# GEOLOGY OF PHIL HARDBERGER PARK
## *TEXAS OVERVIEW*

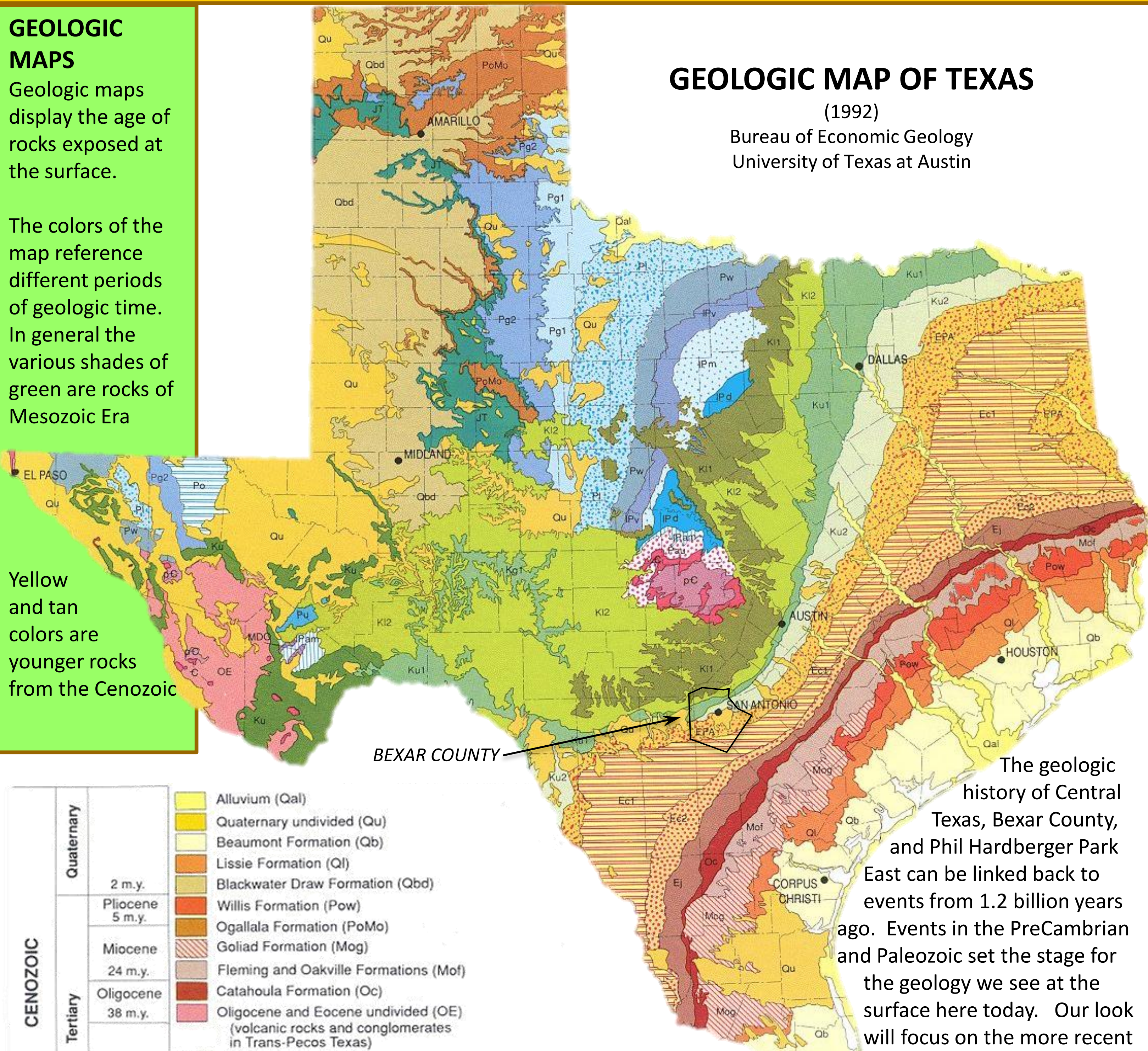


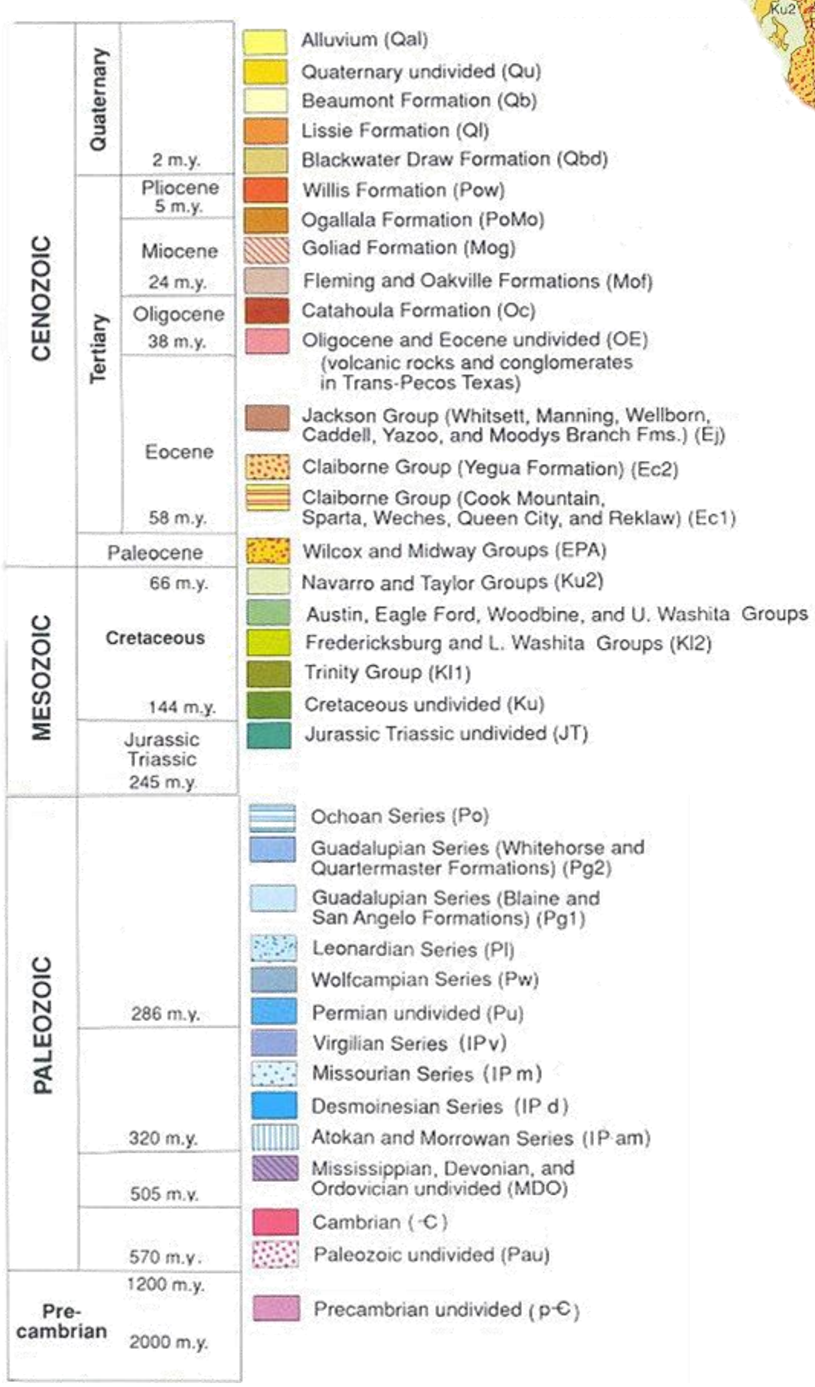
**GEOLOGIC MAPS**

Geologic maps display the age of rocks exposed at the surface.

The colors of the map reference different periods of geologic time. In general the various shades of green are rocks of Mesozoic Era

Yellow and tan colors are younger rocks from the Cenozoic



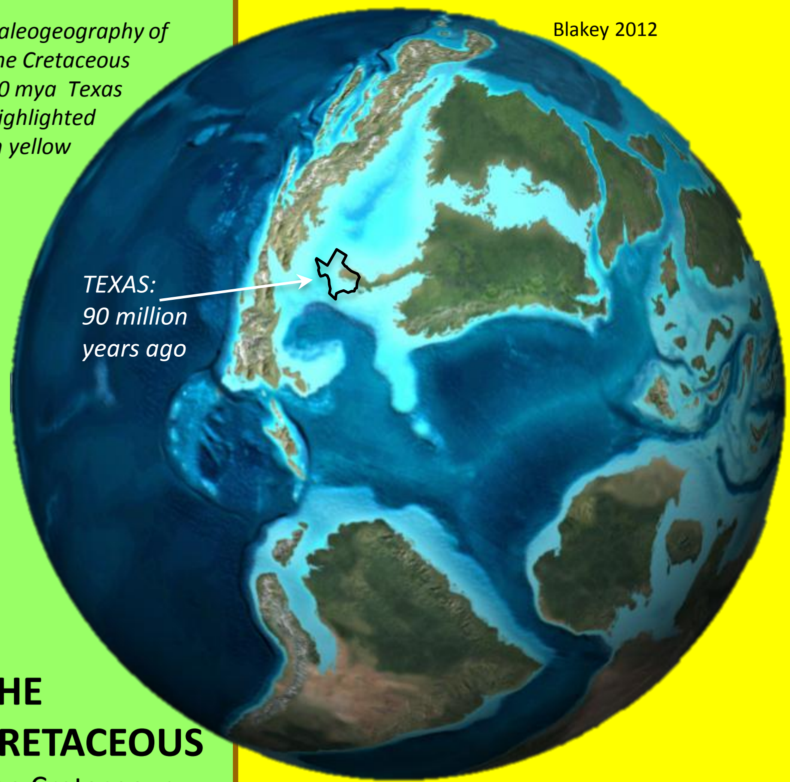




The geologic history of Central Texas, Bexar County, and Phil Hardberger Park East can be linked back to events from 1.2 billion years ago. Events in the PreCambrian and Paleozoic set the stage for the geology we see at the surface here today. Our look will focus on the more recent events that took place from the prolific carbonate deposition in the early Cretaceous period of the Mesozoic Era. The early Cretaceous was a period of repeated deposition and erosion. Carbonate sediments and evaporite minerals were deposited in shallow marine and near shore tidal environments. The sediments were subjected to shallow burial and short periods of subaerial exposure. During exposure shells composed of aragonite and high magnesium calcite were dissolved, as were some of the evaporate minerals, causing collapse features. Erosion was accelerated by regressions of sea-level coupled with the rise of the San Marcos platform. These events created periods of prolonged exposure and dissolution of sediments producing cavernous porosity. During the middle Cretaceous the seas once again transgressed across the region depositing sediments causing deep burial of the early Cretaceous sediments. In the late Cretaceous there was differential uplift that lead to further erosion. The Cretaceous material was removed by rivers that carried the sediment to the ancestral Gulf of Mexico. Prolonged exposure resulted in the formation of abundant karst features. Millions of years later, in the Tertiary, the sediment that had been carried to the ancestral Gulf of Mexico contributed to basin subsidence. During the Tertiary tensional stresses throughout the central Texas region created numerous fault zones

# GEOLOGY OF PHIL HARDBERGER PARK
## *The Cretaceous Period 145.5 to 65.5 million years ago*



*Paleogeography of the Cretaceous 90 mya Texas highlighted in yellow*





## THE CRETACEOUS

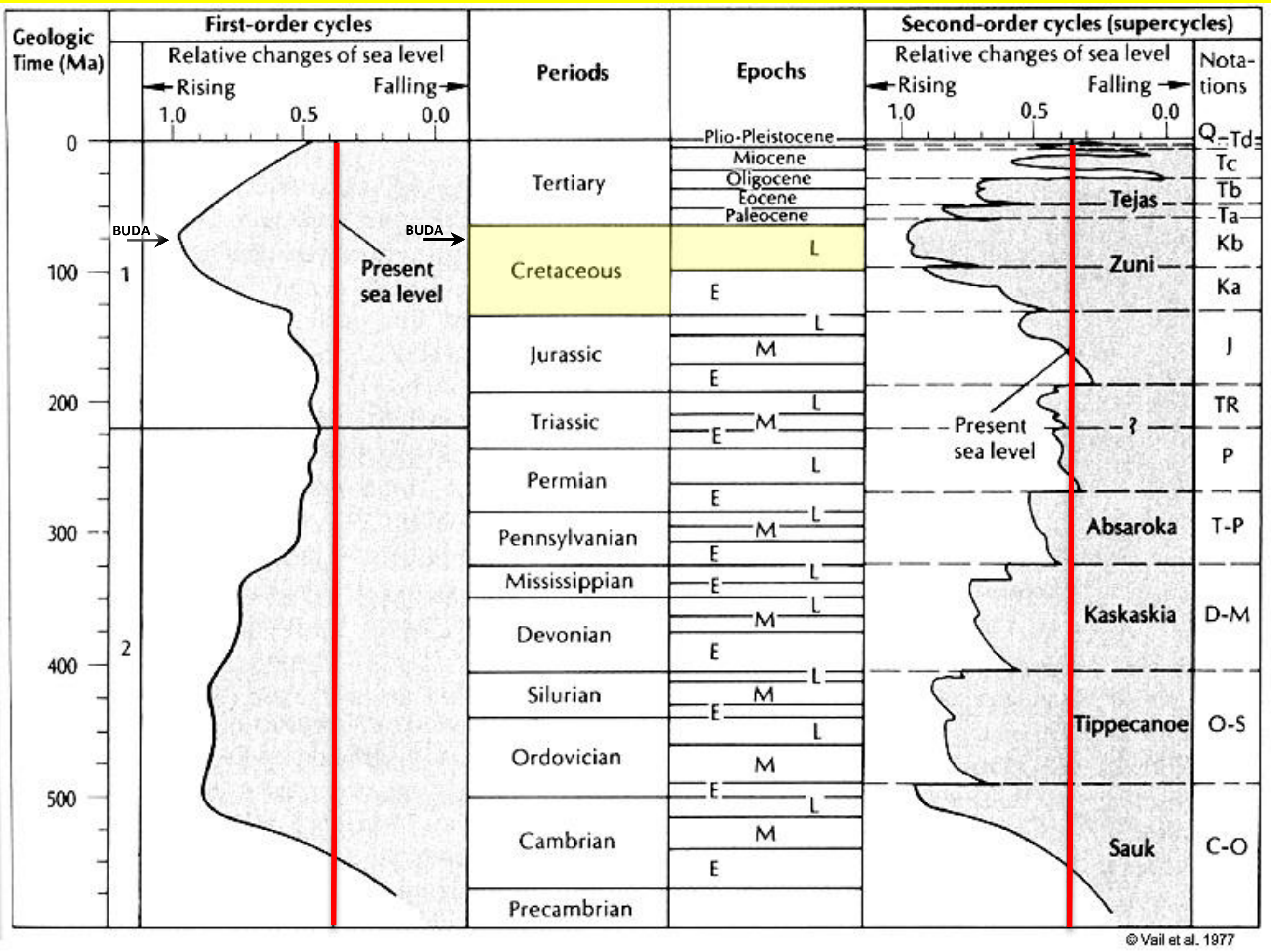
The Cretaceous period 145 to 65 million years ago lasted roughly 70 million years and is the longest period of the Mesozoic Era.

The Mesozoic Era includes the Triassic, Jurassic, and Cretaceous periods and is bookended by mass extinction events at the end Permian 250mya end Cretaceous 65 mya

The Cretaceous was a period of warm tropical climate. For nearly the entire duration of the Cretaceous tropical and subtropical climates extended from 45° north paleolatitude to 70° south paleolatitude. On the modern globe this is roughly between the Montana-Wyoming border and the Southern tip of South America.

Sea-Level may appear to be steady, but over the past 570 million years (Cambrian to Present) sea-levels have fluctuated greatly. In the Cretaceous sea-level averaged ~150 feet (45 meters) *higher* than present day. The result was flooding of continental cratons creating widespread shallow marine seas over much of western North America and central Eurasia. These shallow seas produced extensive deposits of limestone including the carbonates exposed around San Antonio. In North America these shallow marine sediments were deposited in the large Western Interior Seaway that connected the Gulf of Mexico to the Artic Ocean. It reached a maximum width of about 1100km and essentially split North America in two. The western coast of the inland sea followed a line roughly that of the present day Rocky Mountains, while the eastern coast extended from east-central Canada, through Minnesota, Missouri, along the Ouachita-Wichita Mountains in Oklahoma and Arkansas before continuing east.

The chart below illustrates the variation in sea-level over the past 600 million years. The red line represents the current sea-level compared to historic sea-level in black. The Cretaceous was a period of very high sea-levels Since the Cretaceous, the general trend has been a 65 million year sea-level fall. If we look at the present day sea-level and compare it to the historic, we find that for much of the past 600 million years sea-level was higher than our present day levels.



# GEOLOGY OF PHIL HARDBERGER PARK
## *PARK GEOLOGY: INTRODUCTION*

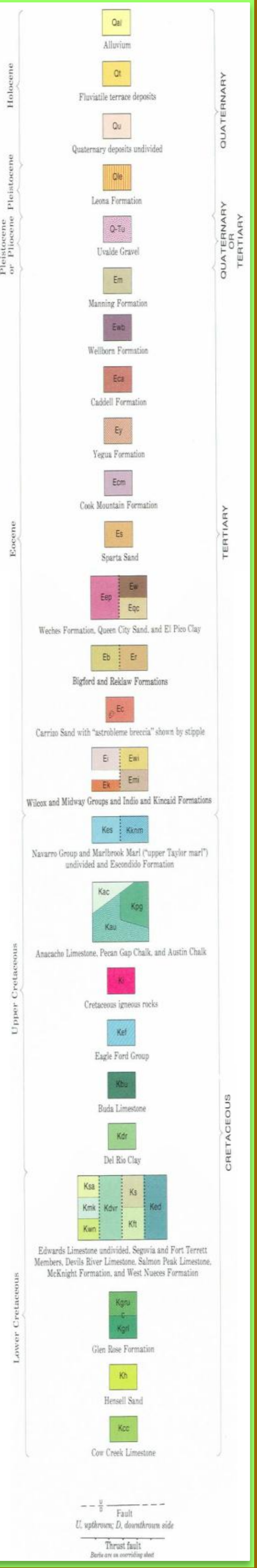


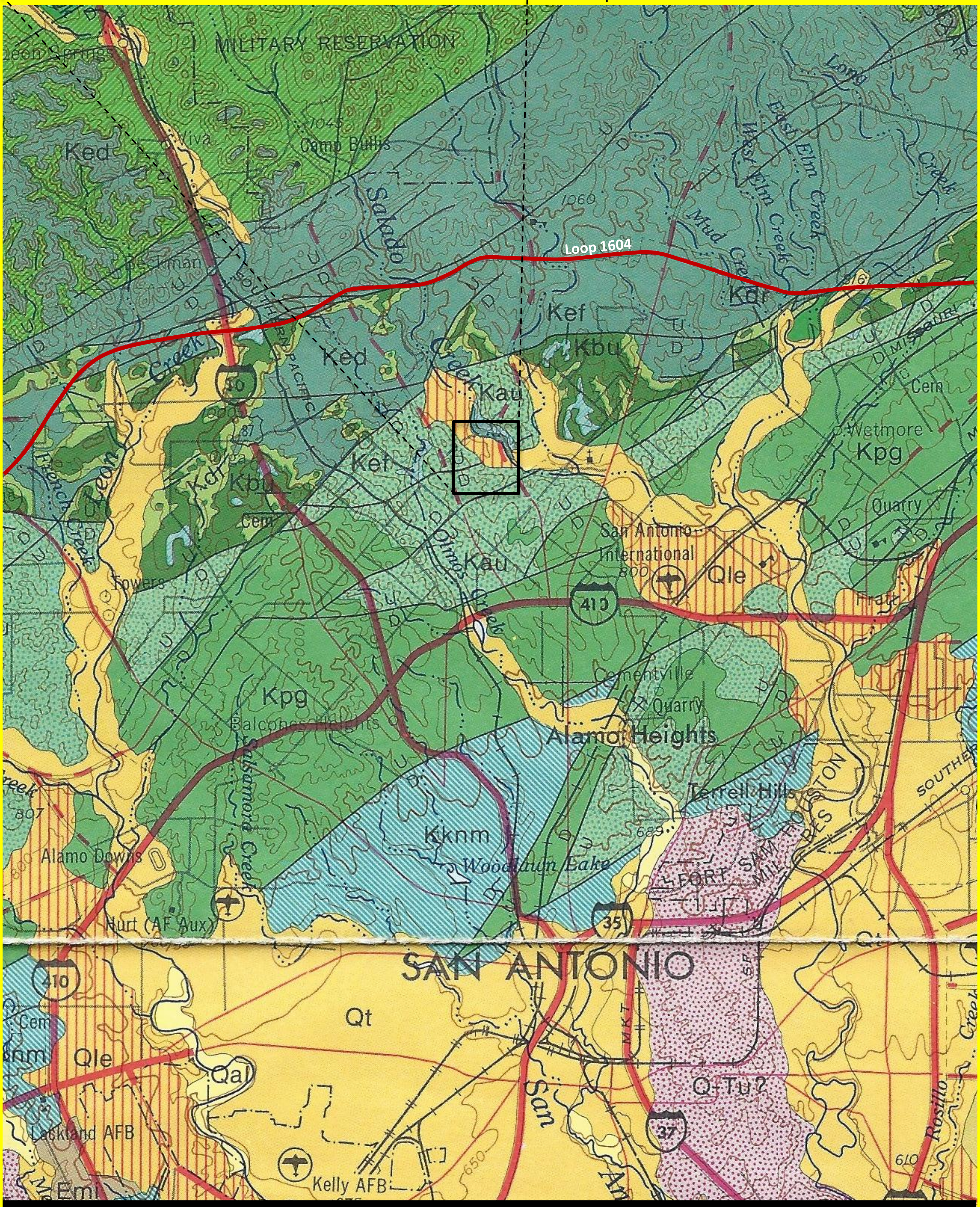
**San Antonio Geology**

A more detailed map of the geology surrounding Phil Hardberger Park East.

Black box outline is the approximate location of the park. The park geology can be broadly divided into Cretaceous (green) and Quaternary (Tan) underlying Geology


Central Texas provides a world class look at what the Earth was like millions of years ago during a period of Earth's history called the Cretaceous. All the clues to build a paleo-reconstruction of the life and environment from that distant past are right here under our feet. Phil Hardberger Park East and the surrounding greenbelts that run through San Antonio provide everyone with the opportunity to get up close with some great geology. Over the next few pages we will look at some basic (and important) geologic concepts, tie them into the surrounding rocks, and see how geology has influenced Central Texas and San Antonio . We will walk the Geology Trail in Phil Hardberger Park East, observe an outcrop at an old borrow pit and discuss some additional points of interest. I would encourage you to explore the geology on other trails throughout the entire park




*Map Section highlighting northern San Antonio and Phil Hardberger Park. from 1983 Geologic Atlas of Texas*

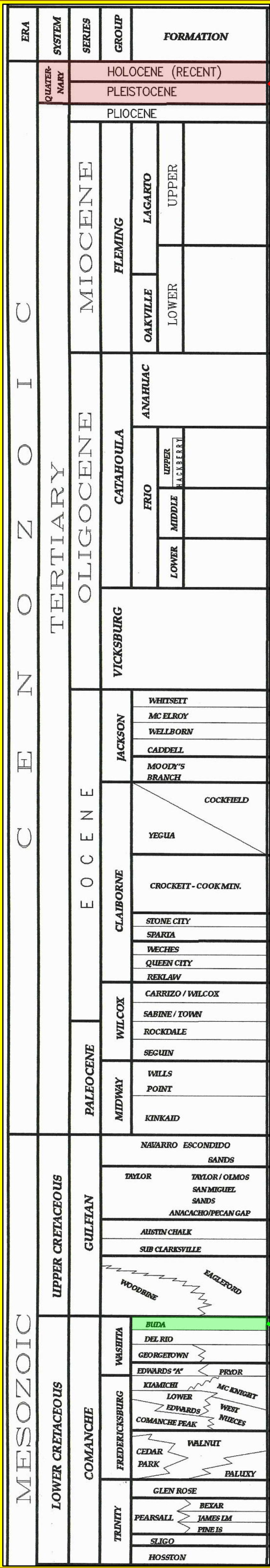
# GEOLOGY OF PHIL HARDBERGER PARK
## *PARK GEOLOGY: GEOLOGIC TIME*



**AGE OF THE ROCKS:**
The Buda limestone ~94.5 Mya (highlighted green) is significantly older than the ~1.8 Mya Quaternary gravels exposed in the *borrow pit* (highlighted red)

**PRINCIPLE OF SUPERPOSITION:**
Nicolaus Steno (1638-1686), a Dutch anatomist, priest, and geologist presented the wonderfully simple principle of superposition in 1669. Steno was one of the first to recognize that an outcrop of sedimentary rocks recorded a sequence of historical events. His claim was that in an undisturbed and undeformed sequence of sedimentary rocks each bed is older than the one above and younger than the one below.

**GEOLOGIC TIME**
The Earth is ~4.56 billion years old and subdivided into Eras and Periods
**ERAS**
Are defined primarily on faunal assemblages (organisms), divisions between the three Era's are marked by mass extinctions
**PERIODS**
Are subdivisions of Eras and are defined by fauna and lithology





*QUATERNARY GRAVEL DEPOSITS FROM BORROW PIT – large tree has made the best of a rather thin soil profile*

Can we determine the age of the rocks at Hardberger Park by absolute dating techniques? No we can't, but there is a good reason why absolute dates can not be acquired here. Absolute dates are only able to be determined when the rock samples contain certain radioactive isotopes (U, Th, K, etc.) that have known, constant, rates of decay. Since the park is dominantly limestone, made of calcium carbonate ($CaCO_3$), it does not contain the elements necessary to measure time absolutely

So how can we determine some age relationships of the rocks here in the park? Relative dating gives an order of events. It will not directly tell the geologist the absolute age of the rock layers, merely the order by which they were deposited. There are several principles of relative dating that we can use right now in the park to help us determine the order of events that occurred here – even if these events are millions of years old!

Sedimentary rocks are all deposited under the influence of gravity, or more specifically the particles that comprise sandstones, shales, and limestones are all deposited under the influence of gravity. They precipitate out of aqueous solutions if they were transported by rivers, streams, or ocean currents. This affords us the opportunity to unravel the chronological order of events that occurred here by relative dating techniques. Applying Steno's Principle of superposition in the Park: The Buda Limestone exposed at the banks of Salado Creek is stratigraphically lower and therefore older than the gravels exposed in the overlying borrow pit.

While the park contains rocks that are 94 million years old, it does not contain a continuous record of that amount of time. Where the base of the gravels contact the top of the Buda is an *unconformity* (a period of non-deposition or erosion) that represents a 'gap' in the geologic record. Here in the Park that thin unconformity represents over 90 million years!

On the following page we will take a more detailed look at the Buda Limestone.


*OUTCROP OF BUDA LIMESTONE IN SALADO CREEK*

# GEOLOGY OF PHIL HARDBERGER PARK
## *PARK GEOLOGY: BUDA LIMESTONE*



**CARBONATES**
Are a group of chemical sedimentary rocks that are defined by the anionic compound ($CO_3$)

**LIMESTONE**
Is a sedimentary carbonate rock comprised primarily of the mineral calcite $CaCO_3$
Varieties of limestone are defined by the type of matrix material and grains

**GRAINS**
Limestone is not always uniform in composition and will often contain fossils, ooids, pellets, or intraclasts
*Fossils:* Can be complete entire fossils or fragments of broken shell
*Pellets:* small grain with no internal structure, fecal pellet
*Ooids:* (small spherical grains of concentric calcium carbonate formed around a nucleus such as a sand grain or fossil fragment)
*Intraclast:* A torn up or ripped up reworked fragment

**MATRIX**
The material between grains that holds the rock together. Typically Limestone matrix is microcrystalline calcite (micrite) sometimes also rich in detrital clay.

*BUDA OUTCROP IN SALADO CREEK*

*BUDA FORMATION (BIOTURBATED) – holes in the rock were created by burrowing organisms when the rock was still a soft lime mud sediment on the Cretaceous sea floor.*

The Buda Limestone outcropping in Salado Creek next to Phil Hardberger Park East is from the Cretaceous Period, ~94.5 million years old. Good exposures can be found where Old Volker Lane meets the trailhead for the Salado Creek Greenbelt at Salado Creek and all along Salado Creek. This formation, and many others in central Texas is limestone. Limestone is valuable to a geologist in helping to reconstruct paleoenvironments from millions of years ago. Since limestone is still being formed today (in regions such as the Bahamas) geologists can use the modern analogs to help understand the geologic past

Carbonate rocks provide geologists with excellent clues to help reconstruct the life and depositional environments of the geologic past. The limestones of Central Texas that were deposited in the Cretaceous indicate that during deposition some ~100 million years ago this part of Texas had a warm climate near the equator and was covered with a calm shallow sea full of life, including echinoderms, bivalves, algae, gastropods, etc. (paleogeographic reconstruction p.2). Key to this interpretation is an understanding of how limestone is formed. Limestone is made of two principle components; grains and matrix. Both of these components give geologists clues about the water depth, chemistry, climate, and general environment of deposition. Limestone is precipitated (biologically and/or chemically) from marine or lacustrine waters. Often the limestone is formed from the remains of calcareous algae. In order for the algae that creates the limestone to flourish it needs to be a warm climate (30°N/S of the equator) with little suspended sediment so sunlight can get to the algae for photosynthesis. When we see the Buda limestone in the creek bed we know it was deposited in a warm, shallow, and clear marine environment. Abundant marine fossils help add to the details of understanding the Cretaceous.

The Exposure of Buda Lime along Salado Creek is extensively bioturbated. Many marine invertebrates live in, or on, the sea floor and feed by burrowing into the substrate looking for organic material to consume. This activity results in the destruction of the original depositional fabric, ingestion of sediment by the organism, and excretion of pellets. This stirring activity of the sediment by the organisms is called bioturbation. We can easily recognize burrows by the contrast of the burrow fill and the surrounding rock. Burrows are trace fossils, not actual remains of the organism itself, but rather evidence of an organism's activity. Other types of trace fossils include trackways, nests, and coprolites. How did shallow marine organisms burrow into this solid layer of limestone? Remember that when this layer of strata was initially deposited it was a fine calcium carbonate mud. Only after burial and lithification did it become a solid rock. The burrows ended up as holes after preferential dissolution of the burrowed sediment. Identifying these burrows allows us to conclude that the substrate back in the Cretaceous at this locality was a nice soft muddy environment

# GEOLOGY OF PHIL HARDBERGER PARK
## *PARK GEOLOGY: KARST*



**KARST:**
A type of topography that is formed over limestone, dolomite, or gypsum by dissolution, and is characterized by sinkholes, caves, and underground drainage.

**LIMESTONE**
Is a sedimentary carbonate rock comprised of the mineral Calcite $CaCO_3$

**DOLOSTONE**
Is a sedimentary carbonate rock comprised of the mineral Dolomite $Ca\,Mg\,(CO_3)_2$

**GYPSUM**
Is a chemical sedimentary rock (evaporate) comprised of the mineral Gypsum $CaSO_4\,(nH_2O)$

**ANHYDRITE**
Is a chemical sedimentary rock (evaporate) comprised of the mineral Anhydrite $CaSO_4$

**CAVE ENTRANCE IS SEALED**
It is both illegal and dangerous to enter caves; in addition to potential injury there is risk to sensitive species that inhabit these delicate environments – ***Please refrain from entering any caves***

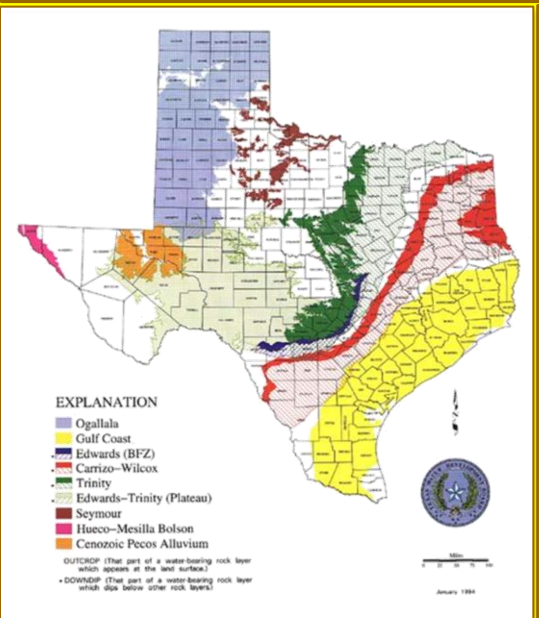
*Enchanted Forest Pit cave in the Buda Limestone*

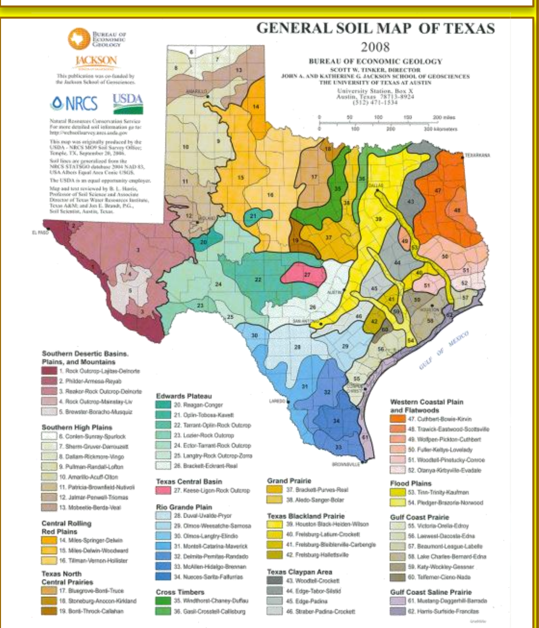
After deposition and lithification the rocks do not remain unchanged, they typically endure post-depositional modifications. Weathering is one example. A characteristic of carbonate weathering is the development of Karst and Caves.

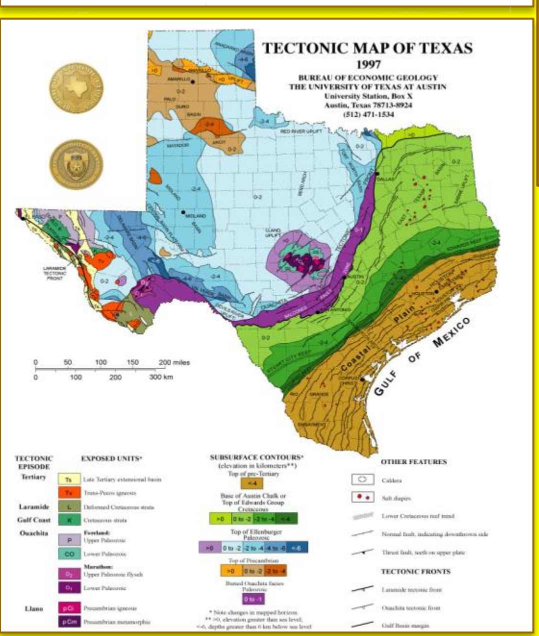
One of two known caves (Enchanted Forest Pit and Peacock Pit) formed in the Buda Limestone in Bexar County is exposed in Salado Creek. The Buda is not as prominent as the Edwards or Austin Chalk (the two formations with the most caves in Bexar County). Several factors contribute to the lack of caves in the Buda; it lacks significant areal extent (not much outcrop in Bexar County), it lacks vertical thickness, and it has poor fracture porosity. Enchanted Forest Pit was discovered by Randy M. Waters in 1977 and named after the nearby subdivision. Surveyed November 15$^{th}$ 1980 by Gary A. Poole, George Veni, and Waters. The cave was formed in outcrops of Buda Limestone along Salado Creek. There are two entrances, a lower entrance (pictured above) with a sloping floor leading to a small round opening that extends upward ~20ft to a second 'sinkhole' opening about 5ft in diameter.

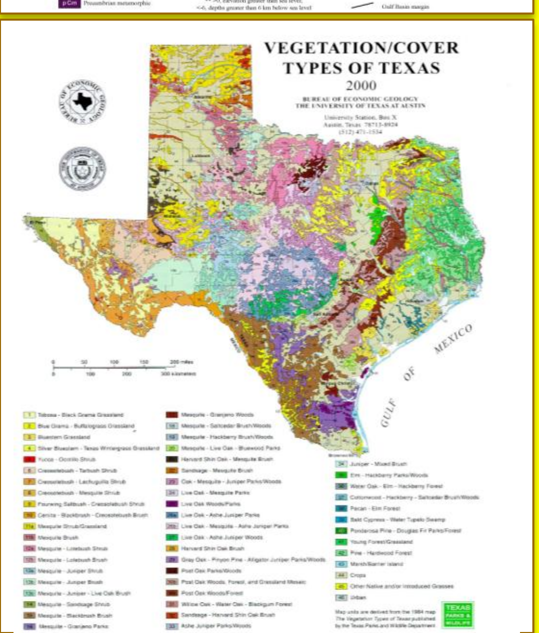
# GEOLOGY OF PHIL HARDBERGER PARK
## *CONCLUDING THOUGHTS*

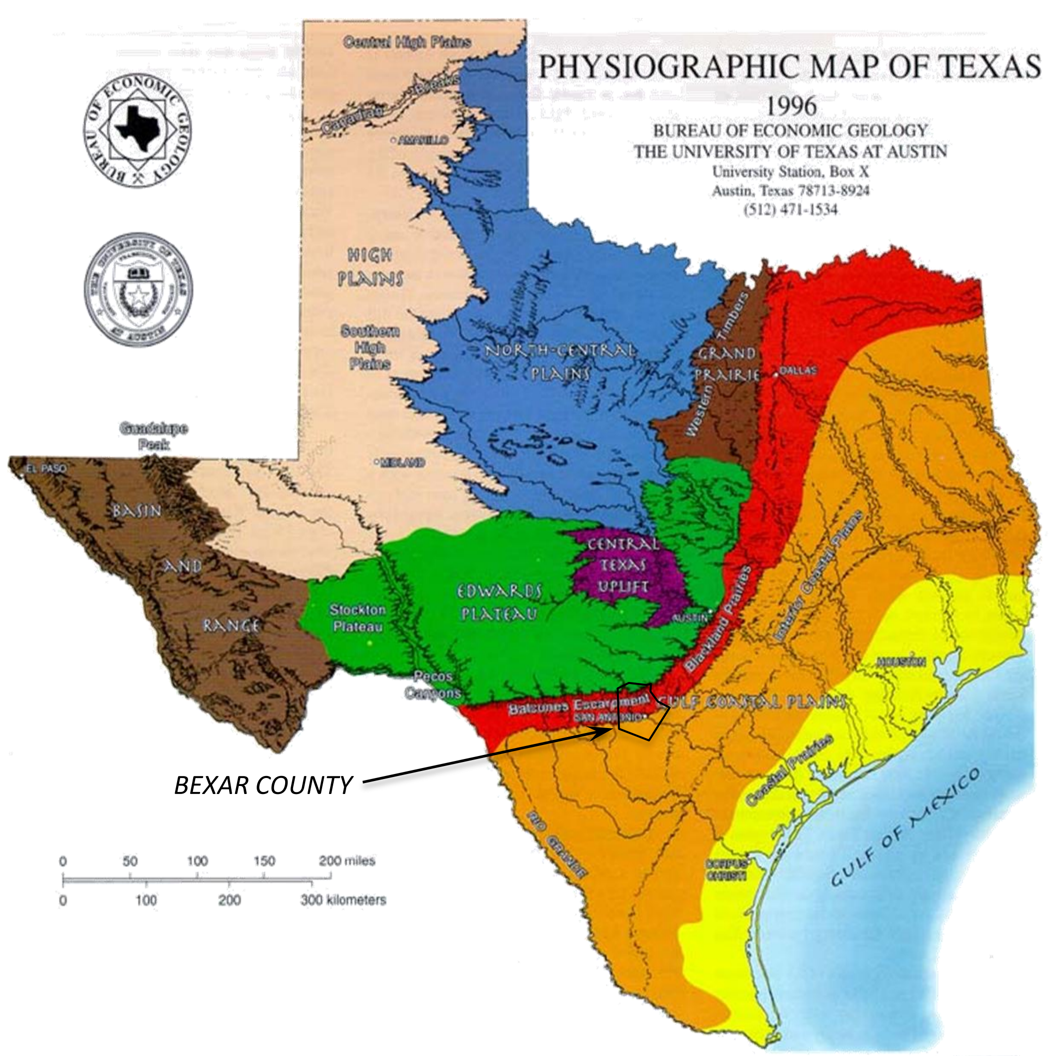





| PROVINCE | MAX. ELEV. (ft) | MIN. ELEV. (ft) | TOPOGRAPHY | GEOLOGIC STRUCTURE | BEDROCK TYPES |
|---|---|---|---|---|---|
| Gulf Coastal Plains | | | | | |
| Coastal Prairies | 300 | 0 | Nearly flat prairie, <1 ft/mi to Gulf | Nearly flat strata | Deltaic sands and muds |
| Interior Coastal Plains | 800 | 300 | Parallel ridges (questas) and valleys | Beds tilted toward Gulf | Unconsolidated sands and muds |
| Blackland Prairies | 1000 | 450 | Low rolling terrain | Beds tilted south and east | Chalks and marls |
| Grand Prairie | 1250 | 450 | Low stairstep hills west; plains east | Strata dip east | Calcareous east; sandy west |
| Edwards Plateau | | | | | |
| Principal | 3000 | 450 | Flat upper surface with box canyons | Beds dip south; normal faulted | Limestones and dolomites |
| Pecos Canyons | 2000 | 1200 | Steep-walled canyons | | Limestones and dolomites |
| Stockton Plateau | 4200 | 1700 | Mesa-formed terrain; highs to west | Unfaulted, near-horizontal beds | Carbonates and alluvial sediments |
| Central Texas Uplift | 2000 | 800 | Knobby plain; surrounded by questas | Centripetal dips, strongly faulted | Granites; metamorphics; sediments |
| North-Central Plains | 3000 | 900 | Low north-south ridges (questas) | West dip; minor faults | Limestones; sandstones; shales |
| High Plains | | | | | |
| Central | 4750 | 2900 | Flat prairies slope east and south | Slight dips east and south | Eolian silts and fine sands |
| Canadian Breaks | 3800 | 2350 | Highly dissected; local solution valleys | | |
| Southern | 3800 | 2200 | Flat; many playas; local dune fields | | |
| Basin and Range | 8750 | 1700 | North-south mountains and basins | Some complex folding and faulting | Igneous; metamorphics; sediments |

The Physiographic map of Texas (above) illustrates seven distinct physiographic provinces in the State. Each province is characterized by distinct geology, soil types, vegetation, and climate. Landforms within each province are a creation of their depositional and erosional processes. Bexar County is located at the intersection of three of these provinces; the Edwards Plateau, Balcones Escarpment, and Gulf Coastal Plain.

Similarities between the Geologic map (pg. 1) and the Physiographic Map (above), Major Aquifer Map (top left), Soils (upper left) Tectonic Map (lower left) and Vegetative cover (bottom left) can easily be observed. These similarities are not accidental as the geology is (literally) the underlying material that determines the aquifers of Texas, soils, vegetative cover, distribution of industrial materials (ex: rock quarries), as well as oil and gas reservoirs.

We have in a few short pages attempted to cover millions of years of local geology, a task that leaves much remaining to be discussed. We would encourage you to attend one of the Saturday Morning Geology Talk & Walks for additional information, the opportunity to spend some time with the rocks of Phil Hardberger Park East, ask questions of a geologist and to become more familiar with your local geology.

# GEOLOGY OF PHIL HARDBERGER PARK
# SELECTED DEFINITIONS & REFERENCES



## SELECTED TERMS AND DEFINITIONS

**Bioturbation:** The churning and stirring of sediment by organisms

**Borrow Pit:** An excavated area where material has been dug for use as fill at another location

**Collapse Features:** Any rock structure resulting from removal of support and consequent collapse, e.g. gravitational sliding on fold limbs, salt solution causing collapse of overlying rocks in salt basins, sink hole collapse, or collapse into mine workings

**Extinction:** Total disappearance of a species or higher taxon so that it no longer exists anywhere. (**Mass Extinction** is the extinction of a large number of species within a relatively short period of geologic time, at least 5 mass extinction events have been identified in the geologic record)

**Fauna:** The entire animal population, living or fossil, of a given area, environment, formation, or time span.

**Isotope:** One of two or more species of the same chemical element i.e. having hte same number of protons in the nucleus, but differing from one another by having a different number of neutrons. The isotopes of an element have slightly different physical and chemical properties owing to their mass differences

**Lacustrine:** Pertaining to, produced by, or inhabiting a lake or lakes.

**Lithification:** The conversion of newly deposited into a solid rock, involving such processes as cementation, compaction, and crystallization. It may be concurrent with, soon after, or long after deposition

**Weathering:** The destructive process by which rocks are changed on exposure to atmospheric agents at or near the earth's surface, with littl eor no transport of the loosened material; specif. the physical disintegration and chemical decomposition of rock that produce an in-situ mantle of waste and prepare sediments for transportation.

**Lithology:** 1. The description of rocks esp. in hand sample and outcrop, on the basis of such characteristics as color, mineralogic composition and grain size. 2. the physical character of a rock

**Radioactivity:** the emission of an energetic particles and/or radiation during radioactive decay.

**Subaerial:** Formed, existing, or taking place on the land surface; contrasted with subaqueous.

**Subsidence:** Sinking or downward settling of the Earth's surface, not restricted in rate, magnitude, or area involved.

**Unconformity:** A break or gap in the geologic record, such as an interruption in the normal sequence of deposition of sedimentary rocks or a break between eroded metamorphic rocks and younger sedimentary strata.

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**Texas Maps**

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