No Frills, No Fear Geology

A User-Friendly Geologic Overview for CAMN Trainees

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Preface

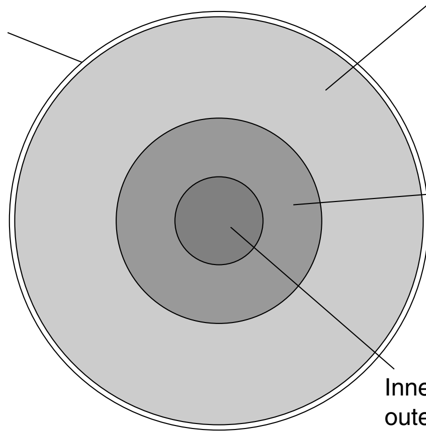
The geology of Central Texas is largely a story about limestone, faulting, and ground water. There is a great story to be told here, but it needn't take the form of a Master's dissertation on Miocene Faulting Along The Ancient Ouachita Continental Suture! To help understand the basic picture of what has happened here (and is STILL happening!) it should be useful to review a few basic geologic concepts. A concerted effort has been made here to keep things simple, it is by no means comprehensive.... but it may help you field the occasional question about the seemingly omnipresent rock layers we see at every turn.

IMPORTANT CONCEPT #1: THE EARTH IS VERY, *VERY*, OLD

Let's start at the very beginning (...a very good place to start!). Perhaps the single most important contribution geology has made to our understanding of the world is to reveal to us just how long it has taken to reach its present form. A mere 200 years ago it was popularly believed that the earth, based on calculations by biblical scholars, was no older than 6000 years! We now know that the beginning is way back....we're talking ***waaaay*** back!.... ~4,560,000,000 years back. Such numbers cause the eyes to glaze over in normal people, so lets compress those years into one year for a very simplified but nonetheless illuminating glimpse of the whole picture. (Study the chart on page 2 before reading any further.) As you can see, there wasn't a whole lot going on until late in the year. By mid-November there were abundant primitive life forms in the sea, but it was almost December before there is any life on land, and that is only primitive plants. So much of what makes up the present landscapes did not arrive on the scene until the last week of December on our compressed calendar. Let's look at page 3 to check out just the month of December. (Study the chart on page 3 before reading further.) It is rather humbling to realize that the earliest traces of civilized society do not appear until the last minute before midnight on December 31st! Geologic eras and periods have been purposely omitted to keep things simple. A simplified chart of the major subdivisions of geologic time, compared to the one-year scale, is included on page 3 for the compulsive types among you who just *have* to know.

Cross-Section of the Earth: What *Is* Underneath Our Feet, Anyway?

The center of the earth lies about 4,000 miles beneath our feet. At present the nature of the earth's interior in known only from indirect evidence collected from studies of rocks and minerals, seismic waves, heat flow from the interior, and the earth's gravity and magnetic field and through comparisons of the earth with other planets, with meteorites, and with the sun and other stars. The following diagram summarizes the results of these studies:



For our purposes you will want to understand that the crust is very thin compared with the whole and that it is broken into numerous, moving plates. The location, movement, and interaction of these plates over time has played an instrumental role in the evolution of the Texas landscape that we see today.

* *minerals containing iron and magnesium including biotite, hornblende, olivine among others.*

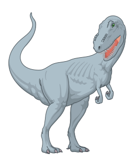
Geologic Time Represented on a One-Year Scale

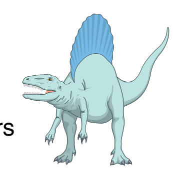
Month	10^9 yrs. bp	MAJOR EVENTS
JAN	4.5	• Oldest known moon rocks, meteorites • Period of extensive meteorite and planetisimal bombardment adds heat and bulk to earth
FEB	4.0	• The "Iron Catastrophe" remelts and segregates the earth into core, mantle, and crust • Worldwide volcanism releases large quantities of water vapor; crust cool enough for seas to form
MAR	3.5	• Oldest known rocks found in Greenland • Oldest evidence of microscopic life forms found in Australia
APRIL		
MAY	3.0	
JUNE	2.5	• First stable continent-size land masses; crust thick enough for major mountain ranges • Photosynthesis by blue-green algae, mostly in the form of stromatolites, slowly adds oxygen to the atmosphere
JULY	2.0	• Large worldwide deposits of iron oxides indicate oxygen level has risen high enough for iron to rust
AUG		• Deepest layer of the Grand Canyon is laid down • First oxygen-dependent life forms
SEP	1.5	
OCT	1.0	• Emplacement of granite batholith that would later become Enchanted Rock
NOV	0.5	• First organisms visible to the naked eye • First jellyfish • First appearance of abundant yet primitive sea life, first seashells, age of trilobites • Rise of fishes • Sahara under an ice cap at the south pole; first plants colonize the land
DEC	Present	• Age of coal forests, giant insects; much of earth is swampy and tropical; N. America and Africa collide; Ouachita Mountain Range begins to rise as Gondwana and Laurussia collide to form Pangea • Pangea forms • Pangea breaks up, N. Atlantic ocean grows as N. America and Europe are pushed apart • Balcones Fault Zone forms early on December 30th

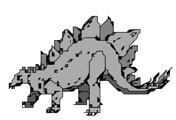
See page 3 for an expanded look at December.

The Month of December on Our Compressed Geologic Time Scale

Dec.	10^6 yrs. bp	MAJOR EVENTS
1		• Rise of fishes
2		• First amphibians
3		
4		
5		• First insects
6		
7	300	• Trilobites die out
8		• Ouachita Mountain Range in Texas rivals Himalayas of today; erosion off western slope lays down the sediments of the Permian Basin
9		
10		
11		• Rise of reptiles
12		
13		
14		
15	200	
16		
17		
18		
19		• Age of dinosaurs
20		• Birds and mammals appear
21		
22		
23	100	
24		• Age range of most Central Texas limestones
25		• Pilot Knob eruption
26		• Last of the dinosaurs becomes extinct
27		
28		
29		• Colorado Plateau begins to rise, directing massive sediment load toward the Gulf of Mexico
30		• Balcones Fault Zone forms along ancient trace of Ouachita Range suture zone
31	Present	• Australopithicus stumbles upon the stage at 8:06 p.m., New Years' Eve (Let's get humble, folks.)







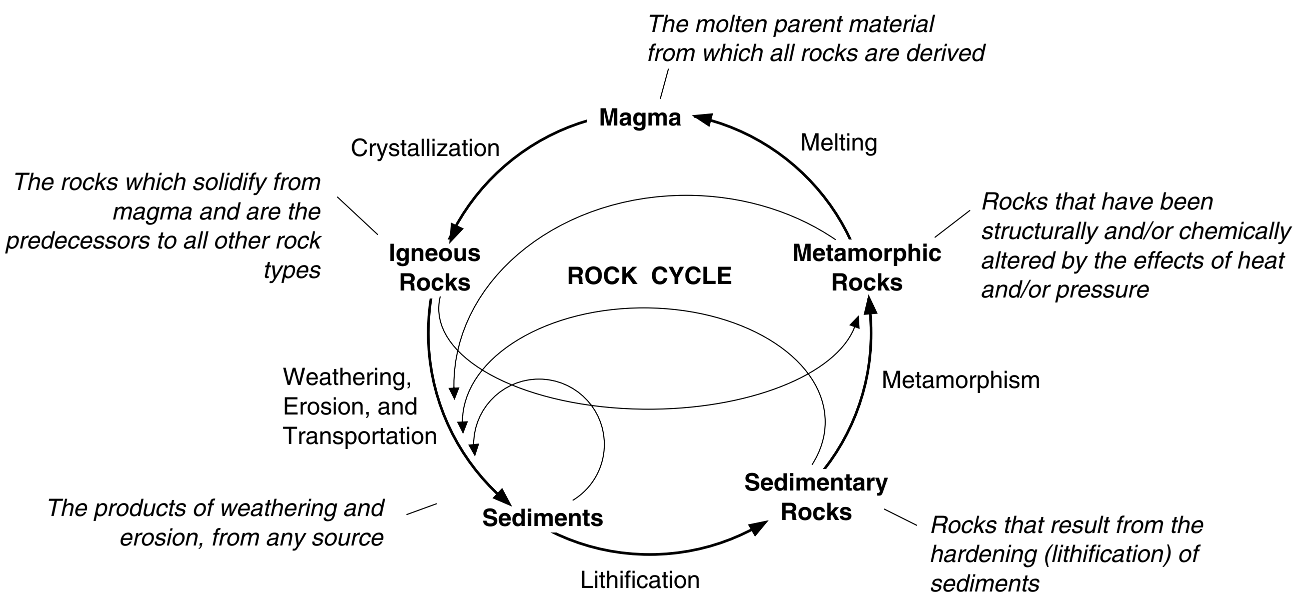
Major Geologic Time Divisions on the 1-yr. Scale

Mo.	Elapsed Time	Era	Period	Date Begun	Millions of Years Ago
J F M A M J J A S O N D	Jan. 1 to Nov. 14	Precambrian		1 Jan.	4,500
	Nov. 14 to Dec. 12	Paleozoic Era	Cambrian Ordovician Silurian Devonian Carboniferous Permian	14 Nov. 20 Nov. 26 Nov. 29 Nov. 5 Dec. 8 Dec.	570 500 430-440 395 345 280
	Dec. 12 to Dec. 26	Mesozoic Era	Triassic Jurassic Cretaceous	12 Dec. 16 Dec. 20 Dec.	225 190-195 136
	Dec. 26 to Present	Cenozoic Era	Tertiary Quaternary	26 Dec. Dec. 31, 8:06 p.m.	65 1.8

In the 1 minute before New Years' Eve!	
11:59:05	Earliest towns
11:59:18	Recorded History begins
11:59:32	Pyramids
11:59:42	Confucius
11:59:43	Buddha
11:59:46	Christ is born
11:59:56.5	Columbus "discovers" America
11:59:58.5	Declaration of Independence signed
11:59:59.0	Texas becomes a state
11:59:59.9	Man sets foot on the moon

IMPORTANT CONCEPT #2: CHANGE IS THE MAJOR CONSTANT

Now that we have the idea down that we have had a lot of time to work with, it is easier to accept that seemingly insignificant forces of change, given enough time, can bring about major changes. Though the entire surface of the earth started out as hard, igneous rock, none of that original surface remains today. The rocks of the earth's crust have been recycled many times. Mountain ranges have been pushed up and worn away. Sea bottoms have been pushed up to form lofty peaks only to be ground up and returned once again to the sea floor. Fossils of animals that teemed in ancient seas 500 million years ago can now be found outcropping on some of the highest mountains on earth. Sea floor sediments have been dragged deep down below the continents and have recrystallized to form heat- and pressure-altered rocks. Others have been completely remelted to form new molten rock (magma). This ongoing process is referred to as the "rock cycle":



This leads into the next important topic. As you can see, every rock type ultimately falls victim to the ravages of weathering, erosion, transportation, and deposition. Without weathering and erosion there would be no soil to support and nurture plant growth. Regardless of how determined humanity seems to pave the planet, if there were no plants everything else would fall apart. Even if life were sustainable without plants, can you imagine what our landscapes would look like were they devoid of forests, meadows, flowers, grasslands, and the myriad of critters that call such places home? Hey, it's those very things that stimulated us to become Master Naturalists in the first place!

Weathering the Heights (sorry)

There are two types of weathering: *mechanical* and *chemical*. These often work together but it is useful to discuss them separately. **Mechanical weathering** involves the physical breakdown of bigger pieces of rock into smaller pieces of rock and includes the action of such agents as frost, expansion and contraction, exfoliation, plant roots, and animal activities. Finally, agents such as running water, glacial ice, wind, gravity, and ocean waves all help to reduce rock material to smaller and smaller fragments. While these are erosive agents, they help the process of mechanical (and chemical) weathering along. **Chemical weathering** changes the composition of the original rock into something different. It involves the chemical reaction and decomposition of rocks through reactions with other substances in their environment. Most reactions involve the interactions of minerals with water, air, or organic compounds released by plants and animals. Generally, the warmer and moister the conditions, the faster chemical reactions can occur, so chemical weathering is most pronounced in the tropics. Also, for chemical reactions to take place, the reactants have to be in contact with one another. It follows that the larger the surface area in contact, the greater the effect of chemical weathering. Each time you break a rock you increase its surface area. Therefore, the finer the rock is broken up, the more rapid will be the chemical weathering.

Weathering and Erosion: Effect on the landscape

Weathering goes hand in hand with erosion to wear down the high areas and fill in the low areas. Were the world a static, unchanging place, there would no longer be any mountains....in fact there would be no land at all. The earth would be an oceanic world with a sea floor covered with sediments. The fact that we have such variety in our landscapes is proof that the forces that created the mountains in the first place are still at work today. They tend to work imperceptibly slowly by human standards, but geologically we are still riding on a very dynamic and rapidly changing planet.

In addition, the products of weathering play an important role in determining the kinds of flora and fauna a given area can sustain. Soil is the ultimate product of weathering. Different kinds of rocks contain different assemblages of minerals. These minerals break down under chemical weathering to form a major constituent of the nutrient base in the soils that sustains plant life. Different types of rocks weather to produce different types of soil. Different soil types favor or deter the growth of different plants. Often the underlying geology of an area can be determined by looking at the kind of plants that are growing on it..... and visa versa. The correlation of the 7 biogenic zones of Texas to the major soil zones offers a wonderful example of this relationship between soil type and floral distribution and adaptation.

IMPORTANT CONCEPT #3: THE CONTINENTS ARE MOVING!

Undoubtedly the most revolutionary discovery in the field of geology in the last century has been the now widely accepted process of plate tectonics. It was not until the mid-1960s that hard and reliable evidence started to be amassed to confirm what had for decades been a highly speculative and controversial theory advanced by a few brash and imaginative investigators. With such a seemingly preposterous notion that whole continents could actually be drifting about on the earth's surface, a highly skeptical scientific community cast a derisive and judgmental eye on those foolish enough to admit their belief in the theory. Careers were being destroyed here, folks.

With the plate tectonics model to work with, geologists have made incredible strides in better understanding the mechanics of earth processes. Connections have been made between continental drift, seafloor spreading, subduction, volcanism, major crustal boundaries, and earthquakes that have given us a far more holistic picture of what is going on. There are still many questions to be answered and inconsistencies to be explained, but more than any one thing, the theory of plate tectonics has turned the science of geology on its ear. Continental collisions and tectonic uplift have played an important role in the continuing evolution of our varied Texas landscapes.

A GEOLOGIC OVERVIEW OF THE AUSTIN AREA:

Austin is situated on the eastern edge of the Edwards Plateau which forms the core of the Texas hill country. It sits astride the Balcones Fault Zone which serves as a major geological dividing line between old, deeply eroded dry rocky terrain of the Plateau to the west, and younger, moister, and richer soils of the coastal plain to the east.

Aside from the ancient rocks found in the Llano uplift area, most of the exposed rocks of south central Texas are layered sedimentary limestones, dolomites, and poorly consolidated marly rocks of Cretaceous age. These rocks date from roughly 120 to 65 million years ago. Generally, older rocks are exposed to the west of the Bacones Fault Zone and younger ones to the east. The oldest formation that is exposed in our area is the 118 million year old Sycamore formation whose conglomertes can be observed forming much of the bedrock along the course of the Pedernales River in Pedernales Falls State Park. As one goes southeast from the Balcones Fault Zone, the surface rocks get progressively younger.

West of the Balcones Fault, most of the exposed rock belongs to the deeply eroded Glen Rose formation. Only the tops of the highest hills still have outlying remnants of the younger Walnut and Edwards formations. The Glen Rose is characterized by fairly thin alternating layers of hard and soft rock that erode to produce a distinctive stairstep topography. In 1756, Bernardo de Miranda y Flores, an early Spanish explorer to the region, was reminded of the terraced balconies of his native Spain and reported in his journal of traveling through a landscape of “balcones”. The name lives on in the Balcones Fault Zone which so dominates the geologic character of this part of Texas.

Balcones Fault Zone:

Regional uplift over the past 80 million years or so, including the rise of the Colorado Plateau and Rocky Mountains to the west, caused the shoreline to retreat to the southeast toward its present location. During this period erosion of the land increased and vast amounts of sediment were transported from the west to the Gulf. During wetter periods it is believed that the Rio Grande brought in as much sediment as the Mississippi does today. Incrementally, the weight of all these sediments began to add tremendous stress to the crust beneath the Gulf. About 15-20 million years ago this stress caused the underlying rocks to fail and subside along the eastern side of a series of parallel faults that formed along the weak continental suture demarking the former trace of the Ouachita Mountains. This marked the formation of the Balcones Fault Zone. Overall, rocks to the east were dropped down a total of about 1200 feet, with the westernmost Mt. Bonnel Fault experiencing the greatest offset of about 600 feet. There has been little or no movement along the Balcones Fault Zone since that time.

Edwards Aquifer:

With the formation of the Balcones Fault Zone, relatively higher rocks to the west were subjected to intensified erosion while those to the east were lower and eroded more slowly. The soft late Cretaceous rocks were quickly eroded off the top of the new Edwards Plateau, leaving the resistant rocks of the Glen Rose to battle the downcutting rivers flowing from the west. When looked at from a geological perspective, it is better to call this region the Texas Canyon Country rather than the Texas Hill Country! To the east of the Mt. Bonnel Fault, erosion wore down to the fractured Edwards formation which slowed the erosive power of the streams and rivers by absorbing much of the water into its lacy labyrinth of subterranean cracks and water channels. Throughout most of the Balcones Fault Zone, the Edwards formation is found at the surface. Much of the rain falling on the Edwards finds its way into this vast labyrinth, making it a superb aquifer. Austin lies squarely within the Balcones Fault Zone with the wells and springs of the Barton Creek segment of the Edwards Aquifer alone providing the sole source of water for about 45,000 residents. It is easy to see how critical it is that we take care to prevent the contamination of this aquifer with the effluent of our society and industry. This is why there are so many signs around town telling you when you are entering or leaving the aquifer zone and why new development is so closely scrutinized within the Edwards.

The Austin Chalk:

Mention should be made of this important rock group. Chalk is a soft, porous variety of limestone comprised largely of the calcareous skeletal remains of single celled foraminifera. The Austin Chalk Group is made up of 6 member formations that are representative of rocks that characterize upper Cretaceous deposits, particularly in North America and Europe. Perhaps the most well known of these are the white chalk cliffs of Dover in England. In Texas, the Austin Chalk is exposed in a band that extends from north of Dallas, curving SSW through Waco, Austin, San Antonio, then on out to the Big Bend area of west Texas. Statewide, it is an important reservoir rock for petroleum, and for this reason has been extensively studied. In our area it generally follows immediately to the east of the trend of the Balcones Fault Zone and is the rock upon which many of our neighborhoods are built, particularly in the NNE and SSW parts of town.

Pilot Knob Volcanics:

The Pilot Knob volcanics provide an interesting geological anomaly amidst the omnipresent Cretaceous sedimentary limestones of the area. About 80 million years ago, contemporaneous with the deposition of the Dessau Member of the Austin Chalk Group, a series of volcanoes began to erupt along the old Ouachita suture line as magma began to rise along newly formed cracks in the rocks which would later result in the subsidence and formation of the Balcones Fault Zone. These cracks formed in response to the stresses imposed by regional uplift resulting from geotectonic forces associated with continental drift, collision, and accretion. Today we can see the eroded remnants of one of these volcanoes, Pilot Knob, standing out as low hills just east of McKinney Falls State Park, where lenses of volcanic ash from Pilot Knob can be seen between the limestone (Dessau Chalk) layers at the base of the lower falls. There are several other volcanic explosion craters of similar age in the Austin area, most notably on the campus of St. Edwards University.

The eroded and contorted remnants of the Ouachita Mountains still underlie all of south central Texas and comprise the basement rock upon which all that we see at the surface rests.

Some common questions you may be asked about local geology:

What kind of rock makes up our local outcrops?

Almost all the rocks we see exposed around the Austin area are sedimentary limestones, dolomites, and marls that were deposited in a warm, shallow sea which covered this part of Texas about 80 to 120 million years ago. All of these rocks are predominantly calcium carbonate ($CaCO_3$) which in crystalline mineral form is called calcite.

How were these rocks formed?

Limestones have both chemical and organic origins. In this area, most of the **limestone** was laid down as a result of the accumulation of billions and billions of tiny calcium carbonate skeletons and secretions from microscopic sea creatures. If foreign material like sand, silt, or clay makes up a substantial portion of the limey sediment, it tends to form softer layers called **marl**. Such materials usually indicate a near shore environment and often contain shallow water marine fossils. If magnesium replaces some of the calcium in limestone, it forms a harder rock called **dolomite** and usually indicates cooler and deeper water conditions of deposition. Dolomite often weathers to exhibit a darker surface than limestone. With the frequently fluctuating sea levels of the Cretaceous it is easy to see how beds of limestone, dolomite, and marl interspersed to bring about the stairstep topography we see today.

How much time does an inch of limestone represent?

Deposition rates can be quite variable, but the Glen Rose Formation in our area, for example, is about 500 feet thick and took about 5 million years to be deposited. That works out to little more than an <u>inch</u> every <u>1000 years</u>, ignoring compaction!

What kinds of fossils are found in these rocks?

Having been deposited in a warm shallow sea, our limestones contains many fossils of shallow water marine animals. The fossils that are most commonly preserved in the rocks are the remains of hard shelled creatures like clams, oysters, snails, ammonites, and echinoids that flourished in warm shallow waters. Less commonly, the remains of large deeper water marine reptiles and shark teeth are occasionally found.

Were there dinosaurs here?

While dinosaurs were contemporaneous with the Cretaceous, the area around Austin appears to have been typically too far from shore to allow for many dinosaur bones and footprints as are found in the Glen Rose formation farther north toward the town of Glen Rose, from which the formation derives its name. There are, however, a few dinosaur footprints exposed on the grounds of the Austin Nature and Science Center.

Were can I go to collect fossils?

Central Texas is probably one of the most prolific places to look for fossils anywhere! The best places to look are along steep slopes with little soil or vegetative cover. The steeper the slope, the more layers of rock (and therefore the longer period of geologic time) exposed, which increases your odds of encountering a fossiliferous layer. Roadcuts are often excellent places to search, but care must be taken to not interfere with traffic or stray onto neighboring private property. Don’t cross any fences without the landowners permission. Take careful notes of where you found your fossils to aid in determining the formation the fossils are in and identification of the individual fossils. Streambeds can also be excellent places to look as they are constantly exposing new material along the banks and in the streambed while depositing loose fossils in the streambed. These loose fossils, however, are sometimes harder to date and identify because they have been removed from their rock of origin and worn by the erosive action of the stream.

Why do limestones often make good aquifers?

One of the definitive characteristics of limestone is that it is readily dissolved by acid. Rain falling through the atmosphere absorbs some CO_2 from the air on its way down. This produces a very weak solution of carbonic acid. While exceedingly weak it is quite effective at dissolving limestone given enough time, and one thing geology offers is a LOT of time! Over time, water seeping into cracks in the limestone gradually dissolve and wash away the limestone, widening and connecting cracks and creating a labyrinth of underground waterways throughout the rock. Eventually the limestone can begin to take on the character of Swiss cheese. This makes for an exceptional underground water storage and transport system.

What causes stalactites, stalagmites, and dripstones in limestone caves?

Water can only hold so much calcium carbonate in solution before it becomes saturated and can hold no more. This saturation point in contingent on several factors such as pH, temperature, and pressure. Calcium carbonate is unusual in how it dissolves. Most substances that dissolve in water (i.e., sugar, salt) dissolve better in hot water. Calcium carbonate is the opposite. The warmer the water, the less can be held in solution. (This explains the layer of white crud that forms on the walls of your coffee pot.) As cool spring water rises to the surface, particularly during the hot summer months, the water is warmed and any pressure the water was under is relieved. Less pressure causes CO_2 to come out of solution, like taking the cap off a soda bottle. This diminishes the strength of the carbonic acid, causing the pH to rise (low pH = more acidic). All these factors decrease the ability of the water to retain calcium carbonate in solution, and so it is incrementally deposited in the form of stalactites, stalagmites, and dripstone (aka calcareous tufa, calc tufa, or travertine).

P.S. Yes, this **does** mean that your (strong) calcium carbonate teeth are being attacked by (weak) carbonic acid when you drink carbonated beverages. Keep drinking them for 10,000 years and you’re likely to have no teeth!

Learn more about it...
Below is a list of some of the references and information sources I used in preparing this handout. They can provide much more in-depth coverage of these topics for those of you who wish to learn more about the geology of Central Texas:

Publications:

Guide to Points of Geologic Interest in Austin
(Guidebook Number 16) by A. R. Trippet and L. E. Garner (1976, fourth printing 1992)
Bureau of Economic Geology

This is an invaluable guide for the person wanting to learn more about our local road cuts and rock formations, describing where to find and how to get to many interesting sites. It also contains stratigraphic columns, fossil illustrations, and a full size color geologic map of the Austin area.

Environmental Geology of the Austin Area: An aid to urban planning
(Geology Rept. Inv. No. 86) by L. E. Garner and K. Young (1976)
Bureau of Economic Geology

The source of much of the information shown in the guidebook above, it goes into greater detail regarding the geology of the Austin area.

Geology of the Wild Basin Area
by L. E. Garner
Bureau of Economic Geology

Generally, the Bureau of Economic Geology is a great resource for geology related information.

Web Sites:

http://www.utexas.edu/ftp/student/geo/ggtc/toc.html (Geology of the Austin Area)
This is a great site with comprehensive information on geologic history, rock formations, fossil content, stratigraphic columns, locations of outcrops, etc.

http://www.lib.utexas.edu/geo/BalconesEscarpment/contents.html (The Balcones Escarpment)
A compendium of information related to the Balcones Escarpment.

http://www.cretaceousfossils.com/ (Cretaceous Fossils)
A site dedicated to the study of Cretaceous Fossils in the U.S. and around the world. Good information on the paleogeography of Texas during the Cretaceous.

People:

Carter Keairns teaches geology at Texas State University - San Marcos and provided excellent geological insights during a couple of CAMN field trips to view the stunning new gorge carved out below Canyon Lake as a result of the flood of July 2001.

Charles R. "Chock" Woodruff, Jr. is a Senior Lecturer in the Geotechnical Engineering Division of the Civil Engineering Dept. at UT . An engaging and humorous speaker and outstanding instructor, Chock knows the geology of the Austin area like the back of his hand and is well steeped in the storied history of local attempts to tame the Colorado.

Note: You will obtain a much more comprehensive list of geologic and soil references as part of the materials you receive during the geology and soils class on January 28th.