain in a few days from Hurricane Alice's remnants than they average in a year. The heavy rains caused deadly flash flooding. Ozona, Texas, was particularly hard hit, sustaining damages of $2 million (1954 USD) and with 15 deaths reported. "A wall of water," approaching 30 feet in height, poured out of Johnson Draw, a tributary to Devil's River, early June 28, engulfing much of the town. The floodwaters led about a third of Ozona's residents to evacuate and rendered hundreds of the town's families homeless. Elsewhere in the region, the intense flooding washed out a highway and three railroad bridges, stranding several trains. Helicopters had to rescue several passengers onboard one Southern Pacific Train. The International Boundary and Water Commission remarked that it was "probably the greatest rate of runoff for a watershed of [that] size in the United States." The Rio Grande crested well above flood stage, causing major flooding and heavy losses at Eagle Pass, Texas, and its sister city, Piedras Negras, Coahuila, Mexico. Unlike Eagle Pass, the citizens of Piedras Negras did not evacuate. This decision proved to be deadly when the dike designed to protect the Mexican city failed. At least 38 people in the city lost their lives. Further downstream and back on the U.S. side of the river, at Laredo, Texas, forecasters predicted only moderate flooding before the heaviest rain fell. Instead, the river rose to just over 61 feet, its second highest crest ever recorded. The city was without fresh water for days as the flooding caused the water treatment plant to fail. Considered a 1-in-2,000-year event, the flooding of the Rio Grande at Laredo due to Hurricane Alice remains the second highest level ever recorded, only behind the flood of 1865 when the river peaked at over 62 feet. Due to some victims remaining unaccounted for, the death total from Hurricane Alice's flooding ranges between 53 and 153, with 17 to 38 of those occurring in Texas. The fatal flooding along the Rio Grande accelerated the Amistad Dam project, a series of flood control dams, designed to limit similar catastrophes in the future.

From **https://www.ncdc.noaa.gov/news/month-climate-history-hurricane-alice-june-1954**

Eagle Ford Shale - Overview

(by Thomas Gentzis)

General Background

The Eagle Ford Shale is one of the most prolific petroleum resources in the United States. It is both a source rock for oil and gas in conventional reservoirs in Texas, as well as it is unconventional reservoir by itself producing oil, gas, condensate, and natural gas liquids (NGLs). It is located both in outcrop and underneath the southern part of the US in the state of Texas stretching for about 400 miles (640 km) from the border with Mexico into East Texas, underlying 26 counties (Atascosa, Bastrop, Bee, Brazos, Burleson, De Witt, Dimmitt, Fayette, Frio, Gonzales, Grimes, Karnes, La Salle, Lavaca, Lee, Leon, Live Oak, Madison, Maverick, McMullen, Milam, Robertson, Walker, Webb, Wilson, and Zavala) (Rail Road Commission (RRC) of Texas, 2016) (Figure 1).

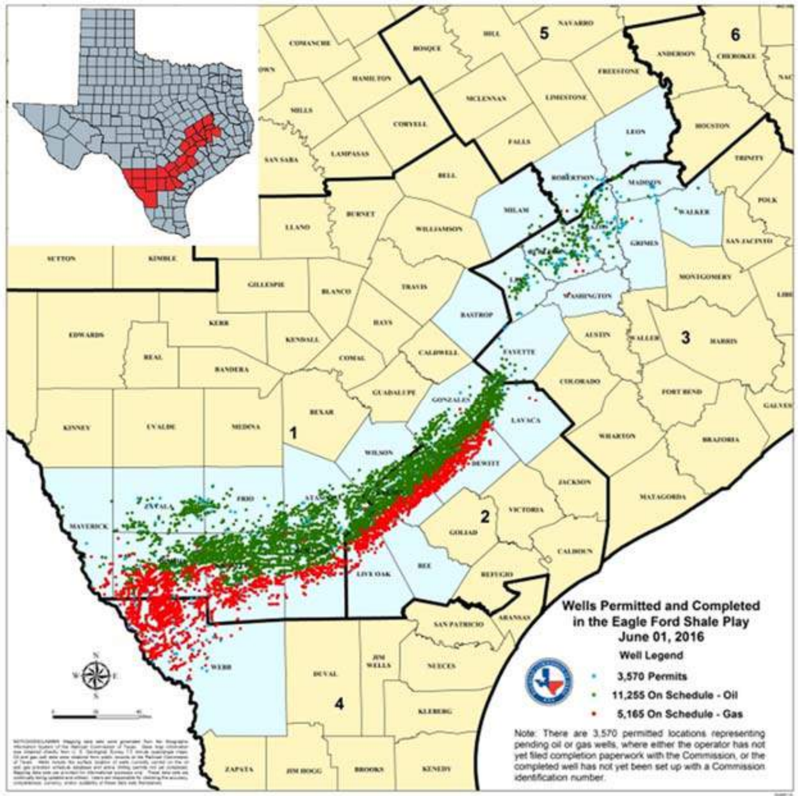


Figure 1
(Modified after a 2016 well permit map by Rail Road Commission of Texas)

According to updated Eagle Ford maps [Energy Information Administration (EIA) 2014] (Figure 2) and RRC 2016, the Eagle Ford Play, where the formation is currently producing hydrocarbons, is approximately 50 miles wide (80Km), and is the area bounded by the Rio Grande River in the west, the Sligo Reef Margin in the south, and the boundary between the lower Eagle Ford and the Pepper Shale in the north-east. The northern limit of the play follows the boundary between thermally immature and mature parts of the Eagle Ford occurring at subsea depths of 3650ft, 2900ft, and 650ft in Frio and eastern counties, Maverick County, and Zavala County, respectively.

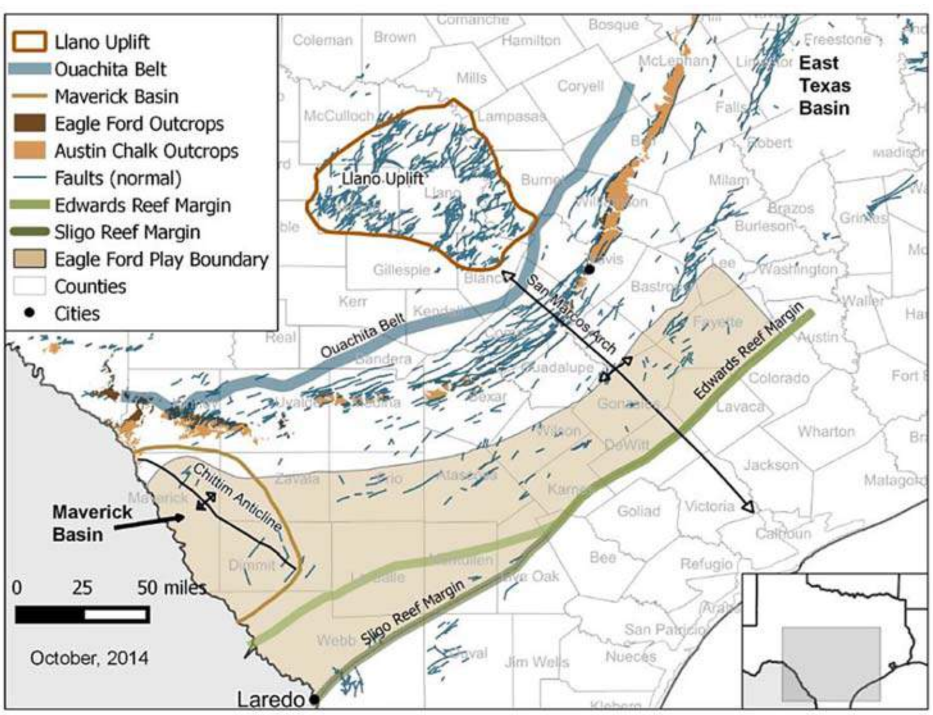
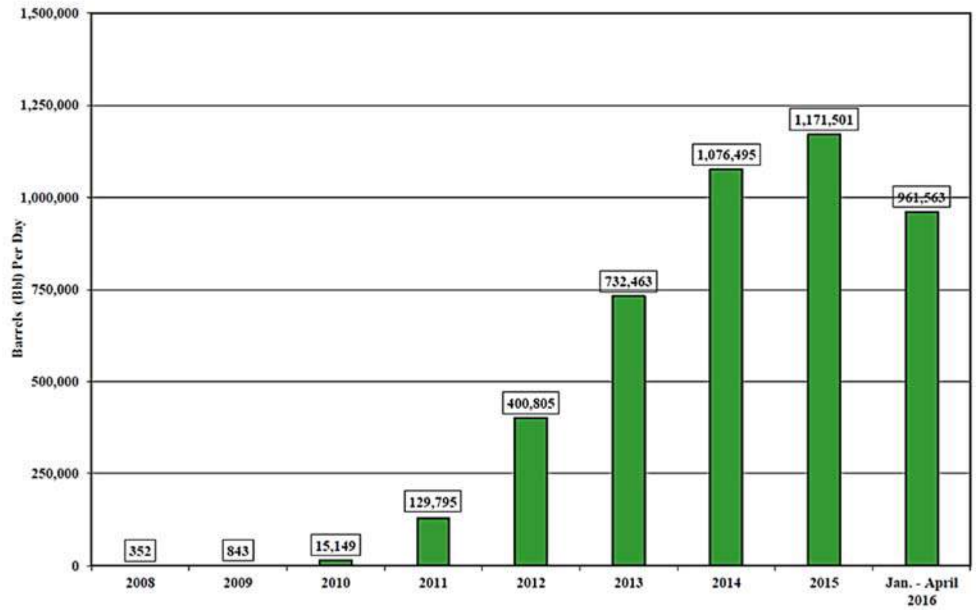


Figure 2
EIA 2014 Eagle Ford Shale Play boundaries and major structural and tectonic features.

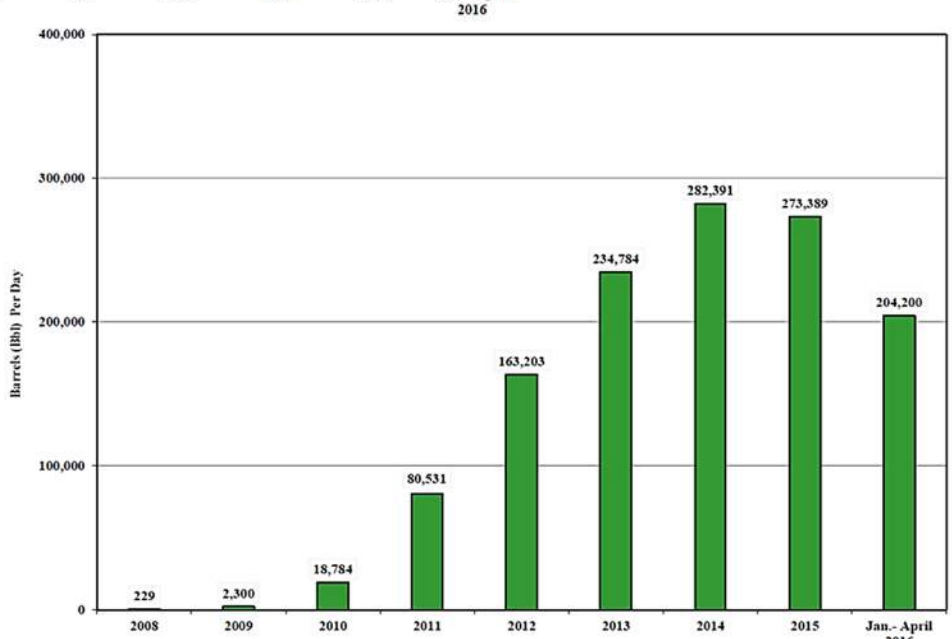
Thickness, Drilling Depth and Production of the Eagle Ford Play

The Eagle Ford Shale has an average thickness of 250ft, ranging from 660ft (~200 m) in the Maverick Basin, to approximately 12 to 17ft (~4 to 21m) in the San Marcos Arch, to about 450ft (~150 m) at the center of the East Texas Basin (Hentz and Ruppel, 2010; RRC, 2016). The depths at which the Eagle Ford Shale produces also vary: mainly oil at about 5,000ft (~1,500 m) in northwest Texas; mainly gas at about 12,000ft (~3,600 m) in the southwest; natural gas from up to 15,000ft (~4,570m) in the southeast; more oil relative to gas in the eastern half of the play for wells that intersect the reservoir between 5,000 and 12,000ft (~1520 and 3,657m); and more gas relative to oil from wells having a wider depth distribution intersecting the formation from as deep as 14,000ft (4267m) and as shallow as 2,000ft (~610m) in the western part of the play (EIA 2014; RRC, 2013).

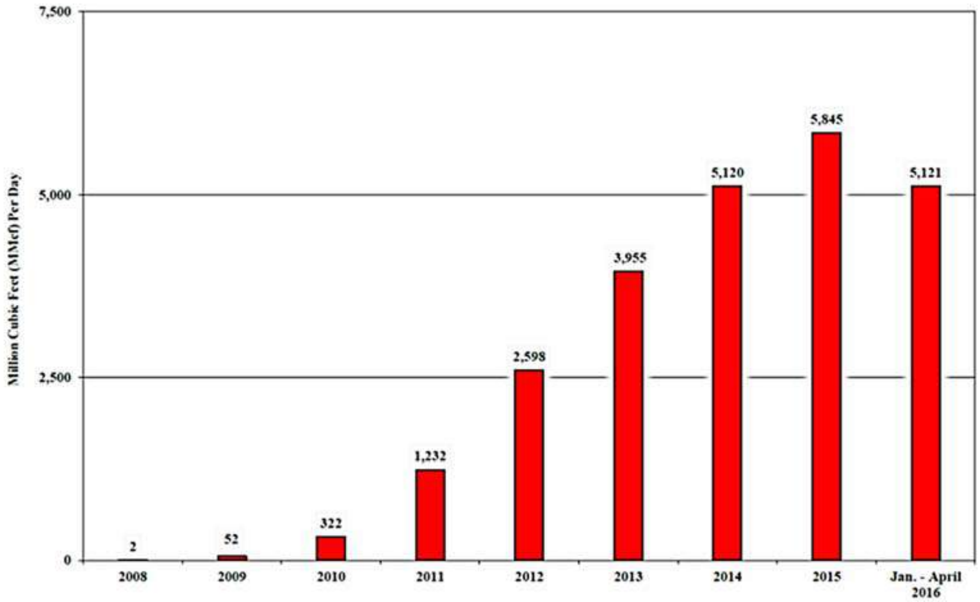
Although the Eagle Ford Shale is known to be a world-class source rock, it also became a world-class oil reservoir recently, with the oil production picking up from 352 BOPD (barrels of oil per day) in 2008 to about 1.17 million BOPD in 2015 (AAPG Memoir 110; RRC 2016 (see Figure 3 a to c). Like other resources affected by the drop in the recent oil price, oil production from the Eagle Ford Shale has also been declining as evidenced from a June 2016 rig count report by Baker Hughes. From a total rig number of 103, comprising 83 oil and 20 gas rigs in June of 2015, the number of rigs declined to a total of 34, comprising 27 oil and 7 gas rigs in June of 2016. Condensate liquids production has been declining since 2014 because of the price of natural gas. The industry reacted by switching to oil production from the shallow Eagle Ford, which is in the oil window (see Figures 3a & b for the trend).



3a. Oil production



3b. Condensate liquids production



3c. Total natural gas production

Figure 3: Texas Eagle Ford Shale Production: a) oil, b) condensate liquids, and c) total natural gas production, from 2008 through April 2016. (Source: Railroad Commission of Texas Production Data Query System (PDQ), 2016).

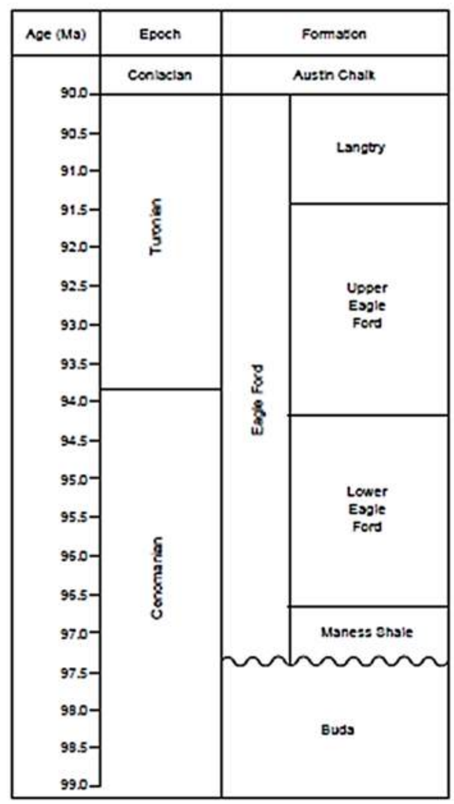


Figure 4 (Top left): Location of the Cenomanian-Turonian Eagle Ford Group (red star) and the Western Interior Seaway during the Late Cretaceous (~85 Ma) (modified from Robinson and Kirschbaum, 1995, and Blakey, 2011).

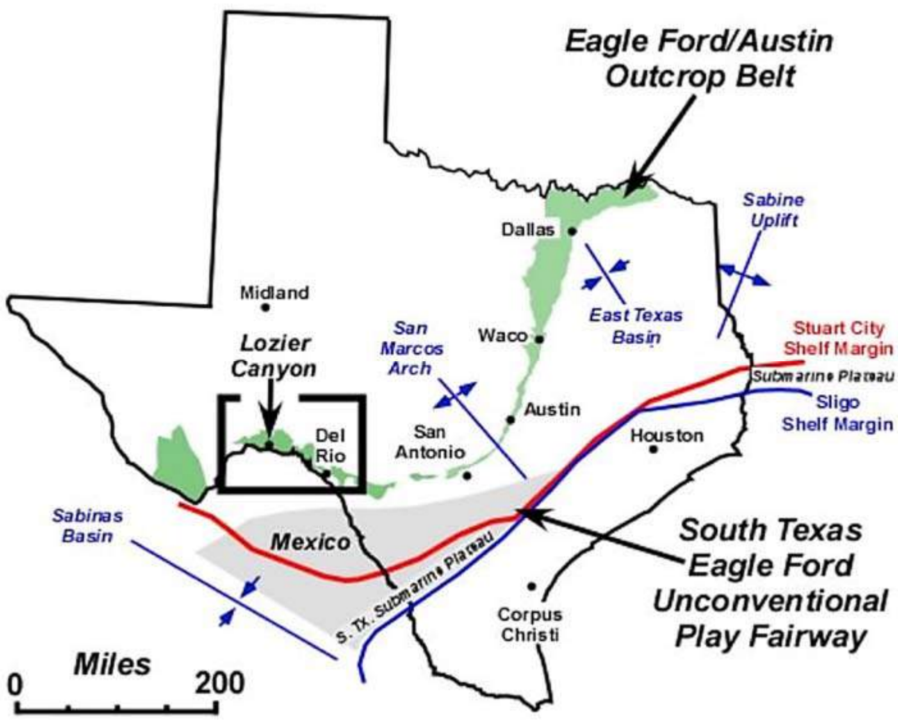
Figure 5 (Top right): Stratigraphic column for the Eagle Ford Formation (from Hammes et al., 2016).

Geological Framework

1. Depositional setting and environmental conditions

The Eagle Ford Shale is an organic-rich mudrock deposited over a Cretaceous carbonate platform south of the Western Interior Seaway and west of the Tethys Sea. It is Upper Cretaceous (Cenomanian-Turonian) in age. This time period was characterized by a global phenomenon encompassing the combination of a series of events (warm climate, tectonism, volcanism, variation in ocean chemistry, seal-level rise and transgression, increased nutrient levels resulting from higher weathering rates and upwelling, global increase in organic productivity, the Oceanic Anoxic Event 2 (OAE2), an increase in burial of organic carbon followed by drop in atmospheric CO_2, and lack of a major siliciclastic influx). (Robinson and Kirschbaum, 1995; Dean and Arthur, 1998; Corbett et al., 2011; Alaniz et al., 2016; Denne and Breyer, 2016; Schieber et. al., 2016). (see Figure 4) The carbonate platform comprises the Sligo and Comanche shelves, which were formed in early Cretaceous (Alaniz et al., 2016) (see Figure 2). Fossils contained in the Eagle Ford and associated sedimentary structures point to a body of water that was frequently dysoxic with intermittent anoxic and oxic intervals (Schieber et al., 2016).

Figure 5a. Texas map showing the main structural and physiographic features influencing the Gulf of Mexico Coastal Plain (from Donovan et al., 2013a)



2. Regional Geology

The Eagle Ford Shale was deposited on the Gulf of Mexico Coastal Plain. Geological structures which influenced this deposition included: the Maverick Basin and East Texas Basin (intra-shelf depocenters formed by subsidence in Middle to Late Cenomanian and where the primary sedimentation from marine transgression that deposited organic-rich carbonate mudstones, such as the Eagle Ford, was the thickest), the San Marcos Arch, and the Sabine Uplift (Hentz and Ruppel, 2010; Donovan et al., 2012) (Figure 5a and b). According to Donovan et al. (2012), the depth of the water where the Eagle Ford Formation was deposited was as shallow as 100 to 200ft (~30 to 60m) in the central Texas and 400 to 660ft (~120 to 180m) in the deeper south Texas sections.

3. Local Geology and Stratigraphy

The Eagle Ford Shale is uncomfortably overlain by the Austin Chalk and underlain by the Buda Limestone Formation (Figure 5). The Eagle Ford Shale is believed to be the source rock for the Austin Chalk (e.g., in the Pearsall and Giddings fields), the Buda Formation, as well as other plays in the south and east Texas (the prolific sands of the Woodbine and the Eaglebine formations) (Denne and Breyer, 2016). The Eagle Ford Group in west and south of Texas is divided into Lower and Upper formations, which, in turn, are separated by a regional unconformity at the contact The Eagle Ford Group in west and south of Texas is divided into Lower and Upper formations, which, in turn, are separated by a regional unconformity at the contact between Facies B and C of Donovan et al. (2012; 2013 a and b). Facies B consists of black organic-rich calcareous mudstone with scattered limestone interbeds, and Facies C is comprised of medium gray thick bedded limestone with mudstone interbeds. There also exists a Middle Eagle Ford but, according to Denne et al. (2016), it is restricted to those counties near the San Marcos Arch (Figures 6 and 7). Breyer et al. (2016) described the lithology of the Eagle Ford as generally comprising argillaceous mudrocks (shales), calcareous mudrock (marl) (45-65% calcite and 10-20% dispersed clay), and limestones, where the marls are associated with planktonic foraminifera, the clays with coccoliths, and the limestones with calcispheres and mainly altered radiolarians. Stratigraphy of the Eagle Ford Shale varies across the south and west, the central, as well as the eastern parts of Texas (Hentz and Ruppel, 2010) (Figure 6, 7, and 8).

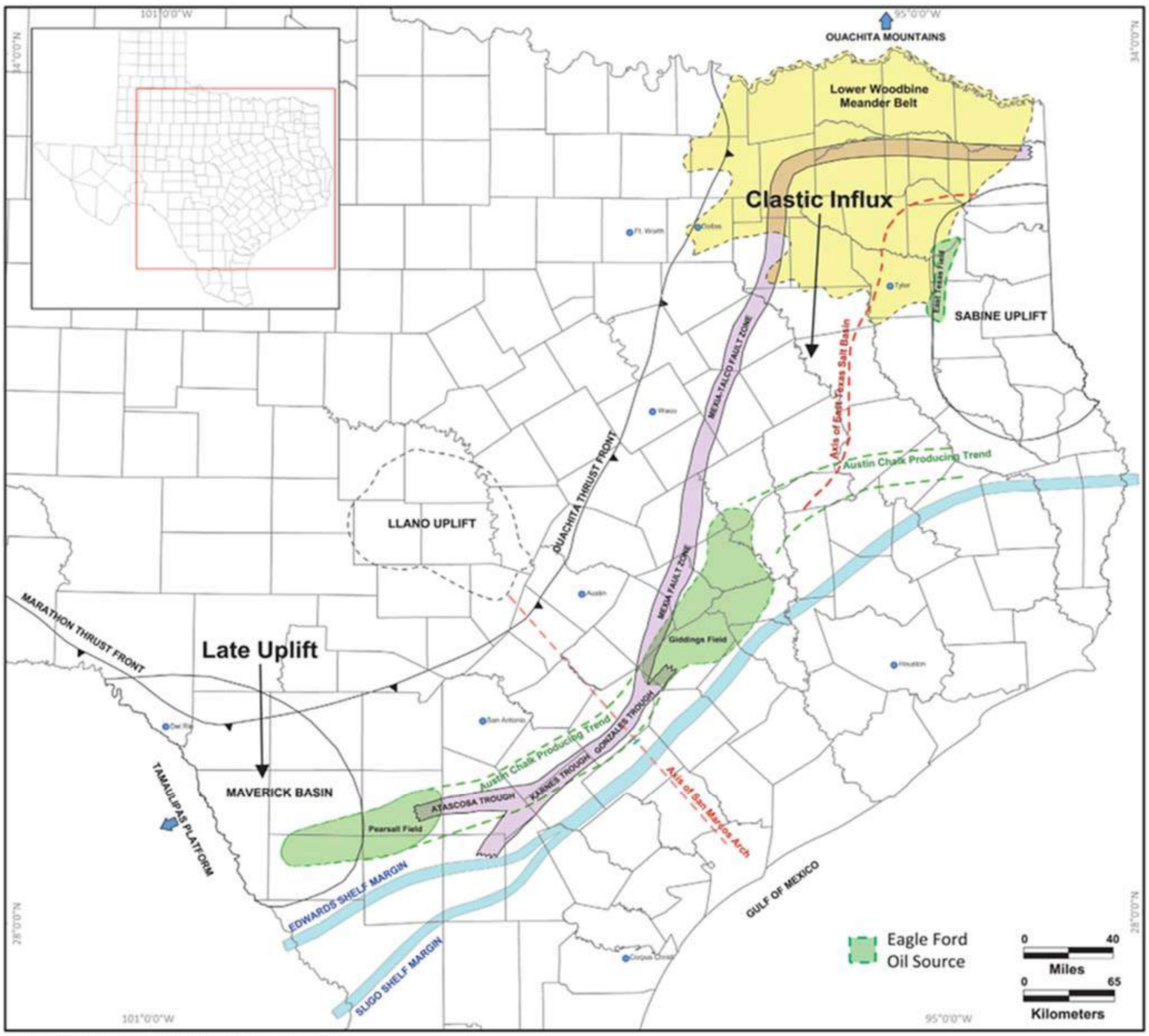


Figure 5b: Active tectonic/depositional features during Eagle Ford deposition. (from Alaniz et.al., 2016)

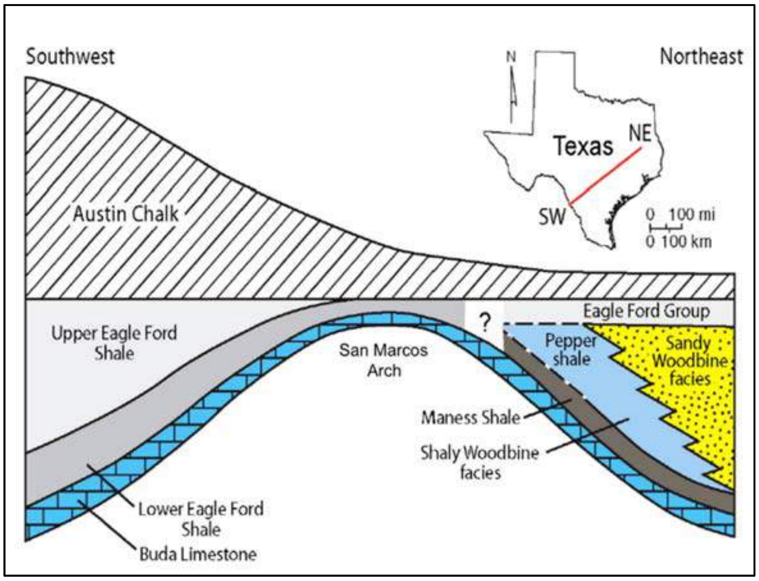
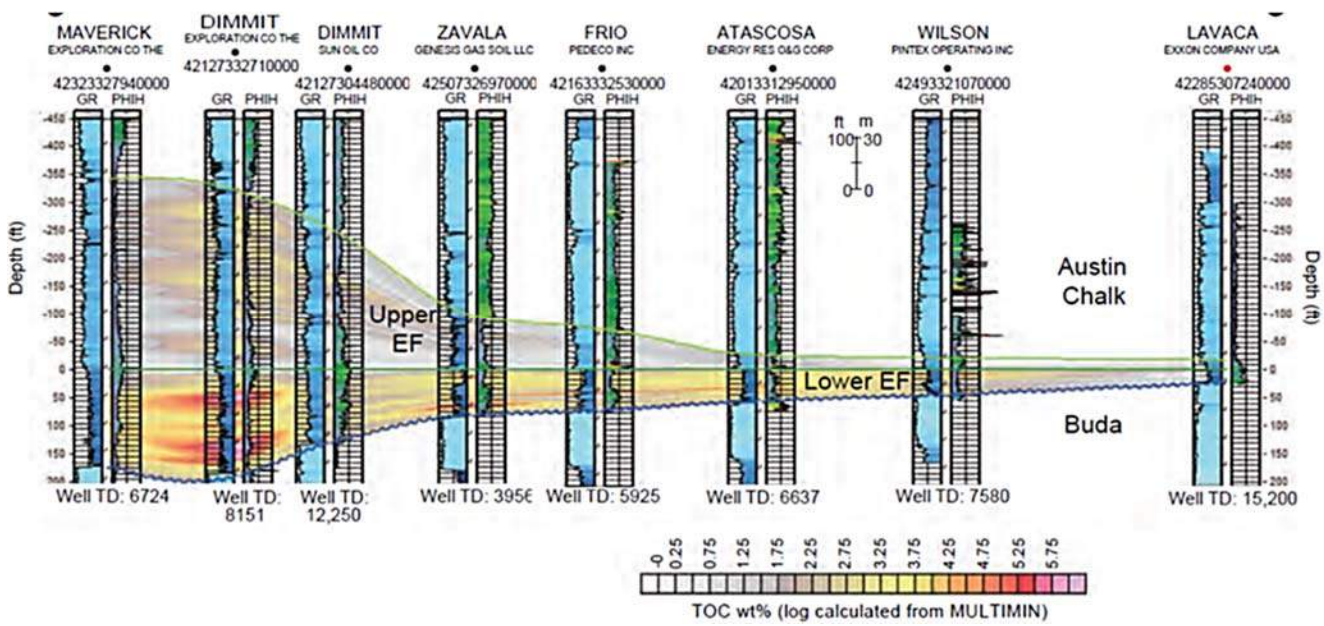


Figure 6: Generalized SW-NE schematic strike cross section illustrating the relationships among lithostratigraphic units across the Eagle Ford Shale Play (from Hentz and Ruppel, 2010).



SW

Figure 7: Eagle Ford strike cross section from SW to NE (modified after Hammes et al., 2016).

NE

The Eagle Ford at Lozier Canyon (part of the Eagle Ford in west and south Texas) was referred to as the Eagle Ford Group by Donovan et al. (2012). These authors also suggested that this rock succession comprises, from base to top, five facies and called them Facies A to E, where each facies comprises different set/s of lithological units consisting of limestones, calcareous mudstones, black organic-rich calcareous mudstones, marls, and fossils.

The Eagle Ford in central Texas contains massive argillaceous mudrocks, massive argillaceous foraminiferal mudrocks, laminated argillaceous foraminiferal mudrocks; laminated foraminiferal wackestone; cross-laminated foraminiferal packstones and grainstones massive bentonitic claystones; and nodular foraminiferal packstones and grainstones (Fairbanks, 2012). Donovan et al. (2012; 2013 a and b) interpreted the Eagle Ford section in west and south Texas as the Eagle Ford Group and determined that it comprises five facies, each being lithologically distinct but overall consisting of limestones, grainstones, calcareous mudstone beds, black organic-rich calcareous mudstones, packstones, echinoid-bearing marls, and nodular limestones.

The Eagle Ford in east Texas consists of shales that are calcareous, organic-rich, dolomitic, in association with laminated marls, sandstones, and occasional thin ash beds. Arthur and Sageman (2004) and Jennings and Antia (2013) have interpreted these facies as delta to prodelta deposits. According to Hentz and Ruppel (2010), the interval between the Austin Chalk and the Buda Limestone includes (from base to top) the Maness Shale, Pepper Shale, and the Eagle Ford Shale (Figure 6). The siliciclastic Woodbine Group occurs between the Eagle Ford Shale and the mudrocks of the Maness Shale (Figure 6).

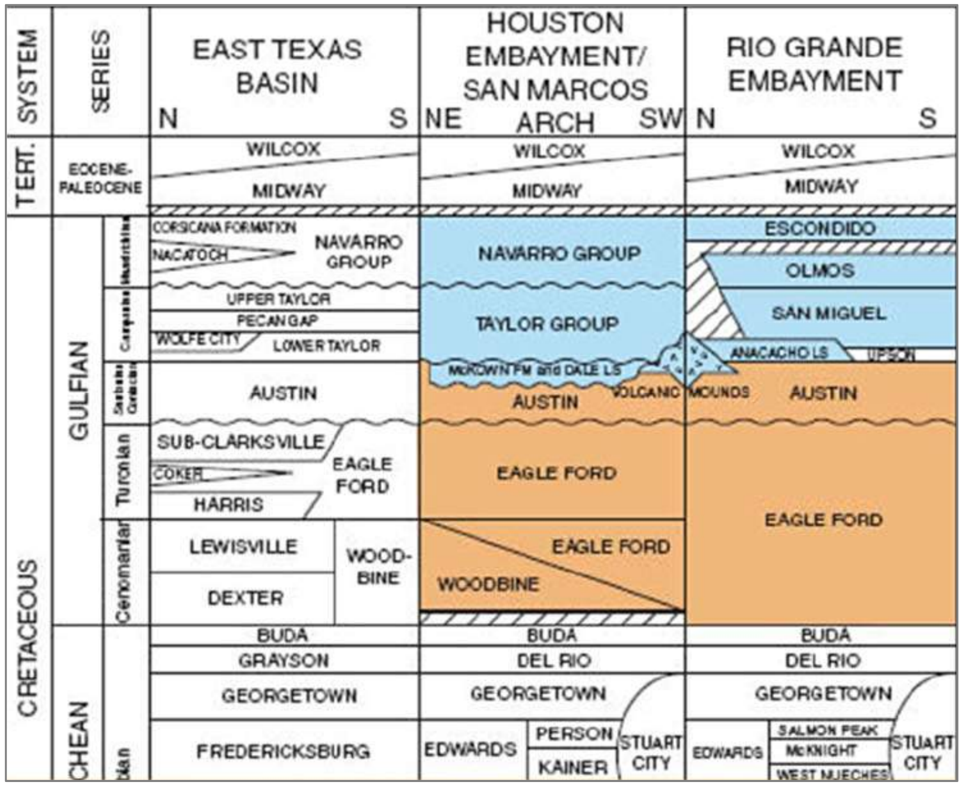
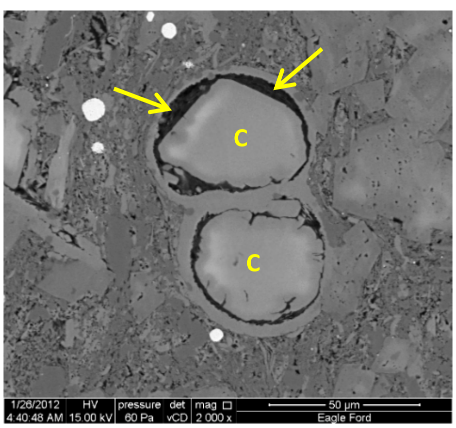
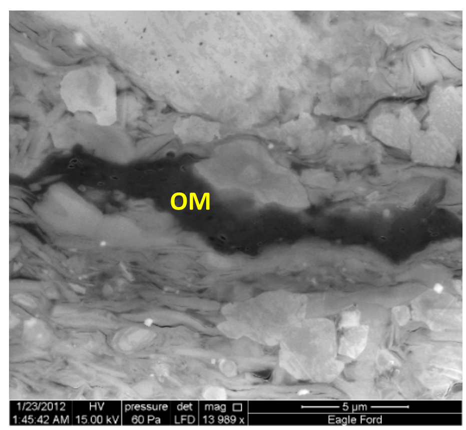


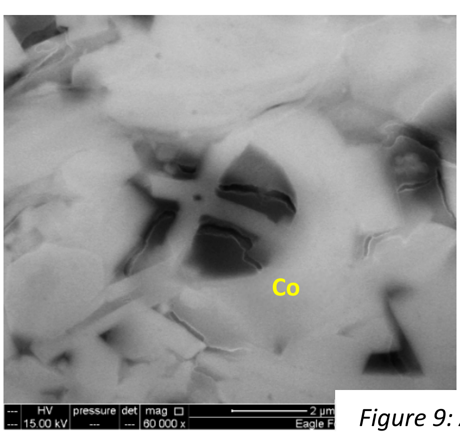
Figure 8: Stratigraphic column of the Eagle Ford Shale (from Condon and Dyman, 2006).



Left: Foraminifera test chambers filled with calcite (C) and organic matter (arrows). Also seen are pyrite framboids (white particles) set in a calcite/clay matrix.

Right: A film of organic matter (OM) in intergranular space.





Left: Organic matter inside coccolith (Co).

Right: The same view as in the photo in the left, enhanced to show available porosity (arrows) that is associated with the organic matter.

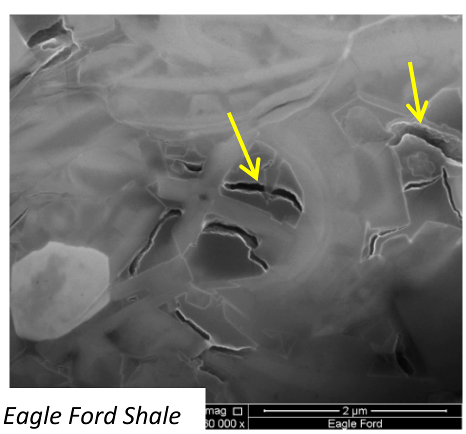


Figure 9: AIM-SEM images of the Eagle Ford Shale

4. Rock fabric, porosity & permeability; Scanning Electron Microscopy

Average porosity of 9% (EIA, 2011) and average permeability of 1000 nD (Jarvie, 2012) have been suggested for the Eagle Ford Shale Play. Schieber et al. (2016) identified different pore types in the Eagle Ford Shale that is in the gas window: intergranular pores that are occupied by clay and calcite, pores associated with microfossils (the largest being inside foraminifera tests), and pores in organic material due to maturation. The above authors also suggest that the distribution of pores is not uniform but varies with facies change. Kosanke and Warren (2016) found out that the Eagle Ford Shale has both a small- (associated with microfractures) and a large-scale (associated with tectonism) porosity system and suggested that the permeability in the Eagle Ford increases with calcite content and the degree of lamination. This results in the foraminifera-rich marls with the highest calcite and thickest laminations to have the highest permeability. For limestones of the Eagle Ford Shale, permeability is high where primary depositional textures have been replaced during diagenesis (Kosanke and Warren, 2016).

Organic Petrology & Geochemistry

A map of Eagle Ford organic matter thermal maturity windows (EIA, 2010) (Figure 10) shows that the organic matter in the Eagle Ford Shale is mature to post-mature, where the maturity increases from NW to SE, and produces oil, condensate liquids/wet gas, and dry gas depending on depth. The Eagle Ford consists of mixed marine Type II and Type III kerogen, and the present-day TOC is 1.84 wt. % (Edman et al., 2011), but can reach up to 8.0 wt.% (Robison, 1997; Figure 12). The lower part of the Eagle Ford is the organic ally richest part of the group (Zumberge et al., 2016).

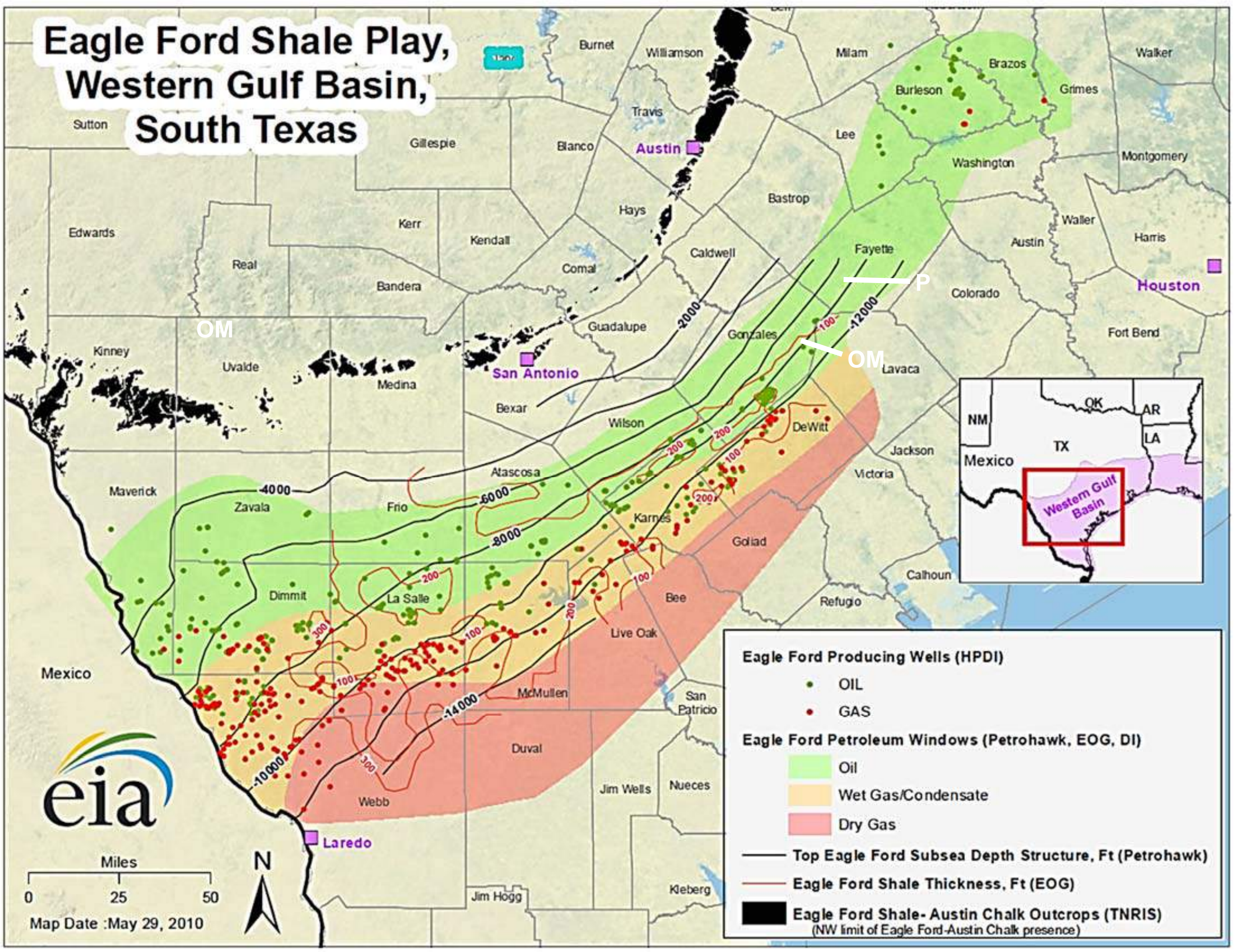


Figure 10: Organic matter thermal maturity windows and the type of hydrocarbon produced in the Eagle Ford Shale Play (EIA, 2010).

Organic matter in the Eagle Ford Shale consists of rare primary vitrinite and vitrinite-like dispersed grains, reworked vitrinite, alginite, migrabitumen that fills foraminifera tests, granular bitumen, amber-colored bitumen staining/lamellae, pyrobitumen, and inertinite (fusinite, semi-fusinite, and granular inertinite or micrinite-like) (Figure 11). The vitrinite have a reflectance range of 0.6-1.75%. The bitumen and pyrobitumen have reflectance of 0.40%-0.70% and up to 2.0%, respectively. Equivalent VRo of 0.53% (immature) was suggested by Slatt et al. (2012) based on Rock-Eval Tmax of 427^{o}C from Eagle Ford Shale outcrops at Comstock West locality, northwest of Del Rio in Val Verde County, Texas.

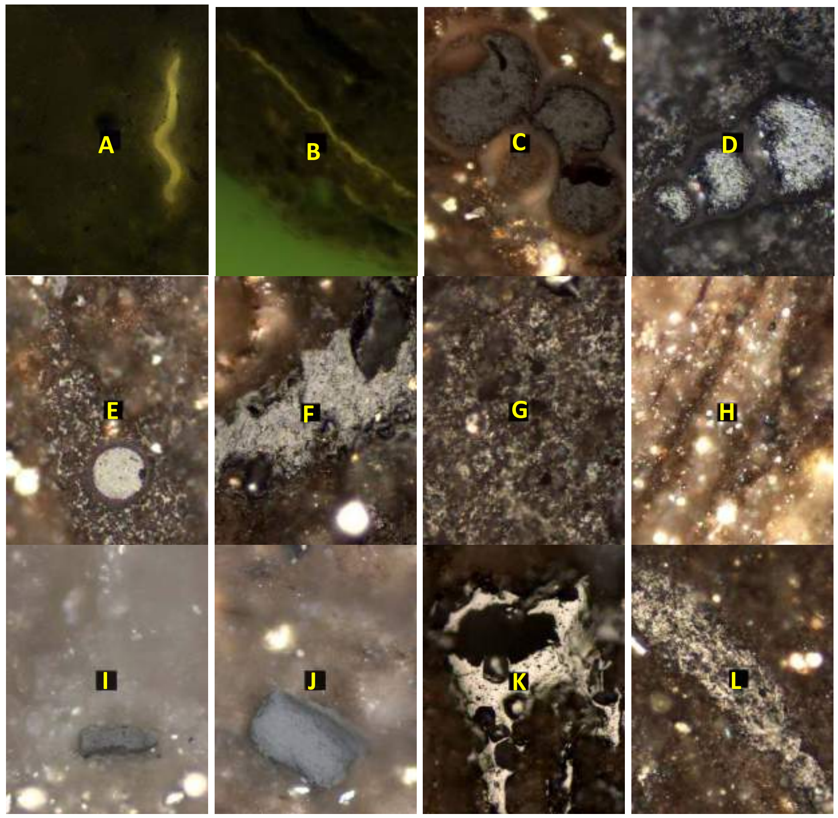


Figure 11: Eagle Ford Shale photomicrographs, showing from top left to bottom right: A) dull-yellow fluorescing alginite, B) thin-walled dull yellow fluorescing alginite, C) low-reflecting migrabitumen inside foraminifera tests, D) high-reflecting migrabitumen inside foraminifera tests, E) high-reflecting bitumen inside a calcisphere, F) reservoir bitumen in intergranular space, G) network of matrix bituminite, H) amber-colored bitumen lamellae, I) a grain of primary vitrinite, J) reworked vitrinite showing relief, K) fusinite showing cell structure, and L) granular inertinite (micrinite).
Photos were taken under reflected light, oil immersion. UV light photos (first two of the set) were taken using an excitation filter at 465 nm and beam splitter/barrier filter having a cut at 515 nm. Total magnification of photos is x500.

Robison (1997) conducted a geochemical and petrological study of organic matter in Eagle Ford Shale outcrops located in two Texas localities: Austin and Waco. The results are shown in the figures below. With regard to organic enrichment (TOC) and source potential, he reported a TOC range of 1.0 to nearly 10.0 wt.%, which is within the limits set for a hydrocarbon source rock (TOC >1.0%, Peters and Cassa, 1994) (Figure 12). The total hydrocarbon generation potential (THGP), a crucial factor to evaluate whether good TOC content translates to hydrocarbon generating potential, was also good to excellent (THGP ranged from 1 to 50 mg HC/g rock) compared with Rock-Eval® pyrolysis yields of S_1 plus S_2 thresholds set by Peters and Cassa (1994) (i.e. S_1 and S_2 for good petroleum potential are >1 and >5 mg HC/g dry rock, respectively) (Figure 12). The author also performed oil proneness study (level of hydrogen enrichment) based on plots on modified van Krevelen diagram (Figure 13a), and suggested that most of the Eagle Ford samples contain a mixture of type II (hydrogen-rich) and type III (hydrogen-poor) kerogen, which led to the conclusion that the rocks are both oil and gas prone. Assuming the samples were free of contamination, the author also determined the KTR (Kerogen Transformation Ratio, computed as S1/[S1+S2]) (which was for the most part 0.2), and plotted it against Tmax (which ranged from 4350C to slightly over 4400C) to identify maturity levels; the results showed that the Eagle Ford samples were at the onset of hydrocarbon generation and expulsion stage (Figure 13b). From the petrographic visual kerogen analysis, a qualitative determination of percentage oil-prone kerogen (fluorescent amorphinite plus exinite) showed levels expected from a good source rock, with oil-prone kerogen making up 60-75% (with the richest intervals having as high as 80-85%) of the kerogen in the Eagle Ford samples analyzed (see Figures 12 and 13c).

Slatt et al., (2012) studied outcrop samples from "Comstock West", a road cut located along Highway 90 about 30 miles NW from Del Rio, in Val Verde Co., TX. They found that the TOC averaged 5.3%, and the samples contained Type II kerogen. However, the organic matter was thermally immature with Tmax values of 423-429°C and average Ro of 0.53%. Rock-Eval pyrolysis data across all parts of Eagle Ford Shale Play (producing area) from depths 1660 to 14,044ft is shown in Figure 13. The data shows distinct groups based on maturity, falling in the Type II and III kerogen regions.

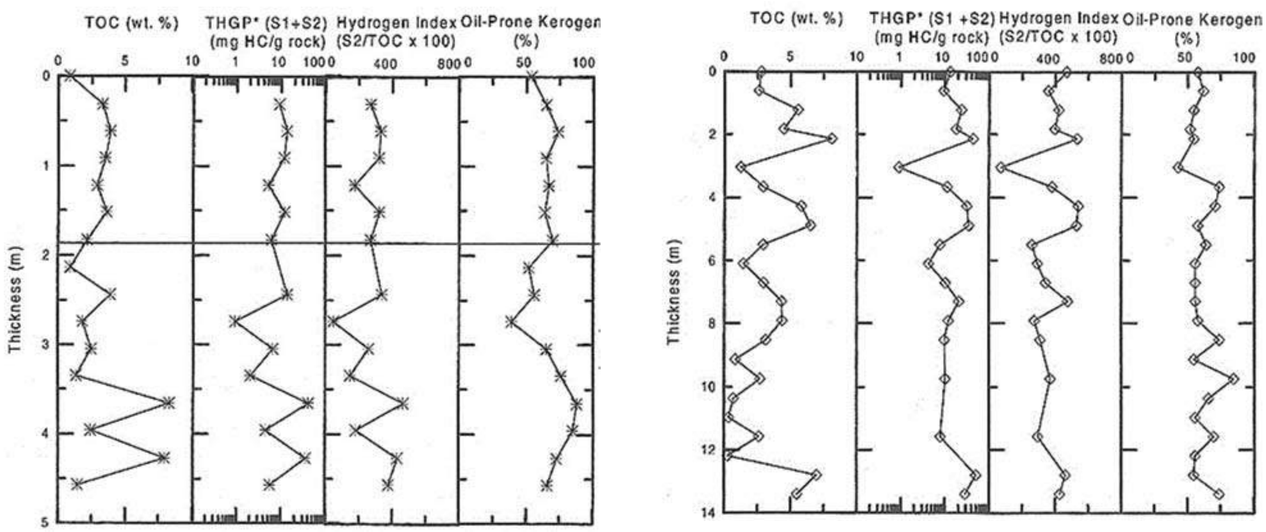


Figure 12: Geochemical profiles of source rock attributes for the Eagle Ford Shale at Austin, TX (left) and Waco, TX (right) localities. THGP=total hydrocarbon generation potential. From Robison (1997).

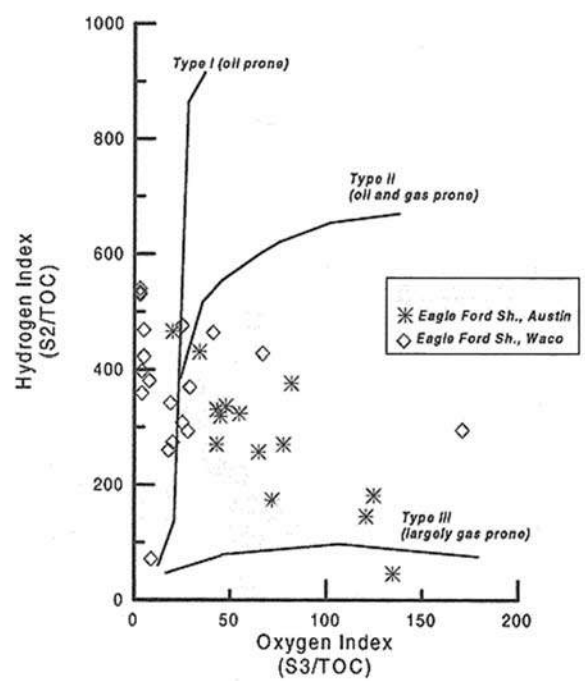


Figure 13a: Oxygen vs. hydrogen index for outcrop samples of the Eagle Ford Shale at Austin, TX and Waco, TX localities.

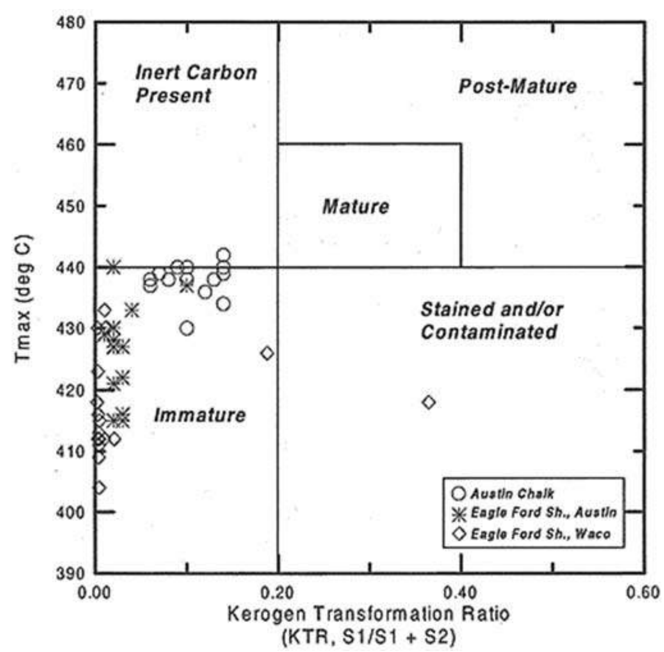


Figure 13b: Source rock maturity levels as indicated by a cross plot of the kerogen transformation ration and Tmax values from Rock-Eval ® pyrolysis.

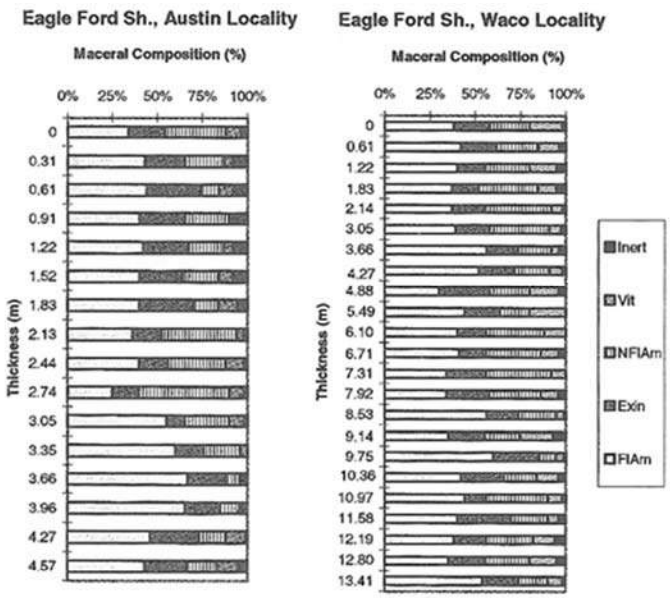
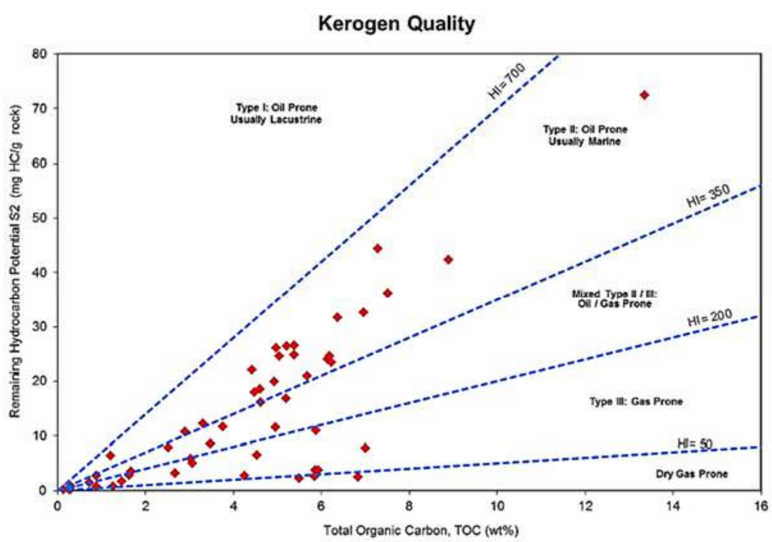
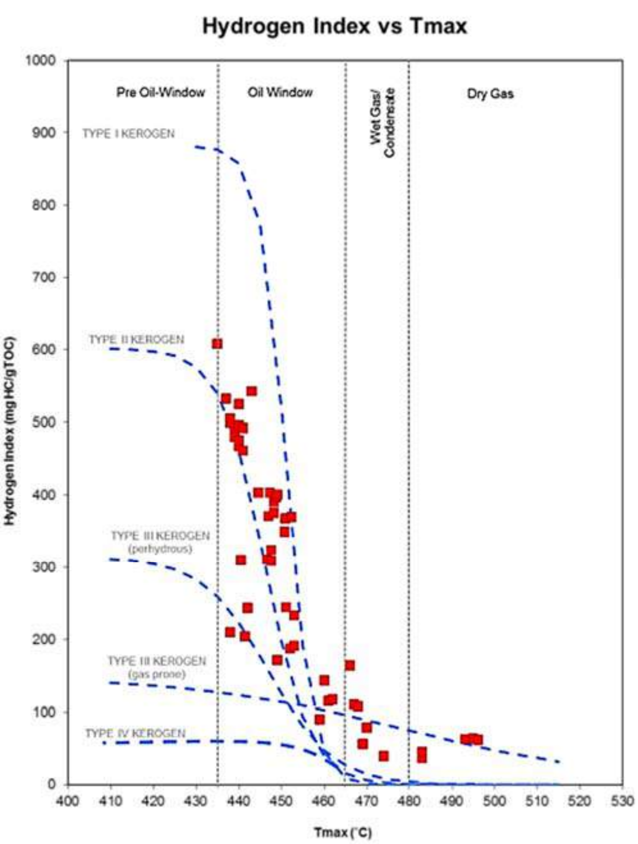


Figure 13: (a) Oxygen vs. hydrogen index for outcrop samples of the Eagle Ford Shale at Austin, TX and Waco, TX localities. (b) Source rock maturity levels as indicated by a cross plot of the kerogen transformation ration and Tmax values from Rock-Eval ® pyrolysis. (c) Distribution of maceral types in samples of the Eagle Ford Shale from Austin (left) and Waco (right) localities in Texas. Inert=inertinite, Vit=vitrinite, Exin=exinite, NFIAM= nonfluorescent amorphinite, and FIAm=fluorescent amorphinite). From Robison (1997).

Figure 13c: Distribution of maceral types in samples of the Eagle Ford Shale from Austin (left) and Waco (right) localities in Texas.





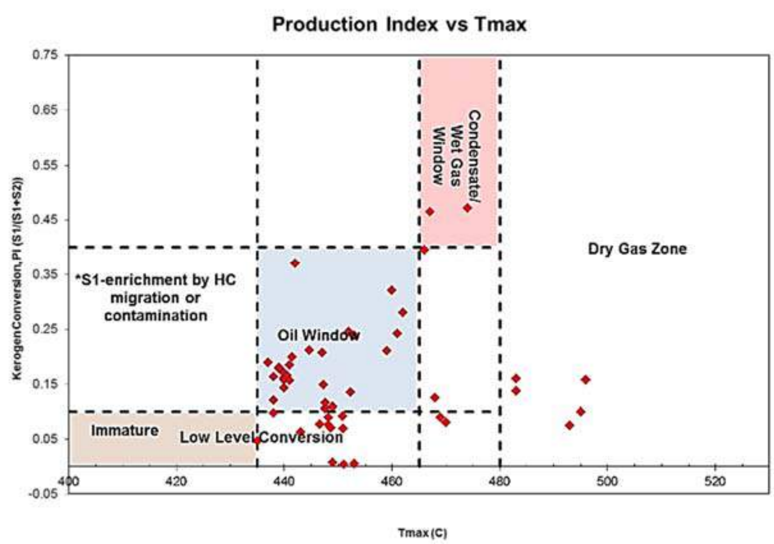


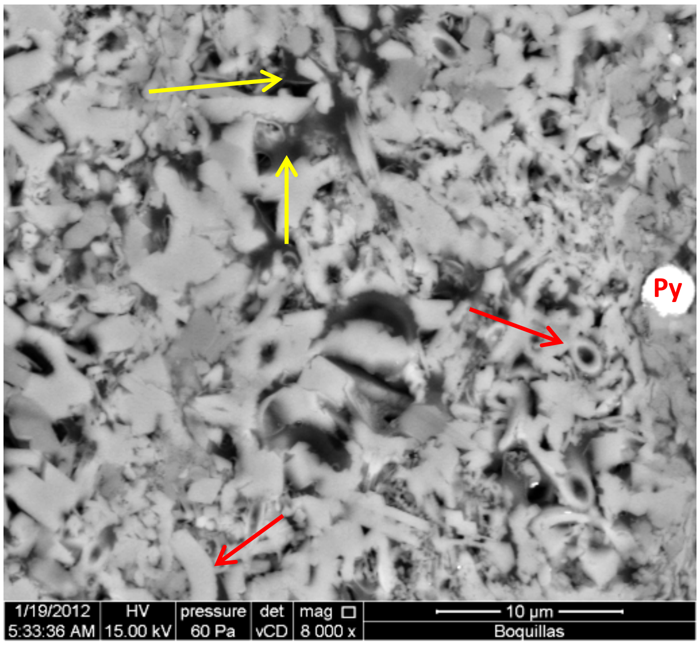
Figure 14: Rock-Eval data for the Eagle Ford Shale Play across Texas. Zumberge et al. (2016) identified 8 compositionally distinct oil families based on a comparison of organic geochemical data from south Texas, and related these differences to variations in depositional environment of the Eagle Ford Shale Group.

SEM images of Pore System – Boquillas/Eagle Ford Samples.

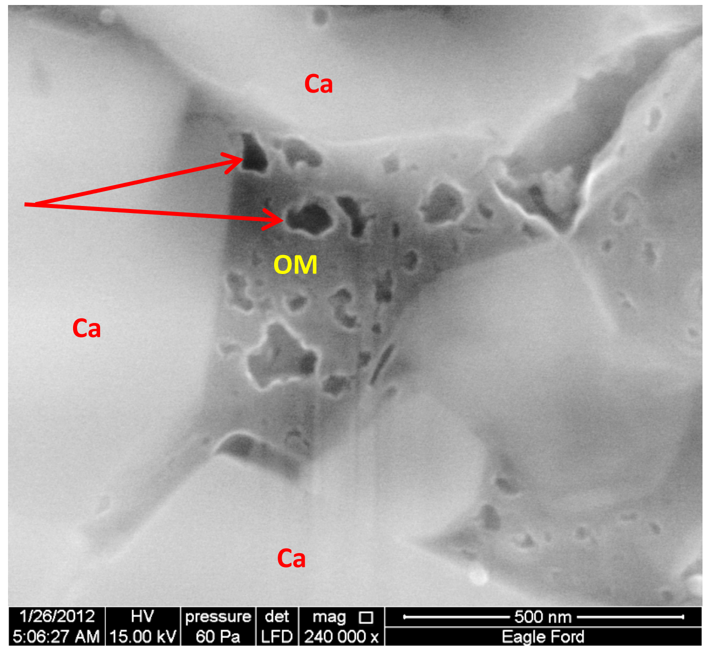
Photo A. Boquillas Formation. Sample is from laminated, neomorphosed limestone that occurs at the base of the road cut seen at Stop 1. The individual particles are predominantly pieces of disarticulated calcareous nannoplankton (red arrows). Note also, occurrence of pyrite framboid. The pore system is predominantly interparticle micropores along with a small amount of intraparticle pores. Organic matter (yellow arrows) partially fills some of the interparticle pores.

Photo B. Eagle Ford - subsurface. Image shows porous ('spongy texture') organic matter (OM) filling an interparticle pore. The pore sizes in the organic matter range from less than 10 nanometers to over 90 nanometers. The size of the pores indicated by the red arrows is 71-78 nanometers. The adjacent particles are predominantly calcite (Ca).

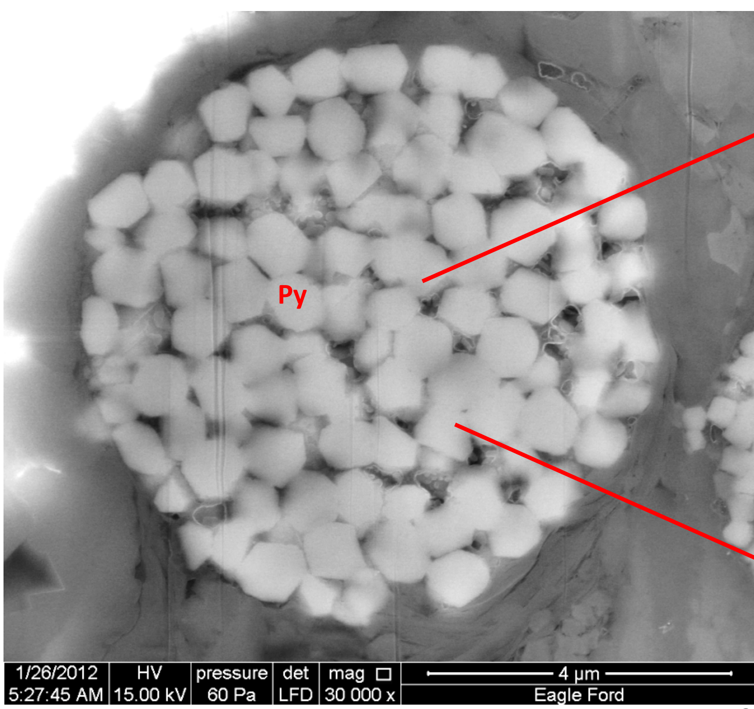
Photos C and D. Eagle Ford – subsurface. Photo C shows a pyrite framboid (Py) that contains intraparticle pores between the individual pyrite crystals. The higher magnification image seen in Photo D that many of the pores are partially filled with organic matter (yellow arrows) that coats the exposed surface of the pyrite crystals. The size of the pores is typically in the 100's of nanometers.



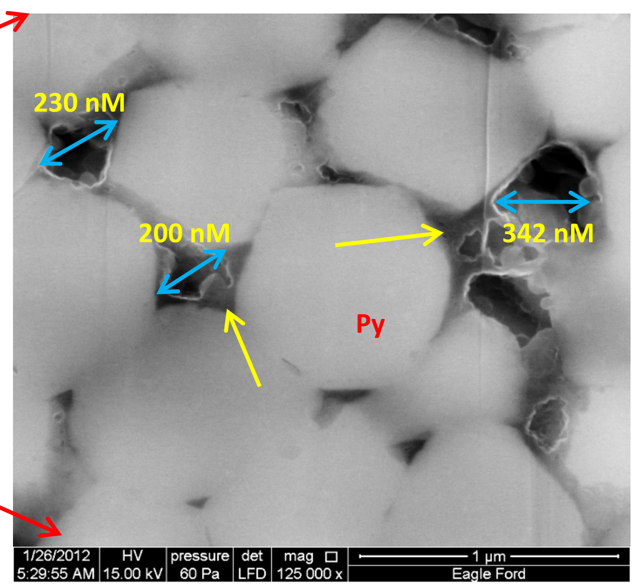
A



B



C



D

Road Log (2): U.S. Highway 90 - Del Rio to Langtry

Outboard Mileage: Del Rio to Langtry

0.0 Intersection of US 90 with US-277, west of downtown Del Rio.

4.6 Lower Cretaceous Salmon Peak formation – both sides of road.

7.6 Intersection with Spur-349 - to Amistad Dam.

Outcrops of fossiliferous wackestone in the Lower Cretaceous Salmon Peak Formation at interchange with Spur-340 (to Amistad Dam).

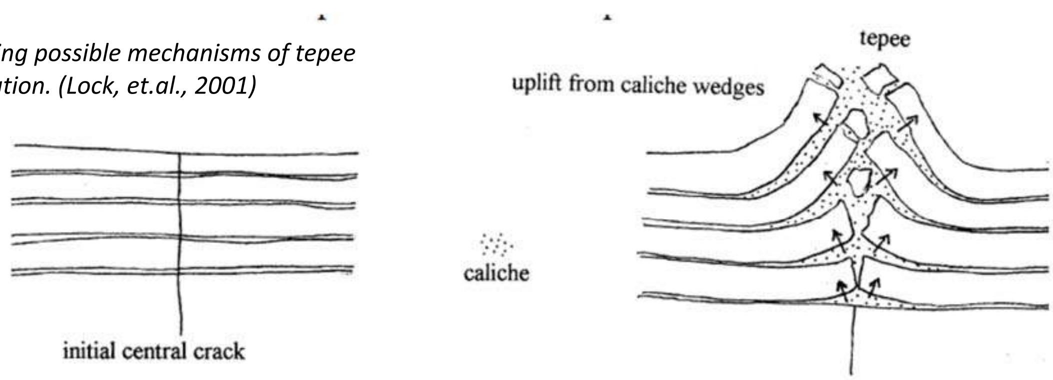
9.2 Crossing arm (Dirty Devil / Devils River) of Amistad Reservoir – mid channel.

13.9 Tilted beds – result of fault we crossed 0.2 mile to the east. Fault is covered.

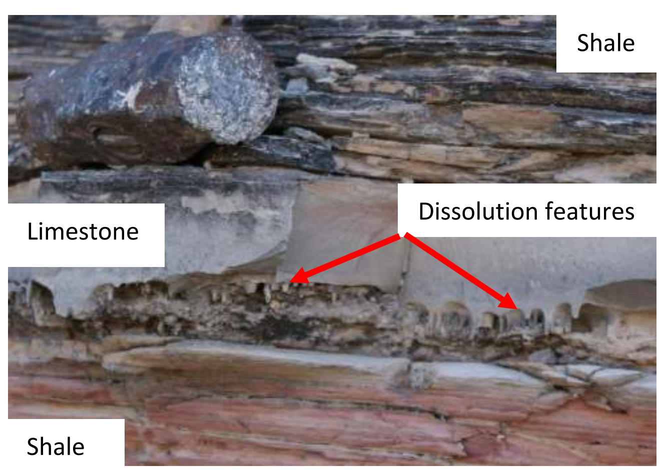
16.1 – 17.1 Series of several outcrops on both sides of road showing tepee structures.

Tepee structures in middle Boquillas Formation

Diagram showing possible mechanisms of tepee formation. (Lock, et.al., 2001)



B — Tepees from caliche wedging and uplift



Lock, et. al. (2001) investigated these structures and compared them with similar structures in other parts of West Texas and the Permian outcrops at Walnut Canyon, near Carlsbad Caverns, New Mexico. Traditionally the tepees seen in these Cretaceous outcrops were thought to be analogous to the Permian outcrops and thereby considered to have been formed in tidal flat deposits. Lock, et.al. maintain that the tepees are related to processes associated with the development of caliche near the present-day land surface. They suggest water carrying calcium carbonate penetrated the Boquillas along vertical fractures and then along the shale horizons. Since the shales can be expected to be aquicludes to vertical fluid migration, but water can migrate along lamination parting surfaces (see photo, bottom of previous page, right side), the caliche is deposited at the shale/limestone interface. These conclusions are based on several different observations: 1) Tepee structures are seen only at the tops of outcrops, but also occur at slightly different stratigraphic horizons. They occur near the present surface of the land, never more than ~6-feet below the surface and are truncated by the land surface. 2) The tepees occur in a weathering facies that is distinctly blackened – close examination shows that the black color is a superficial lichen coating confined to caliche. The caliche often contains millimeter-scale accretionary structures and when fresh, is chalky white. 3) This part of the Boquillas Formation consists of alternating limestones and silty shales and the caliche only occurs in the shaly layers. 4) in most cases, there is a vertical crack running down the axial surface of each tepee. 5) The shaly layers thicken towards the axes of the tepee anticlines and towards the present surface where it is inclined toward the surface.

22.8 Comstock Border Patrol Station (all non-US citizens should have their papers ready for inspection).

26.0 Comstock East road cut – Stop 9; we will visit this road cut on the inbound portion of the field trip.

27.1 Traffic light in Comstock, intersection with Tx-163.

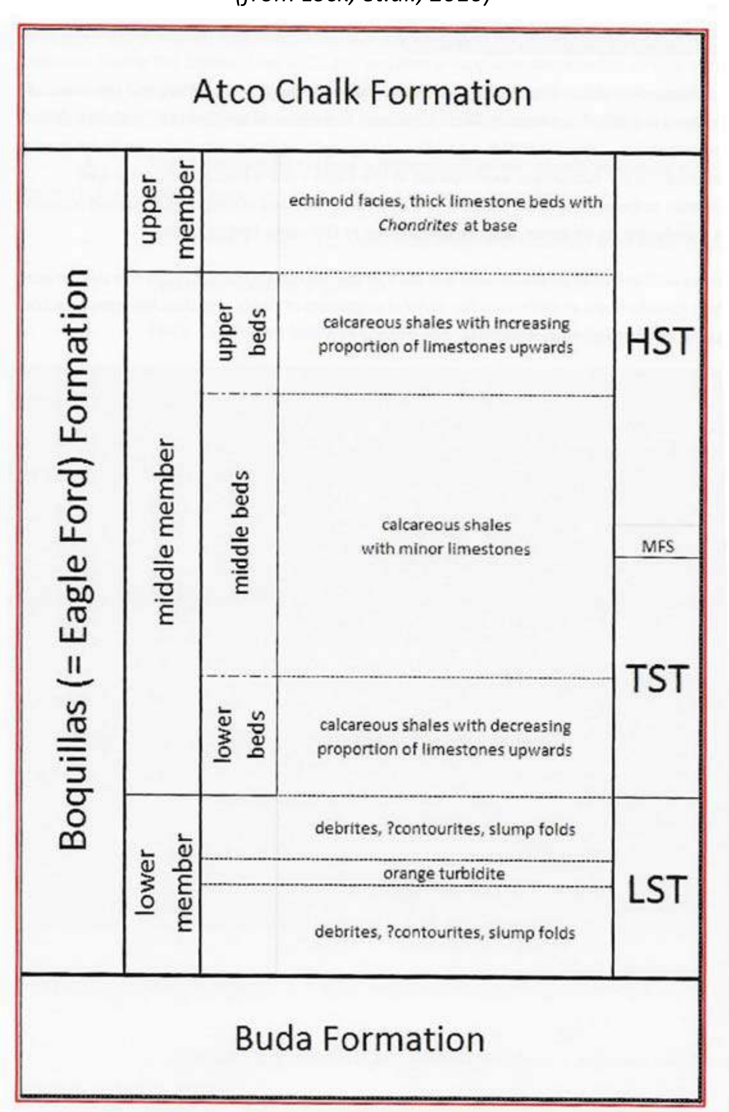
28.2 Comstock West road cut – Stop 8; we will visit this road cut on the inbound portion of the field trip.

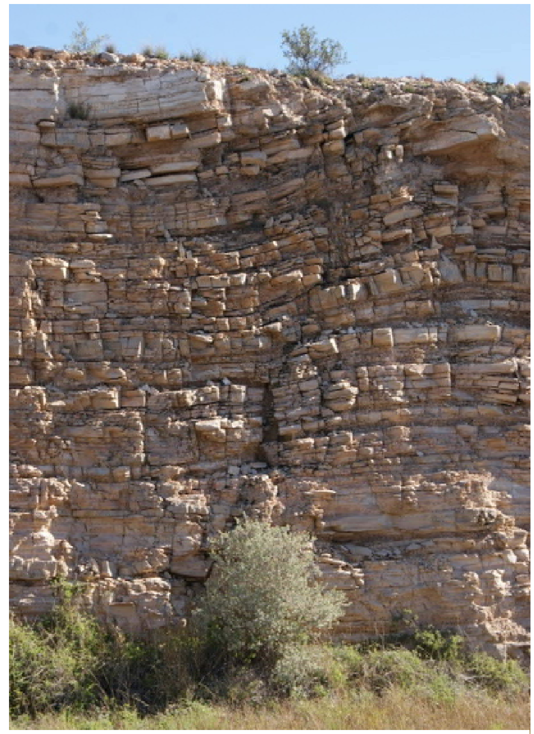
28.4 Intersection with FM-1024 (to north).

31.3 Stop 1.
Lower beds, middle member, Boquillas Formation.

This is our first encounter with the least weathered portion of the Boquillas that we will see on this trip. The outcrop is about 25-feet high and some 2000-feet long. The strata are very consistent and the exposed section can be traced over the entire length of the exposure. The light-gray color on the lowermost beds represent weathering that has occurred since 1978, when the highway was rerouted through this area. When you break off a corner of the rock it has a black color and a very thin oxidation rind. The gray color results from oxidation and removal of carbon while the red/yellow colors seen in the overlying rocks are caused by oxidation of iron. The less-weathered rock contains fine-scale laminations, some of which are concentrations of foraminifer and calcispheres. The only macrofossils are thin-shell Inoceramid bivalves. The hydrocarbon odor, lack of bioturbation, and paucity of benthos (except inoceramids, which survive in conditions of low water) indicate anoxic to dysaeroic bottom conditions. Conventional sequence stratigraphy would classify the lower beds of the middle member as a Transgressive Systems Tract and the upper beds as the first part of the corresponding Highstand Systems Tract with a maximum flooding surface located in the middle beds of the middle member (see diagram on the next page). Minor faults (photo) with minimum displacement and fractures that are often limited to a single bed (photos) are also identified in this outcrop. (Lock & Wawak, 2010)

Sequence stratigraphy – Boquillas Formation
(from Lock, et.al., 2010)





Small fault with minor displacement.

(above and left) Fractures that appear to be contained within a single bed (red arrows).

32.8 Stop 2.
Lower member, Boquillas Formation overlying Buda Formation.

This is a good road cut to see the distinctive basal member of the Boquillas Formation. There is an abundance of sedimentary features to be seen here. The basal contact between the Boquillas and the underlying Buda Formation is unconformable and the surface is marked by irregular dissolution hollows in the white Buda limestone. Foraminiferal assemblages from the uppermost Buda and the lowermost Boquillas indicated the Middle Cenomanian is missing to the west in the Big Bend area. At this outcrop the unconformity surface is a microkarst, indicating subaerial exposure and meteoric diagenesis. Individual stratal units exhibit contorted bedding, pinch-and-swell features and locally the lowest beds contain a variety of benthic fossils, mostly bivalves. Individual beds include sedimentary breccias (with varying clast sizes), grainstones (sand-size particles of crinoids), and a prominent, continuous bed that is orange in color. The combination of features suggests an unstable slope, potentially in deep water with slumps, grain flows, and debris flows. The pinch-and -swell features are interpreted to be contourites, cross-bedded units deposited by contour-parallel submarine currents and are common in deep-water environments, with the lenticular ripple shapes exaggerated by diagenetic differentiation. Limestone nodules (better exposed in other outcrops) are common and indicate that diagenetic differentiation is a significant process in this strata. The orange limestone bed can be seen at this stratigraphic level in all the outcrops with this package of strata throughout Val Verde County (24-miles). The lateral extent, poorly defined gradational bedding, and possible dish structures suggest this is a turbidite. (Lock and Wawak, 2010)

Left. Limestone breccia, basal Boquillas Formation. Right. Gastropod in upper Buda Formation.

35.9 Cretaceous unconformity – Stop 7; we will visit this road cut on the return trip.

36.3 Entrance to Seminole Canyon State Park.

Seminole Canyon State Park and Historic Site.

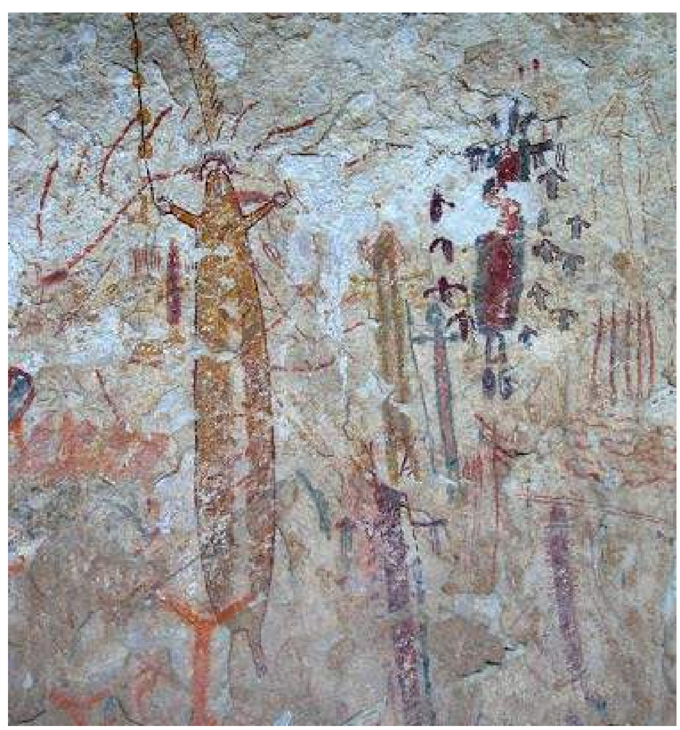
During the Pleistocene (~12-10,000 ybp) the regions temperate climate supported lush vegetation that included pine, juniper and oak woodlands in the canyons and luxuriant grasslands on the uplands. Ice age hunters pursued now-extinct species of elephant, camel, bison, and horse across the plains. By 7000 ybp the drying landscape resembled that of today. A new culture emerged in this changed environment. The Archaic people lived in the dry rock shelters that line the canyon walls and subsisted on many of the same arid-adapted plants and small animal species that inhabit the park today. Today's semiarid landscape represents a mixture of species from the Edwards Plateau, the Chihuahuan Desert and the South Texas Plains. The past inhabitants of Seminole Canyon left their mark most notably though rock paintings. The park and surrounding areas contains some of the world's outstanding examples of pictographs. Extensive pictographs of the Lower Pecos River Style adorn rock shelters throughout its canyons. Guided walks to the Fate Bell rock shelter is provided during the summer months. Fate Bell Shelter (pictographs shown above left) was one of the first rock shelters in the Lower Pecos Canyonlands to be excavated by a professional archeologist. A.T. Jackson carried out relatively modest excavations there in 1932 on behalf of the University of Texas and its archeological leader, Professor James E. Pearce. His excavation report was the first reasonably detailed description of a rock shelter. Several years later he published a study called *Picture Writing of Texas Indians* that described the pictographs found at Fate Bell and dozens of other localities in the Lower Pecos and elsewhere in Texas. Fate Bell Shelter is massive, stretching over 150 yards from

one "end" to the other, but narrow, only 40 feet or so at its widest point. It was used as a habitation site, a cooking place, a burial place, and as a rock art gallery. The thick deposits once contained a wealth of information, but, sadly, most of the cave was dug up by untrained people intent on finding showy artifacts. In the 1970s the property became part of Seminole Canyon State Park and the site is now protected by law. Visitors to the park can take special guided tours of Fate Bell Shelter.

Lower Pecos Canyonlands Rock Art

The Lower Pecos River Canyonlands of southwest Texas and northwest Coahuila house some of the most complex and compositionally intricate prehistoric rock art in the world. Nestled along the United States-Mexico border, the Lower Pecos River Archeological region encompasses an area of about fifty square miles. Though this cultural region is fairly small, more than 2,000 archeological sites have been recorded. These sites cover a time span from the 19th century to over 10,000 years ago. Over 325 pictograph sites have been documented containing some of North America's oldest and largest pictographs. These pictographs range in size from isolated motifs just a few inches tall to huge panels stretching more than 100 feet along the back of rock shelter walls. Unlike other remote regions in the western United States, the vast majority of pictograph sites in the Lower Pecos River region are situated on private property and are therefore not open to public visitation. Over the years, many well-intentioned (and some not so well-intentioned) visitors have deliberately trespassed on private land to visit rock art sites that they had seen either on television or illustrated in books and articles. Many ranchers object to strangers wandering around on their property and may file charges against anyone caught doing so.

The Lower Pecos Canyonlands provide one of the best preserved and longest record of hunter-gatherer lifeways in North America. Over 250 rock shelters are known to contain rock art. Pictographs are the most abundant form of rock here. Four main styles of rock art have been identified: 1) Pecos River Style, 2) Red Linear Style, 3) Red Monochrome Style, and 4) Historic Period. The Pecos River Style is exemplified by multi-colored, human-like figures accompanied by an assortment of enigmatic designs. AMS radiocarbon dates for these images range from 4200 to 2750 BP. Panels, some over 300-feet long, are impressive in scale and intricacy. Many of the Pecos River pictographs are widely regarded as expressions of shamanistic ritual. As summarized by Carolyn Boyd and Phil Dering in a 1996 article: "*Shamans are found primarily within Native American societies that rely heavily on hunting and gathering or fishing … In these societies, the shaman serves a crucial role as diviner, seer, magician, healer of bodily and spiritual ills, keeper of traditions, and artist. Acting as the guardian of the physical and psychic equilibrium of the society, the shaman, through altered states of consciousness, journeys to the spirit world where he will personally confront the supernatural forces on behalf of his group.… Access to the spirit or Otherworld can be achieved through such methods as the use of hallucinogenic*



or psychoactive plants, fasting, thirsting, blood-letting, self-hypnosis and various types of rhythmic activities ….” As the article documents, there is clear evidence of hallucinogenic plants including peyote, mountain laurel beans (seeds), and datura (jimson weed) in the rock art and cave deposits of the Lower Pecos Canyonlands. Controversy has arisen concerning the specter of prehistoric "drug" use, despite ample evidence of the ritual and medicinal importance of such psychoactive plants in many Indian cultures in the New World. Politically correct or not, the use of these plants was part and parcel of shamanistic ritual in the Lower Pecos Canyonlands as elsewhere in the hunter-gatherer world. While ingesting psychoactive plants can be very dangerous and even fatal, they obviously played a critical role in certain of the rituals depicted in the Lower Pecos rock art. The ritual use of peyote continues today by members of the Native American Church, a traditional religious practice that has been ruled constitutionally protected by the United States Supreme Court.

The Red Linear Style is characterized by animated, small, fine-lined figures of animals and humans. Although most are red (as implied by the classification) some images are black or yellow. Based on subject content and radiocarbon dates the Red Linear Style was believed to have been produce around 1280 ybp, but discovery of ‘older’ Pecos River Style pictographs painted over ’younger’ Red Linear style has brought this date into doubt. The Red Monochrome Style portrays static, frontally posed human figures associated with bows and arrows and realistically depicted animals in dorsal or profile view. This style began in the Late Prehistoric period, sometime around 1050 ybp. There are relatively few known Red Monochrome sites. Historical Period rock art includes images reflecting European contact, depicting missions, crosses, men on horseback, cattle, and robed figures.

Panther Cave is the region’s most famous pictograph site. The rear wall of the shelter is covered, floor-to-ceiling, with hundreds of motifs which collectively form an uninterrupted panel more than eighty feet in length. The namesake of the site, a giant red-painted mountain lion or panther, is over ten feet long from nose to the tip of the tail. To reach Panther Cave boaters should launch at the Black Brush boat ramp; the boat ride is about fifty miles round trip. The currently there is no access to the Rio Grande from the Pecos boat ramp. From the boat dock at Panther Cave, visitors climb a sixty-foot steel staircase up to the rock shelter. A steel fence and an elevated catwalk limits where visitors can walk and helps reduce potential damage to vegetation and buried archeological remains. The steel fence, designed to maximize photographic vantage points, was completed in 1996 by the NPS. Unobtrusive interpretive panels provide visitors with information about the pictographs, the prehistoric cultures that once lived in the reservoir basin, and the need to protect and preserve Panther Cave as well as to the other sites in the region. Panther Cave is a "high lonesome" shelter situated on a cliff overlooking the Rio Grande at the mouth of Seminole Canyon. This cave is known for its spectacular rock art, especially a huge red panther (mountain lion). This site lies within the boundaries of the Amistad National Recreation Area and is protected by federal law. It is managed jointly by the National Park Service and the Texas Parks and Wildlife Department. With a good pair of binoculars, the famous panther can be seen from the scenic overlook trail in Seminole Canyon State Park. When lake levels allow, special guided tours can be arranged through Seminole Canyons State Park. Sadly, vandalism forced the NPS to erect a heavy chain link fence to protect the cave.

Before Amistad Dam was completed numerous salvage sites were surveyed before being covered by Amistad Reservoir. One of the more important of these was the Devil’s Mouth site that was excavated during 1961-62 field seasons. This site is a deep, open occupation or terrace site located at the confluence of the Devils River and the Rio Grande. Brief testing of the Devil's Mouth site in late 1959 led to extensive excavations in the fall of 1961 and early winter of 1962. LeRoy Johnson, Jr. directed this work and wrote the report published in 1964 by the Department of Anthropology at UT Austin. Devil's Mouth proved to be one of the most important sites excavated during the Amistad salvage program, rivaled only by Bonfire Shelter and Arenosa Shelter. The work at the Devil's Mouth site proved highly informative because of its deep stratification—24 layers were defined, the oldest some 36 feet below the surface. The layers yielded a remarkable sequence of projectile points dating from the Late Paleoindian period (about 7-8,000 B.C.) to the Late Prehistoric and Protohistoric periods, just before the Spanish first entered the area in the 16th-century. The deep layers at the Devil's Mouth site were formed mainly by periodic flood deposits left behind by one or both of the major rivers (Devils and Rio Grande). Between floods, prehistoric groups often camped on the terrace, leaving behind debris that formed layers within the flood deposits. Erosion and slope wash also contributed sediments to the development of the terrace deposits and to some mixing of materials of differing ages. Compared to the deposits in most of the known rock shelters, the cultural layers at Devil's Mouth were much less mixed and much easier to place in correct chronological order. Johnson's study provided the first reliable chronological sequence of projectile points, a sequence that other researchers found very helpful.

Contrasting time markers reflect over 8,000 years of prehistory at the Devil's Mouth site. At the left are two rows of Late Prehistoric arrow points dating to between A.D. 1000-1600. At the right are two rows of Late Paleoindian dart points dating to between 8000-7000 B.C. TARL archives.

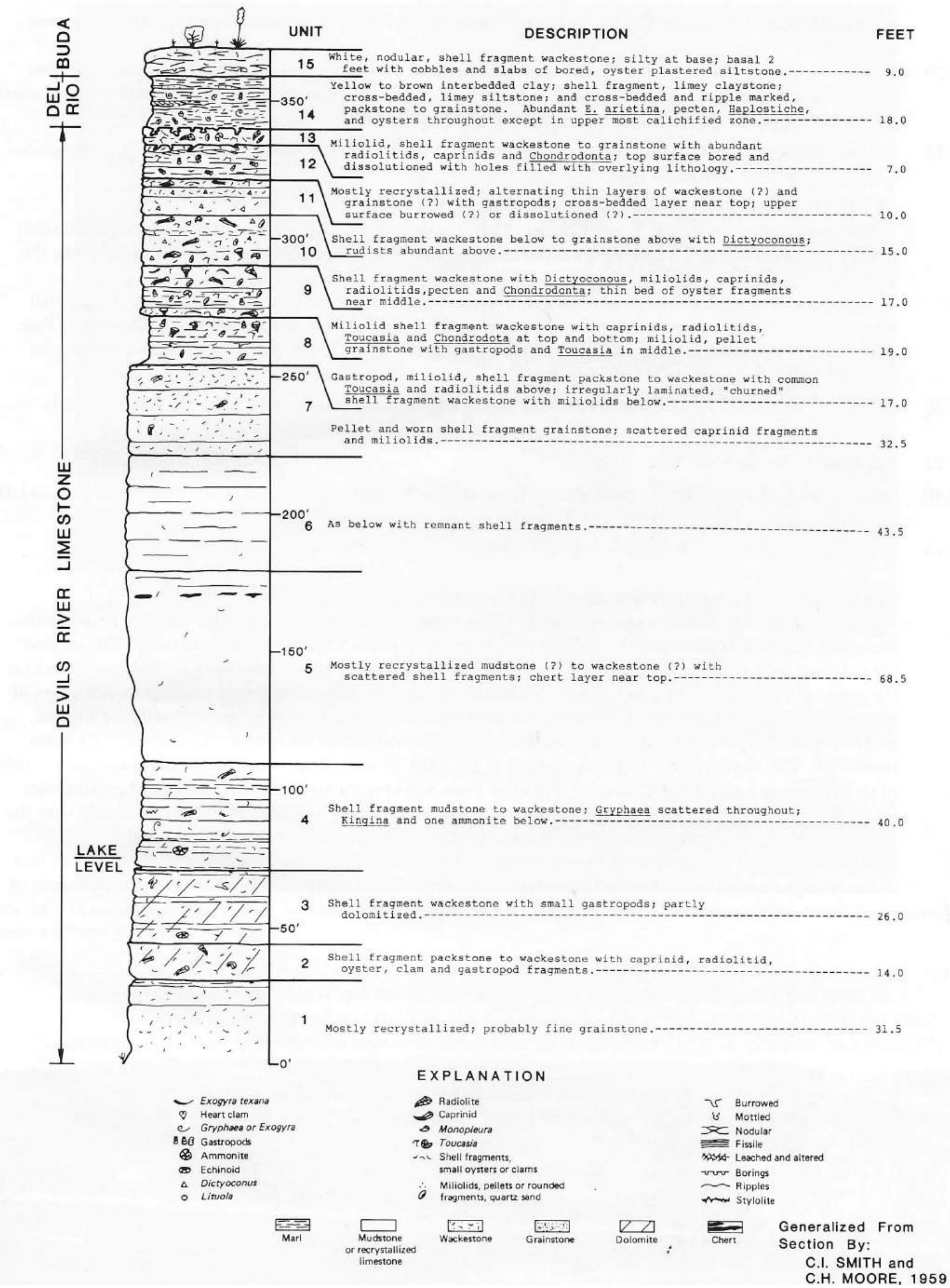
Sources; http://www.texasbeyondhistory.net/pecos/art.html; http://benedante.blogspot.com/2012/06/rock-art-of-lower-pecos.html; https://www.nps.gov/amis/learn/historyculture/images/whiteshaman1_1.jpg; Johnson, et. al.; and Interpretive Guide for Seminole Canyon State Park and Historic Site – Texas Parks and Wildlife.

38.1 US-90 road cuts; Buda, Del Rio, & Devils River.

38.3 Photo Stop.
East end of Pecos River bridge.

The stratigraphic section exposed here lies just north of the arbitrary cut-off boundary between the Maverick Basin facies and the Devils River Formation. The section was measured in 1959 prior to the filling of the Amistad Reservoir. Present average lake level is about the 75'foot level of the section. From about 30-feet below to about 20-feet above the present lake level the section exhibits aspects of the Salmon Peak Formation – lime mudstone and wackestone with ammonites, echinoids, *Kingena* sp., and scattered *Gryphaea*. Both above and below this interval the facies is more typically Devils River limestone. The massive cliff-forming section of the canyon wall below the overlook is a coarsening upward sequence from wackestone to worn shell fragment grainstone. The uppermost 85-feet of the formation, which can be examined in the road cut east of the bridge is well bedded rudist limestone. The sequence is interpreted to represent progradation of high-energy grainstone shoals and banks into deeper water of the Maverick basin, followed by development of a rudist populated shallow shelf. The abundance of rudists and the large bivalve *Chondrodonta*

Measured section at Pecos River Bridge (Kettenbrink, 1983)

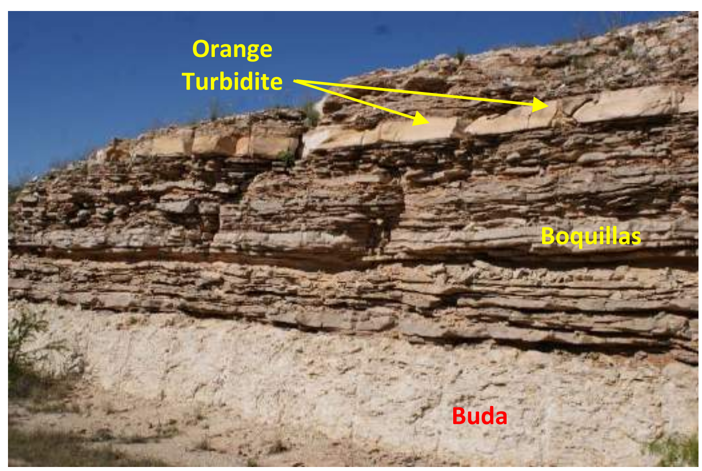


Chondrodonta in the beds over the grainstone probably reflects deposition in a relatively higher energy environment near the shelf margin. The Del Rio Formation is particularly well exposed in the road cuts. The top of the Devil's River was subaerially exposed and dissolution cavities developed to a depth of about two feet. The total amount of erosion is not determinable but regional relationships suggest not more than a few feet. As submergence began the area was initially swept clean by wave action and boring clams riddled the bare rock surface. Subsequently as deeper, quieter water environment developed the lower Del Rio filled in the cavities and covered the area. The Del Rio-Buda contact is also disconformable as indicated by a conglomerate of bored clasts and boulders derived from the silty flagstones of the Del Rio within the basal foot of the Buda. Between this locality and a point 3.5 miles west of Shumla Station (a distance of about 8-miles northwest) the Del Rio thins to zero and the Buda directly overlies the Devils River. Former presence of the Del Rio is indicated by small pieces of bored Del Rio flagstone within dissolution cavities at the top of the Devils River which are now filled by Buda Limestone. (Kettenbrink, 1983)

Mouth of Pecos River at confluence with Rio Grande River

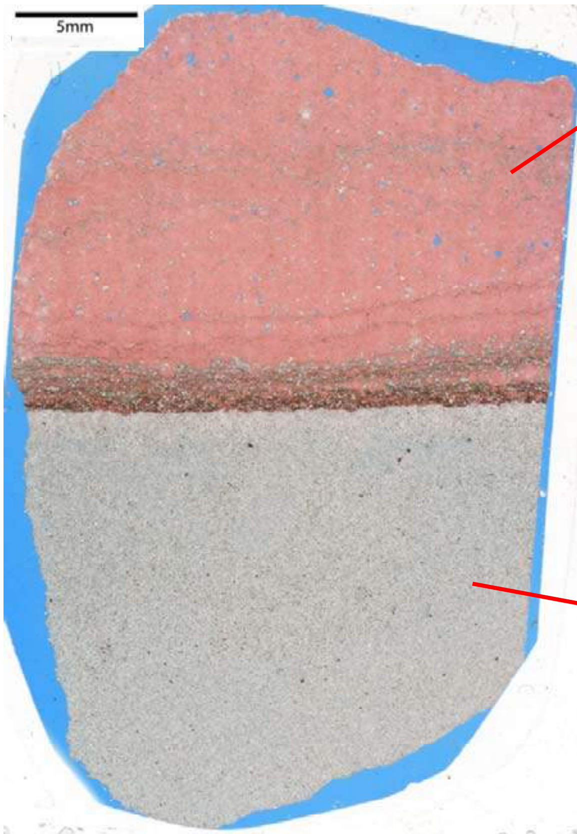
38.6 West end of Pecos River bridge.

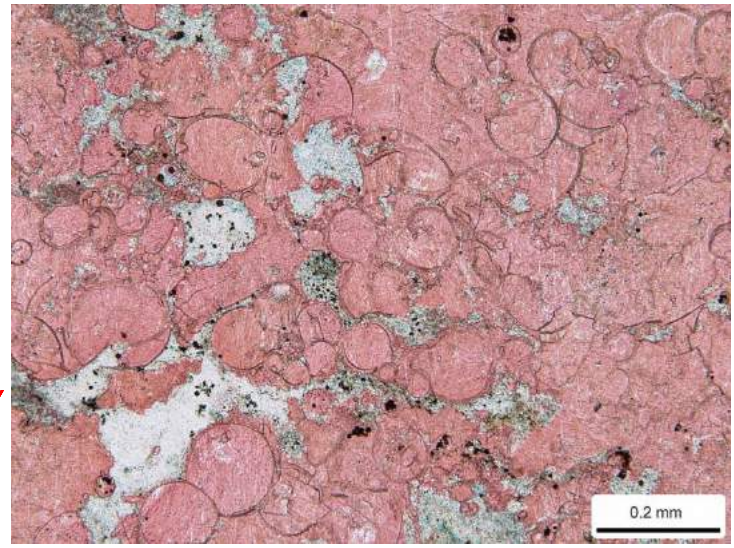
43.1 Alternate Stop _ Gazebo Section.
Lower Boquillas overlying Buda Formation.

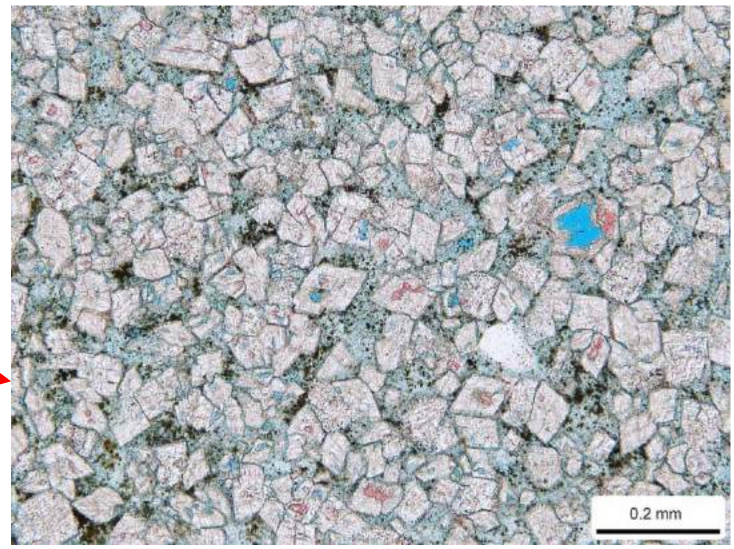


This is a good alternative road cut to Stop 2 where we can see similar features of the distinctive basal member of the Boquillas Formation that are seen at Stop 2. The basal contact between the Boquillas Formation and the underlying Buda Formation is unconformable and the surface is marked by irregular dissolution hollows in the white Buda limestone. Individual beds include sedimentary breccias (with varying clast sizes), grainstones (sand-size particles of crinoids), and a prominent, continuous bed that is orange in color. The combination of features suggests an unstable slope, potentially in deep water with slumps, grain flows, and debris flows. The pinch-and -swell features are interpreted to be contourites, cross-bedded units deposited by contour-parallel submarine currents and are common in deep-water environments, with the lenticular ripple shapes exaggerated by diagenetic differentiation. Limestone nodules are common and indicate that diagenetic differentiation is a significant process in this strata. The orange limestone bed can be seen at this stratigraphic level in all the outcrops with this package of strata throughout Val Verde County (24-miles). The lateral extent, poorly defined gradational bedding, and possible dish structures suggest this is a turbidite. (Lock and Wawak, 2010)

Thin Section scan (below) showing upper contact between turbidite bed and overlying limestone. Thin Section photomicrographs (right) indicate the limestone bed is predominantly calcite cemented foraminifera tests (the presence of silica cement (gray) indicates the rock has been at least partially silicified) and the turbidite bed is predominantly dolomite that exhibits partial de-dolomitization (calcite cores). The interparticle area between the dolomite rhombs is mostly filled with silica cement.

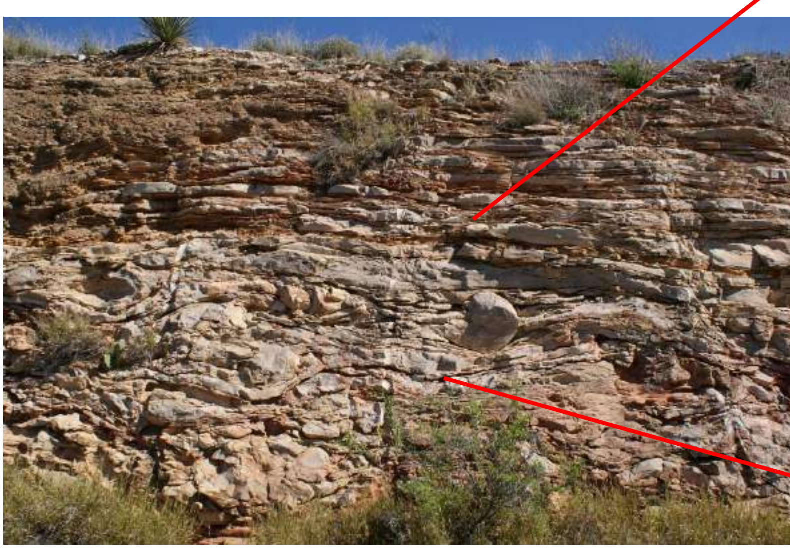


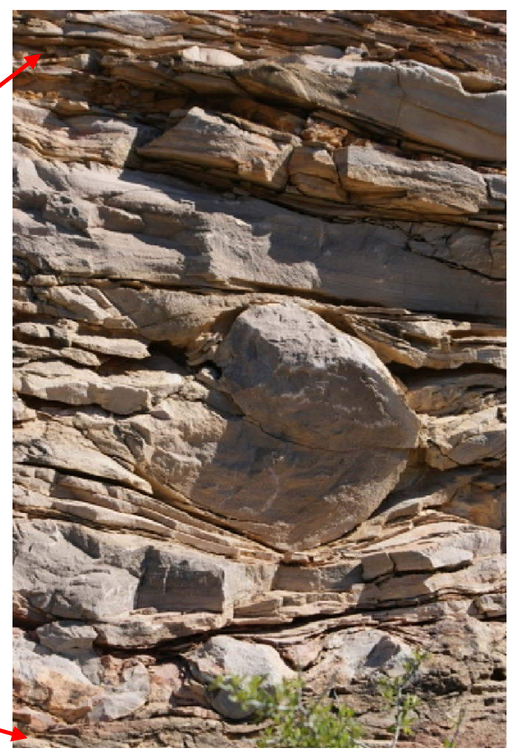




47.6 Boquillas/Buda contact about 20-feet above road level.

50.3 Contorted / deformed beds in Lower Boquillas.



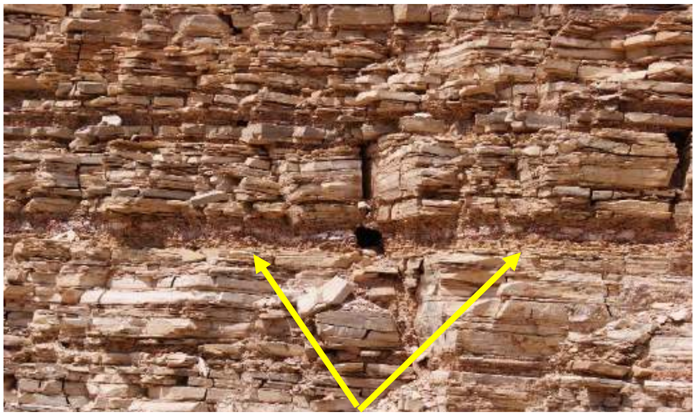


52.2 Upper Member Boquillas Formation.

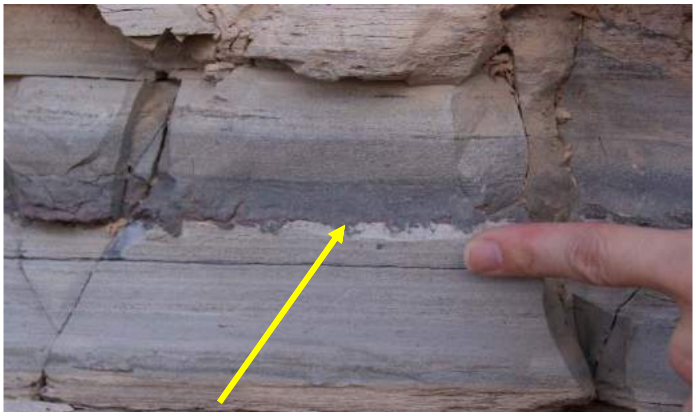
52.4 Middle and upper beds, Middle Member, Boquillas Formation.

Stop 3 – Middle to Upper Members, Boquillas Formation. Discussion of the upper part of the Boquillas.

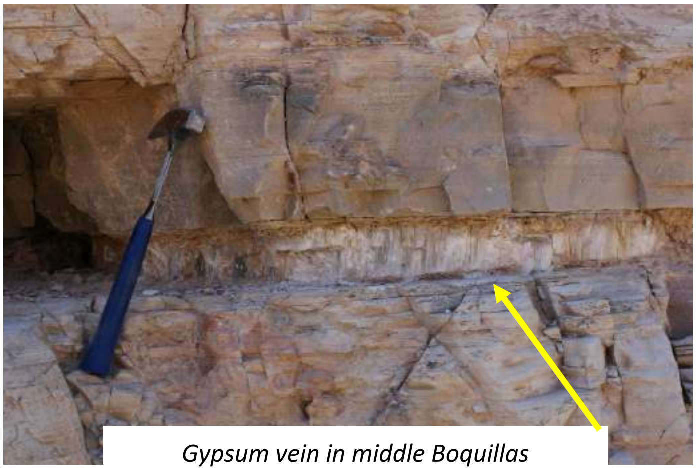
This stop at consists of several road cuts – on both sides of road, over a distance of less than 0.5 mile that exhibit the characteristics of the middle and upper Boquillas Formation. We will stop at the last large double road cut at the west end of the series of road cuts. At the easternmost road cut (mileage 52.2) is an outcrop of the upper Boquillas that contains abundant irregular (infaunal) and regular (epifaunal) echinoids and occasional ammonoids casts. The most common irregular echinoid is *Hemiaster jacksoni*. The fossil fauna suggests a return to well oxygenated conditions. As we head west along the road cuts, note the increase in proportion of limestone, thicker light-colored limestone beds with *Chondrites* (indicators of the base of the upper member) and common ash beds. In thin section these light colored limestones are chalk-like lime mudstone to wackestone, quite different from the neomorphosed limestones of the middle member. The lower outcrop exposes relatively fresh-neomorphosed limestone (often called 'shale) that is characteristic of the middle member of the Boquillas. This lithology typically has very low matrix permeability, fair porosity, and favorable TOC. Crossplots of Hydrogen Index vs. Oxygen Index indicated a lacustrine or marine algal source with is oil prone. The pattern of parasequences can be easily seen in this outcrop. Each parasequence starts with a resistant limestone bed, a few inches in thickness followed by several feet of 'shale' with well-defined cycles of more/less carbonate rich beds. A singular marine flooding surface with burrows and localized oxidation (Fe, Mn) is seen near the base of limestone 3B and also occurs at a similar stratigraphic level at Stop 4. Gypsum also is relatively common in the middle Boquillas beds. The gypsum is interpreted as a later diagenetic product. (Lock and Wawak, 2010)



Volcanic ash bed.

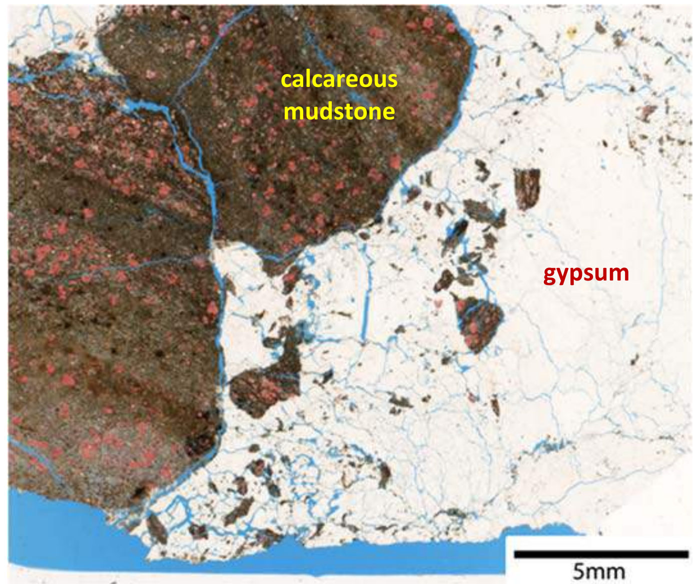


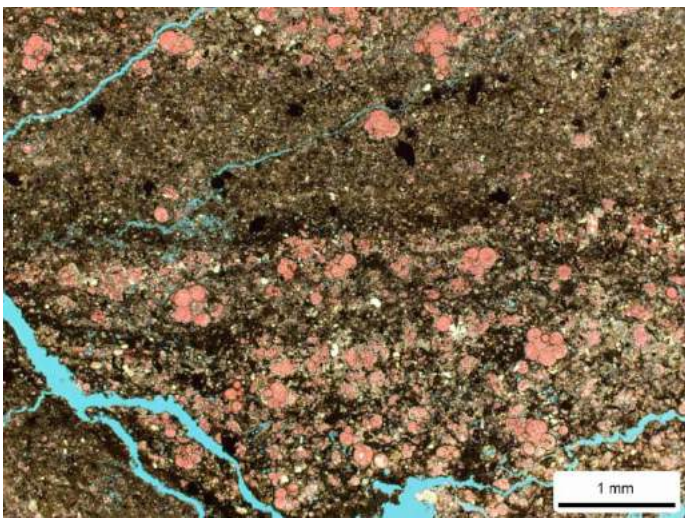
Marine flooding surface

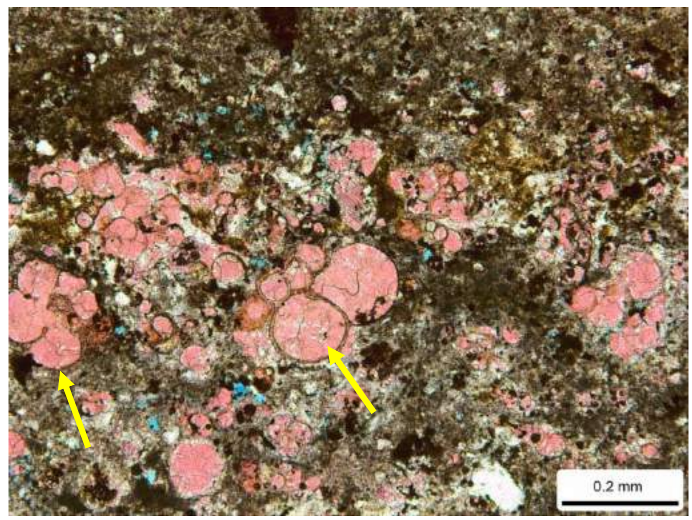


Gypsum vein in middle Boquillas

Thin Section scan (right) showing gypsum and calcareous mudstone from road cut at Stop 3. The gypsum is interpreted as being displacive cement associated with late-stage diagenesis. Thin section photomicrographs (below) are enlargements of the calcareous mudstone showing the laminated fabric (left) and abundance of foraminifera tests with calcite cemented test chambers (right, arrows).







53.1 Steeply tilted strata in Boquillas - a result of a series of caves that has collapsed in the underlying Buda.

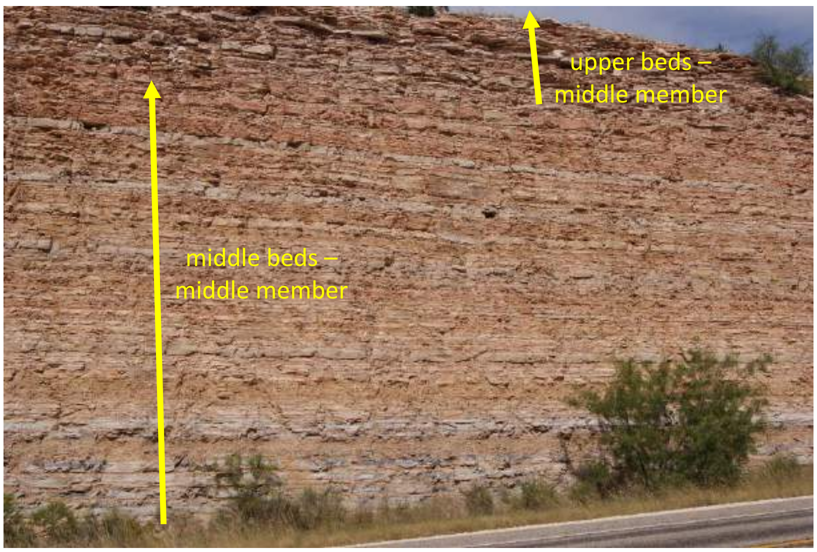
54.7 East end of Langtry Loop (Loop 25 – to Langtry, Judge Roy Bean Visitor Center).

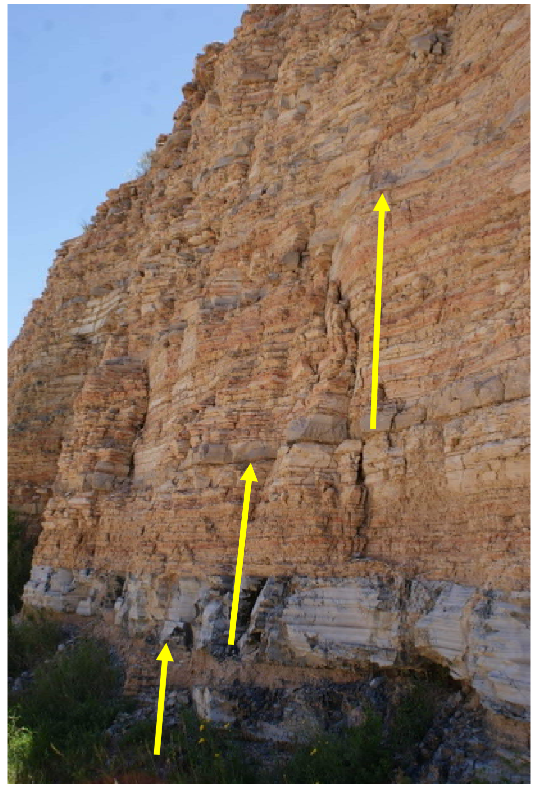
55.4 West end of Langtry Loop.

57.1 Stop 4.
Middle and upper beds, middle member, Boquillas Formation

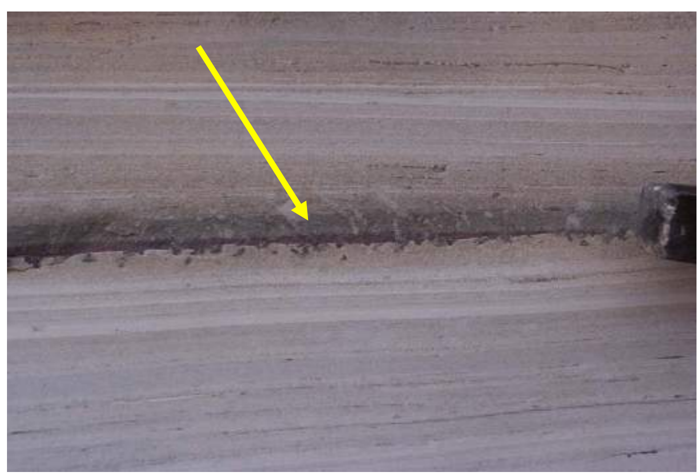
Deep road cut exposing thick section of the Boquillas Formation with another good exposure of the fresh rock (gray colored, black on broken surface). This provides another opportunity to examine both the lower member and parasequences in the lower beds of the middle member. The pattern of parasequences can be easily seen in this outcrop. Each parasequence starts with a resistant limestone bed, a few inches in thickness, followed by several feet of 'shale' with well-defined cycles of more/less carbonate rich beds. The marine flooding surface seen at Stop 3 can also be identified at this road cut at the same stratigraphic level. (Lock and Wawak, 2010)

Parasequences (yellow arrows, photo at right). Lithostratigraphy (yellow arrows, photo below).





Marine flooding surface – same stratigraphic level as seen at Stop 3.



59.2 Stop 5 – Osman Canyon
Atco Chalk.

The contact between the Boquillas Formation and the overlying Atco Chalk is not exposed here at this road cut, but can be seen along the old highway in the hills to the south (now on private land). This contact appears conformable, although an unconformity has been recognized elsewhere. The thin rust-colored beds are kaolinite/smectite-rich volcanic ash. These road cuts reveal a section throughout the basal part of the chalk, here called the Atco Chalk. Unlike most chalks, this unit is very well bedded with thin partings of dark, pyrite-bearing shale. Shallow channels are scattered throughout the outcrop at various horizons. Levees are present adjacent to some of the channels and others have pronounced thickening of the bed immediately below the axis of the channel. At least one coral fragment has been identified in the middle of a chalk bed near the top of the hill. Otherwise the chalks are very fine-grained, except for sand-sized fossil fragments filling burrows restricted to the bottoms of the channels. These fossils include calcispheres, planktonic foraminifera, *Inoceramid* shell fragments and echinoderm ossicles similar to those seen in the Boquillas Formation. The thickening of underlying beds that seems to anticipate subsequent channel formation is best explained by comparison with a delta mouth bar. Sea floor leveed channels slowly prograded with deposition of a large part of the transported load in front of the 'mouth' (i.e. levee termination) as a 'mouth bar', which subsequently became dissected by channel erosion. A depositional scenario that is consistent with the bedding geometry would include a slow, but continuous flow of fine-grained material into somewhat deeper water around the margins of the shelf platform, as a low-density gravity flow. The shale partings represent the low-stand portion of high-frequency cycles and therefore the history of progradation of each channel most likely lasted for ~hundreds of years. (Lock and Wawak, 2010)

59.2 – turnaround at end of road cut;

Return to Langtry Visitor's Center for lunch & rest stop

Road Log (3): U.S. Highway 90 - Langtry to Del Rio

Langtry Visitors Center (Lunch Stop)

State Historical Marker – Law West of the Pecos (1963)

"Judge Roy Bean lived a life in which fiction became so intermingled with fact that he became a legend within his lifetime. Basis for his renown were the decisions which he reached in this building (Jersey Lily Saloon) as the law west of the Pecos. Court was held as frequently on the porch, spectators grouped about on horseback, as within the building. Nor was Bean above breaking off proceedings long enough to serve customers seeking services dispensed by the other businesses carried on in his courtroom-home.

The judge's 'law library' consisted of a single volume. An 1879 copy of the revised statutes of Texas. He seldom consulted it. However, calling instead on his own ideas about the brand of justice which should apply. This he effectively dispensed together with liberal quantities of bluff and bluster. Since Langtry had no jail, all offenses were deemed finable with Bean pocketing the fines. Drunken prisoners often were chained to mesquite trees in front of the building until they sobered up enough to stand trial.

Bean reached a peak of notoriety when, on February 21, 1896. He staged the banned Fitzsimmons-Maher heavyweight title fight on a sand bar in the Rio Grande River, a stone's throw from his front porch. By holding it on Mexican territory he outwitted Texas Rangers sent to stop the match --- and turned a handsome profit for his shrewdness.

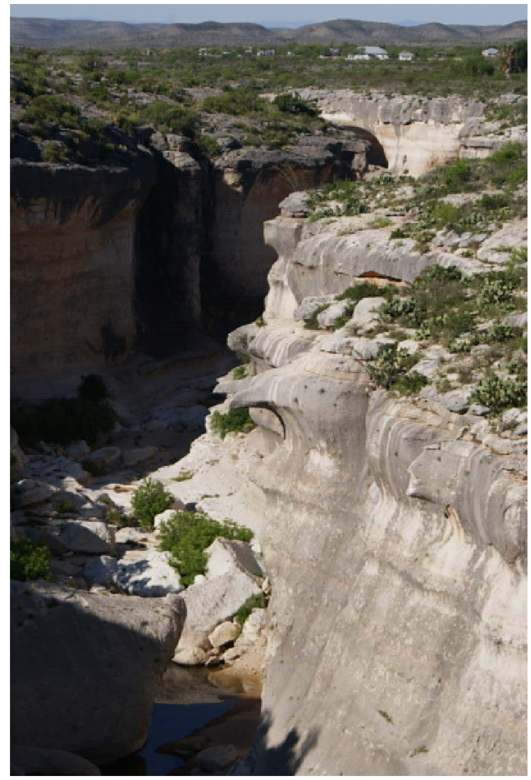
The building was named the "Jersey Lilly" for the famous English Actress Lillie Langtry whom Bean admired and form he claimed to have named the town. His lamp frequently burned into the night as he composed letters to her. But he never saw here since her only visit to Langtry occurred in 1904, less than a year after Bean died."

The visitor's center is a pleasant rest stop in the desert with clean rest rooms, air-conditioned museum exhibits, information on things to see and do in west Texas, and outdoors various building associated with Judge Roy Bean and a desert arboretum.

Inbound Mileage Log - Langtry to Del Rio

0.0 Loop 25 (east) – Langtry Loop intersection with U.S. Highway 90.

0.6 Eagle Nest Creek – exposures of lower Cretaceous massive limestones (photo - right).



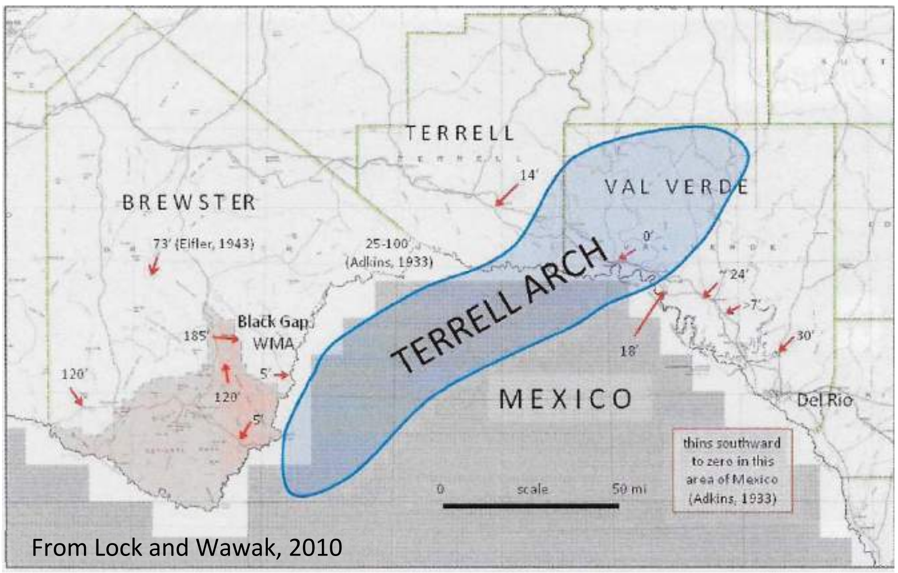
1.1 View to northwest toward Rio Grande canyons and Langtry.

1.9 Middle Boquillas with gypsum veins.

2.8 Middle Boquillas.

3.1 Middle to Upper Boquillas.

6.2 Stop 6 – Terrell Arch.



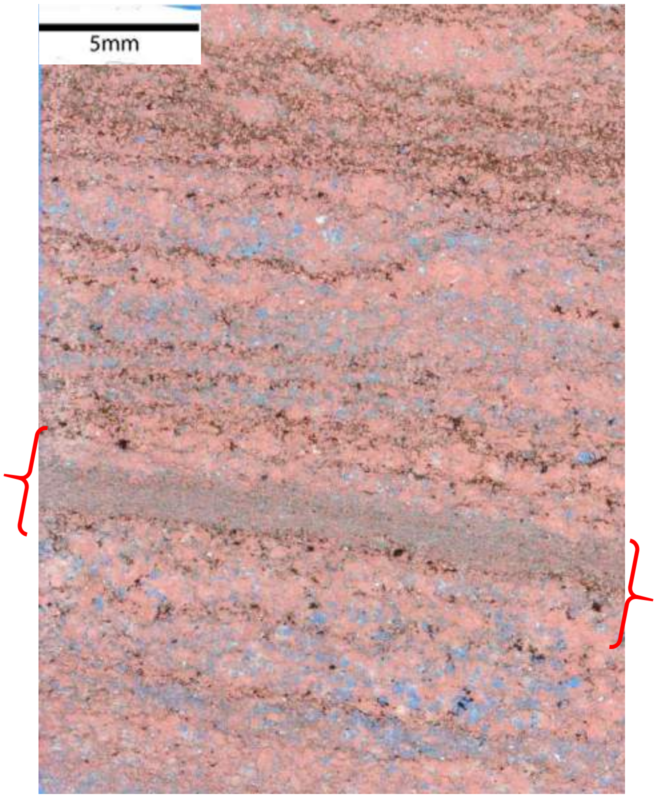
From Lock and Wawak, 2010

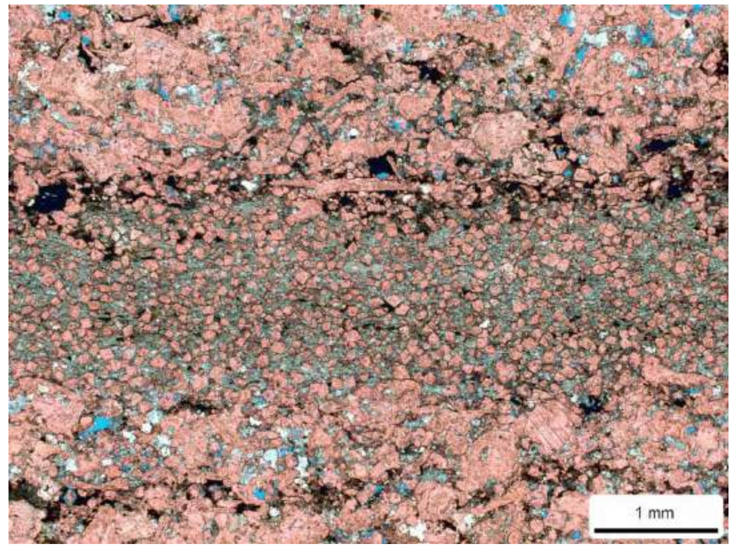
Abundant toucasiad (above) and other rudists (cross sections, photo at left). Lower Cretaceous 'Devils River' rudist buildup. Main part of outcrop seen at Stop 6.

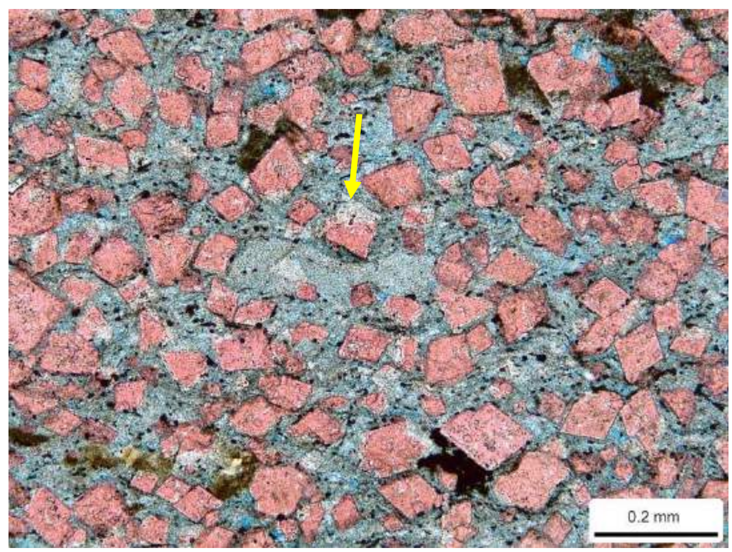
Several road side outcrops in this area expose Buda lying unconformably on the Lower Cretaceous, with the Del Rio Formation entirely missing. This is expression of the crest of the Terrell Arch. Both formations are two white limestones, but the Lower Cretaceous is relatively coarsely crystalline, slightly darker and contains abundant rudist fossils. The Buda is more clearly stratified and is very fine grained. The extent of the Terrell Arch is shown on the diagram seen above. The Del Rio Formation is seen again at Prairie Creek, in Terrell County (14-foot thickness) and throughout Brewster County and beyond. Outcrops at the southern end of the Black Gap Wildlife Management Area are thin and poorly exposed, but include superb examples of proximal tempestites, while at Terlingua, west of Big Bend

National Park the Del Rio is comprised of thin discontinuous sandstones that have gutter casts at their base and *Kinneyia* on the top surfaces. This particular set of road cuts are in a rudist buildup in the upper part of the Lower Cretaceous Devil's River Formation. Note heterogeneous texture and abundance of fossils (predominantly rudist bivalves) in this limestone. (Lock and Wawak, 2010)

7.1 Deep road cut – Boquillas/Buda contact ~20' above road level.







Thin Section scan (above) showing laminated fabric of the basal limestone bed in Boquillas Formation at the Gazebo road cut. Thin Section photomicrographs (right) indicate the lamination indicated by the red brackets is predominantly de-dolomite (dolomite replaced by calcite) cemented with silica. Some of the de-dolomite rhombs are also partially silicified (lower photo, arrow).

11.6 Gazebo rest area on west side of highway.

State Historical Marker – Railroad Bridges over the Pecos (2002)

A major tributary of the Rio Grande, the Pecos River was long a barrier to transportation, particularly across the deep gorge that once marked its joining with the Rio Grande. Construction of the first railroad bridge over the Pecos took place in 1882 as part of the transcontinental route of the Southern Pacific railroad across the lower portion of the United States. Access to the bridge, which was then deep in the canyon, was by means of a circuitous route and two tunnels.

In 1890, Southern Pacific officials began planning for a new bridge, one that would directly across the ravine by means of a high-line viaduct that would save miles and straighten the route. Work began in late 1871 and was completed within three months at a cost of more than $250,000. Supported by 24 towers, the bridge was the highest in North America and the third highest in the world at the time of its completion. Passenger trains slowed to six miles per hour before crossing it and stopped while on the bridge to afford travelers a view.

During World War II, the Pecos High Bridge became essential to the transportation of war materials. In response to heavier trains and the war demand, a new bridge was built in 1944, with special permission from the war production board to use "critical materials" in its constriction. The 1944 Pecos High Bridge remains in use, although the gorge is not so deep as it once was, due to the rising of the river with the construction of Amistad Reservoir.

State Historical Marker – Silver Spike (1967)

Nearby site of Southern Pacific ceremony of Silver Spike marked completion of Southern Pacific railway. Eastern part originated in Texas in 1850's, then was re-chartered 1870 by Texas legislature as Galveston, Harrisburg and San Antonio Railway. Designed to join Houston and San Antonio to the Rio Grande.

T.W. Pierce of Boston gained control in 1874, meantime, C.P. Huntington of California was building the Southern Pacific eastward. He wanted a Texas line to join his tracks, and reach agreement with Pierce on Jan 12, 1883. The two railroads met near the Pecos High Bridge and were joined by a silver spike.

State Historical Marker – Site of Vinegarroon (2001)

Crossing the Pecos River Canyon was the last major obstacle the Southern Pacific Railroad faced in completing its southern transcontinental route linking New Orleans and San Francisco. As "Tunnel No. 2" was excavated on the west side of the canyon in 1882, a camp for the railroad workers was established near the site. Named Vinegarroon for a type of scorpion found in the area, the camp served as a temporary home for thousands of primarily Chinese laborers. Roy Bean had a saloon and served as justice of the peace in Vinegarroon until it was abandoned after the rail line was completed in 1883.

16.4 Pecos River Bridge – east end.

16.9 Entrance to Roadside Rest Area - Pecos River overlook.

State Historical Marker – Medal of Honor Fight, 1875

In the 1870's, the U.S. Army relied on Black Seminole (Seminole-Negro) Indian scouts in campaigns against raiding Native Americans along the Texas-Mexico Border. In April, 1875, Lt. John L. Bullis and three scouts – Sergeant John Ward, Private Pompey Factor and Trumpeter Isaac Payne – left Fort Clark to scout for raiders in this area. After four days, they found a fresh trail and on April 25, within a half-mile of this site, they engaged a party of about 30 Comanche Indians with dozens of horses. Outgunned and outnumbered, the scouts withdrew, but Bullis' horse bolted, stranding him. Factor and Payne provided cover fire, and Ward rescued his lieutenant. The Three Seminole scouts later received medals of honor for their gallantry.

State Historical Marker – Pecos River High Bridge (1995)

High canyon walls dominate the last fifty miles of the Pecos River before it enters the Rio Grande. The Southern Pacific Railroad built the first high bridge across the Pecos River in 1891. The first highway bridge to span the river was built one mile down river from here in 1923. Just 50-feet above the water, the 1923 bridge was destroyed by floodwaters in 1954. Two temporary low-water bridges built nearby in 1954 and 1955 were also destroyed by floodwaters. A new 1310-feet long bridge was completed here in 1957. At 278 feet above the river, it is the highest highway bridge in Texas.

State Historical Marker – The Pecos River in Literature and Folklore (2006)

Noted for mineral-thick waters and sudden floods, the Pecos River snakes through Texas on its way to the Rio Grande. Historian J. Evetts Haley and Folklorist J. Frank Dobie, who called it a 'a strange river,' and a 'barricade' are among many who have immortalized the Pecos in writing. Zane Grey wrote, 'rising clear and cold in the mountains of northern New Mexico, its pure waters cut through rough country that changed its flood to turbid red.' Storytellers have likened the river and the arid land along it to Hell, Death, and Violence. A natural border for several counties, the Pecos is where the mythic wild west begins, the land that produced the legendary Judge Roy Bean and fabled Pecos Bill.

18.4 Entrance to Seminole Canyon State Park.

18.7 Stop 7 – Unconformity, Seminole Canyon.
Del Rio Formation – unconformable contact with Lower Cretaceous limestones.

This road cut shows the regional unconformity at the top of the Lower Cretaceous (Salmon Peak Formation) and the overlying Del Rio and Buda Formations (out crop photo, top next page). The Lower Cretaceous limestone includes massive grainstones and packstone lithofacies with radiolitid rudists and gastropods as the primary macrofossils. The top few inches of the Lower Cretaceous limestone have a red/brown discoloration immediately below the contact. Borings and cracks in the contact surface are filled with yellow-brown Del Rio clay. Gastropods (originally aragonite) near the contact surface which have dissolved to create moldic pores filled with Del Rio clay (photo below, left). Locally the red oxidation colors affect the top few feet of the Albian limestones indicating this is a major, regional unconformity. Moldic pores associated with gastropods indicate meteoric water diagenesis. The overlying Del Rio contains thins sandstone beds (tempestites) with tool marks and various burrows, including *Thalassinoides*, on the base of the beds, and beds that are essentially *Ilymatogyra arietina* coquina. (Lock and Wawak, 2010)

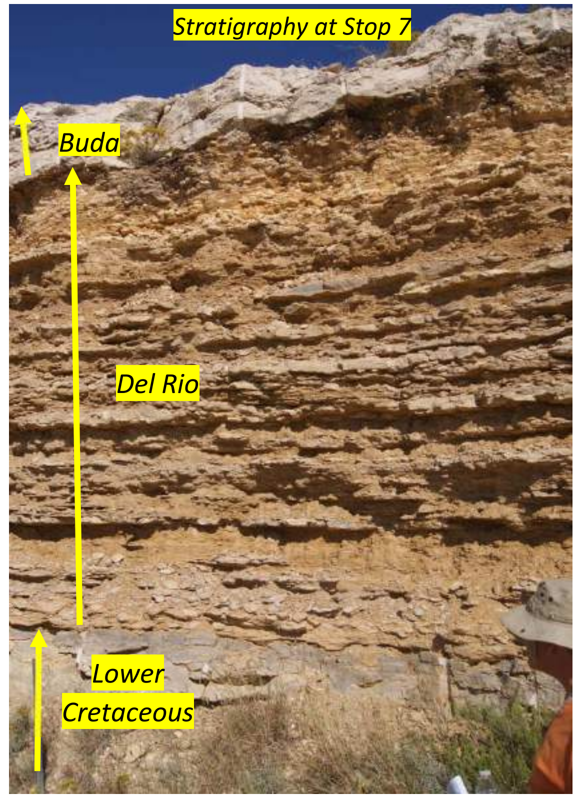
Gastropod mold filled with Del Rio sediment (Lock and Wawak, 2010)

Oxidized zone (brown layer) at top of Buda.

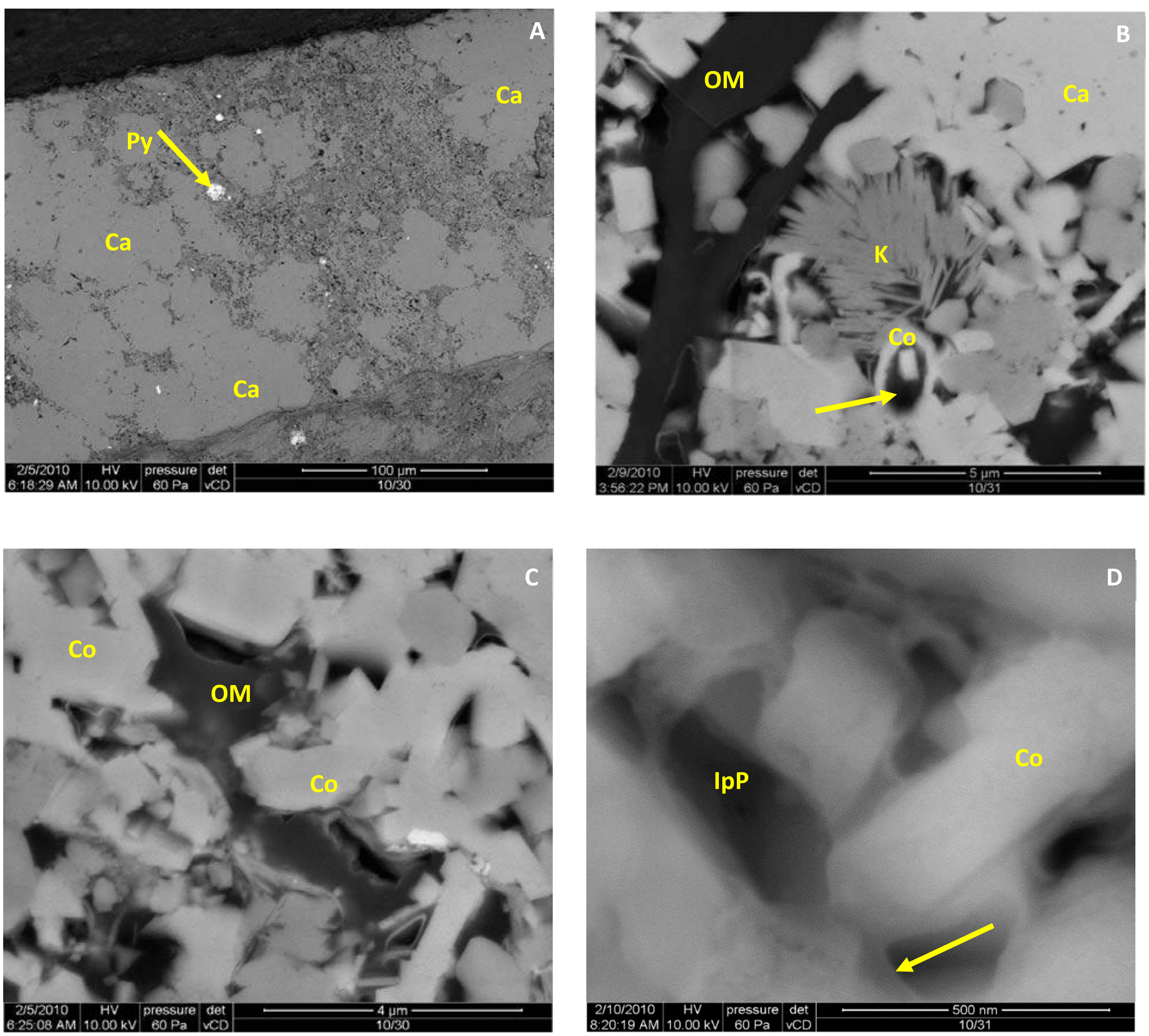
19.3 Seminole Canyon bridge.

21.8 Basal member, Boquillas Formation. Stop 2, this morning.

23.2 Middle member, Boquillas Formation. Stop 1, this morning.



SEM photomicrographs (below) of argon-ion milled (AIM) surface of laminated, neomorphosed limestone at the base of the road cut at Stop 1. Rock is gray on weathered surface and dark black on freshly broken surface. Organic matter partially fills interparticle pores (OM, Photos B and C) and coats particles (arrow, Photo D). Calcite particles include recrystallized foraminifera, disarticulated coccolith particles (Co, Photos B, C, D) and neomorphic cement (Ca, Photos A, B). Micro- and nanopores available for fluid transport include unfilled interparticle nanopores (IpP, Photo D) and some intraparticle micropores (arrow, Photo B). Small amounts of kaolinite (K, Photo B) and pyrite (Py, Photo A) are also identified.



26.3	Intersection with Farm to Market Road 1024.

**26.5	*Stop 8 – Comstock West.***
Del Rio Formation.

The Del Rio Formation is unusual in west Texas because it is calcareous shale with few limestones and sandstones, while most of the Cretaceous in west Texas is predominantly carbonates. This road cut has relatively abundant slabs of sandstone from low in the outcrop that contain burrows (*Thalassinoides*, *Spongeliomorpha*) and the bases of the beds exhibit oriented sole marks. These are common tempestite structures and in this case indicate a flow form 70^{o} or 260^{o} azimuth. Macrofossils are primarily oysters (*Ilymatogyra arietina*) and arenaceous foraminifera (*Cribitina texana*) but also include relative rare echinoids and other bivalves. This fauna suggests periodic influx of fresh/brackish water from a not-too-distant land area. (Lock and Wawak, 2010)

Burrows (Thalassinoides) and sole marks on sandstone beds.

27.5	Traffic light in Comstock, intersection with Texas Highway 163.

State Historical Marker – Comstock (2011)
In the early 1880's, Comstock developed as a station on the Galveston, Harrisburg and San Antonio railway because of the natural lake and water supply. The former townsite of Soto or Sotol City was replaced with Comstock, named after John B. Comstock, a railroad dispatcher. The Community quickly grew and boasted a variety of establishments. The town was a key element in the wool and lamb industry and served as a temporary home to several Texas Rangers. After World War II and advances in technology, the population declined. Comstock is an example of the influence of small communities that led to the development of larger commercial cities.

**28.6	Stop 9 – Comstock East.**
Buda Formation overlying Del Rio Formation.

This road cut exhibits the top few feet of the Del Rio and the basal beds of the overlying Buda Formation, both are Cenomanian age (~99 mya). Several features of interest can be seen here. In the upper Del Rio limestone beds composed of *Ilymatogyra arietina* packstone occur where the oysters were probably concentrated from shells originally scattered throughout the calcareous shale facies by storm-wave action. Two of these beds have well-develop large-scale symmetrical mega ripples (7-foot wavelength). Some of the sandstone beds have a *I. arietina* packstone lithology at the base of the bed (photo at right). Some of the sandstone beds have abundant cross stratification (Photo C, next page). Microbial mat structures, known as *Kinneyia*, have been identified on the top surfaces of some of the sandstone beds (photos below). These are common in the Proterozoic, but less so in the Paleozoic. These represent the youngest known occurrence of this fossil. The base of the Buda contains sandstone and limestone pebbles that are identified as derived from Del Rio lithofacies. These pebbles/cobbles are generally intensively bored (*Gastrochaenolites* borings, Photo A, next page). The base of the Buda forms a syncline, but this structure is a result of caliche introduced into the Del Rio shales at either end of the outcrop, and not a tectonic structure. The sandstone beds are tempestites, products of tropical storms creating storm surge and resulting in high energy seaward flow of the surge waters after the storms pass. This is different from the inferred environment of Porada and Bouougri (2007) who indicate *Kinneyia* preferentially occurs on the upper flat surfaces of fine-grained event layers deposited in intertidal or shaly subtidal environments. The amount of erosion between the Del Rio and Buda deposition may have been extensive. The thickness of the Del Rio varies greatly in this area, and the contact may be a sequence-bounding unconformity. Microbial mats on sandstones are uncommon in the Paleozoic and rare in the Mesozoic. The survival of the mats implies inhospitable environments for grazing gastropods. This preservation of these mats may be related to salinity changes resulting from large inflows of fresh water associated with storms. (Lock and Wawak, 2010).

Microbial mat (Kinneyia) on top surface of sandstone beds.

Photo A. Del Rio clast incorporated into basal Buda. Clast contains Gastrochaenolites, and possibly other borings. Del Rio clasts are common in the basal Buda throughout this area.

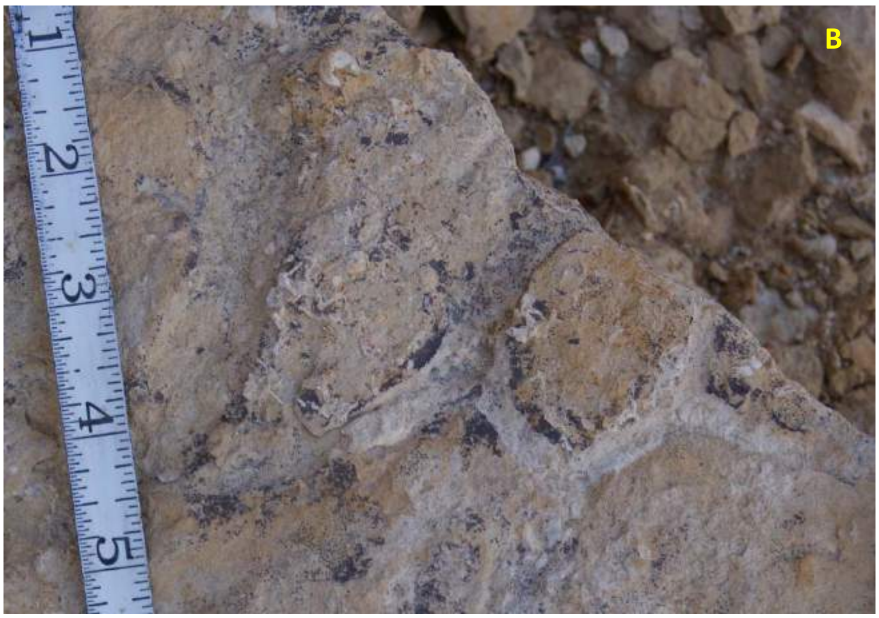


Photo B. Paleodictyon burrow on base of sandstone bed.

Photo C. Cross-stratified sandstone bed.

31.7 Comstock Border Patrol Station.

37.6 Tepees in road cuts on both sides of the road.

42.0 Box Canyon Road.

45.4 Amistad Reservoir – mid channel.

47.0 Road to Amistad Dam.

Amistad National Recreation Area

The land throughout most of southern Val Verde County is undulating to nearly level, but with steeper slopes and eroded canyon walls having ten to several hundred foot elevation differentials close to the rivers. The subsurface geology surrounding Amistad NRA is one primarily of limestone in the Edwards Plateau. Many geologic studies have been performed in the region for several reasons: easily accessible formation exposures in eroded river channels and road cuts; geotechnical studies for dam and petroleum studies; and the presence and great interest in large subsurface springs in this dry region. The long stretch of US 90 north-northeast of the reservoir lies on a thick gray lower cretaceous limestone. It is seen in numerous eroded and exposed locations in Amistad NRA including bluffs and cliffs west of the US 90 bridge over the reservoir and on the west side of the Pecos River canyon (US 90 bridge). The lower cretaceous limestones are overlain by upper cretaceous limestones of the Austin chalk, Boquillas formation, the Buda limestone, and the Del Rio Clay in descending order. Excavations for the Amistad Dam construction and nearby drill cores gathered by the IBWC yielded detailed limestone bedrock definition. Nearly 450 feet (137 m) of the Salmon Peak Formation, consisting of lime mudstone overlays about 300 feet (91 meter) of limestone shales, anhydrite grainstones, and lime mudstones of the McKnight Formation. The geologic history and hydrogeologic setting of the more than 42,000 square mile Edwards-Trinity aquifer system is described in a 1994 publication by the U.S. Geological Survey (USGS). Amistad NRA receives major groundwater flow through springs and partially spring-fed rivers that tap the Edwards-Trinity aquifer. Extensive fractures, joint cavities, and porosity caused by the dissolution of unstable carbonates and evaporates provide the conduit for the aquifer to Amistad Reservoir.

Soils along the United States side of Amistad Reservoir were derived from the parent limestone rock and formed through weathering and biological processes over thousands of years. The soils are almost entirely classified as Langtry-Rock outcrop Zorra. Most of these shallow, loamy soils are moderately alkaline, cobbly or stoney, about 8 inches deep, and usually found over fractured limestone bedrock or strongly cemented caliche; with exposed limestone outcrops commonly found on uplands. Suitability of these soils lies primarily for wildlife habitat or range, while urban and recreational uses are poor, because of depth to bedrock and slope considerations. None of the soils surrounding NRA or nearby are prime farmland soil types, but southeast of Amistad NRA and Del Rio some would be classified as such, but only if irrigation water was employed. On the United States side of the Rio Grande, Amistad NRA lies within Val Verde County, Texas. On the Mexico side, the reservoir is located entirely within the state of Coahuila. The entire Val Verde county and State of Coahuila, in proximity to Amistad NRA, is rangeland for sheep, goats, and cattle (even with the increasing development of United States lands surrounding the reservoir for residential use). Rangeland use, while a suitable use of the soils types and vegetation surrounding Amistad Reservoir, can also be a cause of erosion, non-native plant/animal influx, and potential water quality impacts.

Springs, the discharge of groundwater at the surface, have been very important to inhabitants of the border area between Texas and Mexico. The springs' significance precedes even the arrival of the first humans in the area, as formative agents of hydrogeological processes and important factors for vegetative and wildlife habitat developments. Early human discoveries of springs in more arid regions or dry seasons would have established potable water sources. They also would have laid the patterns for early hunting sites, trails for communication and commerce, settlements, and some agriculture by irrigation. In a study published in 1975, Texas was found to originally have had more than 280 major and historically significant springs, with more than half of those significantly decreased in flow or having ceased to flow entirely. More than half of the significant springs were found to emanate from the Edwards and the Edwards-Trinity Aquifers, with the larger springs in the Amistad NRA originating from the latter. Known springs at the Amistad NRA and the large San Felipe spring in Del Rio flow from the Georgetown Formation Limestones of the Edwards-Trinity Aquifer. The Georgetown Formation Limestones, known locally as the McKnight and associated limestones, actively transmit much of the ground water and spring water to the south-southwest in Val Verde County.

Historically, springs such as San Felipe Spring, Goodenough Spring, and many others throughout the state, flowed under large amounts of pressure and produced fountains at the surface. Pressure release due to well drilling, and head decrease due to long years of pumping for drinking supply and agricultural use have reduced the flows significantly at these and many other springs. Some spring flow may also have decreased due to reduced recharge over the watershed due to a shift from grass to shrub cover, and the resulting loss of infiltration capacity, resulting from grazing over the past 100 years. The completion of the Amistad Reservoir in 1969 covered many springs in the area and increased the flow of others downstream. The Cantu or Cienaga Spring, located just downstream of the Amistad Reservoir dam on the Rio Grande also has had an increased flow since the reservoir construction.

It is estimated that there are more than 1,500 cultural resource sites adjacent to the more than 540 mile (870 kilometer) shoreline on the United States side of Amistad Reservoir. These resources span more than 10,000 years of Native American prehistory and include historic remains associated with the 19th century Southern Transcontinental Railroad and early 20th century ranching. Prehistoric archeological sites are the most common, with an estimated 900 sites within the immediate flood pool of the reservoir (Labadie, 1994). Prior to the impoundment of waters behind Amistad Reservoir in 1969, there had been over 10 years of archeological fieldwork, which inventoried and documented sites that would be inundated by the future reservoir. Over 300 major prehistoric sites were documented. Twenty-two sites, mostly caves and dry rock shelters were excavated; several sites had more than 20 feet (6 m) of cultural deposits (Anderson, 1974). The preinundation research generated more than 4,000 photographs, 65 linear feet (20 m) of documents, and produced a museum collection estimated to contain more than 1,000,000 artifacts, all of which are now managed by the park.

In the Spring of 1994, lake levels began dropping in response to what would become a multi-year, regional drought affecting most of southwest Texas and northeastern Mexico. By the Summer of 1998, Amistad Reservoir had dropped 56 vertical feet (17 m) and covered less than 20% of the area it did at normal operating levels. Since 1994, Archeological surveys in drawdown zones have documented over 150 new archeological sites and re-documented nearly 50 sites identified by the pre-inundation research. Many of the recently discovered sites initially appeared as silt-covered mounds of fist sized rocks rising above the unvegetated mud flats; some were unapproachable because of the quicksand-like nature of the mud. These new sites range from the isolated remains of a single prehistoric campfire pit to sites covering over 5 acres (2 hectares) that have several hundred campfire pits, tipi rings, and grinding holes (Labadie, 1999). The overall shape of these features, circular concentrations of tightly packed fire-cracked rock, are intermixed with darker soils, suggesting that many may still have intact archeological deposits despite nearly 30 years of inundation. Intermixed within these soils are small, modern Asiatic clam shells (Corbicula fluminea). Because of its widespread distribution throughout the reservoir, continuous burrowing behavior, and high population densities, the Asiatic clam is adversely affecting most submerged archeological sites throughout the entire reservoir basin (Shafer et al, 1997) More than 1500 individual fire-cracked rock features have been documented since 1994, nearly all of which have been significantly affected by wave-action from high winds, passing boats, and fluctuations in reservoir levels. It is now believed that the modern ground slope of exposed terraces is a basic determinant of the severity of wave-action damage to all archeological sites or individual features. An optimum ground slope angle appears to exist where wave action effects are negligible; above or below this angle, wave action is intensified resulting in somewhat predictable dispersal patterns across recently exposed ground surfaces (Collins and Labadie, 1999). Typically, sites with ground slopes above eight degrees will have a series of individual cutbanks often resembling stair-steps with each step representing a different lake elevation. Sites with low ground slope angles usually have a parallel series of drift lines or windrows (similar to high-tide lines at the beach) composed of corbicula shells, chert flakes, and small fraction fire-cracked rocks (Labadie, 1999). In either setting, horizontal relationships among artifacts or feature specific lithic associations are highly suspect given the number of times most sites have been subjected to the cycle of inundation, exposure, and reinundation. It is also becoming clear that wave-action differentially affects the various classes of archeological materials at recently exposed archeological sites (Gustavson and Collins, 2000). Small items, such as flint flakes and arrowheads, bone or shell fragments and organic materials are the first to be relocated as wave passes across the site. Larger items, such as metates or rock-lined cooking pits, require greater amounts of wave-energy to move individual items or before the waves systematically dissemble a fire-cracked rock feature. It has also been demonstrated that as a wave sweeps across an ancient campfire or cooking pit, it is capable of dislodging the associated soil matrix and, over time, can fill these voids between the rocks entirely with modern lacustrine deposits. The result of this process is that although a fire-cracked rock feature may look intact, the interior deposits can be entirely modern (Collins et al, 2000). The regional drought that has gripped the Amistad NRA has been making national headlines for several years now. Visitation has dropped substantially and the reservoir has receded to its lowest levels since it began filing in the late 1960s. On the brighter side of things, the drought has provided archeologists and other earth scientists an unprecedented opportunity to study a portion of the prehistoric landscape thought to have been long lost under the waters of Amistad Reservoir.

(excerpted from: http://www.nature.nps.gov/Geology/parks/amis/index.cfm)

49.7 Amistad National Recreation Area – Visitor's Center.

54.6 US-277 intersection – west of downtown Del Rio.

End of Inbound Road Log

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Online resources

Amistad National Recreation Area;
http://www.nature.nps.gov/geology/parks/amis/index.cfm

Archaeology;
http://www.lithicsnet.com/golondrina.htm
http://www.texasbeyondhistory.net/st-plains/prehistory/images/golondrina.html

Paleogeographic maps;
http://jan.ucc.nau.edu/~rcb7/ (Dr. Ron Blakey, No. Arizona University)

Energy Administration Agency (EIA), EIA Eagle Ford Play Map:
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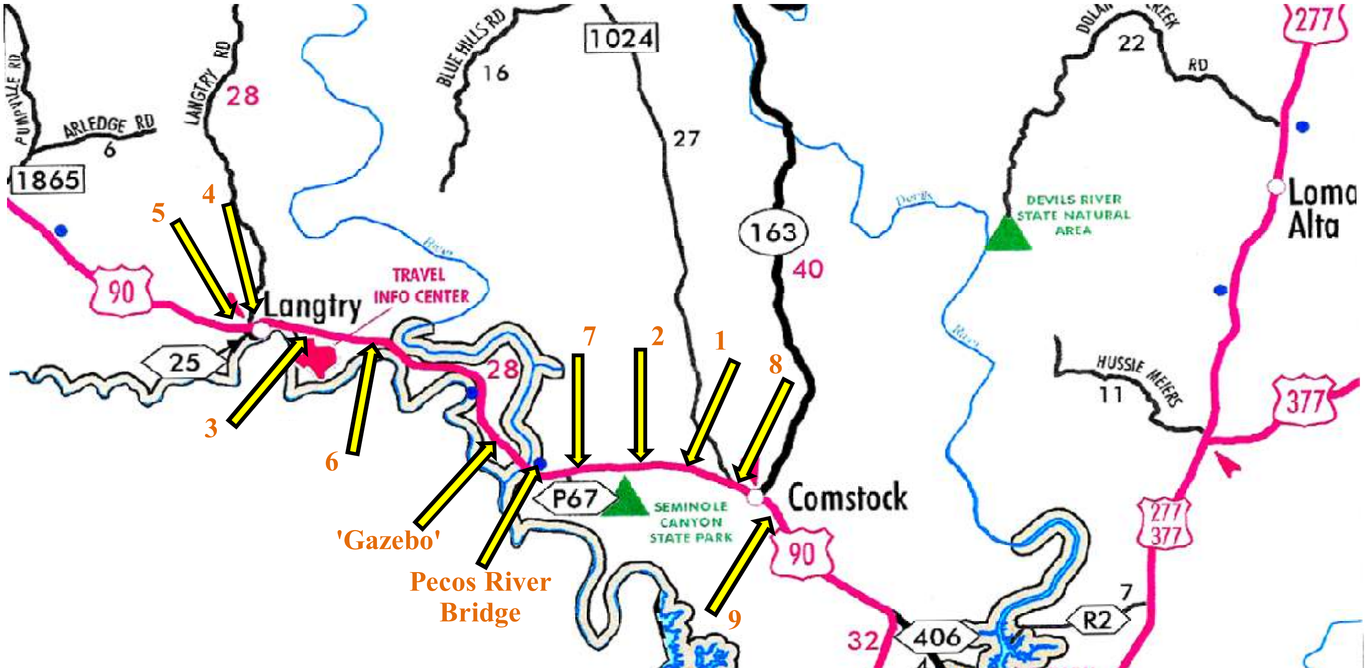

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AMISTAD NATIONAL RECREATION AREA
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LAUGHLIN AFB
'Gazebo'
Pecos River Bridge
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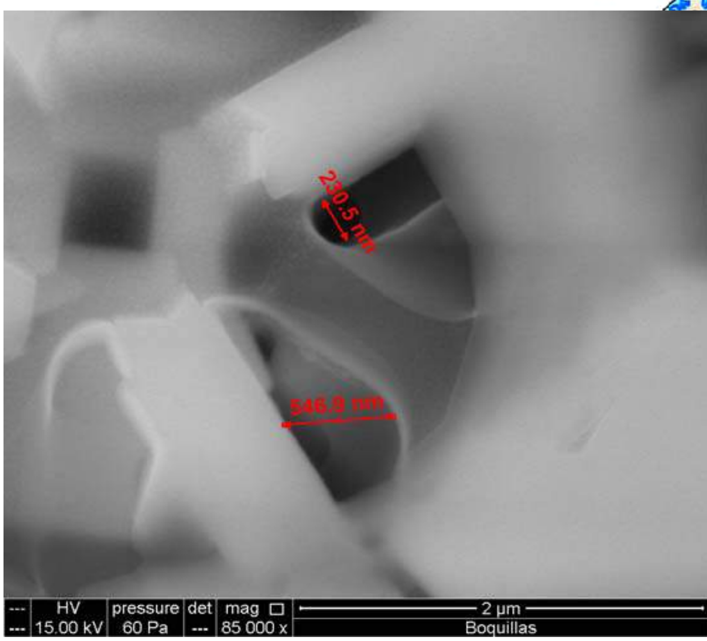

230.5 nm
546.9 nm
HV 15.00 kV
pressure 60 Pa
mag 85 000 x
2 μm
Boquillas