TRAVEL GUIDE FOR UT QUEST TRAVELERS DURING THE WEST TEXAS TRIP TO BIG BEND NATIONAL PARK AND McDONALD OBSERVATORY

PREPARED BY BOB BLUNTZER

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INTRODUCTION

This guide is intended to inform you and help prevent you from having boring bus rides while traveling several hundred miles during the UT Quest West Texas Trip to Big Bend National Park (BBNP) and McDonald Observatory (MO). The first day of travel will be from Austin along Highway 290 West to IH 10 West to Highway 385 South to BBNP (471 miles). Other routes from BBNP to MO and other destinations may vary (see Sandy's travel schedule). The information in this guide will cover the history, geology and water resources of selected towns along and near the routes through central and west Texas. Similar information will cover selected special places and things; including 19th century US Army camps and forts, the Caverns of Sonora, the Pecos River, a vineyard and winery, Comanche Springs, BBNP, MO, the springs near Balmorhea, a flower seed farm, Gillespie County peaches, special nurseries, mountain cedar, saltcedar, etc. The information given in this guide was obtained from numerous internet web sites, reports and data files of Texas' state water agencies, and other published articles and documents. The preparer apologizes for the compressed presentation of this guide, but it was done to "shorten" its length for duplication purposes, and yet is an earnest attempt to give the traveler interesting and hopefully entertaining information.

DEFINITIONS AND EXPLANATIONS

It may be necessary for you to review and become acquainted with some definitions and explanations of some of the words and phrases used in this guide. If you need further clarifications, please feel free to see Bob Bluntzer.

Groundwater or Ground Water- Underground water that can be removed from a water-bearing unit by wells, and that provides the flow of springs and baseflow seepage to streams. All other water in the ground is termed "subsurface water" and cannot be removed by wells. Ground water in Texas is owned by the property owner, but can be controlled through legal means stipulated in the Texas Water Code which provides for the creation of Underground Water or Groundwater Conservation Districts. This guide will use both spellings, but the US Geological Survey uses two words; "ground water" as a noun and "ground-water" as an adjective. The two word spelling will be used most frequently in this guide.

Surface Waters- All forms of water found on the surface of the earth; such as rainfall, snow, ice and water in streams, ponds, lakes and water supply reservoirs. What is interesting according to this definition, once ground water is discharged by wells, springs and baseflow onto the surface it becomes surface water which in Texas is owned by the State of Texas and is subject to regulation stipulated in the Texas Water Code.

Aquifer- Is one or more underground, water-bearing, geologic formations capable of yielding ground water to wells, springs and baseflow; all of which beneficially meet the water needs of municipalities, other urban and rural public water systems, industries, irrigation, households, individuals, livestock, fish, wildlife and plants. An aquifer has water inflow (recharge) and water outflows (discharges), and contains water in storage.

Aquifer Inflows- Natural Recharge is water that percolates from the land surface downward through the soil and through existing unsaturated geologic units and enters the saturated zone of an aquifer. Recharge water sources are rainfall, snow and ice melt, water from streams, lakes, ponds, ditches and canals, return flows from water uses and treatments, and inflows from other aquifers. Artificial Recharge is an aquifer inflow and is surface water purposely placed in the aquifer by wells, either by gravity flow or by injection pressure, and by gravity flow through man-made surface structures such as specially designed and constructed pits, ponds and ditches. The main problem with artificial recharge is finding a conveniently available, adequate quantity of suitable quality surface water for recharge. Another problem with artificial recharge in Texas is that ground water is a property right, and recharge water placed under one property may not necessarily benefit that property owner, and may only benefit other adjoining property owners. There are some public

water systems in Texas using artificial recharge, and it's called "Aquifer Storage and Retrieval" or ASR.

Aquifer Outflows- A Spring is a place where, without the agency of man, ground water flows (outflows) from a rock or soil upon the land surface or into a body of surface water such as a stream or lake. "Springs" is used when there is more than one outlet from the rock or soil. A spring is an easily recognized place which has a natural flow of ground-water discharge from an aquifer usually into a stream or lake. Baseflow is ground-water discharge (outflow) that enters into a reach of a stream that is hydrologically connected to the aquifer. Ground-water discharge as baseflow is unseen, but is measurable seepage from an aquifer into a reach of a stream where the water-table of the aquifer and the stream interface. Evapotranspiration causes the discharge of ground water to the atmosphere by evaporation of a shallow water table which is very near the land surface and/or by the transpiration by plants. The mountain cedar (juniper) of the Texas' Hill Country and the saltcedar of west Texas are classified as phreatophytes which are plants which intercept and transpire (discharge) unusually large amounts of potential ground-water recharge and ground-water storage to the atmosphere. Artificial discharge consists of the withdrawal (outflow) of ground water by wells.

Aquifer Storage- Is the amount of ground water in place (stored) in the pores or opening of an aquifer. Only a part of the ground water in aquifer storage can be removed by wells, and is called recoverable storage. Removal of ground water from recoverable storage by wells causes water-level declines and the reduction of the pressure of artesian aquifers.

Aquifer Classification- The Texas Water Development Board (TWDB) has assigned a major or minor aquifer status to the state's aquifers on a basis of the quantity of water supplied by each aquifer. However, the distinction of a source of ground water as a major or minor aquifer may have no bearing on the importance of ground water for a particular locality or need. Major Aquifer- is an aquifer that is capable of producing large quantities of ground water or produces ground water over a large area. Major aquifers that will we addressed along the route of the Trip from east to west are the Edwards Balcones Fault Zone (BFZ), Trinity Group, and Edwards-Trinity Plateau Aquifers (please refer to the Major Aquifers of Texas map). Minor Aquifer- Is a source of ground water that produces small quantities of ground water or produces ground water in a limited area. Minor aquifers that will be addressed during the Trip from east to west include the Ellenburger-San Saba, Hickory, Marathon, Presidio Bolson and Igneous Aquifers (please refer to the Minor Aquifers of Texas map).

Desalination- Is any of several processes that remove the excess minerals (salts) from water in order to obtain fresh water suitable for drinking or irrigation. Reverse osmosis (RO) is the process most used to desalinate slightly saline ground waters in west Texas for public drinking water supplies. RO is the process of pushing saline waters through a filter that traps the mineral solute on one side and allows the fresh water to be obtained from the other side. RO produces a saline water effluent that is disposed of in properly lined evaporation ponds or by deep saline-water injection wells. During the Trip the travel guide will mention RO desalination of slightly saline ground waters for public supplies at Fort Stockton in Pecos County and for a Study Butte–Terlingua water system, Big Bend Motor Inn and Longhorn Ranch Motel in Brewster County.

GPM or gpm- Means gallons per minute which is a measure of the rate of yield of a well or spring. The capacity classification of a well or spring by yield is as follows:

Classification	Range in Yield in GPM
Very Small Capacity	5 or Less
Small Capacity	6 to 20
Moderate Capacity	21 to 100
Large Capacity	101 to 500
Very Large Capacity	More than 500

MGD or mgd- Means million gallons per day which is another expression for the rate of yield of wells or springs.

TDS or tds- Means total dissolved solids of water expressed in parts per million (PPM or ppm). TDS characterizes the amount of mineralization of waters which are classified as follows by ppm of tds.

Classification	Range in PPM of TDS
Very Fresh Water	Less than 500
Moderately Fresh Water	500 to 1,000

Slightly Saline Water	1,001 to 3,000
Moderately Saline Water	3,001 to 10,000
Very Saline Water	10,001 to 35,000
Brines	Greater than 35,000

Acre-feet- One acre-foot of water equals 325,851 gallons. Usually expressed as a rate "acre-feet per year."

Explanations of Geologic Sections of Surface and Subsurface Geologic Units and Aquifers

For this guide; System and Series are geologic age names and designations. For this guide; Group, Formation and Member are stratigraphic names and designations. A Group can have one or more Formations which if subdivided should have two or more Members. Aquifer is defined above. The geologic sections will be referred to in the discussions of the geology and water resources for each town, and along our routes of travel.

HISTORY, GEOLOGY AND WATER RESOURCES OF SELECTED TOWNS AND DISCRIPTIONS OF SELECTED PLACES AND THINGS ALONG THE ROUTES

As we travel through Austin, we will cross the famous Edwards Balcones Fault Zone (BFZ) Aquifer. We will start crossing the aquifer after we cross the Mopac Bridge over Town Lake. The aquifer is controlled by the Barton Springs Underground Water Conservation District. The aquifer supplies the flows to Barton Springs and Deep Eddy Springs which discharge ground water to Town Lake. Such spring flows are an important source of the City of Austin's public water supply. The aquifer is an important source of ground water for public and household water supplies in the Manchaca and Buda area of Travis and Hays Counties. We will continue across the aquifer's recharge zone (Edwards Limestone outcrop) until we reach Oak Hill on Highway 290 West. We will pass over the hidden main fault of the Balcones Fault Zone in Oak Hill and will see a prominent cliff of limestone, dolomite and anhydrite beds of the Glen Rose Formation on the upthrown side of the fault. These geologic conditions at Austin and Oak Hill are shown in the following Geologic Section I:

GEOLOGIC SECTION I - AT AUSTIN AND OAK HILL

System/Series	Group	Formation	Member	Aquifer
---------- Land Surface-Austin to Oak Hill ----------				
Cretaceous/ Comanchean	Fredericksburg	Edwards	Undivided	Edwards BFZ*
In Oak Hill – These Geologic Units Are Displaced by the Main Fault of the BFZ*				
----------Land Surface at Oak Hill West of Main Fault ----------				
Cretaceous/ Comanchean	Trinity	Glen Rose	Undivided	Trinity Group
Undifferentiated Older Geologic Units				

* Means Balcones Fault Zone

After leaving Oak Hill, we will travel on Highway 290 West across the outcrop of theGlen Rose Formation for about 48 miles through Dripping Springs to a point just south of Johnson City. The Glen Rose Formation outcrop is the contributing zone for the Edwards BFZ Aquifer in parts of Travis and Hays Counties, and is the recharge zone for the Trinity Group Aquifer in Travis, Hays and Blanco Counties. During our travel all the way to Fort Stockton, we will see "layer cake geology" having essentially horizontal bedding of the various geologic units at the land surface.

DRIPPING SPRINGS, HAYS COUNTY

History- Before the settlers came, the dripping springs (Dripping and Walnut Springs, and others) were convenient "watering holes" for the Tonkawa Indians, and later for wagon trains from Austin which supplied Fredericksburg and Fort Martin Scott along a difficult and primitive wagon road. The first settlers were the Fawcett family in 1849 who were followed in 1854 by the families of Dr. Joseph McKegg Pound and John L. Moss. They came from Mississippi from Austin by way of the wagon road which later became a stage coach route. Dr. Pound was Hays County's earliest doctor and became a noted area farmer. After vacated, the Pound house became a community hospital and church. John Moss became the post master in 1857, and his wife, Nannie named the town "Dripping Springs." In the early 1850s, the area was settled with numerous farming families, and the town became an important activity center before the Civil War. The settlers included Germans, English, Irish, Scotch-Irish, French and Americans. By 1884 the town had a steam driven grist mill, cotton gin and a population of 130. Later along with farming, the area became noted for ranches which raised cattle, sheep and goats. Today, some ranches using high fencing, raise whitetail deer and exotic game animals for hunting and special breeding and marketing. Dripping Springs has developed into the principal town of northern Hays County and likes to be noted as the "Gateway To The Hill Country." It has developed into a very convenient and important "bedroom community" for workers in the Austin Metropolitan Area. The 2000 population of the town was 1,548, and the town has an elevation of 1,156 feet and an average annual rainfall of about 33 inches (notice the increase in elevation and a decrease in rainfall at towns as we travel west to our destination of Big Bend National Park).

Geology- The surface and subsurface geologic units and the aquifer at Dripping Springs are shown in Geologic Section II given below. The town and surrounding area occurs on the outcrops of the limestone, dolomite and anhydrite beds of the Glen Rose Formation which is the upper ground-water-bearing unit of the Trinity Group Aquifer. The Hensell Sand, Cow Creek Limestone and the Sycamore Sand which are members of the Travis Peak Formation, are deeper water-bearing units of the Trinity Group Aquifer, and are in the subsurface beneath the Glen Rose, the town and the surrounding area.

Water Resources- Since the springs in and near the town have very small and intermittent flows from the Glen Rose of the Trinity Group Aquifer, the town and parts of the surrounding area are provided a public water supply by wells completed by the Dripping Springs Water Supply Corporation (WSC) which started in 1964. Other area households and ranches use water wells for drinking water and livestock watering. The WSC's public supply wells and the area's private water wells withdraw ground water from the various water-bearing units of the Trinity Group Aquifer. Because of the increased demand for a public water supply due to recent, large population growth in the Dripping Springs' area, the WSC purchases a supplemental surface water supply from the LCRA. The water is delivered from the Colorado River by pipeline. The WSC is very "water supply wise" by practicing the conjunctive use of ground water and surface water which will help them to meet the increasing future demands. In 1985, the WSC used only two Trinity Group Aquifer wells that supplied 0.262 mgd to its area customers. The water was fresh having tds ranging from 861 to 944 ppm. In 2003, the WSC supplied about 0.514 mgd from the aquifer and the Colorado River. About 0.226 mgd was from the aquifer and about 0.288 mgd was from the river. In August 2003 the peak water use by WSC customers was 0.821 mgd with about 54 percent from the Trinity Group Aquifer. The ground-water resources of the Trinity Group Aquifer in the Dripping Springs' area and western Hays County is monitored and protected by the Hays Trinity Groundwater Conservation District which was authorized by local voters and is supported by taxes to permit and control the spacing of wells, to promote conservation, preservation, and recharge and prevent the waste of ground water.

GEOLOGIC SECTION II – AT DRIPPING SPRINGS

System/Series	Group	Formation	Member	Aquifer
----------		Land Surface	----------	
		Glen Rose	Undivided	
		----------		All
Cretaceous/	Trinity		Hensell Sand	

Comanchean	Travis Peak	Cow Creek Limestone Sycamore Sand	Trinity Group

Undifferentiated Older Geologic Units

TRAVEL FROM DRIPPING SPRINGS TO JOHNSON CITY- After we pass through Dripping Springs we will continue traveling on Highway 290 West which continues to be located on the Glen Rose Formation. As we travel we will be able to observe 1.) the characteristic "stair step" topography of the Glen Rose on some hill sides due to differential erosion and weathering of resistive beds and non-resistive beds, and 2.) several very prominent, steep road cuts consisting of exposed Glen Rose limestone, dolomite and anhydrite beds demonstrating the "layer cake geology" previously mentioned. We will leave the outcrop of the Glen Rose Formation just before we enter Johnson City.

JOHNSON CITY, BLANCO COUNTY

History- The Johnson City area was probably first visited by the Spanish explorer, Miranda who searched for silver deposits in the Llano area to the northwest. One of the first settlers was Andrew Johnson a distant relative of LBJ, who in 1850s established a ranch having McCarty Springs and bordering the Pedernales River; both of which became important "watering holes" for the ranch, travelers and wagon trains using the wagon road from Austin to Fredericksburg. During these times through the 1870s, Comanche raids were common and terrorized the settlers. Andrew's ranch eventually passed on to Sam Johnson who sold the ranch to James Polk Johnson. A post office was establish in the area in 1878 and one year later James Polk Johnson provided 320 acres for a Johnson City (JC) townsite, and established a grist mill, a hotel, a courthouse and a jail and donated additional land for a school. Settlers in and around JC, included Germans, English, Irish, Scotch-Irish, French and Americans. In 1883 the JC newspaper, *Record Courier,* was first published, and in 1890 JC became the county seat of Blanco County defeating the rival town of Blanco in a county wide election. In the 1930s, JC was one of the first towns to receive reliable electric power furnished by the Pedernales Electric Cooperative which was established by legislation sponsored by LBJ. JC was incorporated in the mid-1950s, has a beautifully lit county courthouse at Christmas time, and has a LBJ National Historic Park Visitor's Center which shows how LBJ influenced his hometown. Another such visitor's center is located west of JC off Highway 290 West at the LBJ State Historical Park and the LBJ Ranch. Johnson City had a population of 1,191 in 2000, has an elevation of 1,193 feet and receives an average annual rainfall of about 31 inches.

Geology- The surface and subsurface geologic units and the aquifers at Johnson City are shown in Geologic Section III given below. Once we enter Johnson City we are traveling on the Hensell Sand, a member of the Travis Peak Formation. The Glen Rose Formation outcrops in the upland areas (hills) in and near Johnson City. The Hensell Sand which is the lower most water-bearing unit of the Trinity Group Aquifer at JC, is directly underlain in the subsurface by Ordovician age formations of the Ellenburger Group and the older Cambrian age Wilberns Formation and Riley Formation which includes the Hickory Sand Member. The formations of the Ellenburger Group and the underlying San Saba Limestone Member of the Wilberns Formation contain the water-bearing units of the Ellenburger-San Saba Aquifer, and the deeper Hickory Sand is the water-bearing unit of the Hickory Aquifer.

Water Resources- The Trinity Group Aquifer and the Ellenburger-San Saba Aquifer are the ground-water sources that have been developed by JC's public water supply system. The system also sometimes uses surface water under an annual permitted 200 acre-feet per year appropriation from the Pedernales River. In 1985, JC used 0.163 mgd from the aquifers and the river. About 72 percent was provided by three wells completed in the Ellenburger-San Saba and Trinity Group Aquifers. In 2003, JC used six wells that produced 0.279 mgd from the Ellenburger-San Saba Aquifer. The ground water had very fresh water with tds that ranged from 364 to 466 ppm. JC did not use surface water from the Pedernales River in 2003. Upstream of JC, the Pedernales River receives spring flows that are capable of providing a maximum flow (during "wet" conditions) of about 3.8 mgd which is mainly from springs issuing from the Ellenburger-San Saba and Hickory Aquifers. This

amount does not include the baseflow component to the river from the aquifers. It should be noted that JC can not appropriate all of this water, but if water demand increases Johnson City surely can appropriate more than the 200 acre-feet of permitted surface water it currently has. The ground-water resources of Johnson City and Blanco County are protected through well permitting and other controls imposed by the management and elected board of the Blanco-Pedernales Groundwater Conservation District funded by an ad valorem tax of $0.029 per $100 property evaluation. The District's budget was set to spend almost $200,000 in 2006 for the protection of Blanco County's ground-water resources.

GEOLOGIC SECTION III – AT JOHNSON CITY, ALONG HIGHWAY 290 AND AT AND NEAR FREDERICKSBURG

System	Group	Formation	Member	Aquifer
		Land Surface		
Cretaceous	Trinity	Glen Rose *	Undivided	Trinity Group
		Travis Peak	Hensell Sand *	
Ordovician	Ellenburger	Honeycutt	Undivided	All
		Gorman	Undivided	
		Tanyard	Undivided	
		Wilberns	San Saba Limestone And Others	Ellenburger-San Saba
Cambrian	Moore Hollow	Riley	Hickory Sand And Others	Hickory
		Undifferentiated Older Geologic Units		

* Both the Glen Rose and the Hensell outcrop at the land surface in the area (see title), but the outcrop of the Hensell occurs over most of the area and is the only water-bearing unit of the Trinity Group Aquifer in the area. The Glen Rose is not water-bearing in the area.

TRAVEL FROM JOHNSON CITY TO FREDERICKSBURG

Geology- We will continue traveling through the Hill Country from Johnson City to Fredericksburg on Highway 290 West on the outcrop of the Hensell Sand Member of the Travis Peak Formation (see the Geologic Section III above). The main aquifer will be the Ellenburger-San Saba Aquifer which directly underlies the Hensell Sand, and supplies ground water to the LBJ State Historical Park, the LBJ Ranch, the Stonewall Water Supply Corporation, the Wildseed Farm and the majority source of the City of Fredericksburg's water supply. We will make a "pit stop" at the Wildseed Farm, observe peach orchards and pass by the site of Fort Martin Scott before arriving at Fredericksburg. They are addressed as follows:

Wildseed Farm is about seven miles east of Fredericksburg. The farm which is a commercial wildflower seed producer having a motto, "Come for the flowers, Stay for the atmosphere." The farm occurs on fertile soils which developed on the bedrock of the Hensell Sand. The owner claims that it is the largest working wildflower farm in the U. S. where the flowers are grown in rows and harvested for seed. Cameras are welcome and photos can be taken along trails adjacent to the wildflower fields. The farm has a picnic area where flower bouquets can be made, and a butterfly house which features native varieties of the southwest. There is a Market Center which has gifts and wildflower seeds. It has a "Brew-Bonnet Biergarten" were there are cold drinks and special foods for sale. The farm uses ground water from wells completed in the Ellenburger-San Saba Aquifer.

Gillespie County Peaches (known also as "Fredericksburg Peaches" and "Stonewall Peaches") - As we travel between Stonewall and Fredericksburg, you may notice peach orchards. The raising and

marketing of Gillespie County peaches is a very erratic type of commercial farming due to possible changing weather and climatic conditions during the calendar years from season to season. However, the Hill Country does have good diurnal temperature variations that help produce peaches with a famously good sweet flavor. The peach trees also produce the sweet fruit because of the fertile and very drainable soils which have the needed minerals left by the erosion and weathering of the underlying, porous bedrock of the Hensell Sand. Gillespie County is the largest peach producing area in Texas with about 1,400 acres of commercial peach trees. There are 27 known orchards on the 1,400 acres which is about 40 percent of Texas total acreage. A mature peach tree can produce an average 3 ½ bushels or about 175 pounds of fruit. From May to July, production includes 12 varieties of peaches with Springgold the earliest and Jersey Queen the latest. There are "cling" peaches which ripen in May, "semi-freestone" which ripen in early June, and "freestone" which ripen in June and July. Some of the orchards are irrigated by wells that supply ground water from the Ellenburger-San Saba Aquifer. The 2006 season was a "bust" (95 percent lost), because of 1.) a fall 2005 drought, 2.) frigid weather in November 2005, 3.) too mild daytime 2005-06 winter temperatures, 4.) the freeze of March 24-25, 2006, 5.) a 30 percent bud loss in the spring, and/or 6.) damage by six hail storms. A large, commercial peach grower said, "The peach business was worse than going to Vegas."

Fort Martin Scott is located before we reach downtown Fredericksburg. Look for the inconspicuous site which is on the east (right) side of Highway 290 West (East Main Street) near Barons Creek and across from Fredericksburg's Industrial Center (2 miles southeast of downtown). The site was originally a U. S. Army "Camp Houston", and later was renamed "Fort Martin Scott" in December 1849 after Major Martin Scott a hero killed during the Mexican War. The camp and later fort was established to protect the town, area settlers and mainly the wagon trains that traveled along the primitive wagon roads supplying the fort and Fredericksburg from Austin and San Antonio. The fort was garrisoned with a company of infantry and dragoons (mounted infantry) that had some minor skirmishes and "battles" with the Comanches and Kiowas that were raiding and plundering in the area and along the wagon roads. The "Fort Martin Scott Treaty" with the Indians in 1850 improved the situation enough to prevent open hostilities. As settlers eventually pushed farther west, the fort lost strategic significance. The fort property was used for the first Gillespie County Fair. During the early 1850s, the Army used the fort as a forage depot, and closed the fort in December 1853. During the Civil War it was reoccupied by Confederate troops. After the Civil War General Philip Sheridan ordered that the fort be reoccupied by the 4th U. S. Cavalry to help secure the area from postwar white terrorist and Indians. Fort Martin Scott was finally closed in late 1866. The Fredericksburg Heritage Association currently leases the site of Fort Martin Scott as a park and historic site, and continues with archeological projects and historic renovations.

FREDERICKSBURG, GILLESPIE COUNTY

History- The first settlers in the Fredericksburg area were the Tonkawas. By the 1800s, the mounted Comanches and Kiowas dominated the area. In 1845, the area was explored and surveyed by John Meusebach who observed abundant water, stone and timber for settlement. He returned to New Braunfels and purchased 10,000 acres, and took 120 German settlers to the area in 1846. The Fredericksburg townsite was then surveyed by Herman Wilke, named after Prince Frederick of Prussia, and settled by additional German immigrants. There were many hardships experienced by the settlers; including 150 who perished in one year from diseases. By 1847, about 1,000 persons settled in the area which included families that received a town lot and 10 nearby acres for cultivation. The Germans constructed houses made of vertical post oak logs with the walls sealed and supported by limestone rocks and plaster. As soon as possible, the German settlers made the Meusebach-Comanche Treaty to try to stop the Indians from raiding, killing and capturing settlers and stealing their livestock (the mounted Indian's favorites were mules and horses). The treaty was not at all popular with other settlements in Texas, because they knew raiding and stealing by the Indians was a "way of life" to achieve value, prestige and survival. The Germans constructed the Vereins-Kirch (a large building) that served for about fifty years as a fortress, meeting hall, church, and school. It eventually became the home of the Gillespie County archives. In 1848 Gillespie County was formed and Fredericksburg became the county seat. The Nimitz Hotel, Fort Martin Scott, and a Catholic Church were established in 1848, and a Lutheran Church built in 1852. Both Catholic and public schools using only the German language were started in 1856. The first English

was used in the public schools after 1900. During the Civil War both Confederate and Unionist sympathizers suffered under the tyranny of martial law administered by a corrupt gangster group that actually tracked down and killed some families who tried to escape to Mexico. The first flight by man may have been accomplished by a German Texan, Jacob Friedrich Brodbeck at Fredericksburg after the Civil War in 1868. It was a spring- powered "airship" that was reported to have "crashed upon landing." The first German newspaper was started in 1877, and the first County Fair in Texas was held on Fort Martin Scott property in 1881. Sunday Houses which exist today were used by local ranchers and farmers for overnight accommodations; particularly over Saturday night to attend church on Sunday. Fredericksburg got an electric light company in 1886, and an ice house plant in 1907. Railroad service was established in 1913 and discontinued in 1942 (improved roads with autos and trucks took over). Fredericksburg and Gillespie County have enjoyable tourist and historical attractions consisting of peach markets, German restaurants and bakeries, antique shops, art galleries, attractive B & Bs, the Nimitz Museum and Historical Center, the Vereins-Kirche Museum, Fort Martin Scott Historic Site, the Fredericksburg Herb Farm, the Gillespie County Fair, Lady Bird Johnson Municipal Park and Golf Course, a race barn and track, in town and nearby wineries, the hillside Easter Eve Fires, Octoberfest, Luckenbach, spring wildflowers along the Willow City Loop, and Enchanted Rock State Natural Area (see the mural in the Austin Airport). The town has the Texas Hill Country University System and a branch of Texas Tech University, both having a wide variety of academic programs. The economy of the area is supported by tourism, ranching, farming, breeding and marketing of whitetail deer and exotics and the lease hunting of whitetail deer, wild turkey, quail, dove and exotic animals. Fredericksburg had a 2000 population of 8,911, and has an elevation of 1,742. It has an average annual rainfall of about 30 inches.

Geology- Fredericksburg and adjacent areas are on the outcrop of the Hensell Sand Member of the Travis Peak Formation of Cretaceous age. The Hensell which has water-bearing deposits of the Trinity Group Aquifer is underlain in the subsurface by the tilted, fractured and faulted formations of the Ellenburger Group of Ordovician age, and the Wilberns Formation of the Moore Hollow Group of Cambrian age. The water-bearing formations of the Ellenburger Group and the San Saba Member of the Wilberns Formation make up the Ellenburger-San Saba Aquifer.

Water Resources- The City of Fredericksburg uses ground water from the Trinity Group and Ellenburger-San Saba Aquifers. The city's largest public water source is three well fields which pump ground water from the Ellenburger Group formations of the Ellenburger-San Saba Aquifer. These well fields consisting of numerous wells are located outside of the city on leased lands southeast and east of the city, and are purposely located adjacent to the Pedernales River. The well fields have been strategically located so that multi-well pumping will intercept much of the spring flows (ground-water discharges) that enter the river from upstream aquifers such as the Edwards-Trinity Plateau Aquifer. The spring flows from the Edwards-Trinity Plateau and other aquifers into the Pedernales River upstream of the Ellenburger well fields has been estimated to be about 2.6 mgd during "dry periods" and about 15.8 mgd during "wet periods." In 1985, the city used 1.43 mgd of water provided by wells completed in the two aquifers. For 2003, the city reported water use of 1.96 mgd which was provided by nine wells completed in the two aquifers. In May 2003, the peak water use was 2.93 mgd. The ground waters produced from the three Ellenburger well fields is fresh water having an average tds of 580 ppm. The ground-water resources of Fredericksburg and Gillespie County are protected through controls administered by the Hill Country Underground Water Conservation District which is funded by an ad valorem tax imposed on county property owners. The District's tax rate is set at $0.0083 per $100 property evaluation.

TRAVEL FROM FREDERICKSBURG TO BAKERSFIELD

We will leave Fredericksburg on Highway 290 West from its intersection with Highway 87 North and travel westward on the outcrop of the Hensell Sand. We will cross over Live Oak Creek (look for sign) and continue to and pass over Honey Creek (look for sign) onto a relatively small exposure of the Glen Rose Formation. We will travel upward from the Hill Country on to the Edwards Plateau consisting of the limestone and dolomite (carbonate) beds of the Segovia Member and the underlying Fort Terrett Member of the Edwards Formation. Once on the plateau we will travel about 180 miles to Harper, Segovia, Junction, Sonora (lunch stop) Ozona and Bakersfield over the Edwards-Trinity Plateau Aquifer consisting of water-bearing rocks of the Fredericksburg and Trinity Groups as indicated in the following Geologic Section IV.

GEOLOGIC SECTION IV – EDWARDS PLATEAU ALONG HIGHWAY 290 WEST AND IH 10 WEST FROM JUST WEST OF FREDERICKSBURG TO BAKERSFIELD IN PECOS COUNTY

System/Series	Group	Formation	Member	Aquifer
Quaternary	Consists of Pleistocene to Recent dry and water-bearing alluvium (*) and terrace deposits (*) along streams			Alluvium (#)
	Washita	--------Buda Limestone (*)--------		Not Water Bearing
Cretaceous/ Comanchean	Fredericksburg	Edwards	Segovia *	Edwards-Trinity Plateau
			Fort Terrett *	
	Trinity	Hensell Sand (*) in East, Antlers Sand in West Also is called "Trinity Sands" in West		

Undifferentiated Older Geologic Units

* Denotes geologic units found at the land surface at various places on the Edwards Plateau along Highway 290 West and IH 10 West from just west of Fredericksburg to Bakersfield in Pecos County.
# Hydrologically connected to the Edwards-Trinity Plateau Aquifer at Junction and other areas of the Edwards Plateau.

HARPER, GILLESPIE COUNTY

History- The community of Harper was initially settled in the early 1860s by the Taylor and McDonald families. In 1864 the "McDonald Massacre" occurred when Kiowas terrorized the family, killing the male members and capturing a young mother and four children. (The Indians during such raids killed the men because they fought back and tried to escape, and captured the women and children who were treated relatively well and were used by the squaws as laborers.) Years later the Kiowas released the captives through an exchange program which occurred near the Texas-Oklahoma border. The community was named after George Harper who opened and ran the first post office in 1883. The community was settled by Germans, Irish, English, Americans, Scotch and Polish immigrants. Harper has 6 churches, a fire department, an ambulance service, and a public school; all of which serves the town's people and growing nearby subdivisions (part of the community is probably a "bedroom city" for employment in Fredericksburg and Kerrville). The town serves a large sheep, goat and cattle ranching area, and is a supply point for hunters having leases in western Gillespie County. Harper has a population of about 400, an elevation of 2,056 feet and receives about 29 inches of average annual rainfall.

Geology- Harper occurs on the outcrops of the Fort Terrett and Segovia Members of the Edwards Formation (see Geologic Section IV above). The Edwards consists of hard to soft, relatively thick beds of limestone and dolomite. In the subsurface, these beds where fractured and dissolutioned, contain fresh ground water and compose the upper portion of the Edwards-Trinity Plateau Aquifer (see Geologic Section IV). Near Harper, ground water is naturally discharged from the Edwards portion of the aquifer by Headwater Springs which flows in to the Pedernales River, and has been estimated to flow as high as 9,000 gpm or about 13.0 mgd during "wet" periods.

Water Resources- Harper has one public supply well which is completed in the Hensell Sand of the Edwards-Trinity Plateau Aquifer at a depth of 655 feet (see Geologic Section IV above). The Hensell is believed to be the lowest (deepest) water-bearing unit of the aquifer. The well has been tested to yield about 300 gpm or about 0.432 mgd. No measurement of tds is available.

TRAVEL ON HIGHWAY 290 WEST AND IH 10 WEST TO SEGOVIA

From Harper to Segovia, we will be traveling on the Segovia Member of the Edwards Formation (see Geologic Section IV above). The "type stratigraphic section" of the Segovia Member was measured and described near the community of Segovia; thus its name. The Segovia Member will be exposed in highway road cuts that consist of fractured and dissolutioned limestone and dolomite beds. The generally rounded, contrasting deposits in some of the roadcuts are large dissolution cavities or caves which have been filled through geologic time with younger rock material and cave deposits. During this stretch of travel we will briefly discuss the community of Segovia and the cedarwood oil industry.

Segovia, Kimble County- In the 1860s, Segovia was one of the earliest settlements in Kimble County started on Johnson Fork which is a major tributary of the Llano River. We will cross Johnson Fork on IH 10 West soon after passing Segovia on our way to Junction. Named after a Spanish town, Segovia obtained a post office in 1900 but lost it in 1964. During the 1920s the Segovia area was a famous vacation site for camping and fishing, had a tourist park, a filling station and a general store. Currently the community has a large, convenient truck stop and a general store which are popular stops for truckers, tourist, locals, and hunters. A cedarwood oil producing plant is nearby and is a very important business supporting the area economy and employment (see the discussion about mountain cedar below). Just south of Segovia, we have entered the Johnson Fork Valley which is spring fed. We have passed over the Edwards Formation's Segovia Member which got its name from the community of Segovia. However, the community of Segovia occurs on the outcrop of the Fort Terrett Member of the Edwards Formation (see Geologic Section IV). The private residents, truck stop, store and ranches in and near Segovia are supplied ground water by very small to small capacity, private wells completed in the Hensell Sand which is the lower water-bearing unit of the Edwards-Trinity Plateau Aquifer (see the Geologic Section IV).

The Mountain Cedar; Its Uses and Problems- FIRST A HISTORICAL BACKGROUND - Before the settlers occupied the Hill Country and the Edwards Plateau from Austin to the Pecos River, most of the region was open grass land, except in the floodplains of major streams which had elms, oaks, cottonwoods and other trees. The region was a grassy plain which was a vast grazing area for the abundant herds of buffalo which were "the life blood" of the plains Indians. The grassy plains were devoid of mountain cedar and other trees because the grasses were burned by lightening strikes, and as needed, purposely burned by the Indians. Under these conditions, sprouting trees were destroyed and healthy stands of grass could readily return from unaffected roots. Once the settlers and buffalo hunters arrived, the buffalo herds were eliminated followed by the plains Indians. This allowed trees to grow. Eventually the mountain cedar became the dominant upland vegetation replacing the grasses and other trees.

The Texas mountain cedar or the Mexican ashe juniper (*Juniperus ashei* or *J. mexicana*) forms extremely thick "cedar brakes" on the carbonate terrane of the Edwards Plateau. It has been estimated that Texas has 10 million acres of "cedar brakes." This includes the mountain cedar of the Hill Country and Edwards Plateau and the red cedar (*Juniperus virginiana*) which is found in Bastrop County south of Austin. Dried mountain cedar is used for fuel and burns extremely hot with lots of sparks. Mountain cedar has been used by ranchers and farmers as poles, fence posts and crossties. It is used by craftsmen to make woodenware and other articles. The bark of the mountain cedar along with spider webs is used by the endangered Golden Cheeked Warbler (*Dendroica chrysoparia*) to make nests in nearby Spanish oaks. Also, the endangered Blacked-Capped Vireo (*Vireo atricapilla*) nests in the lower branches of the mountain cedar. During droughts, the foliage and apples of the mountain cedar are browsed by deer and goats. The apples are eaten by birds and other mammals. The plant is known to be very resistant to cedarapple rust. The most rewarding use of the mountain cedar is the manufacture of cedarwood oil. Ranchers cut and pile the cedarwood and let it dry for long periods (years) to eliminate the bark and the thin cover wood over the heartwood. The dried cedarwood is taken to a cedarwood oil refinery were it is dried further and ground into a fine wood pulp. Selected portions of the wood pulp are subjected to a partial pressure steam distillation process which produces refined extracts of cedarwood oil. The other portion of the wood pulp is used for fuel in the boilers producing the steam for the distillation process. In 1984, about 1,400 metric tons of cedarwood oil was produced in Texas. Some cedarwood oil is used as feedstock to manufacture certain chemical derivatives including cedrol used in the synthesis of odorants and very fine perfumes. Cedarwood oil is used as a scenting agent in the manufacture of

soaps, detergents, floor polish, cosmetics, deodorants, massage oils, air fresheners, insecticides, insect repellents, and candles. Leftover wood pulp at the refinery is used by others to make potpourris, soil mixture, mulch, floor sweep, dog and cat liter, decorative ground cover, bedding for horse stables, and lost circulation material in oil well drilling operations. The refining of cedarwood does not involve any additive chemicals or solvents, and does not produce any harmful solids or liquid wastes. But the pollen of the mountain cedar is well known to cause human allergies. Mountain cedar is a well known phreatophyte which discharges very large amounts of rainfall infiltration and ground water to the atmosphere. Some Quest members who attended another trip, surely remember our visit to the Bamberger Ranch having selective mountain cedar removal and the beneficial rejuvenation of spring flow to Millers Creek in Blanco County. Mature mountain cedar brakes have such thick canopy that the shade prevents the growth of other beneficial plants for livestock grazing and wildlife.

TRAVEL ON IH 10 WEST FROM SEGOVIA TO JUNCTION

After we pass by Segovia and over Johnson Fork on IH 10 West, we will climb up a steep grade of the highway passing by roadcuts exposing the limestone and dolomite stratum of the Fort Terrett and Segovia Members of the Edwards Formation. We will then travel about 6 miles on top of the Plateau and then start down a relatively steep grade through very large roadcuts exposing (from top to bottom – youngest to oldest) the Fort Terrett Member and the underlying Segovia Member of the Edwards Formation and an underlying roadcut exposure of the Hensell Sand of the Trinity Group. This is classic "layer cake geology." We will travel further on IH 10 West over the Llano River and its floodplain with its water-bearing alluvium which overlies the Hensell Sand in the river valley (see Geologic Section IV). We have reached the town of Junction which is 142 miles from Austin, is about 60 miles from Sonora and lunch, and is about 300 miles from the Big Bend National Park Headquarters.

JUNCTION, KIMBLE COUNTY

History- Downtown Junction is located east of the IH 10 West and Highways 377-83 intersection (look for signs). The town got its name from being originally located at the "junction" of the North and South Llano Rivers. Initial settlers in the area included Americans, English, German, French and Scotch-Irish. The town of Junction was formed in the spring of 1876. It became the Kimble County seat, and obtained a post office in the fall of 1876. The *West Texan,* the first newspaper was started in 1882. By 1881, the town had Baptist, Episcopal and Methodist churches. By 1933 the town had Church of Christ and Catholic churches. Junction became incorporated in 1930 with a population of 1,400. The economy of the town and county are supported by cedarwood oil production, pecan growing, processing and marketing, and a company called Native American Seed with native Texas plant seeds. The town is an important west Texas marketing and shipping center for sheep, goats, cattle, wool, mohair and grains. The fall economy of the town and county are enhanced by the leasing of lands to hunters for the taking of whitetail deer and other game. The town's businesses sponsor a "Wild Game Supper" having a "hunting gun and equipment lottery" for area hunters during a Saturday evening of the fall hunting season. Junction has a Texas Tech University academic center for 250 students who can earn undergraduate and graduate degrees supported by courses in English, Biology, Zoology, Ecology, Geography, Mammalogy, Ornithology, Archaeology, Water Resources, Photography, Music, Voice, Art, Theater, and Design. All Kimble County public schools are consolidated at Junction. Each August, Junction holds "The Billie Sale & Parade" celebration, and in September "The Kimble Kow & Kick" celebration. The 2000 population of Junction was 2,924. The downtown area has an elevation of 1,722 feet, and an average annual rainfall of about 26 inches.

Geology- The downtown area of Junction lies on the outcrops of the Quaternary age, terrace and alluvium deposits along the North and South Llano Rivers. The alluvial deposits are underlain by the Hensell Sand of Cretaceous age. The limestone and dolomite (carbonate) outcrops in the uplands bordering the terrace and alluvial deposits are the Fort Terrett Member and the overlying Segovia Member of the Edwards Formation of Cretaceous age. The ground-water-bearing portions of these geologic units in and near Junction including the Quaternary alluvial deposits are hydrologically connected and make up the Edwards-Trinity Plateau Aquifer (this is all shown on Geologic Section IV).

Water Resources- Currently, the Junction public water supply system's source of water is Lake Junction established in 1904 and located behind a dam on the South Llano River adjacent to the downtown area. The first town's public water supply was obtained from the South Llano River in 1895, and in 1896 from a lake (reservoir) behind the first dam on the river. After 1904, the town's water supply was obtained from Lake Junction by shallow wells which pumped the water from galleries constructed beneath the lake's banks a short distance from the lake in water saturated alluvium which is hydrologically connected to the lake (see Geologic Section IV). The alluvium between the lake and the galleries serve as a filter to obtain cleaner water from the lake. Some individual gallery wells are capable of yielding 500 to 750 gpm (0.72 to 1.08 mgd) of very fresh water having tds of 250 to 550 ppm. Lake Junction is supplied by upstream flows of the South Llano River which are partially supported by 21 identified upstream springs in Kimble and Edwards Counties. These springs were estimated to be capable of discharging about 47 mgd of ground water from the Edwards-Trinity Plateau Aquifer. In 2003, Junction pumped 166.8 million gallons or about 0.457 mgd from Lake Junction for its public water supply. The peak use was in August 2003 at 28.6 million gallons or 0.922 mgd. Kimble County's ground-water resources are protected and controlled by the management and an elected board of the Kimble County Groundwater Conservation District which is financed by an ad valorem tax of $0.002 per $100 property evaluation.

TRAVEL BETWEEN JUNCTION AND SONORA

As we travel westward from Junction on IH 10 West, we will proceed upward in the geologic section from the Quaternary alluvium and the underlying Hensell Sand in the North Llano River Valley to the upland carbonate terrane of the Fort Terrett Member of the Edwards Formation. We will pass by the exit to the community of Roosevelt and the exit to the old Fort Terrett site (both described below). Further on from the Fort Terrett exit as we head toward Sonora for the next 22 miles, we will travel on the carbonate outcrops of the Segovia Member of the Edwards Formation and the Buda Limestone of the Washita Group. All of the above geologic units are shown in Geologic Section IV.

Roosevelt, Kimble County- The community of Roosevelt is located north of its exit from IH 10 West. It was founded by W. B. Wagner who named the community after Teddy Roosevelt. Actually TR and his Rough Riders, the 1st United States Cavalry visited the area after TR had formed the famous unit consisting of Texas cowboys in the Menger Hotel Bar in San Antonio. The community of Roosevelt was established and received a post office in 1897. The area was the first to start the raising of angora goats for mohair production starting in about 1897. A little later, the Roosevelt area became most noted for horse ranching which produced excellent polo ponies and the most desired horses for the US Cavalry. The community became noted for the Marc-Key Company Nursery and its famous growing and marketing of Christmas time poinsettias. In 1990, the nursery shipped about 35,000 poinsettia plants to markets in Texas and elsewhere. The Roosevelt area of western Kimble County has excellent hunting opportunities for whitetail deer and wild turkey. This is the area where the preparer of this guide killed his first wild turkey and his son killed his first deer.

Fort Terrett, Sutton County- The "type section" where the Fort Terrett Member of the Edwards Formation was first measured and described is located in the old Fort Terrett area of Sutton County. The site of the old Fort Terrett is located north of an exit from IH 10 West about 4 ½ miles west of the Kimble-Sutton County line. The site of the old fort can not be seen from IH 10 West, and is located in the North Llano River Valley on the private property of the Fort Terrett Ranch. The fort was established in 1852 by Lt. Col. Henry Bainbridge and named after Lt. John Terrett who was killed in the Battle of Monterrey during the Mexican War. The site of the fort was selected by the US Army because of the large flow from Fort Terrett Springs from the Edwards-Trinity Plateau Aquifer into the headwaters reach of the North Llano River. It was thought that such a strategic location of the fort near a water supply used by the Indians would help the Army control the hostile Indians and Mexican bandits from the raiding of settlers, travelers and wagon trains along the San Antonio – El Paso Road (Old Spanish Trail). It was occupied by the Army under a requirement stipulated in the Treaty which ended the Mexican war. The Army staffed the fort with poorly trained "raw recruits" who consisted of mostly infantry and limited cavalry which usually lost their horses to raiding Indians. Can you imagine the fort's infantry trying to protect settlers, travelers and wagon trains from mounted, very mobile and hostile Comanches and Kiowas. Fort Terrett was abandoned in

February 1854. Fort Terrett property was bought by Jim West in the early 1900s and stocked with the first Hereford cattle in west Texas. In 1975 the Fort Terrett property was purchased by William D. Noel who stocked the ranch with exotic animals. Noel promoted the historical research of Fort Terrett and preserved the fort's headquarters building and made it his ranch headquarters. He planted and developed some of the first pecan orchards of the Western Schley and Wichita varieties in the floodplain of the North Llano River.

SONORA, SUTTON COUNTY (We will have a "pit stop" and a lunch break here)
History- The town of Sonora is located about 201 miles from Austin and about 270 miles from the Chisos Basin in Big Bend National Park (today's final destination). The town is about 65 miles from San Angelo the nearest large city. Downtown Sonora is located in a valley near the confluence of the Dry Devils River and Lowery Draw. The townsite was donated by a rancher, Charles Adams who in 1887 named the community "Sonora" after an Adams family servant from Sonora, Mexico. Adams drilled a water supply well and offered free lots to settlers and local ranchers. In 1890 the town became the county seat of Sutton County. At that time the town had numerous dwellings, three stores, livery stables, two hotels, a school house and a tent city. A post office was established in 1889, and a newspaper, *The Devils River News* was started in 1890. By then the town had 700 residence, two saloons, a grain and flour mill, a cafe, three doctors, a church and a stage coach and mail connection with San Antonio. Sonora and Sutton County were settled by American, German, English, Irish, French and Scotch-Irish immigrants. The Sutton County courthouse was built in 1893 on land donated by R. W. Callahan. Supplies were received by wagon trains which took 6 to 15 days to reach Sonora from San Angelo. The Topeka & Santa Fe railroad was completed and the first train arrived in Sonora in May 1930 from San Angelo. Baptist, Episcopal and Methodist churches were established between 1912 and 1920. Sonora was incorporated in 1917 and a new newspaper, *New Era* was started in 1914. During the early 1900s, Sonora prospered through the raising of sheep and goats for the wool and mohair. The Sonora area received a Texas A&M University Agricultural Station in 1916 which researched livestock diseases and methods to improve livestock production and marketing. The town has since 1939, the Sonora Wool & Mohair Cooperative for obtaining fair prices, and which sponsors the Sonora Wool & Mohair Show which includes the National 4-H Wool Judging Contest. During the 1930s, the WPA helped Sonora build a new fire station, city hall, and make waterworks and power plant improvements. A new public school was completed in 1936. The Caverns of Sonora was opened nearby as a popular tourist attraction in the 1960s. During the early to mid-1970s, Sonora and Sutton County experienced an oil and gas boom. The population of Sonora in 2000 was 2,924. Sonora has an elevation of 2,133 feet, and an average annual rainfall of about 21 ½ inches.
Geology- Downtown Sonora lies on Quaternary age alluvium along the Dry Devils River and Lowrey Draw. The alluvium overlies the subsurface, carbonate rocks of the Segovia Member of the Edwards Formation which is the geologic unit which is present adjacent to the alluvium in the uplands of the city. The water-bearing limestone and dolomite beds of the Segovia and the underlying Fort Terrett Members of the Edwards Formation and the underlying "Trinity Sands" make up the Edwards-Trinity Plateau Aquifer beneath Sonora (see Geologic Section IV).
Water Resources- Since about 1889 when Charles Adams drilled the first water well at Sonora, the city water system has drilled and used eight wells capable of yielding 250 to 1,650 gpm of very fresh water having tds of 280 to 370 ppm. All of the wells have produced from the Segovia and Fort Terrett Members only, because while they were being drilled the drilling method lost circulation and could not penetrate the "Trinity Sands" underlying the Fort Terrett (see Geologic Section IV). The lost circulation conditions indicate that the limestone and dolomite rocks of the Fort Terrett are very porous. In 2003, the City of Sonora used six wells which produced about 0.978 mgd. The peak production was 1.38 mgd in August. The ground-water resources of Sonora and Sutton County are controlled by the Sutton County Underground Water Conservation District which is operated by a manager and administered by a board of elected officials who are citizens of Sutton County. The District is funded by an ad valorem tax at a rate of $0.0362 per $100 property evaluation.

TRAVEL FROM SONORA TO OZONA
After leaving Sonora and the Dry Devils River Valley, we will travel on IH 10 West toward Ozona on the limestone and dolomite (carbonate) rocks of the Segovia Member of the Edwards Formation and

the Buda Limestone of the Washita Group (see Geologic Section IV). About 7 ½ miles west of Sonora, we will pass the exit to the Caverns of Sonora (look for exit sign). Unfortunately we will not have time to visit and tour the caverns, but a discussion of the most beautiful geologic feature of the Edwards Plateau and west Texas is given below. Some distance further on IH 10 West, we will travel through the Devils River Valley before arriving in the town of Ozona.

The Caverns of Sonora- The entrance to the Caverns of Sonora (COS) is located about 7 miles south of the marked IH 10 West exit and is on the left side of Highway 1989, Cavern Road. The COS is located on the Mayfield Ranch. Legend has it, that in about 1900, a hunter discovered the cavern's opening when his dog chased a raccoon into a cave. Because of the danger to horses and livestock while working and herding livestock, the cave opening was probably partially closed. In the 1920s, teenagers found the cave opening and explored the caverns a short distance using a candle and safety string to keep from getting lost. Candles are used during cave exploration to detect the presents of large amounts of carbon dioxide which is a life threatening gas found in some caves. The COS were eventually opened by a man-made ditch and tunnel, and professionally explored and mapped which indicated 7 miles of passages; only 2 miles of which are used during current tours which started in 1960. The caverns were very slowly developed in the Edwards Formation during a very long period of geologic time during the Recent and Quaternary age systems and earlier (see Geologic Section IV). Part of the COS is still considered a "live cave" and is very slowly continuing to develop. The COS's current passages were formed by millions of years of erosion and dissolution of the carbonate rocks of the Edwards Formation by the infiltration and percolation of rainfall and ground waters through fractures, bedding plains and cavities which were developed in the carbonate rocks. Infiltrating rainfall and "young" percolating ground waters are slightly acidic and readily react with and slowly dissolve carbonate rocks such as those found in the Edwards Formation. Eventually, an interconnected system of large cavernous passages and openings were developed to form the present COS. The erosion and dissolution of the carbonate rocks formed colorful and very beautiful cave deposits such as stalactites, stalagmites, flowstones, etc. Tours of the COS last for about 2 hours. The year around temperature is about 70 degrees F. During the tour you will see the Horseshoe Lake, the Corinthian Room and the Crystal Place Room. Tour prices and arrangements for group tours can be obtained by calling 325-387-3105 or by emailing questions@cavernsofsonora.com.

OZONA, CROCKETT COUNTY

History- Ozona is about 235 miles from Austin and about 236 miles from the Chisos Basin Lodge in Big Bend National Park (we've come halfway). Ozona was initially called "Powell Well." In 1890, E. M. Powell surveyed the area, drilled a water well (into the Edwards-Trinity Plateau Aquifer) near Johnson Run Draw, installed a windmill over the well, and supplied water to the area settlers and travelers. Powell provided land for a school, churches, parks, a courthouse, and a jail, and through his agent, sold lots to settlers who for need of shade and food, planted numerous pecan trees. Cattle ranching was started in the 1880s and Rambouillet sheep and angora goats were imported a little later. In 1891, "Powell Well" was renamed "Ozona" which then meant "quality of air in wide open spaces" to the travelers and settlers of the area. Ozona and Crockett County became a popular settlement area because of the availability of fertile land and a reliable supply of water from wells. The area was settled by American, German, English, and Irish immigrants. Ozona was made the county seat of Crocket County, received a post office, and received a multi-faith, union type Sunday school organized by Mrs. J. W. Odom in 1891. By 1892, Ozona had two restaurants, a saloon, a blacksmith shop, a public school, a feed yard and other businesses. A stage and mail route with San Angelo was established in 1898 using the Crockett Hotel as the station. The *Stockman* newspaper was started in 1914 replacing *The Kicker* started in 1892. Crocket County established a courthouse in Ozona in 1902. It was built with locally quarried limestone. Oil was discovered in 1925 on the Powell Ranch and later in and near the town of Ozona which did not become an "oil boom town." For Quest travelers who are UT alums and fans, the Santa Rita No. 1 oil well that is "an icon" of UT history and funding was completed in May 1923 about 40 miles northwest of Ozona in the Big Lake Oil Field in Reagan County. To protect Ozona from flooding by Johnson Run Draw flood control dams were constructed upstream. The town has a Crockett County Museum which has collections of artifacts, antiques, Indian relics, old ranch and farming implements, and old household items connected to the history of Ozona, Crockett County and west Texas. The Ozona town square has a statue of David Crockett, and a beautiful mural depicting Crockett County ranching, historical

downtown Ozona, and historical Crockett County law enforcement. Ozona had a 2000 population of 3,436, has an elevation of 2,360 feet, and receives an average annual rainfall of about 18 inches.
Geology- Most of Ozona lies on the Quaternary terrace and alluvium in the Johnson Run Draw valley. The alluvium is underlain by the limestone and dolomite beds of the Segovia Member of the Edwards Formation which also is the geologic unit occurring in the upland outcrops within and adjacent to the town. The water-bearing deposits of the alluvium, the Edwards Formation, and the underlying Trinity Group's Antlers Sand are hydrologically connected and form the Edwards-Trinity Plateau Aquifer in and near Ozona (all of this is shown in Geologic Section IV).
Water Resources- All of Ozona public water supply wells, because of lost circulation conditions experienced while they were being drilled, are completed in the Edwards Formation water-bearing rocks of the Edwards-Trinity Plateau Aquifer. The "Trinity Sands" portion of the aquifer could not be reached during the drilling of the wells (see Geologic Section IV). The most productive wells are capable of yielding 500 gpm or about 0.720 mgd. In 2003, the Crocket County Water Control and Improvement District No. 1, which is the entity supplying water to Ozona, used nine wells that produced 387.2 million gallons or about 1.06 mgd from the Edwards-Trinity Plateau Aquifer. The peak water use by Ozona was in August 2003 at about 1.62 mgd. Ground water is protected and controlled at Ozona and in all of Crockett County by the Emerald Underground Water Conservation District which was established in 1991, and is run by a manger and overseen by an elected board of Crockett County residence. The District is funded by an ad valorem tax at a rate of $0.01755 per $100 property evaluation.

TRAVEL FROM OZONA TO THE PECOS RIVER

After leaving Ozona, we will continue on IH 10 West for many miles across western Crockett County toward the famous Pecos River. We will travel over the Segovia Member of the Edwards Formation and the overlying Buda Limestone of the Washita Group which is on the highest flat upland areas of the Edwards Plateau. While we are headed westward we will travel over the Quaternary age terrace and alluvium in the canyons of Howard Creek and tributaries. (For the relationship of these geologic units see Geologic Section IV.) We will pass by IH 10 West Exit 343 the Hwy 290 Loop to Fort Lancaster State Park. We will not see or pass by the site of old Fort Lancaster, but it will be addressed below as one of the very important parts of the U. S. Army's historical presence in west Texas. Look for a sign on IH 10 West which may indicate Live Oak Creek. Fort Lancaster State Park with the old fort site is about 5 miles south (left) down Live Oak Creek which was the fort's water supply supported by Live Oak Springs. After passing Live Oak Creek, we will eventually start down a very long relatively steep grade of IH 10 West toward the Pecos River. As we travel downward, we will pass by prominent roadcuts and outcrops of the Segovia and Fort Terrett Members of the Edwards Formation, the underlying roadcuts of the Antlers Sand of the Trinity Group, and the Quaternary floodplain terrace and alluvial deposits along the Pecos River (see Geologic Section IV). The following discussions cover "Fort Lancaster", "Pecos River" and "Saltcedar."

Fort Lancaster- The old fort site is located in the Fort Lancaster State Park along Live Oak Creek and Highway 290 Loop in Crockett County. Fort Lancaster was established by US Army Capt. Stephen Carpenter and two infantry companies in August 1855. The fort was used before the Civil War as quarters for infantry to protect the wagon trains, travelers and settlers along the Old Spanish Trail (now Highway 290 Loop) from hostile, raiding Apaches, Comanches and Kiowas who were well mounted and very mobile. It was an impractical, if not impossible mission, for infantry in such wild and harsh country against such skillful horsemen. After Texas seceded from the Union, Fort Lancaster was abandoned in March 1861. After the Civil War, the fort was again established as one of the periodically occupied US Army outposts under the command of Fort Stockton (to be discussed in detail further down the road). The fort was occupied on needed occasions by the famous "Buffalo Soldiers" of the 9th US Cavalry led by Lt. Fred Smith. Their mission was to patrol and protect at Live Oak Springs and along the San Antonio – El Paso Road from the raiding Mexican bandits, comancheros, and mainly hostile Comanches who were raiding into northern Mexico. The "Buffalo Soldiers" were blacks that volunteered for the US Army after the Civil War, and served their country with courage and honor in the 9th Cavalry during the west Texas campaigns against the Indians. After the Indian threats moved further west, Fort Lancaster was abandoned in 1873 and the 9th Cavalry's mission was continued at Fort Stockton and Fort Davis. Fort Lancaster State Park

now exhibits the area's natural history, archeology, nature study, the old fort ruins, and has a Texas State Bookstore which sells literature about Texas history and old Texas forts including Fort Lancaster.

Pecos River- We cross the Pecos River on IH 10 West where it is the boundary between Crockett and Pecos Counties. As we pass over the bridge, try to notice the tall thick brush growing upstream on the banks and in the floodplain of the river. It is a problem called saltcedar which will be addressed below. The Pecos River is the major tributary of the Rio Grande in Texas and New Mexico, and has a 900 mile course FROM its head at 13,000-feet elevation in New Mexico's Santa Fe Mountains TO International Amistad Reservoir on the Rio Grande at elevation 1,117 feet in Val Verde County. In Texas the river serves as the eastern boundary of the most mountainous and arid region of Texas known as the Trans Pecos. The Upper Valley of the Pecos River in Texas extends from Red Bluff Reservoir near the border with New Mexico TO the bridge over IH 10 West. The valley has a semi arid climate, and is irrigated with river and ground water, and produces such crops as cotton, alfalfa, forage, grain sorgrum, some vegetables, some fruits, and the famous, sweet Pecos Cantaloupe. The Lower Pecos River Valley extents southeast downstream FROM the IH 10 West bridge TO the International Amistad Reservoir on the Rio Grande. The valley was formed by millions of years of erosion and weathering of the bedrock of the Edwards Formation to form the Pecos River Canyon. The deep canyon makes it impossible to readily irrigate the uplands which have large livestock ranches that obtain their water supplies from windmill wells completed in the Edwards –Trinity Plateau Aquifer. The flow of the river in the Lower Pecos River Valley is supported by spring flows up to 25 mgd or 30,000 acre-feet per year. The spring flows issue from the Edwards-Trinity Plateau Aquifer, and includes the flows from eleven known large springs. In addition the aquifer discharges a large amount of baseflow to the Pecos River in the same reach. These ground-water discharges enter the International Amistad Reservoir and along with upstream Rio Grande water is allocated to users in the US and Mexico by the International Boundary & Water Commission. In 1948, the Pecos River Compact Commission (PRCC) was formed by the Federal government between Texas and New Mexico. Initial independent hydrologic studies were conducted to determine the amount of Pecos River water New Mexico was to deliver annually to Texas through PRCC agreements. As soon as the initial studies were completed, it was determined that New Mexico was not able to deliver the required annual amount of water to Texas. This occurred over many years until Texas brought suit and won the case in the US Supreme Court. However, the Court determined that New Mexico could not deliver the required water because ground-water pumping in the Roswell Basin was intercepting spring flow and baseflow from the flow of the Pecos River. The court decided that instead of water, New Mexico will pay Texas annually, an amount based on the current cost of each acre-foot of water not delivered to Texas under the PRCC agreement.

Saltcedar- The thick brush you may have seen in the floodplain of the Pecos River as we crossed the IH 10 West bridge, is called saltcedar or tamarisk. It is not a native Western Hemisphere plant, and was introduced into the US southwest from Asia and the Mediterranean in the early 1800s for ornamental value and shade, for windbreaks, and for the stabilization of the soil and banks along streams. Saltcedar is a very invasive, extremely prolific phreatophyte in the US southwest with the four most abundant species being; *Tamarix gallicia, T. ramosissima, T. pendantra and T. aphylloa.* The saltcedar along the upper Pecos River and its tributaries in Texas and New Mexico discharge an extremely large amount of rainfall infiltration, ground-water recharge and ground-water storage to the atmosphere. The root of the plant reaches depths of 100 feet or more, and the waste discharge of water to the atmosphere is diurnal. The great concentrations of saltcedar and its large waste discharge of water to the atmosphere has greatly affected the availability and quality of water in the Pecos River and the underlying aquifers. Saltcedar is a prolific seed producer and a very fast grower which quickly invades the area with a canopy that blocks the sunlight for the growth of other plants. The plants roots, trunk and limbs transport salts to the leaves where the salt is discharged and drops to the ground and causes very high salinity of the soils in the floodplains of the river and tributaries. There is a saltcedar eradication program ongoing in the upper Pecos River Valley in Texas. The best way saltcedar can be removed and controlled is by the spraying of Roundup and Rodeo using helicopters. The resulting dead plants and some of their roots are then removed and burned. It takes about three years to effectively remove saltcedar from any particular area.

TRAVEL FROM THE PECOS RIVER TO BAKERSFILED, PECOS COUNTY

After we leave the Pecos River, we will travel westwards on IH 10 upward through Four Mile Draw on Quaternary alluvium toward Bakersfield. The uplands of the draw are outcrops of the Segovia and Fort Terrett Members of the Edwards Formation of the Fredericksburg Group (see Geologic Section IV). As we approach Bakersfield you will see a prominent hill mapped and called "Squaw Teat Peak" which has the outcrop of the Segovia member at the top and the Fort Terrett Member at its base. The peak will be the last outcrop of the Segovia Member and the Fort Terrett Member of the Edwards Formation of the Fredericksburg Group that will be discussed in this guide (see Geologic Section IV).

BAKERSFIELD, PECOS COUNTY

History- We are about 275 miles from Austin and about 196 miles from the Chisos Mountain Lodge in Big Bend National Park. The Bakersfield townsite is on the Old Spanish Trail, and is north of the IH 10 West Exit to Highway 11. We are about 36 miles east of Fort Stockton. The town was named after J. T. Baker who had a post office established there in 1929. It was the same year that oil was discovered in and adjacent to the town in the Taylor-Link Field. Bakersfield became a boom town overnight and had a grocery store, a café, a hotel, a real estate office, a pool hall, and numerous rent houses in 1930, and a population of about 1,000. By the end of the year, because of a drastic decline in oil prices, the town was abandoned as fast as it was established. Many of the buildings were removed, and by 1945 the town only had two businesses and a population of 50. Today the community still exists with a 2000 population of 30. The town has an elevation of 2,539 feet and an average annual rainfall of 14 inches.

Geology- The town occurs on the outcrop of Quaternary age alluvial deposits. As indicated above Squaw Teat peak is a prominent geologic feature having the limestones and dolomite beds of the Edwards Formation (see Geologic Section IV). We may see some drilling rigs in the area that may be exploring for natural gas in the Barnett and/or Woodford Shales which are being explored for natural gas in other areas of Texas.

Water Resources- The community of Bakersfield does not have a public water supply system. Private wells are used in and adjacent to the community and produce ground water from the Antlers Sand of the Edwards-Trinity Plateau Aquifer (see Geologic Section IV).

TRAVEL FROM BAKERSFIELD TOWARD FORT STOCKTON

We will continue to travel westward on IH 10 West toward Fort Stockton. Before reaching Fort Stockton we will observe the "Ste. Genevieve Vineyards & Winery" located about 9 miles west of Bakersfield on the south side of IH 10 West. From Bakersfield to Fort Stockton and vicinity, there will be a change in the surface and subsurface geological conditions which are shown in the following Geologic Section V.

GEOLOGIC SECTION V – FROM WEST OF BAKERSFIELD TO FORT STOCKTON AND VICINITY

System/Series	Group	Formation	Member	Aquifer
Quaternary	Consists of Pleistocene to Recent alluvial deposits (*) which are not considered to be water bearing			------
Cretaceous/ Comanchean	Washita (*)	Undivided	Undivided	Edwards-Trinity Plateau
	Fredericksburg (*)	Undivided	Undivided	
	Trinity	Consist of "Trinity Sands"		

(*) Geologic units found or observed on the land surface at various locations from west of Bakersfield to Fort Stockton and vicinity.

Ste. Genevieve Vineyards and Winery- The vineyards and winery are located in Pecos County about 26 miles east of Fort Stockton on land leased from the University of Texas System's Permanent Land Fund program which was established by the Texas Constitution after the Civil War. Ste. Genevieve leases about 1,000 acres, and established a vineyard in about 1981. In 1986, the vineyard had grown to almost 1,000 acres. Later a large winery was established by a Texas-French consortium. Of all the wineries in Texas, it became the largest. In 1992 it produced 1.0 million gallons of wine and Ste. Genevieve wines won 18 wine awards. The winery only distributes in Texas. The company's success is a result of west Texas horticulturist's successfully combining their knowledge with the near perfect calcareous soils of Escondido Draw, the water resources of the Edwards-Trinity Plateau Aquifer, and the expertise of French winemaking. Ste. Genevieve wines include Sauvignon Blanc, Chardonnay, Pinot Noir, Merlot, Gamay, Texas Red, Texas White, Texas Blush, Fume Blanc, Red Zinfandel and White Zinfandel. The winery also imports and bottles Cabernet Sauvignon, Merlot and Syrah under the French, Lorval label. Arrangements to tour the winery can be made through the Fort Stockton Chamber of Commerce. The vineyards and winery are located on Quaternary age alluvium of Escondido Draw. The average annual rainfall is about 13 inches. It is apparent from State of Texas water records that the vineyards and winery use ground water pumped by wells completed in the "Trinity Sands" of the Edwards-Trinity Plateau Aquifer (see Geologic Section V above). Escondido Draw has two separate springs which flow intermittently from the aquifer. The springs were favorite places for Comanche and other Indian camps along the Old Spanish Trail (old Highway 290). The US Army's experimental camel trains of the late 1800's stopped at Escondido Springs. A nearby, restored stage coach station is located near the springs and just south of the IH 10 East right-of-way toward Bakersfield.

TRAVEL TO FORT STOCKTON

As we travel on IH 10 West from just west of Bakersfield , passing the Ste. Genevieve Vineyard & Winery, passing the stage coach station, and headed to Fort Stockton, we will travel over Quaternary alluvium and observe uplands of the limestone and dolomite outcrops of the Washita and Fredericksburg Groups which are shown in Geologic Section V to be undivided. This is a change from the geologic nomenclature used in Geologic Section IV where the Groups are subdivided. The Groups were not able to be subdivided (mapped) at Fort Stockton and adjacent areas as shown on Geologic Section V.

FORT STOCKTON, PECOS COUNTY

FIRST A NOTE: We will make a "pit stop" in Fort Stockton which is 326 miles from Austin, about 58 miles from Marathon (dinner), and 145 miles from the Chisos Mountain Lodge in Big Bend National Park.

History- Fort Stockton is a very historical place, mainly because of Comanche Springs. (The "Hydrogeology of Comanche Springs" will be presented separately from this discussion and is given below.) Because of Comanche Springs, the area was a very important "living place" having a very consistent water supply which was used by prehistoric man and the Indians for thousands of years. The springs' flow was diverted by the Jumano Indians to irrigate their corn. The Jumanos were raided and replaced by the Lipan Apaches who eventually were dominated by the Comanches after they got horses. Comanche Springs was a very important source of water for explorers such as Espejo in 1583, DeSoto in the 1590s, and Juan de Mendoza in 1684 who described the springs as being large, very beautiful, and gushing forth to form a river. Today the river is called Comanche Creek which, prior to the late 1800s, flowed northeast into a great marsh which eventually discharged water to the Pecos River. The marsh was a supporting environment for local and migrating birds and mammals. The marsh eventually dried up and no longer exists. In 1839, Dr. H. Connelly leading a large wagon train of bullion, visited the springs as they traveled from Chihuahua

City to Arkansas. His trip opened up the Chihuahua Trail connecting San Antonio and the western US with northern Mexico. In 1849, Captain William Whiting and his US Army unit of Topographical Engineers surveyed and explored the San Antonio–El Paso Road. Captain Whiting described Comanche Springs as "a clear gush of water which burst from the plain, unperceived until the traveler is immediately upon it (and) abounding in fish and soft-shell turtles." Captain Whiting and his interpreter named the springs after the Comanches who they encountered at the springs. Also in 1849, Lt. S. G. French and his US Army troops visited the springs and encountered a very large band of Comanches headed to northern Mexico on the Comanche War Trail. He and his troops also observed a wagon train of immigrants at the springs headed from Fredericksburg to Presidio. The springs also were visited by the "49ers" passing through west Texas headed for the California gold fields. In 1858-59, the US Army established Camp Stockton and staffed it with infantry and a few dragons (poorly mounted infantry) to protect wagon trains, settlers and travelers from the hostile Comanches and their brethren. The hostile, well mounted Comanches used the Comanche War Trail to plunder northern Mexico, and continued to raid the San Antonio–El Paso Road, the Butterfield Stage-Mail Route, and the San Antonio–Chihuahua Freight Wagon Road; all of which were "crossroads" at Comanche Springs. The troops stationed in west Texas including Camp Stockton faced poor nutrition (scurvy due to lack of vitamin C) and many diseases including cholera and dengue fever. There were very few Army doctors and very poor medical conditions and facilities which helped cause many deaths. You can imagine how unsuccessful the infantry and poorly mounted dragoons were in their attempts to control hostile, well mounted Comanches. In 1861, the Union Army abandoned Camp Stockton which was then temporarily occupied by Confederate troops. In July 1867, Fort Stockton was established near the site of Camp Stockton. Outpost forts and camps under the command of Fort Stockton were established in west Texas at Fort Lancaster, Fort Hudson, Fort Leaton, Fort Davis, Fort Quitman, and camps at Escondido Springs, Horsehead Crossing of the Pecos, Howard Springs, Camp Melvin, and Camp Pena Colorada. Fort Stockton was established at Comanche Springs on 960 acres of land leased from local landowners. The Army also leased an additional 25 acres on Comanche Creek to irrigate a large garden. Fort Stockton was placed under the command of Col. Edward Hatch who was a white officer commanding the famous 9th US Cavalry Regiment which consisted of Companies A, B, E, and K which were composed of black troops called the "Buffalo Soldiers" by the Indians. Col. Hatch and his cavalry served their country and west Texas with outstanding bravery and great honor by controlling the raiding Comanches, Kiowas, Kickapoos and Apaches in the Comanche Springs area and at and near the outpost forts and camps mentioned above. Such command was taken over later by Col. Benjamin Grierson who commanded the 9th and 10th Cavalry Regiments and the 41st, 24th, and 25th Infantry Regiments; all composed of "Buffalo Soldiers." A small community was started around Fort Stockton where the Army's presence required support from civilians involved in the supply of goods and services. The civilian businesses also supported the needs of local ranchers and farmers. In 1868, Peter Gallagher bought some land in the area of the fort, still leased part of it to the Army, formed the town of St. Gall, and established two supply stores for the fort. By 1870 settlers that immigrated to the area included Irish, German and Mexicans. The first church at St. Gall was Catholic. Soon after 1875, farmers along and adjacent to Commanche Creek, established an irrigation system supplied by the flow of Comanche Springs. The diversion of Comanche Creek flow for such irrigation was probably the main cause for the drying up of the downstream marsh mentioned above. Irrigation acreage was about 7,000 acres in 1877, and about 12,900 acres in 1945. In 1875 Pecos County was formed with St. Gall as the county seat. The town's name was changed in 1881to Fort Stockton after a Mexican War naval hero. It became the biggest west Texas center for sheep and cattle ranching. The fort at Fort Stockton was abandoned in June 1886. Today the site includes a row of officer's quarters, a guard house, enlisted man's barracks, a parade ground, a visitor's center and museum, a Chihuahua Desert Nature Trail, and the old Fort Stockton Cemetery. Today the City of Fort Stockton and its citizens sponsor and celebrate "Living History Days of Historic Fort Stockton", "Christmas at Historic Fort Stockton" and a "Breakfast with Santa at Historic Fort Stockton." The discovery and production of the Yates Oil Field helped support the economy of Fort Stockton. Since WW II, Fort Stockton and Pecos County have developed a broad-based economy from irrigated agriculture with water from the Edwards-Trinity Plateau Aquifer (see Geologic Section V above), sheep and cattle ranching, and the discovery, production, processing, and distribution of oil and gas and sulfur. The possible future exploration and production of natural gas

from the Barnet and Woodford Shales in Pecos County should help the economy of Fort Stockton. The 2000 population of Fort Stockton was 7,846. The city has an elevation of 2,954 feet, and receives only about 12 ½ inches of rainfall per year.

Geology- The City of Fort Stockton occurs on Quaternary age alluvium which is underlain by limestone and dolomite stratum of the Washita and Fredericksburg Groups and the deeper underlying "Trinity Sands" of the Trinity Group. In the subsurface where these three Groups are water-bearing and hydrologically connected, they form the Edwards-Trinity Plateau Aquifer in Fort Stockton and adjacent areas (see Geologic Section V above). The Edwards-Trinity Plateau Aquifer is also the source of Comanche Springs' flow.

Water Resources- In the mid 1940s, Comanche Springs' flow began to decline, and became an unreliable public water supply for the City of Fort Stockton. Since that time, the City of Fort Stockton has used public supply wells which are completed in the Edwards-Trinity Plateau Aquifer (same aquifer providing the flow to Comanche Springs). The city's ground-water supply has been obtained from two well fields; one located in the city and one located about 5 to 6 ½ miles southwest of the city in the Belding Farms' area. The wells located within the city are capable of pumping 300 to 1,100 gpm per well with water having a tds concentration of about 1,400 ppm. The Belding Farms' wells are capable of pumping 1,100 to 2,400 gpm per well with water having a tds concentration of about 1,465 ppm. In 1985, the City of Fort Stockton used about 924 million gallons or about 2,835 acre-feet of ground-water from the aquifer. This ground-water withdrawal averaged about 2.53 mgd. In 1986, the city built a reverse osmosis (RO) desalination plant to improve the water quality of the city's public water supply. The RO plant which has a capability of producing 6 mgd of fresh water, uses the slightly saline ground-water as the plant's raw feed water. The more saline-water effluent from the plant is disposed of by the use of properly lined evaporation ponds. The plant's average production of fresh water is about 4.5 mgd which currently meets the city's peak water need. In 2002, the City of Fort Stockton used about 942 million gallons (2,891 acre-feet or about 2.58 mgd) of fresh water produced by the RO plant which desalted the slightly saline water from the Edwards-Trinity Plateau Aquifer. The peak water use was about 4.21 mgd in May 2002. The ground-water resources of Fort Stockton and Pecos County are controlled and protected by the Middle Pecos Groundwater Conservation District which was created by Senate bill 1911, 76th Texas Legislature (1999).

HYDROGEOLOGY OF COMANCHE SPRINGS

Because of its reliable historical flows, its reasonably good water quality, and its "crossroad" strategic location in the Chihuahuan Desert, Comanche Springs' flow was a very valuable water supply for prehistoric man, the Indians, early explorers, settlers, travelers, irrigation farmers, Camp and Fort Stockton, the town of St. Gall, and later the City of Fort Stockton. In the early 1900s, Comanche Springs was known to be the third largest spring in Texas. During that period its flow was only surpassed by San Marcos Springs and Comal Springs (largest) at New Braunfels. The springs are a natural ground-water discharge point of the Edwards-Trinity Plateau Aquifer. The six outlets of the springs are located in the southeastern part of the City of Fort Stockton at the headwaters of Comanche Creek. The springs are located in the James Rooney Memorial Park just east of the Pecos County courthouse, and have an attractive pavilion and an Olympic size swimming pool. Comanche Springs' property is jointly owned by the City of Fort Stockton and the Pecos County Water Control & Improvement District No. 1. The flows of the springs in 1899 and 1904 were measured at 42.65 mgd and 41.36 mgd respectfully. From 1919 to 1947, the range in the flow of the springs was 27.14 to 31.67 mgd and had slightly saline water having tds ranging from 1,312 to 1,358 ppm. During the period 1949–1954, the flows of the springs ranged from 16.80 to 24.55 mgd, and had an average tds concentration of about 1,345 ppm. The 1958 to 1961 measurements ranged from 0.97 to 1.15 mgd with a tds of 1,348 ppm. The springs did not flow for over 25 years from March 1961 to October 1986. Since 1986 the springs have flowed periodically, and had flow measurements of 2.01 mgd on March 11, 1992 and 8.79 mgd on December 16, 2004. The tds of the March 11, 1992 flow was 2,381 ppm. The "no flow period" experienced from 1961 to 1986 was caused by large, relatively consistent ground-water withdrawals by public supply wells at Fort Stockton and by irrigation wells and other city public supply wells southwest of the springs. The concentrations of ground-water pumpage were at Fort Stockton near the springs, and in an area which is more than five miles southwest of the springs at and southwest of the Belding area. The

main recharge (intake) zone for the Edwards-Trinity Plateau Aquifer and Comanche Springs is estimated to be at and southwest of Fort Stockton, and includes the Belding area and the very large area along Coyanosa Draw all the way to the eastern and southern slopes of the Barrilla, Davis and Glass Mountains (see Figure 2). The very large withdrawals of ground water beneath the springs' recharge zone, intercepted the natural flow to the springs for many years since the early 1900s. The withdrawals of ground water became so large in the 1950s through the mid 1980s that the flow of the springs was completely intercepted by the ground-water withdrawals. Such withdrawals caused the aquifer's water levels and artesian pressures to decline to such extents that the springs stopped flowing during the 25-years period (1961-1986). The springs' flow and water quality measurements possibly indicate that the springs have two components of flow. During high flows the tds concentrations are less, while the tds concentrations are larger during low flow measurements. This may indicate that during low flow, when the tds is higher, that such low flow from the springs is coming from the faraway areas beneath the springs' recharge zone and/or from the nearby ground water having higher salinity in the bottom of the Edwards-Trinity Plateau Aquifer. The other component of flow is represented by high flows and less tds concentrations which results from wetter periods which provide more, nearby fresh water recharge to the aquifer which in turn reaches the springs in a faster manner. During the "no flow" period of the springs in 1982, the shallow, dewatered underground passages leading to the springs' outlets were surveyed and described. Below a ½ acre at the land surface above the passages, cave explorers found about ¾ mile of large passages that could be easily explored and surveyed. The passages occurred in fractured and dissolutioned limestone and dolomite stratum of Comanchean age (see Geologic Section V) at three different levels below the land surface down to a total depth of about 43 feet which was just above the aquifer's water table. The explorers discovered vertical openings which went down to the water table and below and connected with deeper water saturated passages within the aquifer. Before the springs stopped flowing in 1961, it had various aquatic occupiers which included the endangered Comanche Springs Pupfish (*Cyprinodon elegans).* Another small freshwater fish, the Largespring Gambusia (*Gambusia geiseri)* was present and is native to San Marcos Springs and the Guadalupe River and was introduced to west Texas springs in 1937 and 1956; including Comanche Springs. Another small fish (*Gambusia nobilis)* occurred in Comanche Springs before it stopped flowing. They currently have stable populations in the springs at Balmorhea in Jeff Davis County and the San Marcos River in Hays County.

TRAVEL FROM FORT STOCKTON AND COMANCHE SPRINGS TO MARATHON
We will leave Fort Stockton and IH 10 West and travel southwest on Highway 385 toward Marathon (58 miles away) and Big Bend National Park's, Chisos Basin (145 miles away). About 20 miles down Highway 385 from Fort Stockton, we will leave the simple "layer cake" geology and Edwards-Trinity Plateau Aquifer shown on Geologic Section V, and pass through the eastern part of the Glass Mountains, and at the same time enter the more complicated geology and aquifers of the "Basin and Range" physiographic province of west Texas (see the letter size map, "Physiographic Map of Texas"). Once we pass through the eastern part of the Glass Mountains (see Figure 2) we will enter the Marathon Basin or Marathon Uplift with Quaternary age alluvium and various outlier (bedrock) outcrops of much older rocks of the Paleozoic Era. The Paleozoic Era geologic units will be of Permian, Pennsylvanian, Mississippian, Devonian, Ordovician and Cambrian ages (see the Explanation on the letter size map, the "Geology of Texas"). The surface and subsurface geologic units of the Marathon Basin/Uplift and the related water-bearing units of the Marathon Aquifer are delineated and given in the following chart, Geologic Section VI.

GEOLOGIC SECTION VI – SURFACE AND SUBSURFACE GEOLOGIC UNITS OF THE MARATHON BASIN/UPLIFT AND THE VARIOUS WATER-BEARING UNITS OF THE MARATHON AQUIFER IN BREWSTER COUNTY (The Pennsylvanian, Mississippian, Devonian, Ordovician and Cambrian geologic units listed below have been greatly effected by Late Paleozoic Era folding, faulting and fracturing to such an extent that their outcrops at the land surface are not seen as "layer cake" geology, but as very tilted and near vertically dipping stratum. The hard erosion resistant and steeply dipping beds of the white Caballos Novaculite and the darker Maravillas Chert are the most conspicuous as we travel through the Marathon Basin/Uplift.)

GEOLOGIC SECTION VI – Continued.

System and Age	Geologic Units	General Lithology	Water-Bearing Characteristics
Quaternary	Alluvium (*)	Sand & Gravel	Not known to yield water to wells
Permian	Undifferentiated Geologic Units		Not Water Bearing at Marathon
Pennsylvanian	Gaptank Formation (#)	Lime, Sand & Shale	Yields water to some wells
	Haymond Formation	Shale and Sandstone	Not known to yield water to wells
	Dimple Limestone (#)	Granular Limestone	Yields water to some wells
Pennsylvanian and Mississippian	Tesnus Formation (#)	Sandstone & Shale	Yields water to some wells
Devonian	Caballos Novaculite (#)	Novaculite & Chert	Has some small springs
	Maravillas Chert	Chert & Limestone	Not known to yield water to wells
Ordovician	Woods Hollow Shale	Mostly Shale	Not known to yield water to wells
	Fort Pena Formation (#)	Mostly Limestone	Yields water to some wells
	Alsate Shale	Hard Shale	Not known to yield water to wells
Ordovician And Cambrian	Marathon Limestone (@)	Porous Limestone	Major water-bearing in the area
Cambrian	Dagger Flat Sandstone	Sandstone & Shale	Not known to yield water to wells
	Undifferentiated Older PreCambrian Rocks		

(*) The Quaternary age alluvium is the major geologic unit at the land surface in the town of Marathon which also has some bedrock outcrops of the Marathon Limestone, Alsate Shale and Fort Pena Formation.
(#) Minor water-bearing units of the Marathon Aquifer at various locations in the Marathon Basin/Uplift.
(@) The major ground-water-bearing unit of the Marathon Aquifer in the Marathon Basin/Uplift, and is the water-bearing unit developed by the town of Marathon's public water supply system.

MARATHON, BREWSTER COUNTY
FIRST A NOTE – We will make a "pit stop" and have dinner at the famous Gage Hotel in Marathon which is about 384 miles from Austin and about 87 miles from the Chisos Mountain Lodge in the Big Bend National Park.

History- A small community which would become the town of Marathon, was established on the Galveston, Harrisburg and San Antonio Railway which became the Southern Pacific Railroad in 1882. At that time, the major center of population in the area was at Pena Colorada Springs (also "Colorado" is used) which was about 5 miles southwest of the initial railroad community. The US Army established Camp Pena Colorada at the springs in 1879 to control hostile raiding Comanches and Apaches, and perform other duties described below in "Camp Pena Colorada." A post office was established by Albion Shepard at the railroad community in 1883. He named the site "Marathon" because its location and surrounding terrane reminded him of the town of Marathon that he had visited in Greece. In 1885, Mr. Shepard deeded the initial railroad site to his son, Ben Shepard who platted the town of Marathon and sold lots starting in March 1886. A private school was started by a Miss Paxton in the 1880s. A town meeting hall was built in 1888, and also served as a school and community church. At one time Marathon was the county seat of "Buchel County" which was not officially established. Its area officially became part of Brewster County now the largest county in Texas with Alpine as the county seat. A Baptist Church (1898), St. Mary's Catholic Church (1908), and a Methodist Church (1910) were established in Marathon. The first jail was a windmill where the prisoners were hand cuffed to the mill's legs and supports. Eventually a rock building was built as the jail, and furnished with used cells removed from a jail that was being rebuilt in Alpine. Eventually the Southern Pacific Railroad was completed and supplied Marathon with needed goods. The railroad made Marathon a major shipping point for cattle and sheep, for wild game meat and other by products obtained from commercially hunted deer, antelope and bear, for fluorspar and silver from Mexican mines, and for flasks of mercury from the Terlingua mines in southwest Brewster County. From 1907 through about 1926, Marathon had two companies that used the guayule plant to produce a special kind of rubber. The guayule plants were used up by the late 1920s. In 1911 the Mexican Revolution caused Mexican raiders to cross the Rio Grande into west Texas. Marathon became a center for US Army operations to confront and control the situation in Brewster County. A company lead by a Captain Douglas McArthur was one of the initial units that served in the area to protect and establish order. Captain McArthur's company was later replaced by troops under the command of a Lt. George S. Patton. By 1914, Marathon had the Chambers Hotel, a newspaper called the *Hustler*, four cattle breeding operations, three general stores, a bank, a telephone company, and a pool hall. In the 1920s, a Vermont-born banker, businessman, and local rancher, Alfred Gage had the elegant, two-story Gage Hotel built in Marathon. However, Mr. Gage died in 1928 before the hotel was finished. (We will have dinner at the historical Gage Hotel before completing today's journey to Big Bend National Park.) Oil was explored for in and adjacent to Marathon unsuccessfully in 1928. The honey production business thrived in the area from about 1917 to the 1940s. Three wax factories were operated in Marathon from the late 1940s until about 1954. These factories refined and produced the wax from the unusual candelilla which is a common, abundant plant found in most of the Chihuahuan Desert of west Texas. Until the 1950s, Marathon had 6 daily stops for passenger rail service. Today, about 20 times per day Union Pacific cargo trains pass through Marathon. However, Amtrak passenger service can be obtained at the train station in Alpine. The Marathon Independent School District was finally established in 1947. Since 1947, Marathon has served as the gateway to Big Bend National Park, and has a modest tourist economy because of the Park. Marathon had a 2000 population of 455, and has an elevation of 4,045 feet. Marathon has an average annual rainfall of about 14 inches.

Geology- The town of Marathon occurs in the Marathon Basin which geologically also is called the Marathon Uplift. The subsurface geology of the Marathon Basin/Uplift beneath Marathon is very complicated. It is not "layer cake" geology. In the subsurface beneath the Quaternary age alluvium, there are highly folded, faulted and fractured geologic units of Paleozoic age consisting of the Permian to Ordovician units shown in Geologic Section IV above. The occurrence and productivity of ground water in the Pennsylvanian, Devonian and Ordovician geologic units of the Marathon Aquifer shown in Geologic Section IV varies considerably from place to place within the subsurface of the Marathon Basin. This situation is due to the great distortions of the geologic units created by the folding, faulting and fracturing. Fortunately for the town of Marathon, it is underlain by the fractured Marathon Limestone which is capable of yielding moderate amounts (21 to 100 gpm per well) of ground water for public supply purposes.

Water Resources- The Marathon Water & Service Corporation (MW&SC) provides Marathon with ground water produced by two wells completed in the Marathon Limestone of the Marathon Aquifer

(see Geologic Section IV above). The two wells are operated with one pumping and the other as a stand-by source in case additional water is needed. The wells are 346 and 468 feet deep, and have moderate capacity to deliver 55 to 85 gpm of fresh ground water having tds concentrations of about 590 to 600 ppm. In 1985, the MW&SC supplied 20.6 million gallons or 0.056 mgd of ground water for public supply purposes. The MW&SC used 33.0 million gallons or about 0.091 mgd of ground water from the Marathon Aquifer in 2003. The peak water use was about 3.93 million gallons in August 2003.

TRAVEL OVER THE MARATHON BASIN/UPLIFT ON HIGHWAY 385 TOWARD BIG BEND NATIONAL PARK

We will travel the next 40 miles over the very complicated geology of the Marathon Basin/Uplift which is a western, exposed (eroded) remnant of the buried Ouachita Mountain chain, and is composed of the very faulted, folded, tilted and fractured Paleozoic Era geologic units described in Geologic Section IV (see the above chart). The Pennsylvanian, Mississippian, Devonian, Ordovician, and Cambrian age geologic units which are given and described in Geologic Section IV were greatly altered by Late Paleozoic Era folding, faulting and fracturing to such an extent that their land surface exposures (outcrops) are no longer "layer cake" geology, but are very tilted and near vertically dipping stratum. The most obvious geologic units exposed along Highway 385 in the Marathon Basin/Uplift are the steeply dipping white Caballos Novaculite and the dark gray to black Maravillas Chert. These two units are composed of very hard rocks which were very resistant to weathering and erosion over geologic time. The geologic units in Geologic Section IV and the structural geology that has effected them is very adequately explained by referring to the text and illustrations given under the "Marathon Uplift" on pages 18 through 22 of the book titled, Geologic Wonders of West Texas. This publication is available for your review. Also the very complicated geology of "The Marathon Uplift" is described on pages 286 through 288 in the book titled, Roadside Geology of Texas which is also available for your review.

Camp Pena Colorada- The camp site is located southwest of Marathon, and was originally known as Cantonment Pena Colorada. In some of the reference literature, "Colorado" was used instead of "Colorada." Camp Pena Colorada was a US Army outpost established in August 1879 at Pena Colorada Springs when Company F and G of the 25th Infantry Regiment moved to the camp from Fort Stockton. The camp was intended to be a very strategic place for control of the Comanches using the Comanche War Trail; one route of which passed by Pena Colorada Springs on its way to a Rio Grande crossing near the "Big Bend" of the river. Also, Camp Pena Colorada lay on the long road connecting Fort Clark and Fort Davis. It was established on the planned transcontinental railroad route through west Texas, and was within practical support from Fort Stockton and Fort Davis. The outpost camp was founded at the same time that Victorio and his Warm Springs Apaches broke out of the Mescalero Apache reservation in New Mexico and began their flight and raiding across New Mexico, the Trans-Pecos and northern Mexico. It turned out that the main missions of the infantry troops included safety escort of settlers and travelers passing through the area, perform scouting of their assigned area, and attempts to pursue and stop mounted bandits, Mexican raiders, horse thieves, and other law breakers. This was all done by infantry units without using horses for effective mobility. Other US Army units that served at the camp included two companies of the 24th Infantry, and Company K of the 1st Infantry. The troops were housed in crude barracks built of stone and mud. The railroad for a very short period supplied the camp with some goods. In 1884 the camp was staffed with units of the 10th Cavalry composed of "Buffalo Soldiers." The 3rd Cavalry replaced the 10th Cavalry in the summer of 1885, and the 3rd Cavalry was later replaced by the 8th Infantry. Camp Pena Colorada was closed in January 1893 with a shift of the US Army's missions closer to the border. The site of Camp Pena Colorada is located about 5 miles southwest of Marathon on the Post Ranch which is owned by the Combs Cattle Company. David St. Clair Combs donated the land around the site and Pena Colorada Springs in 1935 for a park which is currently used by the locals and visitors as the "Post."

BIG BEND NATIONAL PARK, BREWSTER COUNTY

FIRST DAY NOTE - We will enter the Park at the Persimmon Gap Visitor's Center and Ranger Station (see Figure 3) at a late time of the first day of travel, and travel about another 45 miles directly to the Chisos Mountain Lodge for our first overnight accommodation. The following

discussion will address the geography and climate, plants and wildlife, and human history of the Big Bend area and the Park. These discussions will be followed by the geology and water resources of the Park.

Park Geography & Climate- In the southern Trans-Pecos of west Texas, the Rio Grande meanders across the Chihuahuan Desert leaving in its path a national border surrounded by land almost forgotten by time. A land with a succession of sheer-walled, spring fed canyons that trap the river into meandering southeast from Presidio to just past the Chisos Mountains in the very dry desert of the Big Bend National Park (BBNP or Park), and then abruptly turning northeast at an almost 90 degree "big bend" for which the area north of the river in Texas is known. Inside of this mighty curve of the Rio Grande lies not only a great, out-of-the-way national park, but also a part of the spectacular basin and range province of west Texas known as the "Big Bend Country" (see Figure 2). BBNP covers over 801,000 acres or about 1,250 square miles including about 118 miles of meandering Rio Grande bottomland at a lowest elevation of about 1,730 feet, a very extensive wide open desert plain, and several very abrupt mountain ranges such as the Chisos which has Emory Peak with a top elevation of 7,832 feet (recently measured by satellite technology). This makes the greatest topographic relief within the BBNP about 6,100 feet. In the north-south direction the Park is about 50 miles wide, while in the east-west direction it is almost 55 miles wide. During just a relatively short drive, visitors can be at the water's edge in the linear oasis of the Rio Grande bottomland having shady, moderate comfortable temperatures, then experience a very uncomfortable 100 degree or more heat in the very dry desert, and then a very pleasant cool feeling of 65 degrees in the Chisos Mountains. This indicates that BBNP essentially has three climatic zones. Annual precipitation is less than 10 inches in the desert, while during wet seasons annual rainfall may exceed 30 inches in the Chisos Mountains. Winter and spring are dry while rain occurs in the summer and fall. In November, the average high temperature is about 69 degrees F, the average low is about 42 and the average monthly rainfall is about 0.7 inches (about 4.5 % of the average annual rainfall of 15.3 inches). This doesn't mean that in November it may be near 100 degrees F in the desert or freeze and have snow in the Chisos Mountains. BBNP is a place of great diversity, a place to relax and contemplate the very beautiful and yet in places a harsh natural world, to observe the wildlife, plants, and beautiful scenery of the unusual geology, and to enjoy the vastness and splendor of a great wilderness region of Texas.

Plants & Wildlife- At the end of the last ice age about 10,000 years ago, the climate of the Park was much colder and wetter, and woodlands covered much of the big bend area. Since then the climate has gradually become warmer and much drier. There has been a gradual influx of heat and drought adapted plants in the Chihuahuan Desert, most of which have thorns for protection, and water retention properties. The Park has over 1,000 species of plants. The plants are adapted to the desert conditions by simply waiting out the rains in their seed stage with the seeds remaining dormant sometime for years until adequate moisture arrives. Seeds are coated with a chemical inhibitor which only can be removed by a certain amount of moisture before the seed geminates. Also, adequate moisture from the heavier rains, assures the plant a healthy life cycle for future seed production. Another survival strategy is used by the creosote bushes that produces a toxic resin in their leaves that, when shed, discourages other plants from growing under and nearby the bushes. This makes the creosote bush the most prominent plant in the desert zone of the Park. The various cactus in the Park are protected by thorns, and have water retention and a waxy stem that prevents the escape of water to the atmosphere (evapotranspiration). Other plants which have adapted to the desert are the sotol, ocotillo, lechuguilla, yucca, pricklypear, mesquite, acacia and the candelilla wax plant. Wildflowers including bluebonnets are best seen in the Park after heaviest rains in July and August. Sometimes the wildflowers are so thick due to very heavy rains that the image may change that you are not in a desert. In the Rio Grande bottomlands various deciduous trees are found including the cottonwood. As you go upward into the mountains you will pass grasslands with century plants, then evergreen sumac, mountain mahogany, Texas madrone and bee brush. Further upward at an elevation of about 4,500 feet you will see junipers, small oak and pinyon pine. Some of the rare trees found in the southern most part of the US are in the higher elevations of the Park's Chisos Mountains, and include Arizona pine, Douglas fir, Arizona cypress, quaking aspen and bigtooth maple. These trees are the remnants from the last part of the Ice Age. The Park has abundant wildlife and fish including 450 bird species, 78 mammal species, 10 amphibians, 56 reptile, and 35 fish. You will not see many land animals in the Park's desert during daylight hours because

of the heat. Common animals found in the Park are jackrabbits, kangaroo rats, roadrunners, golden eagles, coyotes, mountain lions and black bears (they've come back by migrating from northern Mexico). Species only found in the Park are Del Carmen whitetail deer, the colima warbler, Mexican drooping juniper, and the Chisos agave. Endangered species in the Park include the peregrine falcon, the black-capped vireo, the Mexican long-nosed bat, and the Big Bend gambusia a tiny fish found only in the Park. In 1976 the UN Educational Scientific Organization designated the Park a "Man and the Biosphere" reserve.

Park Human History- The Park has archeological and historical sites representing over 10,000 years of human habitation. The Native Americans which occupied the Park and adjacent areas included the Jumanos, Chisos, Mescalero Apaches and Comanches. The first prehistoric people of the Park were hunter-gathers who tried to survive with what was available. Their diet included the heart of the sotol and lechuguilla plants. They used 1) various plants to make their baskets, clothing and sandals, 2) the atiati to throw small spears to kill deer, rabbits and other eatable animals, and 3) the Rio Grande and numerous upland springs as their water supplies. There are numerous rock shelters and hearths in the Park indicating their historical presence. Eventually, their trade with people to the south and west showed the hunter-gathers how to cultivate and consume corn, beans and squash which considerably benefited their existence. By 1200 the Jumanos and the Chisos, agricultural Indians, occupied and farmed the Rio Grande floodplain in and west of the Park. Evidence indicates that the Chisos were eventually forced by the Jumanos from the river floodplain into the Chisos Mountains. Very little is known about the Chisos and their way of life in the mountains. By the 1500s the Spanish came to the Park and adjacent area and enslaved the Indians and changed their culture. The Spanish crossed the Rio Grande to explore for and mine gold and silver. The Spanish Catholic Church and its monks avoided the Park area, and established Presidios south of the Rio Grande for conversion of the Indians. But by the 1700s, the Spanish adventurers avoided the Park area which was controlled by the mounted, hostile Mescalero Apaches. The Apaches eventually were pushed out of the Park area by the Comanches who eventually dominated the Trans-Pecos including the Park area by establishing their infamous Comanche War Trails. They annually used two trails in the Park area in the early fall (during the "Full Comanche Moon") to raid back and forth into northern Mexico from their villages in the High Plains. Some hardy Mexicans farmers settled in the Park area by the early 1800s, and along with their southern neighbors in Mexico, opposed the Comanches raiders who killed the men, captured the women and children, and stoled their goods, mules and horses. Eventually the US Army and the numerous buffalo hunters forced the Comanches to occupy the Indian reservations in the Oklahoma Territory. In 1852 Major William Emory and his US Army unit conducted a boundary survey and examined the canyons within the Park area. In 1881, a Texas Ranger party floated and surveyed the Santa Elena Canyon of the Rio Grande in the western part of the Park area. The US Geological Survey floated and surveyed Boquillas Canyon which is within the eastern Park area. In the 1880s, ranchers began to settle the Big Bend, and by 1900, sheep, goats and cattle ranches occupied much of the Park area. However, the desert range was soon overgrazed. Both banks of the Rio Grande floodplain had numerous Mexican farmers by 1900. After the Mexican Revolution in 1920, Anglo-American farmers settled in the Park area. Cotton and food crops were grown around Castolon, and near today's Rio Grande Village along the river. In 1933, the Texas Legislature started Texas Canyons State Park on fifteen sections (about 9,600 acres) of land in the vicinity of Santa Elena, Mariscal and Boquillas Canyons on the northern side of the Rio Grande. Later in 1933, the park name was changed to Big Bend State Park and a large acreage in the Chisos Mountain was added. The National Park Service investigated the site in 1934 and made recommendations for Park improvements. President Roosevelt took an interest in the Park to develop an international park with Mexico. This idea to form an international park with Mexico has been considered many times since. The US Congress passed legislation in June 1935 stipulating the acquisitions to the Park would be obtained only by public and private donations. By 1942, most of the land was purchased by an appropriation from the Texas Legislature. The Park opened in 1944. In 1972, Congress appropriated funds for additional acreage. Later additions increased the Park's acreage to about 801,163 acres or about 1,252 square miles which is its current size. In 1944, only about 1,400 people visited the Park. To date the largest annual visitation was about 456,200 people in 1976. BBNP has a great national significance as the largest protected area of Chihuahuan Desert topography and ecology in the United States. After the late 1980s, about $14 million was used in the Park for roads, bridges, trails, campsites, and the lodge, restaurant and

cabins in the Chisos Basin. In the 1990s, annual appropriations to maintain the Park was about $2.5 million. Recent information strongly indicated that US National Park facilities have deteriorated to such an extent that more appropriations by Congress are seriously needed to improve and increase Park facilities and staffing. Many conservationist and environmentalist strongly recommend that this should be done to meet the great needs for future visitations that definitely will occur from the future increasing US population which recently reached 300 million.

Park Geology- The geology of the Big Bend National Park is very complicated having uplifted, tilted, folded, faulted, highly fractured and slightly metamorphosed geologic units that include volcanic lava flows and large igneous rock intrusions. The surface and subsurface geologic units in the Park are given in the following Geologic Section VII which was taken and modified from Table 1, page 27 of Ross Maxwell's The Big Bend of the Rio Grande.

GEOLOGIC SECTION VII – SURFACE AND SUBSURFACE GEOLOGIC UNITS AND THEIR LITHOLOGY AND WATER-BEARING PROPERTIES IN BIG BEND NATIONAL PARK.

System/Series	Group	Formation	Lithology & Water-Bearing Properties
Quaternary	None	Alluvium	Sand & gravel. The major Park aquifer (1)
Tertiary (5)	Big Bend Park	South Rim (2)	Volcanic basalt. Not water bearing
		Chisos (2)	Volcanic tuff. Has numerous springs (3)
		Canoe (4)	Sandstone. Has a few small springs
	Tornillo	Hannoid Hill (4)	Sandstone & clay. Has a few small springs
		Black Peaks (4)	Clay & sandstone. Not water bearing
		Javelina (6)	Sandstone. Has numerous small springs
Upper Cretaceous/ Gulfian		Aguja (7)	Sandstone & coal. Has numerous springs.
	Terlingua	Pen	Marl & clay. Not water bearing.
		Boquillas (8)	Marl, chalk & limestone. Not water bearing
Lower Cretaceous/ Comanchean	Washita	Buda	Limestone. Not water bearing
		Del Rio	Clay & shale. Not water bearing
	Fredericksburg	Santa Elena	Limestone. Not water bearing
		Sue Peaks	Shale & marl. Not water bearing
		Del Carmen	Limestone. Not water bearing
		Telephone Canyon	Limestone & marl. Not water bearing
	Trinity	Glen Rose	Sandstone & Limestone. Source of Hot Springs?
Undifferentiated Geologic Units of the Paleozoic Age Ouachita System			

Footnotes: (1) Has numerous springs. Has numerous wells that are used for public supply and other purposes in the Park. (2) Outcrops found in the Chisos Mountains. (3) Has Oak Spring which is the source of public water supply for the Chisos Basin. (4) Formations having some of the oldest mammal fossils in Texas, including species that no longer exist, and fossils of the earliest horse, panther, hippos, tapir, camel and small deer. Some of these fossils are found also in the lower part of the Chisos Formation. (5) Includes the very small to very large outcrops of igneous rock intrusions which are estimated to be about mid Tertiary age and currently have numerous small springs. Also includes intrusive igneous dikes which are of later Tertiary age and are readily seen along the Ross Maxwell Scenic Drive. (6) Has dinosaur fossils and large petrified wood trunks and stumps. (7) May supply water to some of the Park's wells. (8) Subdivided into the upper San Vicente Member and lower Ernst Member.

Please refer to Geologic Section VII above which is intended to help you understand the following discussions of the Park's Cretaceous and Tertiary geologic history.

Cretaceous Geologic History of the Park- The geologic history of the Park for our purposes started about 135 million years ago at the beginning of the Cretaceous/Comanchean. At that time the surface of the Park area consisted of the highly eroded and distorted geologic units of the Ouachita System of Paleozoic age. The basal Cretaceous rocks of the Trinity Group (Glen Rose Formation) were deposited along the shoreline of a northwest advancing sea. Eventually the Glen Rose sediments covered the underlying rocks of the Ouachita System. This period of deposition was followed by a clearer and much deeper sea in which great thicknesses of limestone and some shales, marls and clays of the Fredericksburg and Washita Group were deposited. During the early Upper Cretaceous/Gulfian, limestone and mudstone deposits of the Boquillas and Pen Formations covered the Washita Group's Buda Formation. This deposition was followed in the middle Upper Cretaceous/Gulfian by continental drift and uplift which caused the sea to withdraw, and dense forests covered most of the landscape. Some depressions had marshes with ferns, mosses, canes and water-loving trees. This was the time of the dinosaurs and other reptiles represented by fossils in the Javelina Formation. The Upper Cretaceous/Gulfian was abruptly ended by the impact of a large asteroid which smashed into the earth in the southern Gulf of Mexico and northern Yucatan. This event caused the climates of much of the earth to drastically change including the climate of southern and middle North America. This caused the demise of the dinosaurs and other Cretaceous reptiles and some marine life such as ammonites. Also the end of the Cretaceous in North America witnessed uplift and mountain building. The Big Bend area lies between two of these mountain ranges; the Rockies and the Sierra Madre range of Mexico. During this great uplifting of the earth's crust, the Park area's rocks were folded, faulted and fractured and the ridges of the Santiago and Mariscal ranges and the lower ridges along the northwest trending belt through the Chisos Mountains were formed.

Tertiary Geologic History of the Park and Vicinity- Earth movements in and near the Park area caused early Tertiary erosion and later deposition of sand, gravel and conglomerate deposits (Canoe Formation). Starting about 42 million years ago (mya), the Park and adjacent areas were a very dangerous part of west Texas and northern Chihuahua having periodic large and extensive volcanic eruptions and intrusions of small to large igneous rock bodies which uplifted the Park and adjacent areas. These periods of extrusive and intrusive igneous activity were intermingled with long periods of weathering and erosion. Today the remaining volcanic deposits within the Park are the South Rim Formation and the Chisos Formation, and numerous exposed igneous intrusions; all of which are indicated on Geologic Section VII (see footnotes 2, 3 and 5). During the 20 million years, The Park and vicinity in Texas and northern Chihuahua had nine volcanoes and numerous volcanic vents. The volcanoes which are now extinct and represented by calderas include Pine Canyon (in the Park southwest of the Chisos Basin), Sierra Quemada (in the Park northeast of the Chisos Basin), Christmas Mountain (just northwest of the Park), Solitario (in the eastern part of the Big Bend Ranch State Park), Bofecillos (in the northern part of the Big Bend Ranch State Park), Paisano (between Marfa and Alpine), Buckhorn (north of McDonald Observatory in the Davis Mountains), San Carlos (in Chihuahua west of the Park) and Santana (in Chihuahua west of the Park). The area also had numerous volcanic vents which are represented by Burro Mesa, Goat Mountain and Cerro Castallan within the Park. The specific geologic history of the Tertiary age volcanism and igneous

intrusions that occurred in and adjacent to the Big Bend National Park is provided in the following discussions.

42 Million Years Ago – Volcanic Activity- The Christmas Mountain Volcano northwest of the Park erupted due to massive uplift and faulting and fracturing of the bedrock above a large and deep subsurface magma body. There were very massive outpourings of various lavas over the Park and vicinity. These extrusive flows are the oldest volcanic rocks found in the Big Bend area.

38 Million Years Ago – More Volcanic Activity- Between about 38 to 32 mya the Park area had a series of volcanic eruptions initially by the Sierra Quemada volcano and later by the Pine Canyon volcano, other volcanoes, and the Burro Mesa, Goat Mountain, Cerro Castallan and other volcanic vents within the Park and vicinity. Long periods of weathering and erosion occurred between periods of volcanic eruptions. These cycles were repeated numerous times during about 6 million years. Life occurred but was displaced by eruptions in many areas of the Park and vicinity. Over several of these cycles, volcanic eruptions continued and were accompanied by igneous intrusions which uplifted the Park and adjacent areas. These uplifted areas were covered by volcanic flows. The flows and the igneous intrusions were exposed by long periods of weathering and erosion. Examples of prominent igneous intrusions ("frozen magma chambers") that were exposed and occur at the current surface of the Park include Maverick Mountain, Grapevine Hills, Nugent Mountain and Pulliam Ridge.

26 To 22 Million Years Ago – Basin and Range Development and Igneous Dike Intrusions- The extreme movements and pressures of continental drift and related subduction from west to east caused great deformation(faulting and fracturing) of the earth's crust in the region including in and adjacent to the Park area. A very large block of the earth's crust between the current cliff (fault scarp) at Santa Elena Canyon and the current cliffs (fault scarps) of the Sierra Del Carmen in the Boquillas Canyon area abruptly dropped downward along the major faults. Also faulting and fracturing occurred throughout the Park's sunken block. This allowed igneous intrusions to enter the faults and fractures in the subsurface geologic units beneath the Park's sunken block. These igneous intrusions and much of the overlying and adjacent geologic units within the sunken block were then eroded away and some of the intrusive igneous rocks that filled the faults and fractures were exposed. They appear today on the surface of the Park as igneous dikes. Examples of such prominent igneous dikes can be observed parallel to and across the Ross Maxwell Scenic Drive in the western part of the Park.

FIRST DAY VISIT IN PARK- After having breakfast if we have time within the Chisos Basin, you might want to check out the Chisos Basin's famous Window which is a gorge or canyon for drainage of rainfall run-off from the Basin. The peaks on the sides of the gorge are igneous rock intrusions of Tertiary age (see Footnote (5) in Geologic Section VII). The Window allows a magnificent far distant view of Burro Mesa, the Terlingua Creek valley, and other distant terrane of the Park. The view is especially nice during colorful sunsets which we may be able to see later today.

Again after breakfast, we will travel by bus to and down the Ross Maxwell Scenic Drive on the western side of the Park. During the trip you may want to refer to Geologic Section VII. Our first place of interest will be the Sotol Vista Outlook which will provide a very beautiful view of the Chisos Mountains, their western slopes, the Blue Creek valley and other small valleys with western drainage to the Rio Grande. At the Outlook you are on a high lying terrace outcrop of Quaternary-Tertiary age conglomerate and sandstone. You are viewing the South Rim Formation along Blue Creek valley in the foreground, and the Chisos Formation and the Cretaceous-Tertiary igneous rock intrusions in the Chisos Mountains. The Chisos Formation is also on the slopes toward the right (west), and is highly faulted and fractured having shallow drainages with numerous small springs. You can see Santa Elena Canyon in the far distance to the west (right). Our next special feature will be down the Scenic Drive at the Mule Ears Overlook where you will view Mule Ears Peak which is an unusually eroded igneous rock intrusion called a "stock" or a large igneous eroded "plug." We will then travel on and have a rest stop at the Castolon Historic District which was established as a US Cavalry camp in the early 1900s during the Mexican Revolution. It later served as the headquarters of the La Harmonia Company which provided supplies to area farmers and ranchers including those across the Rio Grande in Mexico. Castolon has a visitors center and a store, and the Cottonwood Camp Ground nearby. After we visit Castolon, we will then travel to a location to view Santa Elena Canyon which should give you excellent photo opportunities. The Santa Elena Canyon was formed by the Rio Grande which during millions of years of uplift, gradually eroded a 1,500 feet vertical

chasm through the various limestone beds of Cretaceous-Comanchean age. The eastern facing cliff or fault scarp was formed on the upthrown side of the large vertical movement by the Terlingua Fault. By referring to Geologic Section VII, the Glen Rose Formation will be at the bottom of the scarp and along the river's edge. The following formations are exposed in the canyon and on the great fault scarp (cliff) in ascending order above the Glen Rose Formation: the Telephone Canyon, the Del Carmen, the Sue Peaks and the uppermost Santa Elena; all composed of various beds of limestone. The Glen Rose and the Telephone Canyon Formations make up the lower slope ledges near the mouth of the canyon. The Del Carmen Formation is the lower steep massive limestone cliff above the Telephone Canyon. The Sue Peaks Formation is the vegetation covered slope above the Del Carmen, and the Santa Elena Formation is the upper steep massive limestone cliff. The plateau at the top of the Santa Elena on the Texas side of the Rio Grande is called "Mesa de Anguila" while the plateau on the Mexican side is called "Sierra Ponce." Soon after the view of Santa Elena Canyon is completed, we will have lunch, and then travel to the far eastern reaches of the Park to Boquillas Canyon.

Boquillas Canyon can be viewed from a special overlook. The canyon formed over millions of years as the land steadily rose and the Rio Grande eroded through the massive escarpment that forms the Sierra Del Carmen which is a large and extensive north-to-south mountain uplift that extends across the Texas and Mexico border in this eastern Big Bend area. Cretaceous-Comanchean age limestone geologic units from bottom to top consist of the Del Carmen Formation (lower cliff), the Sue Peaks Formation (shaley slope), and the Santa Elena Formation (upper slope and top).

Mariscal Mine- The mine is located at the northern end of Mariscal Mountain which is located in the southern part of the Park a far distance to the west from Boquillas Canyon. We will not be able to visit the mine site. The north end of Mariscal Mountain is the apex of an overturn, faulted fold exposing the Boquillas Formation of Cretaceous-Gulfian age. The ore is probably found along a fault between the folded Boquillas Formation and an igneous rock intrusion of Tertiary-Cretaceous age (see Geologic Section VII). The abandoned mine shafts are sealed and have grate openings that permit the entry of bats which use the mine shafts for sanctuary. The mine was used to obtain cinnabar which is an ore of mercury which is an important element used in the electrical parts industry and other high tech materials including thermometers. During war times mercury is considered a very strategic element. The mine operated primarily from 1900 to 1943. Approximately 1,400 flask of refined mercury (quicksilver) were produced using an onsite retort (furnace and extractor). A relatively small flask filled with mercury weighs about 70 pounds. The abandoned mine site can be visited, but the mines shafts cannot be entered because they are vertical and are very dangerous for explorations. Besides mercury is a very poisonous element.

Park Water Resources- Big Bend National Park has four public water supply systems using ground water (refer to Geologic Section VII and Figure 3). One system is at Park Headquarters at Panther Junction and has three wells completed in alluvial deposits. These wells can yield 8 to 18 gpm each and have tds of 201 to 279 ppm (very fresh water). Another water system is at the Cottonwood Camp Ground near Castolon and has three wells completed in the river alluvium; one of which yields about 30 gpm. The tds of the ground water at the Camp ranges from about 972 to 1,159 ppm (fresh to slightly saline). Oak Springs which flows from volcanic rock or an igneous rock intrusion, and which supplies water to the Chisos Basin was reported to flow about 120 to180 gpm of very fresh water having a tds of 216 ppm. The water supply at the Rio Grande Village is provided by a shallow well completed in alluvial deposits at a depth of 40 feet. The well produces fresh water having a tds of about 845 ppm. The Rio Grande Village has two springs which flow from unidentified Cretaceous-Comanchean age rocks. These springs have fresh water with a temperature of about 96 degrees F and a tds of 834 ppm. These springs supply water to a pond having rare Gambusia minnows. The Hot Springs in the channel of the Rio Grande upstream from the Rio Grande Village supply unusually hot waters. These springs issue from a deep source probably at a depth of about 2,000 feet, and probably from the Glen Rose Formation (see Geologic Section VII). At one time, the Hot Springs were used by bathers at a resort located nearby on the Texas side. Visitors to the Park and Mexicans still use the Hot Springs for bathing purposes. In 1985, the Park used 24.8 million gallons or about 0.068 mgd of fresh to slightly saline ground water from the alluvium and springs for public water supply purposes.

NOTE: We will leave the Boquillas Canyon area and return to the Chisos Basin Lodge to freshen-up. At that time we may be able to see a beautiful sunset through the "Window." Plans are to travel to Terlingua and have dinner and then return back to the Lodge.

STUDY BUTTE & TERLINGUA, BREWSTER COUNTY

Historically these towns owed their existence to the mercury (quicksilver) mining industry.

Study Butte- Mining here started in about 1900. A post office operated at Study Butte from 1917 to 1921. The town was named after Will Study the manger of the Big Bend mercury mine located near the town. Study Butte was attached by Mexican marauders during the Mexican Revolution in the early 1900s. In the 1940s, the town was supported by employment at the Rainbow Mercury Mine, and Study Butte had a school, a general store and miner's dwellings. After WW II, the town lost much of its population because the mine closed. However, the Diamond Shamrock Corp. reopened the mine in 1970, and the small town prospered again. By the time that the mine was shut down again in 1972, the Study Butte area became a place for retirees and a tourist center related to Big Bend National Park. In 1980 the town had a school, a new motel and scattered dwellings. In 1990 Study Butte had a population of 120. The town has an elevation of about 2,600 feet, and an average annual rainfall of about 10 inches.

NOTE: The Big Bend Motor Inn is the Study Butte community's overnight accommodation and has a desalination reverse osmosis (RO) plant that takes ground water from the Boquillas Formation (see Geologic Section VII) with a tds of about 3,000 ppm (moderately saline water), and provides about 0.041 mgd (41,000 gallons per day) of fresh water. Also the Study Butte Terlingua Water System which is a public water supply facility has a desalination RO plant that takes slightly saline ground water and provides about 0.035 mgd (35,000 gallons per day) of fresh water to customers in the Study Butte and Terlingua area.

Terlingua- The community of Terlingua has been located at different places. The original site was a Mexican village called Terlingua Abaja on Terlingua Creek about three miles from the Rio Grande. Cinnabar which is mercury (quicksilver) ore was discovered in that area in mid 1880s. By 1905, approximately 1,000 Mexican miners working in the Marfa and Mariposa Mines were enslaved and lived like animals by being chained in poor shelters overnight. The mines were closed in 1910, and the post office established in 1899 was moved eastward 10 miles to the Chisos Mining Company Camp, and a new Terlingua was started. The conditions improved for the miners and by 1913, Terlingua had a company owned commissary, a hotel, a doctor, sometime telephone service, a dependable water supply, and reliable mail delivery. The first Brewster County school was started in Terlingua in 1907. In 1930 the mining company erected a permanent school building. The community remained segregated with the Hispanics on the east side and the Anglos on the west side. By 1922, 40 percent of the quicksilver produced in the US came from the Terlingua District. In 1942 the Chisos Mining Company filled for bankruptcy. Eventually, Terlingua became a ghost town. During the 1960s and 1970s, Terlingua was reestablished by tourism related to Big Bend National Park, and retired persons who began to buy up land and settle in the area. The town became famous for the annual chili cook-off and in 1967 became "The Chili Capitol of the World." The former Chisos Mining Company store was reopened as a gift and art shop. Rio Grande float trips can be scheduled there. A dinner theater occupies the former motion picture theater. In 1994 Terlingua had 13 businesses and a population of 25. The town's elevation is 2,890 feet and its average annual rainfall is about 10 inches.

NOTE: The Longhorn Ranch Motel which is 10 miles north of Terlingua, has an RO plant that supplies desalinized water from feed water produced by water wells. The RO unit produces fresh water, and the "saline" effluent is blended with other fresher water and used for irrigation. The fresh water produced by the RO plant is blended with slightly saline well water and makes up the water supply for the motel and its facilities which include an outdoor swimming pool, a restaurant, a small convention hall and an RV park. The motel started using the RO plant in 1990. The RO plant's fresh water when blended with the well water provides a 0.023 mgd (23,000 gallons per day) water supply for the motel and its facilities.

LAJITAS, BREWSTER COUNTY

History- "Lajitas" is Spanish for "little flat rock" and refers to the flagstones of the Boquillas Formation which outcrops in the area and in the nearby Rio Grande crossing which is flat and

shallow all the way across. The Jumanos Indians first occupied the Lajitas area. They were replaced by the Apaches who were later replaced by the Comanches who used the Lajitas crossing of the Rio Grande on their War Trail into and back from northern Mexico which they raided and plundered. Americans first arrived and settled the area in the mid-1800s. The US Army's Emory expedition visited the Lajitas area in 1852. After the Terlingua quicksilver discovery, and after ranching and mining was safe in Mexico, Lajitas was made into a substation port of entry in the late 1890s. By 1912, farmers had settled and irrigated the Rio Grande floodplain and the town had a store, a saloon, a school that had 50 pupils, and a customhouse. H. W. McGuirk operated the store-saloon, managed the Terlingua Mining Company and funded a church and school. A Lajitas' post office operated off and on from about 1901 until its closing in 1939. McGuirk sold his holding to T. V. Skaggs who was a local farmer and was owner of a successful candelilla wax business in Lajitas. In 1916 because of Pancho Villa's raids and plunder of the Big Bend region, Gen. John J. Pershing's troops established a US Army Cavalry post in Lajitas. One of the Lajitas' motels stands on the foundation of the post. In 1949 Lajitas was purchased by Rex Ivey, Jr. who dug a well and installed a generator for electricity. In 1977 Ivey sold part of his property to Houston entrepreneur Walter M. Mischer who started development and restoration of the Lajitas community. In the mid-1980s, it was a resort town with 50 residence and 15 businesses, including 3 motels, a hotel, a restaurant, a golf course, a swimming pool, an RV park and an airstrip. Starting in 1995, Lajitas was being used to make movies, and TV's "Streets of Laredo", starring James Garner was filmed. All visitors who drink beer should buy at least one beer for Clay Henry, a famous Beer Drinking Goat at Bill Valentine's The Trading Post. Big Bend National Park and Big Bend Ranch State Park have helped Lajitas' tourist business grow. A Lajitas' visitors center and entrance to the Big Bend Ranch State Park is located at the Barton Warnock Environmental Education Center. An all day tour guide to the Park can be arranged and taken at the Center. A small commercial airline named Jet Services has flights to Lajitas from Dallas Love Field and Austin Bergstrom International. The population of Lajitas in 1990 was about 50. The elevation of the downtown area along Highway 170 is about 2,340 feet, and the average annual rainfall is about 10 inches.

Geology- Lajitas occurs on the outcrops of Quaternary alluvium and the Boquillas Formation which has been highly displaced and fractured by faulting. The highly fractured Boquillas flagstones of Cretaceous age are overlain by the Chisos Formation of Tertiary age (see Geologic Section VII).

Water Resources- Historically, Lajitas has used the Rio Grande as a water supply. Rex Ivey, Jr. completed the first water well (see above). In about 2000, several deep water wells were drilled and completed into the Santa Elena Formation at depths ranging from 983 to 1,160 feet (see Geologic Section VII). Three of the wells are used to irrigate a golf course, while two of the wells are used for public water supply purposes. The public water supply wells each yield about 250 gpm and have slightly saline waters having tds of about 1,300 ppm. The Lajitas Utilities Company, Inc. uses both surface water from the river and ground water from the two deep wells. In 2001, the Company supplied 24.3 million gallons or 0.066 mgd to its Lajitas customers. About 99 percent of the water supplied in 2001 by the Company was from the Rio Grande. The wells had just been put on line in October 2001.

TRAVEL FROM LAJITAS, BREWSTER COUNTY TO PRESIDIO, PRESIDIO COUNTY

We will leave Lajitas and travel west-northwest along the Rio Grande on Highway 170 toward Presidio. We will travel along Highway 170 which is known as the "Camino del Rio" through canyons, road cuts and the Rio Grande Corridor of the Big Bend Ranch State Park on the Texas side of the river. We will pass through the small community of Redford and by Fort Leaton State Historical Site. All three of these will be addressed in the following discussions before we reach Presidio.

BIG BEND RANCH STATE PARK

History- The Park is located along Highway 170 from near Lajitas to just southeast of Presidio at the Fort Leaton State Historical Site. Most of the Park is located in Presidio County with a small amount in Brewster County north of Lajitas. The Park is composed of more than 300,000 acres and is currently one of the 10 largest working ranches in Texas. The first rancher/settler in the area was Andres Madrid who raised sheep and goats north of Lajitas in the 1870s. Over the years, the ranching area was increased by consolidations by other settler/ranchers including the Woodworth,

the Bogel, and the Fowlke families. Eventually, Robert Anderson, Chairman of the Atlantic Richfield Company, bought the consolidated ranch which was run for him by the Diamond A Cattle Company of Roswell, New Mexico. Anderson and his partner Walter Mischer sold the ranch to the Texas Parks & Wildlife Department for $8.8 million in July 1988. The ranch was opened as a State Park in 1991. The Parks' visitor centers are located in Lajitas at the Barton Warnock Environmental Education Center and at the Fort Leaton State Historical Site in Presidio County. The Park is part of an international biosphere reserve which is a natural area recognized by the UN. It has 90 major archeological sites and 11 endangered species of plants and animals. The plants are representative of the Chihuahuan Desert and include the Hinckley's oak and the Big Bend-Harvard bluebonnet. About 400 birds live in or migrate through the Park. The local fauna includes western mastiff bats, beaver, golden eagles, peregrine falcons, mule deer, mountain lions, black bear, tree frogs, spade foot toads, Trans-Pecos copperheads, Chihuahuan horse-lubber grasshoppers, and tarantulas. The Park has 32 miles of multiuse trails, one unimproved primitive campground, a 30 mile unimproved Rancheria Canyon-Leon-Panther Canyon trail, and all-day guided bus tours from both visitors' centers in Lajitas and Fort Leaton State Historical Site. The Old Ranch Headquarters landing strip near the center of the Park has an elevation of 4,240 feet. The highest mountain is Cienega Peak with an elevation of 5,227 feet in the northern most part of the Park. The Park's range in average annual rainfall is 10 inches in the south along the Rio Grande to 12 inches in the northern most part.

Geology- The very detailed description of the geology of the Big Bend Ranch State Park is available in the UT Bureau of Economic Geology's Guidebook No. 27, "Geology of Big Bend Ranch State Park, Texas" by Christopher D. Henry. A copy is available on the bus for your review. The Park's most noted geologic features are the Solitario Dome and the remnant of the Bofecillos Volcano. Unfortunately, we will not visit the Park's interior to see these features which may be seen by taking the Park's guided bus tour. We will travel from Lajitas on Highway 170, the "Camino del Rio" through the beautiful canyon and Rio Grande "corridor" and view various side canyons and terrane having outcrops of the various sedimentary and volcanic geologic units within the Park. All the features in the following discussions will be seen ahead or on the right side of the bus.

Soon after we leave Lajitas, we will pass Lajitas Mesa with the volcanic Chisos Formation, enter Contrabando Canyon (side canyon) having Cretaceous formations highly faulted and intruded by Tertiary igneous rocks, and then back on the Chisos Formation. Further on we will see the Santana Mesa which is topped with the Santana Tuff, a volcanic flow. We will then pass the base of Santana Mesa by a roadcut of Tertiary igneous intrusive rock, and enter a faulted valley with mesas on each side of the river which are topped by volcanic flows of the Santana Tuff. When we reach Redford, we will be traveling on the Redford Bolson which is a deep subsurface basin filled with Recent, Quaternary and Tertiary age alluvium composed of clay, silt, sand and gravel. The deep part of the basin may have Tertiary age volcanic intrusions and flows.

Water Resources- The Park has several water wells and numerous springs which supply water to Park staff and visitors, the livestock of the working ranch, and the Park's abundant wildlife. Most of the wells are completed in water-bearing volcanic rocks which also have most of the springs.

REDFORD, PRESIDIO COUNTY

History- The small community of Redford is located in Presidio County on Highway 170 near the Rio Grande, and is about 16 miles from the town of Presidio. The original name of the community was "El Polvo" which is Spanish for "the dust." The community was founded in 1876, and it did not get a post office until 1911. By 1914, Redford had 4 general stores. In 1970, the town had a church, several dwellings and a population of 107. It also had a school as part of the Marfa Independent School District. In 1979, Mrs. Lucia Rede Madrid a retired school teacher opened a school library in her store. The store eventually closed, but still has the library and a museum. Hispanic population dominates the Redford community which is linked with a town nearby in Mexico named Mulato. The elevation of Redford is 2,520 feet, and the community receives an average annual rainfall of 10 inches. Redford's population in 2000 was 132.

Geology- The community of Redford lies on the surface of the Redford Bolson which is a deep alluvial filled subsurface basin that was formed by Tertiary age faulting and subsidence and filled with Tertiary, Quaternary and Recent age alluvium composed of clay, silt, sand and gravel. The deepest rocks of the basin may be Tertiary age volcanic flows and/or igneous intrusions.

Water Resources- Redford's water supply is provided by numerous, private household wells completed in the water-bearing alluvial deposits of the Redford Bolson.

FORT LEATON STATE HISTORICAL SITE, PRESIDIO COUNTY

History- The Spanish established and operated "El Fortin" (the fort) at the site from 1773 to 1810. Its actual name was El Fortin de San Jose a La Junta. The Fort Leaton State Historical Site (Site) is located on the south side of Highway 170 in Presidio County about 5 miles southeast of the town of Presidio. In about 1848 after the Mexican War, Ben Leaton and his family established their dwelling on the old "El Fortin" site after he purchased it from Juan Bustillos. Ben Leaton had been a notorious scalp hunter for the Mexican government, probably even through the Mexican War. Leaton's building was not only completed as a dwelling, but as a private fortification (Fort Leaton) and as Leaton's trading post. A stockade was included within the fortification which had thick walls with large gates so that wagons could enter during hostile Indian threats and attacks. Leaton farmed the area producing vegetables and wheat which were irrigated with water from the nearby Rio Grande. In August 1848, Jack Hays, a famous Texas Ranger and his group of rangers stayed in Fort Leaton during their west Texas expedition to help establish a San Antonio-Chihuahua Road through El Paso. Leaton's fortification was a much needed and used Texas frontier defense from hostile Indians, Mexican bandits and comancheros. After his fort was completed, Ben Leaton was friendly with and traded with the Comanches and Apaches. In fact he was accused by the Mexican authorities of trading guns to the Comanches and Apaches for their horses which they stoled during their raids into northern Mexico. Before he could be legally confronted by the Mexican government, Leaton died in 1851. Eventually, Mrs. Leaton sold the property to John Burgers who was killed by Ben Leaton's son in 1875. Before Fort Davis was built, the US Army made Fort Leaton its unofficial west Texas headquarters. After Fort Davis was completed, Fort Leaton was used as a US Army outpost. The CCC in 1934-35 restored some of the old Fort Leaton property. In 1967, the Texas Parks & Wildlife Department acquired 5 acres on the old fort site and established the Fort Leaton State Historical Site which was opened to the public in 1978. Today the Site has a visitor's center and is used as the western visitor's center for and entrance to the Big Bend Ranch State Park. All-day, guided bus tours of the Park can be taken from the Site. The elevation of the Site is about 2,580 feet, and it receives about 10 inches of rainfall per year.

Geology- The Site occurs on the surface of the southern portion of the Presidio Bolson which is a large and very deep subsurface trough or basin filled with Recent, Quaternary and Tertiary age alluvial deposits of clay, silt, sand and gravel. The intermediate to deep depths of the Bolson may have Tertiary age volcanic rocks and/or igneous intrusive rocks intermingled with the alluvial deposits.

Water Resources- The Sites water supply is probably ground water from well (s) completed in the shallow water-bearing alluvial deposits of the Presidio Bolson.

PRESIDIO, PRESIDIO COUNTY

History- The town of Presidio is located on the Rio Grande at its junction with the Rio Conchos which flows from the mountainous terrane of northern Mexico. Today the Rio Conchos is the contributor of practically all of the flow of the Rio Grande below Presidio. Presidio's sister city is Ojinaga, Chihuahua, Mexico which is immediately across the Rio Grande from the town. The Presidio area in Texas is the oldest continuously cultivated area in the US. The area has been so used by farmers for many centuries since about 1500 B. C. In the late 1400s and early 1500s A. D., the Jumanos lived in settlements which the Spanish called pueblos. The Spanish Christianized some of the Jumanos who named the area"La Navidad en Las Cruces" based on a vision of one of their chiefs. The first Spaniard to visit the area was Cabeza de Vaca and his companions. In December 1582, Espejo and his group of explorers, soldiers and Catholic monks visited the Presidio area and named the pueblo "La Junta de Los Rios" after the junction of the Rio Conchos and the Rio Grande. In 1760, the Spanish established a military garrison and a penal colony in the Presidio area. The name changed to Presidio del Norte in 1830. Anglo settlers came to the Presidio del Norte area in 1848 after the Mexican War. One of the first settlers was John Spencer who was a noted horse rancher. Ben Leaton and Milton Faver built private forts in the area. The Comanches raided and almost destroyed Presidio del Norte in 1849 and stoled most of the area's horses and cattle in 1850. Presidio obtained a post office in 1868 and a public school in 1887. During the Mexican Revolution

Pancho Villa used Ojinaga as a base of operations and "visited" Presidio. He fought a battle at Ojinaga with the Mexican Federalis. Presidio was incorporated in 1930 when the Kansas City, Mexico & Orient Railroad reached Presidio. Eventually, this railroad would be connected with the Chihuahua Pacifico Railroad in Ojinaga which headed westward to Cuidad Chihuahua, Copper Canyon and the Pacific coast of Mexico. Presidio had a 2000 population of 4,167, and is composed of a Hispanic majority. The town's elevation is 2,580 feet above sea level, and its average annual rainfall is about 10 inches.

Geology- Presidio lies on the surface of the Presidio Bolson which is a large and very deep subsurface trough or basin filled with Recent-Quaternary-Tertiary age alluvial deposits of clay, silt, sand and gravel. The deep parts of the basin may have Tertiary volcanic flows and igneous intrusions within the alluvial deposits.

Water Resources- The town of Presidio has wells completed in the fresh to slightly saline water-bearing deposits of the shallow river alluvium of the Presidio Bolson Aquifer. In 1985 the Presidio Water Supply Corporation which supplies water to the town of Presidio used 3 wells that supplied 112.9 million gallons or about 0.309 mgd. In 2002, the Presidio Water Supply Corporation's water supply wells pumped 286.4 million gallons or about 0.785 mgd from the river alluvium of the Presidio Bolson Aquifer.

SHAFTER, PRESIDIO COUNTY

History- The very small community of Shafter and the nearby associated silver mines are located about 17 to 18 miles along Highway 87 north of Presidio. The Spaniards prospected and probably mined some of the silver in the area. Shafter community became a mining town in 1880 after John Spencer a wagon master and noted horse rancher discovered and sampled silver ore in the area. The community was named after Col. William Shafter an officer stationed at Fort Davis who had Spencer's ore samples assayed. Later Col. Shafter and a group of investors purchased the land having the silver ore body from the State of Texas. In 1882, the group leased the property to a California mining group that formed the Presidio Mining Company which eventually purchased the property and mines. They continued to mine the silver and associated lead. During the 1880s, the silver ore deposits were valued at $45 per ton. In 1884, the Company hired more miners and installed milling machinery to process the silver ore. The town of Shafter located just northeast of the mines which are located in the southern part of the Chinati Mountains prospered and grew due to the mining personnel and operations. The Company hired 300 miners including mostly Mexicans and black Americans who found the wages very attractive, especially for far west Texas. Miners lived in Company houses, shopped at the Company store, and used Company doctors. In about 1900, Shafter had 2 saloons, a dance hall, and a school. During the 1920s and 1930s, the mines closed and reopened several times. Presidio Mining Company finally sold the mines to the American Metal Company in about 1928 with little change in mining operations. The mines closed in 1942, but Shafter still prospered having 12 businesses that served the US military that stationed troops during WW II at Marfa Army Air Field and Fort D. A. Russell in the Marfa area to the north of Shafter. Shafter's population and economy declined drastically after WW II. The population was about 20 in 1949. Today the abandoned mine sites still exist and the town is considered a ghost town with very few residence in the area. The elevation of the Shafter townsite is about 3,840 feet, and the area receives about 11 inches of rainfall per year.

Geology- The Shafter townsite lies on the Cretaceous age Shafter Formation composed of limestone, sandstone, shale and marl. The mines are located in the mountainous area southwest of the townsite on the northwest and north side of Highway 67. The silver ore is found in deep mining shafts completed in the Permian age Mina Grande Formation which is a faulted and very fractured Permian age reef deposit of marine limestone and dolomite. The silver ore probably was deposited into the Mina Grande Formation by Tertiary age igneous intrusions that carried the silver minerals into the faults and fractures of the Permian reef millions of years ago.

Water Resources- The Shafter community area probably has private household and livestock watering wells completed in the water-bearing rocks of the Cretaceous age Shafter Formation and/or the nearby overlying volcanic Chisos Formation. There are no records that Shafter ever had a public water supply system. However, the mining companies may have had some wells that provided a water supply to the mining operations and the miners and their families.

MARFA, PRESIDIO COUNTY

The city of Marfa was made the county seat of Presidio County in 1885, and is located at the junction of Highways 90 and 67. Marfa is located about 40 miles north of the ghost town of Shafter. The townsite was established in 1883 as a water stop for trains using the east-west Galveston, Harrisburg & San Antonio Railroad (now the Southern Pacific RR). The name Marfa was given to the townsite by a lady who got the name from the Russian novel, "The Brothers Karamazov." Marfa is one of the last towns settled in the remote Texas frontier of the Chihuahuan Desert. The town lies in the Marfa Basin between the Chinati Mountains to the south at Shafter and the Davis Mountains to the north at Fort Davis. In 1885, Marfa had 2 saloons, a hotel, and the Humphris & Company General Store which had a bank, the post office (established in 1883) and a café. Bets in the saloons' poker parlors often were made with deeds to town lots. The Marfa rail stop was used a lot by travelers to west Texas, including merchants and salesmen that used the stop to visit the town and catch stagecoaches to visit Shafter, Presidio, Fort Davis and Valentine. The Presidio County courthouse which was built as 3 stories in the Renaissance-Revival Style, cost the county $60,000. By 1886, Marfa acquired churches, a school, and a newspaper, the *New Era* which later became the *Big Bend Sentinel.* By 1900 the town had grown to 900, and had literary clubs, fraternal groups, telephone service, and another bank. During the Mexican Revolution, Marfa and the Big Bend communities were protected by the US Army units including a cavalry unit and a biplane recon flying unit. The military eventually established Fort D. A. Russell which was located in the southwest part of town. During WW II, the US Army stationed a chemical warfare unit, established and operated a prisoners of war camp, and started an advanced flight-training base, Marfa Army Air Field at and near Marfa. In 1945, the presence of the military made the population about 5,000. The closing of the military facilities at and near Marfa ended an economic and cultural era for the town. The "Mounted Watchmen" of the Federal government were established and combated liquor smugglers during the prohibition era. Today Marfa has US Border Patrol staffs and facilities to protect the country from drug smugglers. Interesting tourist and visitors facilities in and near Marfa include Capote Falls, the Ruidosa Hot Springs Resort, the Shafter Ghost Town, Big Bend National Park, Big Bend Ranch State Park, Ojinaga Mexican Markets, The Marfa Lights, the Chinati (Art) Foundation, the Judd (Art) Foundation and the Lannan (Writers) Foundation. The city of Marfa celebrated its 100th birthday on March 5-7, 1983. Marfa had a 2000 population of 2,121. The town's elevations are about 4,700 feet to 4,830 feet, and it has an average annual rainfall of 12 inches.

<u>Geology-</u> The City of Marfa lies on a relatively thin layer of Quaternary alluvium composed of silt sand and gravel of various sedimentary and volcanic rock materials. The thin alluvium is underlain by the volcanic igneous rocks of the Perdiz Conglomerate which is a silty to very sandy conglomerate composed of volcanic rock pebbles, cobbles and boulders. The Perdiz is underlain in the deeper subsurface by the Petan Basalt composed of greenish gray and brownish gray fractured volcanic basalt. The Perdiz Conglomerate and the Petan Basalt are water-bearing and contain very fresh ground water of the Igneous Aquifer in northern Presidio County.

<u>Water Resources-</u> The City of Marfa has several wells used for public water supply purposes. These wells completed in the Perdiz and Petan water-bearing formations of theIgneous Aquifer yield 700 to 1,000 gpm of very fresh water with tds less than 300 ppm. In 1985. the City of Marfa's wells supplied about 328.6 million gallons or about 0.900 mgd of ground water to its customers. In 2002, three city wells supplied 208.3 million gallons or about 0.571 mgd of ground water to the city's customers. The peak water use in 2002 was about 0.934 mgd in June of 2002.

ALPINE, BREWSTER COUNTY

Alpine is located in northern Brewster County in a valley of the Davis Mountain foothills. Cattlemen lived in camps near the current townsite between 1878-1882. Eventually one of the camp sites was selected as a railroad worker's camp which was located at a spring at the foot of "A Mountain." Historical documents indicate that there was a spring in the northeast Alpine area that had three more recent names including "Burgess, Kokernot, and San Lorenzo Spring." The spring was possibly visited by Cabeza de Vaca in 1535, and definitely used by Juan de Mendoza in 1684. In 1845 it was used as a "watering hole" by travelers using the old trail from Chihuahua to El Paso to San Antonio to the old Texas' Port of Indianola. Documents indicate that the flow of the spring was about 224 gpm in 1929. The spring is currently dry and has not flowed since about 1957. The

railroad camp at the spring was named "Osborne," and was used later as the name for a permanent settlement. The railroad company and the site's landowner, the Murphy family, finally made a deal to let the railroad use the spring as a water supply for their engines, and in turn the community was named Murphyville which was platted as a town in November 1883. The town was eventually renamed Alpine in February 1888 which was the same year a post office was established in the townsite. At that time, Alpine had 12 dwellings, 3 saloons, a hotel, a rooming house, a livery stable, a butcher shop, and a drug store which also served as the post office. In 1921 the University System established Sul Ross State University at Alpine. Due to paved roads, the university, ranching, good city services, and the transcontinental Southern Pacific Railroad, Alpine became a prosperous, well noted and popular west Texas town. Alpine became the entrance town to the Big Bend National Park and later to the Big Bend Ranch State Park. It became and still is a very popular area for the settlement of retirees. Alpine has an Amtrak station, is crossed by Highways 90, 67 and 118, has convenient financial institutions and one of the best medical service facilities in west Texas. The 1904 population was 396. In 2000, Alpine had a population o 5,786. The elevation of the city is 4,480 feet above sea level (not including Alpine Hill and Hancock Hill which are much higher). The City of Alpine receives about 15 inches of rainfall per year.

Geology- Most of Alpine lies on Quaternary age colluvium which is a relatively thin, loosely bedded geologic unit composed of angular, very poorly sorted rock material of sand, gravel, pebbles, cobbles and boulders; all of which were eroded from the various extrusive volcanic and intrusive igneous rock units of the southern Davis Mountains and the foothills at and near Alpine. The thin bedded colluvium in most of the city is underlain by the Tertiary age Crossen Trachyte which is a massively thick bedded, extrusive (flow type) volcanic rock unit composed of various mineral grains and crystals associated with volcanism, including fine to medium grained crystals of quartz and feldspar which are inbedded within a very fine grained groundmass of other extrusive volcanic minerals. Hancock Hill on the northeast side of Alpine consists of a very thick and prominent outcrop of the Crossen Trachyte. Some of the rock material in the Quaternary colluvium was eroded from the Crossen Trachyte. Alpine Hill which is a prominent hill located on the south side of the city, is a late Tertiary age intrusive igneous plug which was intruded through the Crossen Trachyte and older, underlying, subsurface, volcanic and sedimentary geologic units. Some of the Quaternary colluvium was eroded from this late Tertiary intrusive igneous rock. The Crossen Trachyte is ground-water-bearing, but can not yield adequate amounts of water for the public water supply system needed for the growing City of Alpine.

Water Resources- The first water supply for Alpine was the spring mentioned above in the History section. For many years, it was very difficult for a growing Alpine to meet its demand for a reliable public water supply. For years prior to the mid 1950s, adequate water was supplied by the spring and later by about 10 wells scattered within and near the city. But during the mid to late 1950s, Alpine started to grow mush faster and to this day it is still growing. Under these conditions, Alpine since about 1954 has completed about 12 more wells in three well fields located in, near and far from the city. One well field is located in southern Jeff Davis County. All of Alpine's wells are completed in the Tertiary age Igneous Aquifer which in some areas also includes water-bearing Quaternary age alluvium. The wells completed in the three well fields have individual yields ranging from 40 to 500 gpm and produce very fresh ground water. Most of Alpine's wells produce ground water having tds concentrations which are less than 300 ppm. In 1985, the City of Alpine's wells produced 475.1 million gallons or about 1.302 mgd of very fresh water for its customers. The city's wells supplied 570.4 million gallons or about 1.563 mgd of fresh water to about 2,200 customers in 2001.

FORT DAVIS (THE FORT & THE TOWN), JEFF DAVIS COUNTY

History of The Fort- Fort Davis was planned by the Secretary of War, Jefferson Davis in 1854 to be located on Limpia Creek on land leased by John James a pioneer west Texas surveyor. The site was personally selected in the field by Gen. P. F. Smith (US Army Commander of the Department of Texas) because it had "pure water and salubrious climate." He named the location Fort Davis after Jefferson Davis. Gen. Smith's statement about "pure water" was because the site he selected had a spring which later was named Fort Davis Spring, and which was located in the well-known Painted Comanche Camp area of the fort's grounds. During the use of Fort Davis the Army initially used water that was hauled from a place on Limpia Creek about 2 miles north of the fort. Later the fort used water from the spring located within the fort's grounds for drinking, for watering horses and

livestock, and for irrigation of a garden. The spring water eventually caused dysentery among the troops and was not used for drinking. Water for drinking had to be hauled again from Limpia Creek. The spring water was probably polluted by the waste produced by the troops and the horses and livestock which occupied the fort's grounds. The purchase by the US of the Gatsen Purchase territory from Mexico after the Mexican War, the fast growing settlement of west Texas, and the gold rush of potential prospectors to California required several forts be built in west Texas, including Fort Davis. The chain of forts in west Texas were established to protect, surveyors, settlers, travelers, stage and mail coaches and wagon trains from the hostile Comanches, Apaches and other Indians. Six companies of infantry under the command of Lt. Col. Seawell initially built and garrisoned Fort Davis at the spring and Painted Comanche Camp and near Limpia Creek in October 1854. Fort Davis was abandoned by the US Army during the Civil War. It was occupied by Confederate cavalry for about a year until they failed to conquer New Mexico for the Confederacy. After that the Indians used the fort grounds as their camp, and greatly damaged the wooden fortifications by using the wood for camp fires. The Fort Davis was not reused by the Army until June 1867 when Lt. Col. Wesley Merit and his troops constructed a new post with quarters for 600 troops. From 1867 to 1885, Fort Davis was used by Army units composed of white officiers and black enlisted men who were called "Buffalo Soldiers" by the Indians. They served from Fort Davis with distinction, bravery and honor in the 9th and 10th US Cavalry Regiments and the 24th and 25th Infantry Regiments; controlling and combating the hostile, raiding Comanches and Apaches throughout the Trans-Pecos. The "Buffalo Soldiers" in 1879 fought and drove the Apache Chief Victoria and his band of hostile Mescalero Apaches from the Trans-Pecos into northern Mexico. Victoria was killed by the Mexican Army in October 1880. After that the soldiers at Fort Davis spent their duty time drilling, patrolling, repairing roads and maintaining telegraph lines in the Trans-Pecos. Fort Davis was officially closed by the Army in 1891.

History of The Town- Fort Davis is the highest town in Texas at an elevation of 5,050 feet above sea level. Fort Davis is known as the town "where the stars come out to play," and is located as a town at one of the highest levels of the Chihuahuan Desert. Fort Davis is 355 miles from Austin, about 80 miles from Presidio and Ojinaga and about 220 miles from El Paso. The average annual rainfall is about 17 inches. The area and Fort Davis Spring was visited by the Spaniard explorer Espejo in 1582. Travelers on the Old Spanish Trail from San Antonio to El Paso to Chihuahua used Fort Davis Spring as a "watering hole." During the mid 1800s, Anglo Americans came and settled the area with most of them arriving after the Mexican War in 1846. Before Fort Davis was established in 1854, the community was known as "Painted Comanche Camp" because of the Indian art on the spring area's cottonwood trees. The town grew around Fort Davis, and when the fort closed in 1891 the town took the name. The town continued to support ranching and tourism to the Davis Mountains, including McDonald Observatory, Davis Mountain State Park, The Scenic Loop through and around the Davis Mountains, the Overland Trail Museum, and numerous guest ranches. The old fort was restored and opened to the public as Fort Davis National Historic Site in 1963. It is a popular tourist attraction supporting the town's economy. Also the Chihuahuan Desert Visitor Center is a popular research facility nearby having an excellent native desert plant display and a sidewalk explanation of the surface and subsurface geologic units of the Trans-Pecos-West Texas Region.

Geology- The geologic units of the fort and the town can be best seen on the Fort Davis National Historical Site with the flat area having Quaternary age alluvium and colluvium at the land surface with the parade ground and various fort buildings, and the steep cliff composed of three extrusive volcanic geologic units. The base of the cliff has a narrow outcrop of volcanic rock called the Frazier Canyon Formation which is an extrusive volcanic, variously colored crystalline tuff flow. It is probably the water-bearing geologic unit that is the Tertiary age Igneous Aquifer providing ground water to the public water supply wells used by the fort Site and the town of Fort Davis. The Frazier Canyon is overlain by the cliff forming, extrusive volcanic unit called the Sleeping Lion Formation composed of a dark reddish brown, ash-flow tuff which by weathering and erosion developed prominent vertical columnar shaped joint blocks. The Sleeping Canyon is overlain on the very top of the ridge above the cliff and at the western boundary of the Site by the Barrel Springs Formation which is composed of a fine grained extrusive volcanic vitric tuff and a porphyritic rhyolite.

Water Resources- Both the town of Fort Davis and the Fort Davis National Historical Site are provided public water supplies by two wells owned and operated by the Fort Davis Water Supply Corporation. The wells are completed in and produce very fresh ground water from the water-

bearing, porous, volcanic crystalline tuff of the Frazier Canyon Formation which is part of the Tertiary age Igneous Aquifer. In 1985, the Water Supply Corporation's wells produced and supplied 53.5 million gallons or 0.152 mgd of very fresh water to the fort and the town's customers. The Corporation's wells produced and supplied 76.9 million gallons or about 0.211 mgd of very fresh water in 2003 to the fort and the town. The peak water use for the system was 8.201 million galloons or about 0.265 mgd in August 2003.

McDONALD OBSERVATORY, JEFF DAVIS COUNTY

The McDonald Observatory (MO) is located on Mount Locke, the top of which has an elevation of 6,810 feet above sea level. The MO receives about 18 inches of average annual rainfall. The MO is near Fort Davis in Jeff Davis County, and is named after William Johnson McDonald who was a Paris, Texas banker. After his death, his will was contested but it was finally determined that UT would receive $850,000 for an astronomical observatory. Mr. McDonald's intention was to have such an observatory to help improve weather forecasting to help farmers plan and improve their production. At the time of his gift, UT did not have an astronomy faculty, so an agreement was completed with the University of Chicago (UC). UT provided the observatory and UC provided the astronomers. An observatory with an 82-inch telescope (at the time the 2nd largest) was completed and dedicated in May 1939. The 400 acres of the MO site was donated to UT by Mrs. Violet Locke McIvor and Judge Edwin Foulkes. Mrs. McIvor was the granddaughter of G. S. Locke whose name was used to appropriately name Mount Locke. The site on Mount Locke is ideal for an astronomical observatory because of minimal west Texas dust, no artificial light, and the climate which provides a great amount of crystal clear night skies. Soon after the dedication in 1939, a symposium of the world's leading astronomers was held at the MO. The MO operated during WW II and had visits by world famous astronomers some of which had fled from Europe to the safety of the US. In September 1963 after UT established an astronomy department, Harlan J. Smith of UT took over as the first UT Director of the MO, and a faculty of UT astronomers started using the MO with their ideas of how to proceed with research of the universe. Besides the 82-inch telescope, MO has a 36-inch reflector, a 107-inch reflector, a 30-inch lunar laser ranging reflector, a 16-foot radio dish and the Hobby-Eberly Telescope. The MO has these instruments for a wide varity of research of the universe. We will receive an up-to-date lecture on the MO's establishment and its capabilities which will be given by a MO staff member. Later if the late night sky is clear, we will attend a MO "star party."

Geology- The following volcanic extrusive geologic units top Mount Locke in a large upthrown fault block. A very small outcrop of the Wild Cherry Formations lies at the apex of the mountain. It is composed of a fine grained vitric tuff and a foliated black rhyolite. Underlying it is the Mount Locke Formation which is composed of very weathered quartz trachyte and rhyolite porphyry. Just southwest of the apex of the mountain and underlying the Mount Locke Formation is the Barrel Springs Formation composed of fine grained vitric tuff, rhyolite and black foliated vitrophyre.

Water Resources- McDonald Observatory (MO) was supplied water by an old deep well located near the visitor's center. The well eventually caved in and could not produce any water. The MO currently has two public water supply wells on the McIvor Ranch several miles south of the MO on the west side of Highway 118. These well are 525 and 550 feet deep and are located in the Limpia Creek Valley. The wells produce water from the Tertiary age Igneous Aquifer. They have very low yields, but produce very fresh water with tds concentrations less than 200 ppm.

BALMORHEA (THE TOWN AND STATE PARK), REEVES COUNTY

History of the Town- Balmorhea is located in southern Reeves County along Toyah Creek and Sandia Creek, and is near IH 10 and the communities of Toyahvale, Brogado and Saragosa. The Balmorhea area has San Solomon Springs which flows into Sandia Creek, and served for many thousands of years as the "watering hole" for prehistoric man and the later migrating native Americans tribes of the Trans-Pecos Region. The first settlers in the area were Mexican farmers who used the springs as a source of water for irrigating the rich alluvial soils along and adjacent to Toyah and Sandia Creeks. The first white settlers called San Solomon Springs "Mescalero Springs" because the Apaches watered their horses and temporarily camped in the spring area. The Anglo settlers built an irrigation canal system, and used the flow of San Solomon Springs and other

upstream and downstream springs along Sandia and Toyah Creeks as a water supply for the irrigation of upto 14,000 acres. The town of Balmorhea was established in 1906 in the middle of the 14,000 acre tract. It got its name from three initial Anglo settlers with the last names of Balcum, Moore and Rhea. A post office and a school were established at Balmorhea in 1908. In 1911, the Pecos Valley Southern Railroad was completed from Pecos to Balmorhea to Toyahvale. Balmorhea had a 1930 population of about 1,220 and about 33 prosperous businesses. A Texas Agricultural Experimental Station was established nearby. This was all due to the successful results of using irrigation water from the area's springs for the cultivation of many needed and desired crops which were shipped by rail to other areas of Texas and New Mexico. But by the 1960s, the population of Balmorhea had declined to about 600 and there were only 19 businesses. The economy of the area is supported by the locals and tourist using Balmorhea State Park. The population in 2000 was 527. Balmorhea has an elevation of about 3,300 feet, and has an average annual rainfall of about 13 inches.

History of the State Park- The Balmorhea State Park was opened in 1968 by the Texas Parks & Wildlife Department. The Park has a very large and noted swimming pool which gets its very clear and cool water from San Solomon Springs. The Park's 46 acres was donated by local landowners and the Reeves County Water Control and Improvement District No. 1, which is the local entity that helped develop San Solomon Springs and the other springs for irrigation of the 14,000 acres. San Solomon Springs has been measured to flow 22 to 28 mgd through the Park's swimming pool. In the 1930s, the CCC built Spanish Colonial Style limestone buildings, wooden bathhouses, an adobe residence and San Solomon Courts (an early day motel) near the pool within the current Park's acreage. The CCC also constructed the large 77,000 square-feet swimming pool. The springs also furnish a continuous flow of clear, cool water to a "cienega" (wetland) and a refugium which are homes to endangered Gambusia fish, assorted invertebrates and turtles. The large swimming pool has other aquatic life including large catfish. The pool is large enough (3.5 million gallons) for numerous swimmers and scuba and skin divers. The Balmorhea State Park has convenient picnic and camping facilities, an elevation of 3,320 feet above sea level, and receives about 13 inches of rainfall per year.

Geology- The town of Balmorhea and the Park are mostly underlain by Quaternary age stream alluvium and colluvium with rock materials of various grain size, all the way from silt size to boulder size. An area north of Lake Balmorhea has outcrops of the Tertiary age extrusive volcanic rocks of the Huelster Formation composed of tuff with some nonmarine limestone beds, and the overlying Star Mountain Rhyolite having some quartz trachyte. South of Lake Balmorhea is an outcrop of the Cretaceous-Comanchean age Washita Group composed of limestone and marl. The Washita is underlain in the subsurface by the limestone strata of the Fredericksburg Group and the underlying Trinity Group ("Trinity Sands") (see Geologic Section V). These are the Cretaceous age water-bearing geologic units providing the flows to San Solomon Springs.

Water Resources- The town of Balmorhea historically has used both surface water from Lake Balmorhea and ground water from a well leased from a local landowner. In 1985, the town used only surface water from Lake Balmorhea. The amount of water used by the Balmorhea water system in 1985 was about 81.2 million gallons or about 0.222 mgd. In 2003, Balmorhea's water system used ground water provided by the leased well. The town pumped about 36.5 million gallons or about 0.100 mgd from the leased well. The town may have also used some unknown amount of surface water from Lake Balmorhea.