Central Texas Geology Trip

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INTRODUCTION

The rocks of the Texas Hill Country bear witness to the story of a dynamic and constantly changing Earth and reveal the existence of ancient mountains, inland seas, earthquakes, uplift, and power of water to dissolve hard rocks. The legacy of this complex history began more than a billion years ago and is represented by the rugged karst terrain of the Texas Hill Country, granite domes that poke above the landscape, scenic rivers flowing from the northwest to the Gulf of Mexico, crystal clear springs, a wealth of mineral resources, and the fossils of small organisms that flourished in ancient seas.

Traveling southeast from the Llano Uplift toward Austin, one crosses the Edwards Plateau. Composed of limestone that formed a carbonate platform in under a shallow ocean in the Cretaceous Period, the Edwards Plateau was uplifted during the region's complex geologic history. The Balcones Escarpment, an old fault zone, marks the eastern and southeastern boundaries of the Edwards Plateau. The Balcones Escarpment cuts across Austin and is the divide between east and west Texas.

In the Pleistocene Epoch in the late Cenozoic Era, numerous glacial and interglacial periods influenced the climate of Central Texas and made their mark on the landscape. Large mammals roamed the prairie grasslands of Central Texas during the Pleistocene Epoch. The fossil remains of a nursery herd of Columbian mammoths that likely met their demise in a flash flood event approximately 67,000 years ago are preserved at the Waco Mammoth National Monument, a paleontologic research site.

A watershed, or drainage basin, collects water from rain and snowmelt and funnels it downslope into waterways such as streams, which in turn convey the water to larger rivers, lakes, playas, wetlands, estuaries, or the ocean. Several large rivers traverse Central Texas as they flow to the Gulf of Mexico. They shape the land surface through physical and chemical weathering, erosion, transport, and deposition. The Colorado River, which flows through Austin, is the longest Texas River (1,387 km). In the Hill Country, a series of reservoirs on the Colorado River make up the Highland Lakes System. These reservoirs store water for use by people, businesses and industries, provide hydroelectric power, and offer recreational opportunities for boating, fishing, and camping.

Mount Bonnell

We begin the week with a stop at Mount Bonnell. This is excellent vantage point from which to look out over the landscape and for students to orient themselves in time and space as they practice basic map reading and field measurement skills. It is also a good spot to review the main physiographic provinces (Gulf Coastal Plains, Balcones Escarpment, Edwards Plateau/ Hill Country, Llano Uplift) and tectonic regions of Texas that students will learn about during the week. It is also provides the opportunity to introduce students to the major rivers of Texas.

The major rivers in Texas flow from the northwest (NW) to the southeast (SE). The Colorado River flows 862-miles (1,387 kms.) from northwest Texas southeast to Matagorda Bay on the Gulf of Mexico. En route, the river crosses a rolling prairie terrain until it reaches the Hill Country in San Saba County. Here, the river flows through rugged canyons until it encounters the Balcones Escarpment of Austin. Mount Bonnell is on that escarpment and from our vantage point we can look down on Lake Austin, one of several reservoirs on the Colorado River. Lake Austin is located between Mansfield Dam and Tom Miller Dam. Below Austin, the Colorado becomes a slow meandering river.

In the distance to the west is the Edwards Plateau. The Edwards Plateau covers 45,000 square miles (117,000 square kilometers). It is composed of Cretaceous limestone and dolostones that were deposited in a vast inland tropical sea known as the Cretaceous Seaway. This ancient sea covered all of Texas and extended through the western U.S. and Canada as far as the Arctic Ocean from about 100-62 million years ago. It split North America into two landmasses: Laramidia to the west and Appalachia to the east. Streams dissect the Edwards Plateau and over time these have carved deep canyons, exposing geologic strata (such as at Pedernales Falls). Limestone and dolostone are soluble in slightly acidic water. Dissolution of the soluble rock by rainwater infiltrating along faults, fractures and sinkholes has produced a karst landscape. Rainwater is slightly acidic because it contains dissolved CO2 from the atmosphere and from vegetation at Earth's surface. *Note: Instructors may wish to review the chemistry of carbonate dissolution and karst formation.*

The Edwards Plateau is also a karst aquifer known as the Edwards Aquifer, which is an extremely important source of water in Central Texas. The primary water-bearing rock unit in the Edwards Aquifer is the Edwards Limestone, which is highly porous and permeable. Dissolution occurs along faults and joints, and as they widen, water can flow rapidly through networks of fractures in the Edwards Limestone. In some parts of Texas the Edwards Limestone is deeply buried and serves as reservoir for hydrocarbons.

Beginning about 25 million years ago in the Oligocene and continuing into the Miocene Epoch 17 million years ago, Central Texas experienced violent tectonic activity. Earthquakes shattered the layered limestone and large blocks were either uplifted or dropped, creating large extensional faults and fractures in an arc shape from Del Rio to Fort Worth, Texas. This structural feature is the Balcones Fault Zone. The Mount Bonnell Fault is one of many faults that comprise the Balcones Fault Zone. These faults occur in an en echelon pattern. Balcones faulting was related to (1) the existence of an older buried geologic feature, the Ouachita Structural Belt, which served as a zone of weakness along which faults were initiated; and (2) subsidence of the Texas Coastal Plain, most likely from the large amount of sediment deposited on it by Texas rivers and extensional stress due to the downwarping of the Gulf of Mexico in the Tertiary. The Ouachita Structural Belt is thought to be the result of continental collision during the late Paleozoic (300 million years ago). The Balcones Fault Zone has been inactive for nearly 15 million years, with the last activity during the Miocene epoch.

Faulting along the Balcones Fault Zone produced geologic uplift and created a dramatic feature known as the Balcones Escarpment. The Balcones Escarpment is the boundary between the Coastal Plain and the Edwards Plateau. The Llano Uplift is the northern border of the Edwards Plateau. Displacement along the Balcones Fault Zone is as much as 1200 – 1600 feet (366 – 488 meters) between Austin and San Antonio. Portions of the Cretaceous age limestones were exhumed and exposed to the elements after being buried for millions of years. The faults and fractures created weak zones in the limestone, along which dissolution could occur as water helped mediate the processes of weathering and erosion.

The Glen Rose Limestone of lower Cretaceous age outcrops at Mount Bonnell. The rock layers all along Mount Bonnell and vicinity are horizontal and are part of the uplifted section of Mount Bonnell Fault. In contrast, the block that dropped down (creating a graben) is characterized by tilted bedding and lots of fractures. The Glen Rose erodes in a characteristic staircase manner due to differential weathering.

Barton Springs

Over time, water has created a lattice-like network of conduits, caves and enlarged fractures in the Edwards Aquifer. This enables the Edwards Aquifer to store and transmit large amounts of groundwater. Groundwater flow may not correspond to the way in which the rivers and streams on the land surface above flow. To that point, groundwater in the Edwards Aquifer flows nearly perpendicular to the region's rivers. The Balcones Fault Zone acts as a barrier to flow. Where the hydraulic pressure in the aquifer is sufficient, water is forced up through faults to the surface to flow out as springs. Many large springs emerge along the Balcones Escarpment, including Barton Springs in Austin. Barton Springs is the fourth largest spring in Texas and has an average flow of 60 cubic feet per second (448 gallons per second or 1.7 cubic meters per second). Water temperature is a constant 68 degrees Fahrenheit year round and supplies water to Barton Springs Pool. Barton Springs is home to the endangered Barton Springs Salamander, which only inhabits Barton Springs. The Barton Springs Salamander is 2.5 inches long (about 6.4 centimeters) and spends most of its life in the aquifer and at the other springs that comprise Barton Springs.

This area on the surface where water can enter or recharge the aquifer is called the recharge zone. Precipitation and stream flow enters the Edwards Aquifer via fractures, sinkholes and caves and replenishes the aquifer in an area known as the Edwards Recharge Zone. Many streams also flow into fractures and caves to recharge the Edwards Aquifer on land upstream of the recharge zone. This is known as the contributing zone.

Enchanted Rock State Park

The massive pink granite dome that is Enchanted Rock rises 130 meters above the surrounding basin of the Llano Uplift and can be seen for miles around. It is one of many that punctuates the landscape of Central Texas. Enchanted Rock is not only an important Central Texas geologic feature, but also a cultural icon that has attracted visitors from the Paleoindians who first settled North America to day-tripping tourists, avid hikers, and interested geology students from every corner of the Lone Star State and beyond. Indeed, almost every Texan visits Enchanted Rock as a rite-of-passage.

Enchanted Rock and other outcropping granite domes are plutons which collectively are the visible part of a huge underground granite batholith (Town Mountain granite) that formed when molten magma deep with Earth's crust cooled slowly and crystalized into solid rock. These domes and the Precambrian gneiss and schist rock formations that surround the granite batholith are the oldest rocks in Central Texas and are in turn surrounded by uplifted Paleozoic rocks. The area is known as the Llano Uplift. The massive Enchanted Rock granite batholith is 1.083 billion years old (Precambrian).

Enchanted Rock was exposed when tectonic activity initiated the Llano Uplift. As the mountains rose, erosion wore away the younger rocks and sediments that had covered the batholith for millions of years. After the overlying material was stripped away, the granite expanded slightly because there was less weight bearing down on it (try this on a team member and see how they rebound). That expansion caused the dome to split into curved sections, a process known as exfoliation. As the outer layer of rock breaks into smaller pieces and slides off, the next layer begins to peel away from the dome like the layers of an onion or the dead skin on your body in a process called exfoliation. So, Enchanted Rock is an exfoliation dome! These geologic processes that created and exposed Enchanted Rock occurred over many tens of millions to hundreds of millions of years and continue today.

Humans have lived in the area of Enchanted Rock for 12,00 years. Native Americans (Comanche and Tonkawa), who observed glittering and flashing at night, especially after rain, believed that ghost fires flickered on top of Enchanted Rock. They also heard the rock creaking and groaning. They thought the rock was haunted and magical. The flickering, glittering, flashing lights may be caused by the moon reflecting off wet rock, and the creaking noises by contraction of the rock's outer surface as it cools after being heated by the sun during the day.

From this vantage point at the summit of Enchanted Rock, it is possible to see a series of granite domes and hills trending to the northeast and the southwest. These are mark the boundary of the Enchanted Rock batholith. To the east are the Riley Mountains, a fault-bounded area of Paleozoic sedimentary rocks. The Precambrian Enchanted Rock batholith and the Paleozoic sedimentary rocks comprise the Llano Uplift. To the south, the flat landscape is the Edwards Plateau, which is composed on Cretaceous limestone deposited on top of the Precambrian and Paleozoic rocks of the Llano Uplift.

The stations at Enchanted Rock and descriptions are based on the work of Reed (2011), Helper (2011), Reed and Petersson (2011) and the Friends of Enchanted Rock (FOER).

Inks Lake State Park

Stop 1. Inks Lake State Park, Devil's Waterhole

Inks Lake State Park is located on the eastern side of the Llano Uplift. The rocks of this domed structure consist of highly deformed metamorphic rocks that range in age from about 1.37-1.23 billion years old. The original rocks were sedimentary (formed from sand, silt and mud) and igneous (likely granite and volcanic). They were once buried by younger rocks, which have been eroded away, exposing these older, deeper rocks. Enchanted Rock, which we visited yesterday, is part of a younger granite batholith that formed when magma intruded into the older rocks of the Llano Uplift about 1.08 billion years ago.

The area in the park that we will visit is underlain by a metamorphic Valley Springs Gneiss of Precambrian age. Although the Valley Springs Gneiss looks very much like the Town Mountain Granite of Enchanted Rock in color and texture, its protolith (the original, unmetamorphosed rock that was the source for the gneiss) was probably a felsic volcanic tuff. The small amount of granite in the park appears only as veins cutting through the gneiss. Intense heat and pressure applied to the original rocks over millions of years formed gneiss. Expert geologists who have studied the area (e.g., JSG Dean Sharon Mosher) can discern as many as five foliations and four different phases of folding, as well as structures that are associated with extension. The latter include boudinage, which is visible in the rocks at Inks Lake. Notice also the migmatites. A migmatite is a rock that is a mixture of metamorphic and igneous rocks. Migmatites form under extremely hot temperatures when a rock like the Valley Spring Gneiss partially melts and then the melted part recrystallizes into an igneous rock creating a mixture of both igneous and metamorphic rock.The Valley Spring gneiss is characterized by numerous cross-cutting granite dikes

Inks Lake is one of the six Highland Lakes on the Colorado River. Because the Colorado River basin has a long history of major flooding, the Lower Colorado River Authority (LCRA) operates six dams on the lower Colorado River in Central Texas: Buchanan, Inks, Wirtz, Starcke, Mansfield and Tom Miller. These dams form the six Highland Lakes: Buchanan, Inks, LBJ, Marble Falls, Travis and Austin. The LCRA Highland Lakes. How the Highland Lakes System Works.

Lake Waco Wetlands

The Lake Waco Wetlands is a thriving ecosystem along the shores of the North Bosque River in Central Texas. One of the only wetlands of its kind in Central Texas, its 180 acres are home to many animal, insect and plant species, serves to protect the area from floods and improves water quality. The Waco Wetlands have become an important stopover for migrating birds and is now a popular bird watching destination. The Lake Waco Wetlands Research and Education Center hosts many workshops and tells the story of the value of wetlands. Facilities include the Center for Reservoir and Aquatic Systems Research (CRASR site - 1,500 sq. ft.), a 2,000 sq. ft. nature center, and a 900 sq.ft. indoor classroom. There 2.6 miles of trails with 3 elevated observation platforms. The Baylor Experimental Aquatic Research (BEAR) area includes sixteen pond mesocosms (miniature wetlands) and twelve experimental stream mesocosms including the largest riffle study facility in the region, which mimic natural wetlands and stream habitats found in Central Texas.

History. In 1998, the Waco City Council voted to increase the Lake Waco Pool (Lake Waco Reservoir) by seven feet, providing over 20,177 acre/feet more water. This decision was taken to guarantee sufficient water to supply the growing needs of the Waco community in Central Texas. In order to replace the habitat lost when the lake was raised. the City of Waco, the United States Army Corps of Engineers, Baylor University, and the United States Fish & Wildlife Service constructed a 180-acre wetland on Lake Waco. The Lake Waco Wetlands was designed by Wetland Technologies, Inc. out of Houston, Texas. The Waco Lake Wetland Project is now included in the Texas Parks and Wildlife guide to the Piney Woods and Prairies, and is highlighted by the Texas Travel Industry Association publication for "eco-tourism."

The Lake Waco Wetlands provide the opportunity to address issues related to water resource management and the carbon cycle. Points to emphasize include (1) that protection and prudent management of water resources is essential for sustaining economic viability and ecological health: (2) the management and sustainable use of water resources draws from many disciplines, including engineering, biology, geology, chemistry, physics and toxicology; and (3) that wetlands are important for their ability to serve as carbon sinks.

LCRA Red Bud Isle Vistors' Center

The Lower Colorado River Authority (LCRA) Red Bud Isle Visitor's Center is home to the Wilkerson Center for Colorado River Education and LCRA River Operations Center (ROC).The Wilkerson Center tells the story of the Colorado River, which flows through the heart of Texas. At this stop, students learn how the LCRA manages the Colorado River and why it's important to conserve and protect it as this region's main water supply. The LCRA ROC also manages the water supply stored in Lake Buchanan and Lake Travis for use by cities, industry, agriculture, and the environment.

LCRA operates six dams on the lower Colorado River in Central Texas: Buchanan, Inks, Wirtz, Starcke, Manfield and Tom Miller. These dams form the six Highland Lakes: Buchanan, Inks, LBJ, Marble Falls, Travis and Austin. The LCRA Highland Lakes. How the Highland Lakes System Works. The ROC is referred to as the "brain" of the Highland Lakes System. LCRA hydrologists, engineers and analysts use real-time data, including data transmitted from the LCRA Hydromet stations, computer modeling, and communication tools to monitor the Highland Lakes System, including the depth and speed of floodwaters even in the most remote areas of the lower Colorado River basin. With this information, the ROC can respond quickly to manage the floodwaters and help prevent damage to lives and property. When weather conditions are extreme and flooding or other emergencies are imminent, ROC serves as an Emergency Operations Center where LCRA key personnel come together to make decisions and take actions that help protect and inform the public. LCRA staff coordinate response within LCRA with communities upstream and downstream on the river, and with state and federal agencies.

Longhorn Cavern (tour required)

Longhorn Cavern is carved into the Ellenburger Group, carbonate rocks of lower Ordovician Age that formed in a shallow sea covering most of what is now Central Texas. The limestones of the Ellenburger are wary, brown and gray, with many features and fossils (e.g., stromatolites) that are indicative of shallow-water origin. The dolomites of the group have abundant chert layers. Today, the Ellenburger encircles the Llano Uplift and outcrops in areas. At the end of the Ordovician Period, the region was tilted and the carbonate rocks became exposed at Earth's surface. The carbonate rocks were dissolved along cracks and other zones of weakness in the process of karstification, creating sinkholes, caves and expansive subterranean drainage networks.

Karstic features are formed as rain passes through the atmosphere picking up carbon dioxide (CO2), which dissolves in the water. Once the rain reaches the ground, it may pass through vegetation and soil that can provide much more CO2 to form a weak carbonic acid solution, which dissolves calcium carbonate. The primary reaction sequence in limestone dissolution is the following:

$$H2O + CO2 \rightarrow H2CO3$$

$$CaCO3 + H2CO3 \rightarrow Ca2+ + 2\ HCO3$$

The Ellenburger is both an important aquifer and a hydrocarbon reservoir.

Pedernales Falls State Park

The Pedernales River is a tributary of the Colorado River. It flows from west to east draining part of the Edwards Plateau past LBJ's ranch home and discharges into the Colorado River at Lake Travis near Briarcliff. Like other major rivers, the Pedernales has eroded deep canyons in the terrain, exposing strata that reveal the geologic history of Central Texas.

Historical Note: President Johnson loved cars and a good prank. One very special vehicle was his German-made, bright blue Amphicar. He would both frighten and delight unsuspecting guests riding with him on the drive between Johnson City and his ranch by plunging his Amphicar into the Pedernales River or one of the Highland Lakes.

Pedernales Falls

At the north end of the park, the river cuts through strata of Cretaceous age to expose the Marble Falls Limestone of Pennsylvanian age (320 million years old). These older beds dip about 10 degrees to the southeast. They were initially deposited as flat-lying layers in a marine environment. The limestone contains crinoid fossils, stems of "sea lilies" (a flower-shaped animal) that captured their food from the sea. The limestone layers were subsequently tilted as a result of the collision of South America with North America (Laurentia) during the Ouachita tectonic event, which compressed and uplifted continental crust in the the region to form the Ouachita Mountains. After the rocks were tilted, they were eroded off to produce a more or less horizontal surface. Younger limestones were deposited on top of the older tilted beds. Eventually, the rocks overlying the Marble Falls Limestone were eroded away and then flat-lying Cretaceous sediments were deposited. Between 100 to 120 million years ago, early Cretaceous seas covered this part of Texas and deposited sands, gravels, younger limestone and marine fossils. The lowest Cretaceous layer is the Sycamore conglomerate, which exposed at the top of the rock stairs leading down to falls. The Pedernales River is prone to flash flooding and can be turbulent. Most of the time, it is tranquil and welcoming. The action of the river has produced beautiful features, including potholes, and chemical weathering (e.g., dissolution) has created shallow pits and widened fractures in the limestone.

Waco Mammoth National Monument

Waco Mammoth National Monument preserves "in situ" fossils of Columbian mammoths and other Late Pleistocene animals. Columbian mammoths roamed much of what is now the United States, including the grasslands of Central Texas, from ~1.1 million years ago until they went extinct ~13,000 years ago. The Waco mammoths are preserved in the location where they died, and the excellent preservation is related to the catastrophic nature of their death. The mammoths died ~67,000 years ago during a glacial period, when temperatures were ~4 °C (39 °F) cooler than today. Since the first discovery at the Waco site in 1978, twenty six mammoths, as well as a camel and the tooth of a saber-tooth cat, have been uncovered in alluvial deposits within a river terrace of the ancient Bosque River near its confluence with the Brazos River. Dating of quartz grains in the deposits, stratigraphic interpretations and channel reconstruction illustrate that the mammoths likely perished during flooding of a wet, sandy and muddy environment from which they could not escape.

Central Texas remains one of the most flood-prone areas in North America with major and catastrophic flooding a constantly recurring geohazard. Leslie Lee's article, http://twri.tamu.edu/publications/txh2o/fall-2016/do-you-live-in-flash-flood-alley/'Do You Live in Flash Flood Alley' offers insight and advice.

LABS

JSG Vertebrate Paleontology Lab

The University of Texas at Austin Vertebrate Paleontology Laboratory (VPL) at Pickle Research Campus houses one of the largest collections of vertebrate fossils in North America. UT faculty, staff and students collected most specimens, but VPL is also a major repository for important collections from other universities and research organizations. UT researchers and graduate students actively conduct research on specimens at VPL and also engage in fieldwork in the Mesozoic and Cenozoic sediments of Western North America. By partnering with the UT High Resolution X-ray Computed Tomography

Facility, VPL is also applying 3D-imaging to study vertebrate morphology and answer question such as whether or not dinosaurs could fly.

JSG Morphodynamics Lab

In the Morphodynamics Labs, researchers use a model to study the fundamental forces at work in turbidity currents. They run multiple experiments to investigate their flow paths, how they flow over the seafloor, how they reshape the seascape, and how the ancient channels they leave behind reflect past climate and flow rates. Oil and gas companies are also interested in this research because it they want to understand how these currents deposit organic matter that over geologic time gets buried, compressed and transformed into hydrocarbons.

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