

Geologic History of South Central Texas

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Geologic History as it Relates to Modern Vegetation Patterns of South Central Texas

Bill Ward
Boerne Chapter, NPSOT

Introduction

Major patterns of vegetation in South Central Texas closely match the major patterns of the surface geology (Fig. 1). The variety of rock types at or near the surface in South Central Texas ensures that the region has a diversity of soils and landforms, which together with the climate, strongly influence the composition of the flora of this area.

The juxtaposition of diverse rock types and landforms in South Central Texas can be explained through a brief geologic history of this area. For this purpose, there is no need to consider more than the latest seven percent of the Earth's 4.5-billion-year history. The abbreviated geologic history recounted below begins about 300 million years ago during the Pennsylvanian Period and comes forward, in uneven hops, to modern times. This story is based on interpretations of rocks at the surface or in the subsurface of South Central Texas.

Abbreviated Geologic History

Pennsylvanian Period

We begin with the Pennsylvanian Period (Fig. 2), because during that time an event occurred that established the fundamental structural framework of this part of the North American continent and strongly influenced the subsequent geologic history. The effects of this event are seen in the modern geology and, consequently, the modern vegetation.

The area that is now South Central Texas was mountainous during late Pennsylvanian time (Fig. 3). This was because late in the Paleozoic Era (Fig. 2), the continental masses of the world were drawn together by convective currents flowing within the almost-molten upper mantle, the layer of the Earth upon which the large segments (plates) of continental and oceanic crust float.

When the North American continent was brought into collision with the South American continent during the Pennsylvanian Period, the thick layers of marine sedimentary rock that had accumulated on the continental margins were crumpled into a belt of folded, faulted, and partly metamorphosed strata. This zone of deformed rock rose up to form the Ouachita Mountains, a westward extension of the southern Appalachian Mountain Belt. During the continental collision, the Ouachita belt was bent around the stable Llano-area promontory of Precambrian igneous and metamorphic rocks, causing the Ouachita Mountains to trend northeast between San Antonio and Dallas and east-west between San Antonio and Del Rio.

Permian-Triassic-Middle Jurassic Periods

For the next 100 million years or so, the future South Central Texas area was part of a

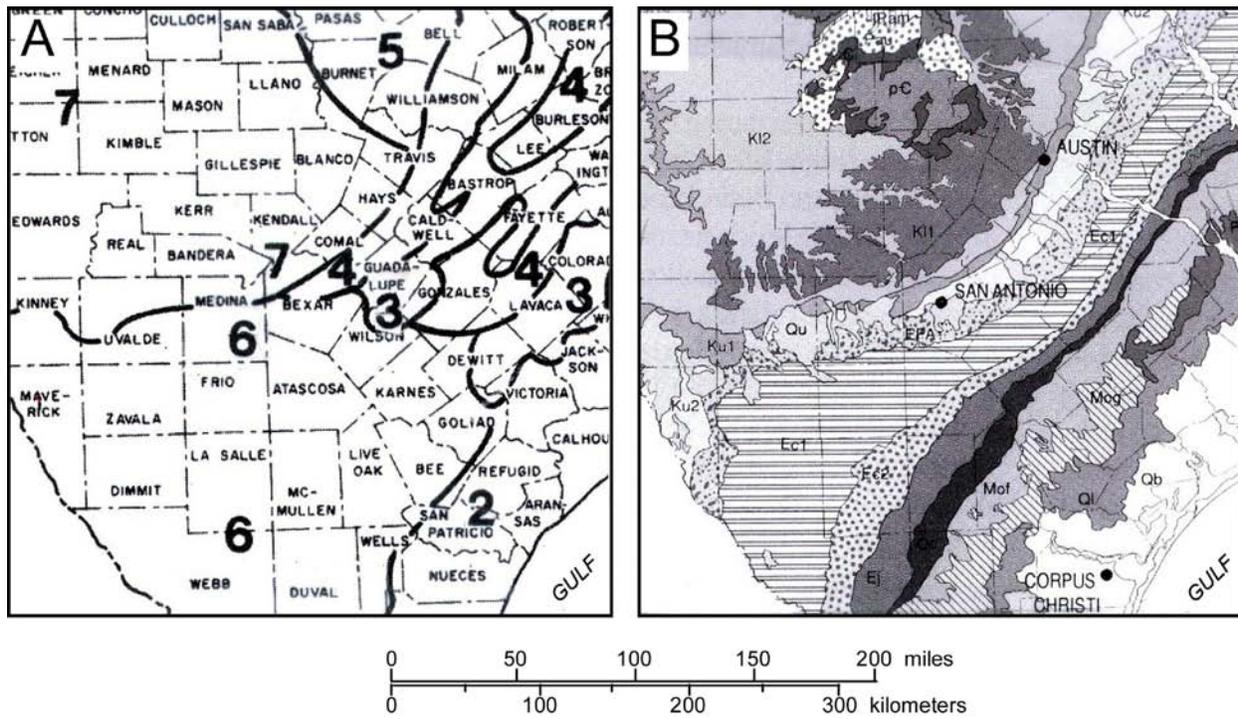


Figure 1A. – Vegetative regions of South Central Texas and adjacent areas (from Hatch et al., 1990). 2 = Gulf Prairies and Marshes; 3 = Post Oak Savannah; 4 = Blackland Prairies; 5 = Cross Timbers and Prairies; 6 = South Texas Plains; 7 = Edwards Plateau

Figure 1B. – Geologic map of South Central Texas and adjacent areas (Bureau of Economic Geology, University of Texas, 1992).

- Qu = Quaternary undivided
- Qb = Quaternary, Beaumont Formation
- Ql = Quaternary, Lizzie Formation
- Pow = Pliocene, Willis Formation
- Mog = Miocene, Goliad Formation
- Mof = Miocene, Fleming and Oakville Formations
- Oc = Oligocene, Catahoula Formation
- Ej = Eocene, Jackson Group
- Ec2 = Eocene, Claiborne Group (Yegua Formation)
- Ec1 = Eocene, Claiborne Group (Cook Mt., Sparta, Weches, Queen City, Reklaw Formations)
- EPA = Eocene-Paleocene, Wilcox and Midway Groups
- Ku2 = Upper Cretaceous, Navarro and Taylor Groups
- Ku1 = Upper Cretaceous; Austin, Eagle Ford, upper Washita Groups
- K12 = Lower Cretaceous, Fredricksburg and lower Washita Groups
- K11 = Lower Cretaceous, Trinity Group
- IPam = lower Pennsylvanian, Atokan and Morrowan Series
- Pau = Paleozoic undivided
- C = Cambrian
- pC = Precambrian

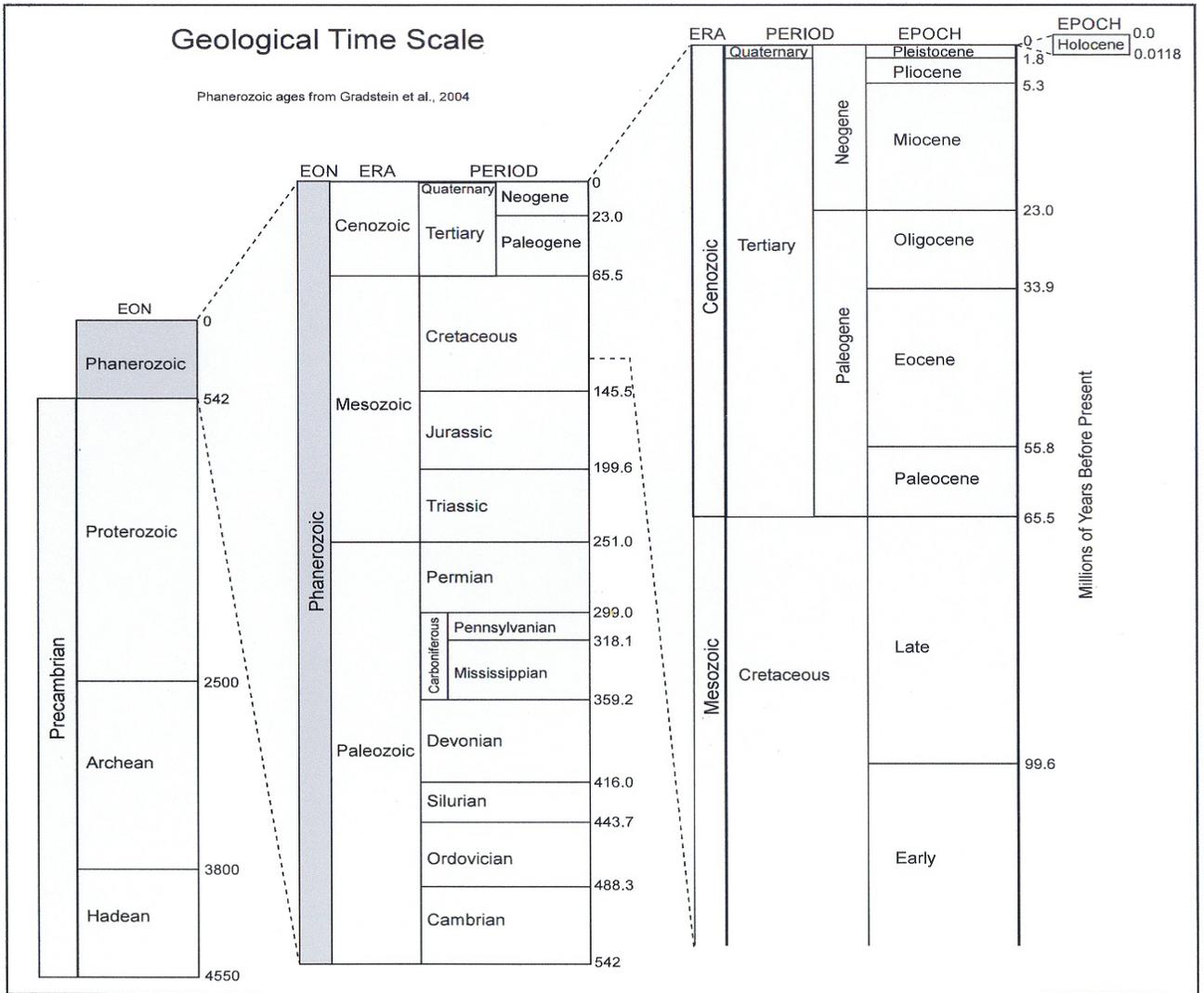


Figure 2. – Geologic time scale showing eras and periods of the Phanerozoic Eon and epochs of the Cenozoic Era. Ages noted at the time boundaries are in millions of years before present.

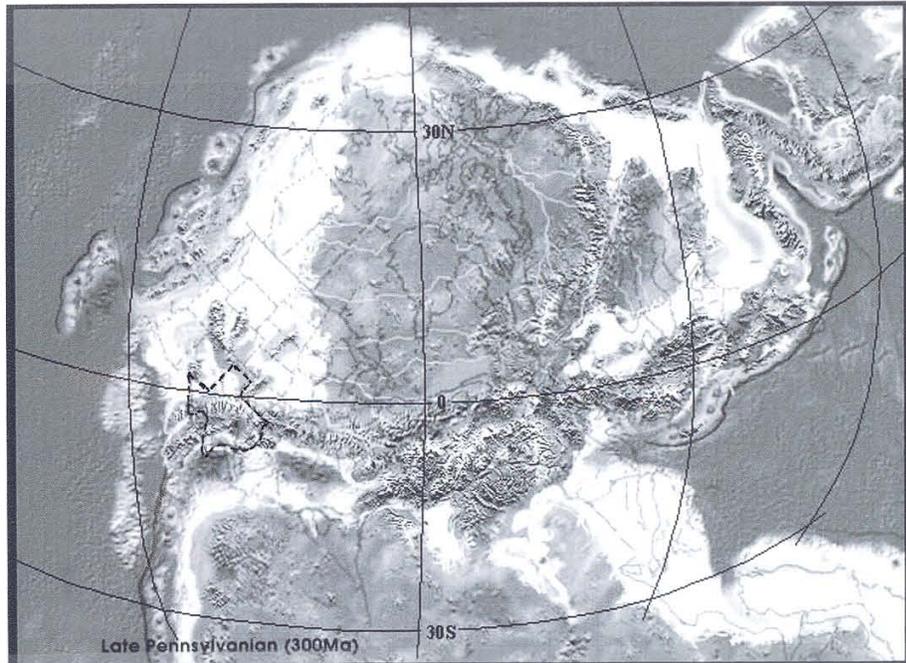


Figure 3. – Paleogeographic map of northern part of megacontinent during late Pennsylvanian time (see Fig. 2 for age dates). Central Texas area lay in a mountain chain related to the collision of the North and South American continents. Approximate position of North Central Texas during the geologic time periods shown on this and following maps is indicated by the outline of Texas on each map. Paleogeographic maps are from R. Blakey (2006) with permission.

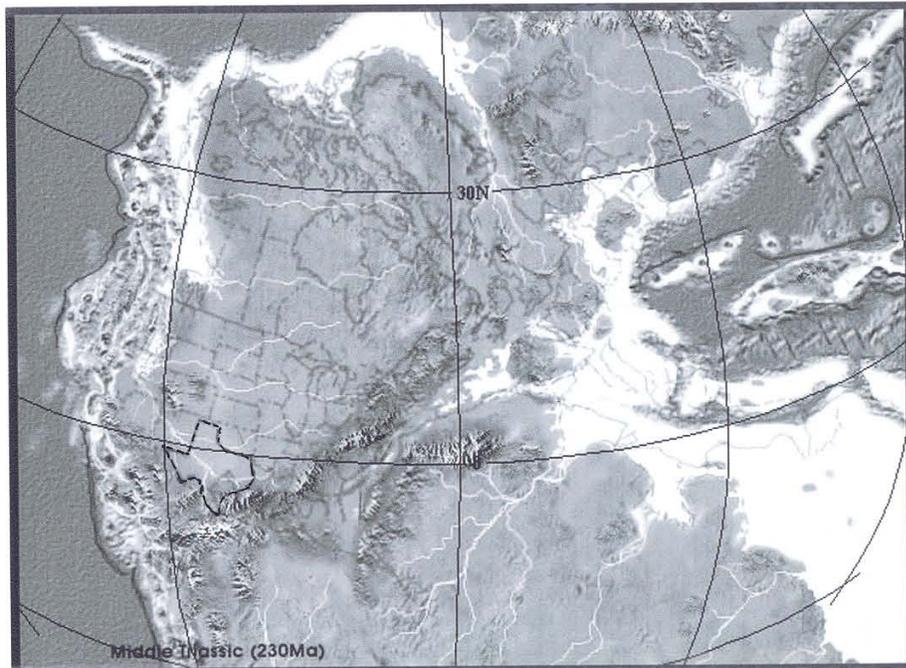


Figure 4. – Paleogeographic map of northern megacontinent during Middle Triassic time. Rift valleys were forming within the megacontinent (e.g., just lower left of center).

continental terrain (Fig 4). Stream systems crossed this area, depositing gravel, sand, and mud. Gradually, the Ouachita Mountains were worn down by weathering and erosion. During the Triassic, rifts in the continental crust began to create elongate basins (Fig. 4) which eventually would continue to split and spread apart to create narrow ocean basins, the first stages of the Atlantic Ocean and Gulf of Mexico (Fig. 5). During this time, the continental crust along the southeastern flank of the Ouachita belt began to subside relative to the land mass on the northwestern side of this belt of deformed rocks. This subsided area would become the northwestern rim of the Gulf basin. The configuration of the early Gulf rim, therefore, was controlled by the location of the old Ouachita Mountain Belt.

Late Jurassic Period

During Late Jurassic around 150 million years ago, the area now South Central Texas lay on the margin of the ancestral Gulf of Mexico (Fig. 6). Circulation of ocean currents into the Atlantic and Gulf of Mexico ocean basins was inhibited by constricted openings, and the climate was hot with high rates of evaporation. Consequently, the water in these narrow seas was extremely saline and dense. Salt precipitated along the margins of the ocean basins, in some places accumulating to many hundreds, even thousands of feet thick. Landward, the salt deposits thinned out against the rim of the ancestral Gulf. Although this salt layer subsequently was deeply buried under younger sedimentary rocks, it played a major role in later geologic history of South Central Texas.

As the Gulf and Atlantic continued to spread wider, oceanic circulation improved and more-normal salinity prevailed in the seaways. With the normal salinity, the typical sediment deposited along the western flank of the Gulf was carbonate sediment (debris of calcium carbonate shells and skeletons of marine organisms living on the sea floor; the source of limestone and dolostone). Sand and mud were eroded off the continent and deposited in the coastal-plain and near-shore zones.

Cretaceous Period

Early in the Cretaceous, the shoreline of the northwestern Gulf was in the South Central Texas area (Fig. 7). The adjacent land area was generally low-lying except for the Llano complex of very old Precambrian and Paleozoic rocks, which stood high and exposed to erosion. The Llano Uplift shed sand and mud into the coastal-plain stream systems and onto the shallow sea floor (future Sycamore and Hensel Sandstones), interfingering with layers of carbonate sediment farther out on the shallow-marine shelf (future Cow Creek and Glen Rose Limestones).

During the Cretaceous Period, the Gulf of Mexico widened almost to its present configuration. The continental margin in the Texas area subsided and the sea gradually encroached farther and farther inland. By about 108 million years ago, even the Llano-area island was inundated and starting to be covered by thick layers of marine calcareous sediment (future Edwards limestone).

As the area slowly subsided and sea level rose, the Late Cretaceous sea covered most of Texas and extended far to the northwest as part of an inland seaway connecting to the North Pacific Ocean (Fig. 8). In time, many hundreds of feet of Upper Cretaceous marine limestone, chalk, and mudstone accumulated in the South Central Texas area.

Around 85 million years ago, at the time the Austin Chalk was being deposited across

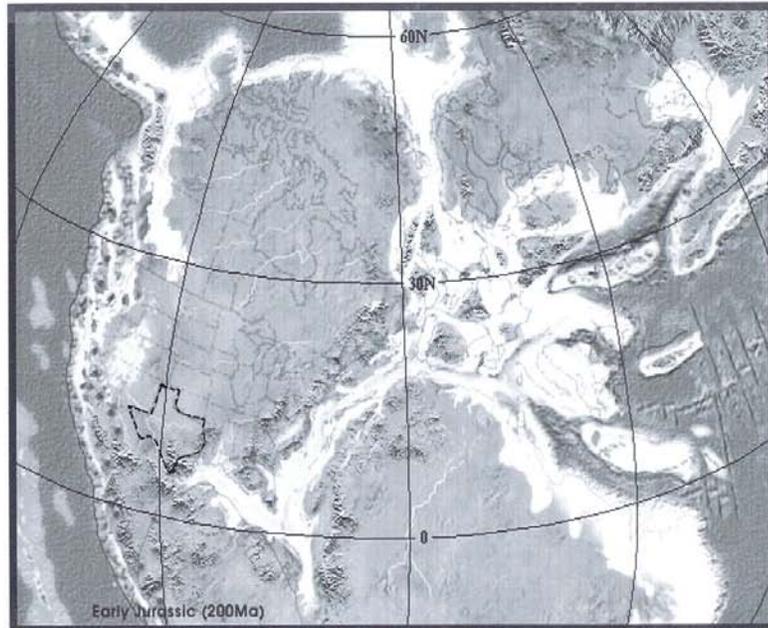


Figure 5. – Paleogeographic map of fragmented megacontinent during Early Jurassic time. Rift zones begun in the Triassic had widened into to the early stages of th Atlantic Ocean and Gulf of Mexico.

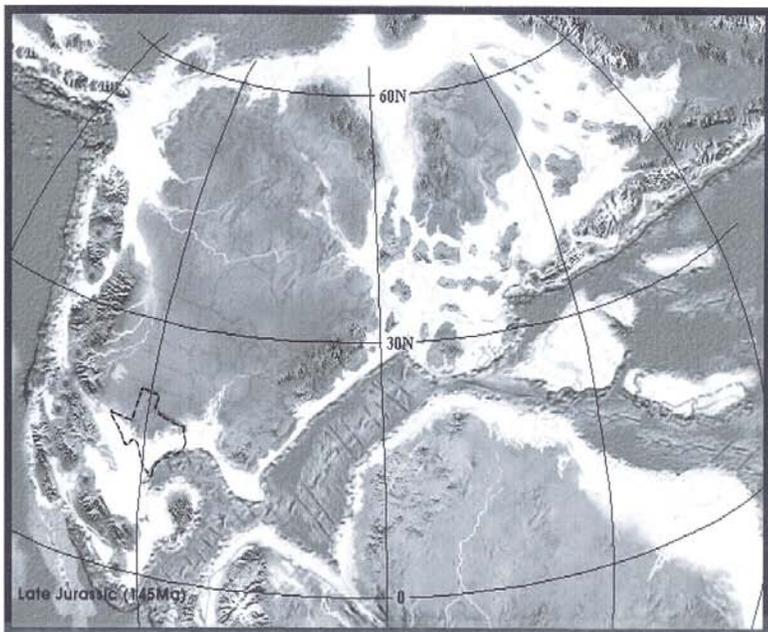


Figure 6. – Paleogeographic map showing proto-Atlantic and proto-Gulf during Late Jurassic time. Atlantic Ocean and Gulf of Mexico had widened in response to creation of new sea floor, but ocean basins were narrow and somewhat constricted on each end.

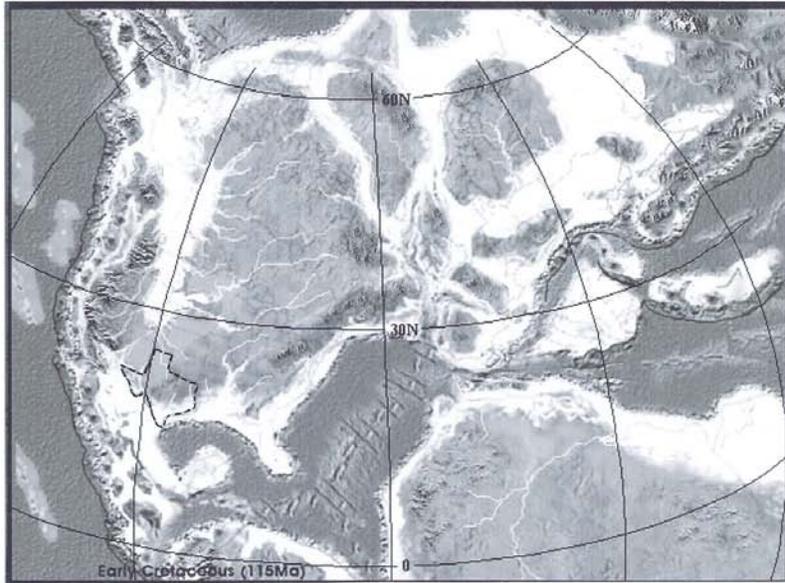


Figure 7. – Paleogeographic map of North Atlantic region during Early Cretaceous. The northwestern margin of the early Gulf of Mexico lapped into the Central Texas area.

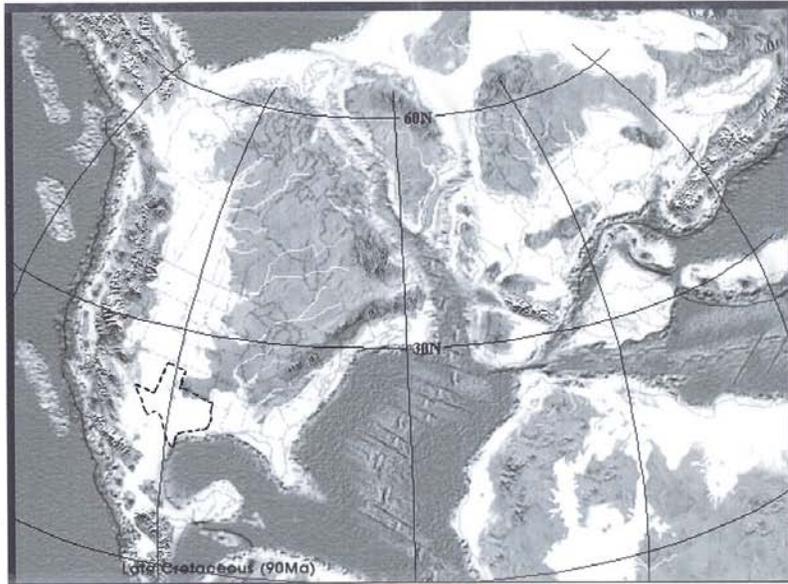


Figure 8. – Paleogeographic map of North Atlantic region during Late Cretaceous. Epicontinental seaway extended through Texas into the North Pacific Ocean.

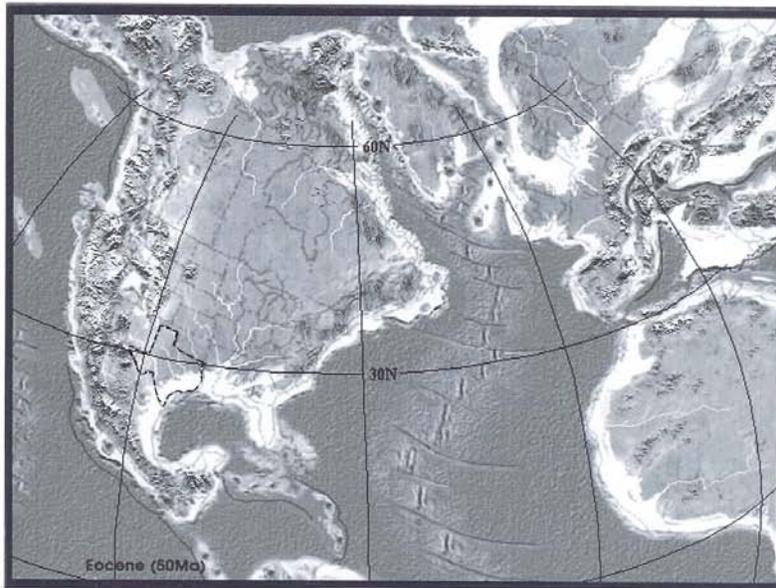


Figure 9. – Paleogeographic map of North Atlantic region during Eocene. South Central Texas was on the margin of the northwestern Gulf of Mexico.

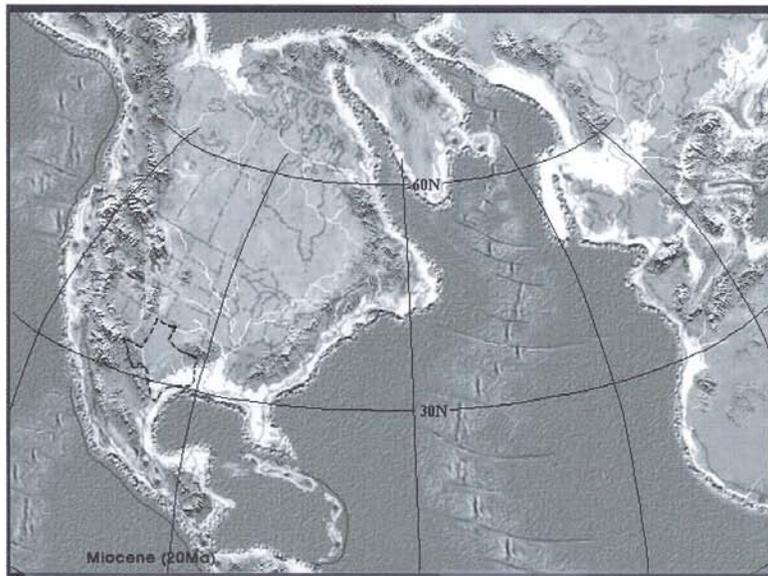


Figure 10. – Paleogeographic map of North Atlantic region during early Miocene. The coastline had move gulfward from South Central Texas.

South Central Texas, several volcanoes erupted on the sea floor along the northwestern rim of the Gulf basin. Some larger piles of lava rock built up high enough to be volcanic islands. These volcanic rocks are dark and heavy, rich in iron and magnesium, indicating they were crystallized from magma generated at great depths. Apparently, pulses of widening of the Gulf basin caused rifts deep into the crust or upper mantle that allowed magma to make its way to the sea floor.

Hundreds of miles northwest of South Central Texas during latest Cretaceous, the Rocky Mountains began to develop. As the mountains rose up and were eroded, streams brought great amounts of sediments onto the marine shelf of Texas where carbonate sediment was accumulating. Uppermost Cretaceous rocks (Navarro Group) in South Central Texas are mostly thick layers of marl and calcareous clay, the product of mixing the carbonate sediment with the influx of mud from the rising land area. As the Cretaceous Period drew to a close 65 million years ago, the extensive continental sea retreated toward the Gulf Basin.

Paleogene (Early Tertiary Period)

At the beginning of the Tertiary Period (Fig. 2), South Central Texas was a muddy sea floor receiving copious amounts of sediment as the continent interior rose higher. During the Eocene, South Central Texas was on the northwestern margin of the Gulf of Mexico, fluctuating in time from coastal-plain to shallow-marine environments (Fig. 9). At times large delta plains with channels, coastal marshes, and bays (e.g., part of the Wilcox Group and Yegua Formation) built out onto the shallow-marine shelf. At other times sheets of coastal-plain and shoreline sand (e.g., Carrizo Sand and Queen City Sand) spread across the area. From time to time, the shoreline advanced farther landward and South Central Texas was a shallow sea floor covered with marine mud and sand (e.g., Reklaw, Weches, and Cook Mountain Formations).

During late Eocene, sediment eroded off the mainland continued to be dumped into the Gulf, gradually building the land area farther and farther gulfward. From late Eocene on, South Central Texas was a continental terrain.

From late Eocene to earliest Miocene, stream systems and westerly winds brought ash and coarser debris from the volcanoes erupting in far West Texas, the western US, and northern Mexico to South Central Texas. This is when the Whitsett and Catahoula Formations, both rich in ash and volcanic-rock fragments, were deposited on the Texas coastal plain.

Neogene

By the beginning of the Miocene Epoch (Fig. 10), the northwestern rim of the Gulf basin had received great volumes of sediment, stacked layer upon layer since the Jurassic Period. All the while as the sediments accumulated, the basin margin slowly subsided to accommodate the many thousands of feet of marine sedimentary rock that now lay under the Texas coastal plain. Near the bottom of this thick stack of rocks was the layer of Jurassic salt, and under great overburden pressure, rock salt flows like warm wax. This is not a stable substrate for overlying rocks.

About 25 million years ago or so, probably in response to a pulse of Gulf widening, the Mesozoic and Cenozoic sedimentary layers crept toward the center of the Gulf by sliding across the top of the Jurassic salt. The slipping rock layers were stretched away from equivalent layers that had been deposited farther landward on more stable substrates beyond the perimeter of the salt layer. The slipping and crustal pull-apart resulted in zones of faults parallel to the rim of the

Gulf basin (i.e., parallel to the trend of the Pennsylvanian Ouachita mountain belt). This is the origin of the Balcones fault system and a similar fault zone near Luling (Fig. 11). The Balcones faults are essentially a series of downsteps that progressively lower the faulted strata toward the Gulf.

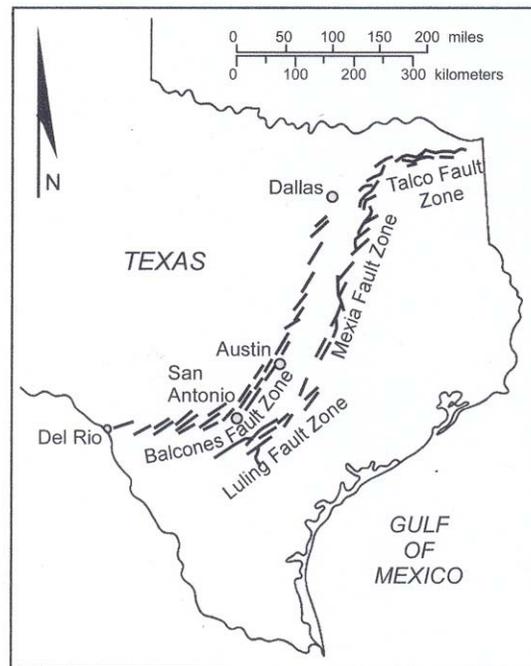


Figure 11. – Schematic delineation of Balcones and Luling Fault zones (from Collins and Hovorka, 1997).

South and east of the fault zone, the Gulf basin continued to slowly subside, progressively warping the Mesozoic and Cenozoic rock layers downward toward the Gulf basin. North and west of the Balcones fault zone the area remained a relatively stable and high platform. Gulfward-flowing streams began to rapidly erode the high plateau, stripping away the layers of Cenozoic and Cretaceous rock and spreading the eroded debris out onto the coastal plain. Miocene and Pliocene stream-system deposits (e.g., Oakville and Goliad Formations) contain chert and Cretaceous fossil fragments eroded from the highland.

Quaternary

Several times during the late Pliocene and Pleistocene (the last few million years), glaciers built up over the North Pole, locking up water and thereby lowering sea level. For example, the Gulf of Mexico was about 400 feet lower than present during the most recent glacial maximum around 20,000 years ago. When sea level was low, stream gradients were increased and the landscape was rapidly eroded.

By the Quaternary, the stream-dissected plateau north and west of the Balcones fault had eroded down to the Lower Cretaceous limestones, which weathered into a karst terrain, now called the Edwards Plateau. Large springs issuing from Edwards Plateau limestones had become headwaters for the major rivers that flow across South Central Texas today.

As the Gulf basin continued to subside, the rock layers underlying the coastal plain were

tilted toward the Gulf so that their landward ends were turned up and eroded off. For example, on the upper coastal plain just southeast of San Antonio, Eocene sandstone and mudstone crop out. Where the sandstone formations (e.g., Carrizo Sand) come to the surface are prominent cuestas with their steep sides facing northwest. Where the softer muddy Eocene rocks crop out are elongate erosional valleys. Between the Balcones fault zone and the Gulf, the outcropping strata are progressively younger toward the sea (Fig. 12A).

Consequences of Geologic Evolution of South Central Texas

The geologic evolution of South Central Texas has resulted in a varied landscape underlain by diverse rock types (Fig.12A). On the southeastern Edwards Plateau, karst topography is developed on Lower Cretaceous carbonate rock (limestone and dolostone) (Fig. 12A). Thin dark-colored basic top soils characterize this area (Fig.12 B).

Paralleling the eastern and southern margins of the Edwards Plateau is a narrow belt of Upper Cretaceous chalk and marl preserved in down-dropped blocks of the Balcones fault zone. This area has thick dark-colored clayey soils that shrink and swell upon drying and wetting (Fig. 12 B) and is the southwestern end of the Blackland Prairies (Fig.1A).

Southeastward of the strip of Upper Cretaceous rock, is a broad area of Paleogene sandstones and mudstones (Fig. 12 A). East of San Antonio these rocks crop out on the Post Oak Savannah (Fig. 1A), and south of San Antonio similar rocks underlie the upper South Texas Plains vegetation region. Soil zones in these areas have leached topsoil and accumulations of clay in the B horizon (Fig. 12 B).

Farther toward the Gulf is a belt of Miocene calcareous sandstone and mudstone (Fig.12A), partly derived from erosion of Cretaceous limestone from the Edwards Plateau. East of San Antonio this outcrop corresponds to a distal belt of Blackland Prairies (Figs.1A and 12B). South of San Antonio the Miocene outcrop belt has soil similar to that of the Edwards Plateau (Fig. 12B).

Even though the Paleogene and lower Neogene sandstone and mudstone units continue to the southwest, they are all included in the South Texas Plains vegetation region (Fig. 1A). This may indicate that climate is a greater influence on vegetation zones in this area than are rock and soil types. The South Central Texas climate is characterized by a southward increase in mean annual temperature and a westward and southwestward decrease in mean annual total precipitation.

In summary, the convergence of the four major vegetation zones in South Central Texas is intimately related to the geologic history of the region. Although not considered in this paper, the geologic history also directly influenced two other important factors that determined the present-day vegetation patterns: plant evolution and climate history.

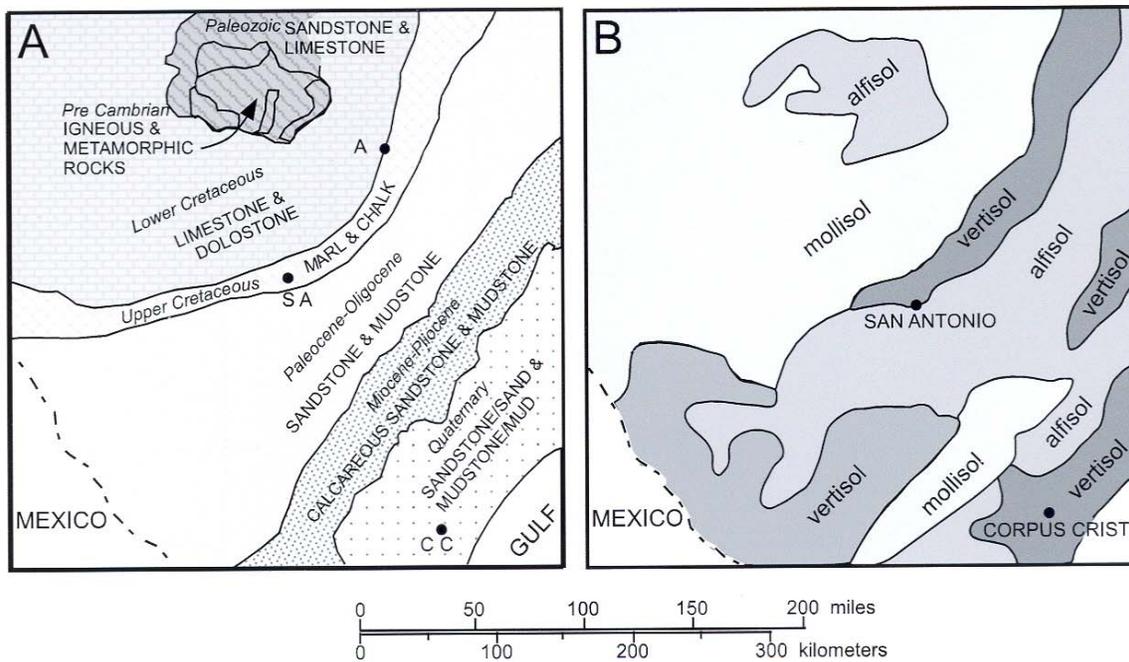


Figure 12A. – Rock types cropping out in South Central Texas and adjacent areas.

Figure 12B. – Major soil orders in South Central Texas and adjacent areas (after TA&MU Soil Characterization Lab, 2006).

Mollisol = grassland soil with high base status

Vertisol = clayey soil with high shrink/swell capacity

Alfisol = moderately leached soil with subsurface zone of clay accumulation and >35% base

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