Geology of the Dallas-Fort Worth Metroplex

A Primer

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THE YEAR IS 2041 AND UT DALLAS ENGINEERING has invented a time machine. You are the best history student at The University of Texas at Dallas and have been selected to take the first trip back in time. The University president asks you, "Where do you want to go? Back to talk with Lincoln at Gettysburg? Jesus at the Last Supper? Galileo at the Papal Inquisition?" You answer, "No ma'am, I want to go back to November 1841 and talk with John Neely Bryan, the founder of Dallas." The president gives you a quizzical look, says, "Wait a minute," whispers to her robotic assistant who whirls and leaves the room. The robot returns soon with a paper bag that he gives to the President, who pulls out a bottle of whiskey and hands it to you, saying, "You're going to need this." A team of engineering students turns a few dials and everything goes fuzzy for a few moments while you go back 200 years in time.

The next thing you know, you are standing on a small wooded knoll overlooking a small river. It is the Trinity River, and you are standing about where Dealey Plaza is in downtown Dallas today. It is late afternoon in November 1841. In the distance you can see a herd of buffalo, heading south for the winter, with a band of Native Americans following on horseback; overhead a sky full of geese flies in the same direction. One hundred yards away a man in a covered wagon is cajoling a team of horses across the river. It is John Neely Bryan.

Bryan, the horses, and wagon reach the riverbank and slowly come up to where you stand. He gives you a suspicious look until he spies the bottle of whiskey in your hand and smiles. After you help him

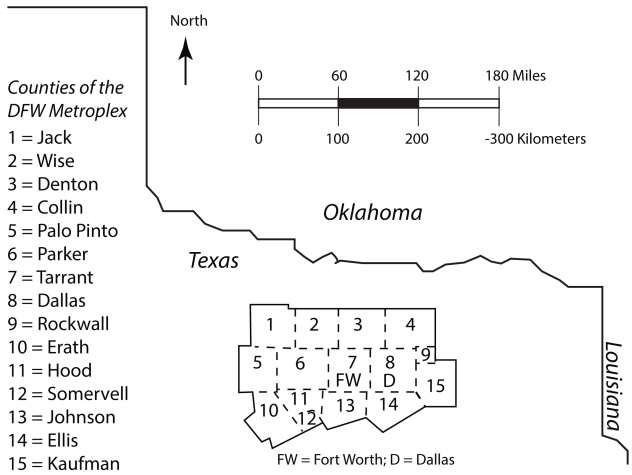

Figure 1 The 15 counties of the Metroplex, divided into three tiers: Northern tier: Jack, Wise, Denton, and Collin Counties; Central tier: Palo Pinto, Parker, Tarrant, Dallas, Rockwall and Kaufman Counties; Southern Tier: Erath, Hood, Somervell, Johnson, and Ellis Counties. D = Dallas, FW = Fort Worth. This is my definition of the DFW Metroplex, a bit different from the Census Bureau's Dallas-Fort Worth-Arlington metropolitan area. This area is about the same as the state of Maryland. Note that this definition of the DFW Metroplex is almost the same as the 16 counties that belong to the North Central Texas Council of Governments (https://www.nctcog.org). The area that is usefully described as the DFW Metroplex is likely to increase in the future. Figure by R. J. Stern.

set up camp and share some beans and bacon for dinner, you open the bottle, share it with him, and talk. He asks you where you are from and you tell him "200 years in the future." He raises a suspicious eyebrow but says nothing. You try to convince him, telling him about the war with Mexico, the Civil War, and how Texas joined the United States, then left, then joined again. You tell him the slaves are free and equal citizens and women have the same rights as men. You tell him about automobiles, airplanes, two World Wars, the atomic bomb, television, credit cards, and the internet. He asks a few questions but is mostly dumbfounded, only breaking his silence to ask for the whiskey bottle. Finally, you stretch his credulity to the breaking point by telling him about the city of Dallas—"How did you know I was going to name the town that I hope grows here that?" he blurts—but you continue. You tell him that what he is starting here will in two centuries be the third largest concentration of people in the USA after the greater New York and Los Angeles areas. You tell him that the great concentration of people will spread out over an area about the size of Maryland and be home to ten million people, and one in three Texans. Bryan grows alarmed and gets up, saying, "I knew you was crazy but now I know you're mad-dog dangerous!" as he points his rifle at you. You press the panic button and are digitally evacuated from the mid-nineteenth century back to UT Dallas just in time to escape with your life.

This little fantasy captures the miracle that is the Dallas-Fort Worth Metroplex. We can't know how many people will live here in two decades, but given its size today and its growth rate, ten million in 2041 is not a bad guess. According to US Census Bureau estimates for 2017, 7,400,000 people call the Dallas-Fort Worth-Arlington metropolitan area "home."[1] The DFW Metroplex is the fourth largest and the fastest growing metropolitan area in the nation (Fig. 1).

There are many stories that could be told about the surprising rise to prominence of the DFW Metroplex; about entrepreneurs, civic leaders, and politics, but these are not of interest here. Instead, the physical setting of the Metroplex is emphasized, especially the subtle natural advantages that the Metroplex has. Most large US cities are older and are located where there were natural harbors for ships like New York, Boston, Philadelphia, and Los Angeles. Others nucleated at key points on the Great Lakes, like Chicago and Detroit. Still others were established at key points on a great river, like St. Louis, New Orleans, or Pittsburgh. Only a few younger urban areas grew up around inland railroad junctions; these include Denver, Atlanta, and the DFW Metroplex. The natural advantages for population centers on ocean, lake, or river are obvious, but what about the inland centers? Their natural advantages may be less obvious, but that doesn't mean they don't exist. We should know about these so we can celebrate and protect them.

This essay outlines the geology of the Metroplex and the natural advantages that this has bestowed on our region. What made the land where the Metroplex is situated? Today the Metroplex is increasingly a "built environment," but the growing skin of asphalt and concrete is thin, and what lies beneath is easy to find in creek beds, roadcuts, and construction sites. It is worth thinking about the ground beneath our feet, not only because it affects our house foundations and fecundity of our gardens, but also so we can better understand our place in the world. To get your juices flowing on this topic, please take six minutes to watch a new video, *The story behind the rocks of Dallas/Fort Worth*, made by UTD's Geoscience Studios.[2]

A common complaint is that the metroplex has no mountains or beaches or even a great river (no offence intended to the Trinity River, about which I'll say more complimentary things later) but in fact mountains and ocean beaches were once here. The mountains were here 300 million years ago, a broad white sand beach was here 110 million years ago, and the great river was here 100 million years ago. These beautiful scenes all existed where we are today; we just arrived too late to enjoy them. But it's not too late to see evidence that these beautiful scenes once existed where we live today. Figure 2 shows the geology that lies beneath the DFW Metroplex.

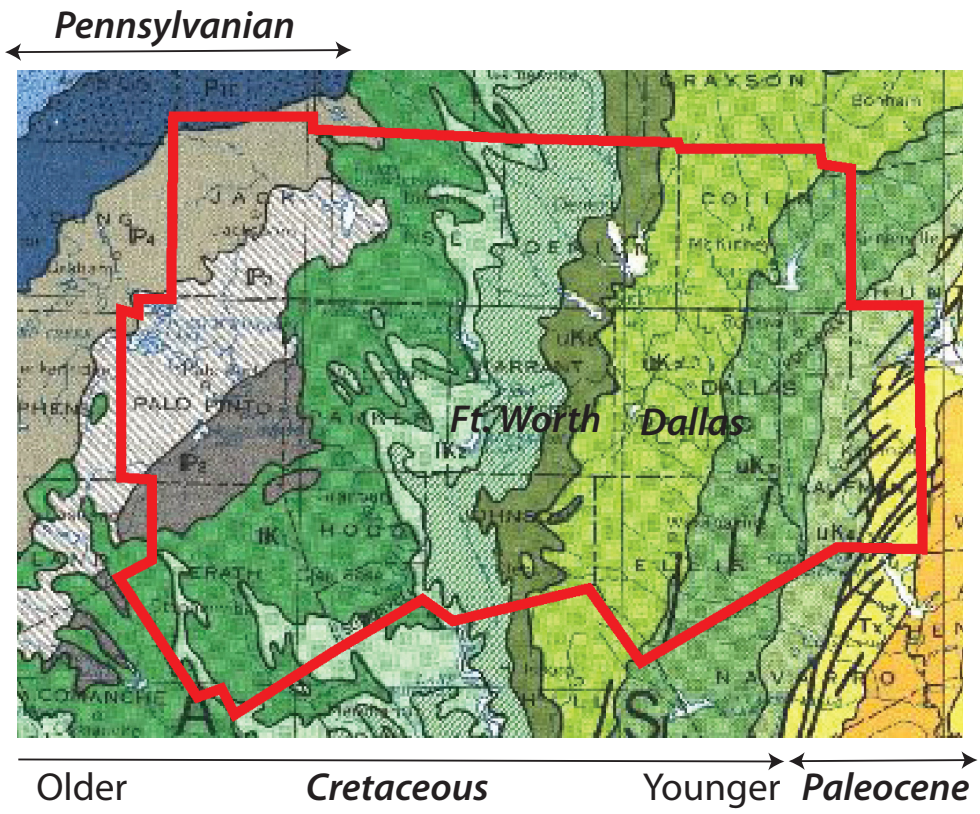

Figure 2 Outline of the DFW Metroplex and age of underlying sediments. Note that sediments from the Pennsylvanian (grey; 383 to 299 million years ago, or Ma), Cretaceous (green; 145 to 66 Ma) and Paleocene epoch (yellow; 66 to 56 Ma). Because Cretaceous and Paleocene sedimentary rocks dip gently east, they are oldest in the west and youngest in the east. A veneer of Quaternary sediments (2.588 Ma to today) is found along river valleys but is not shown. Figure by R. J. Stern.

Dallas didn't exist when the Texas Republic began in 1836, and it barely existed when Texas joined the United States ten years later. Dallas was founded at the best crossing of the Trinity River, where the river cuts southeast across the firm Austin chalk. In 1841, John Neely Bryan set his ferry and trading post on a low hill of the chalk on the north side of the river and Dallas germinated there. A few years later, in 1849, the U.S. Army built a fort overlooking the junction of the West Fork and Clear Fork of the Trinity River. The fort was abandoned almost as quickly as it was built, with the crude structure becoming the nucleus for the great city of Fort Worth.

Rainfall and soil dictated different economies for the regions around Dallas and those around Fort Worth. Dallas and the eastern half of the Metroplex receive an average of 37 inches of rain per year, while Fort Worth and the western half receive a little less. Just as important as the rainfall itself are the rocks that this rain has fallen on

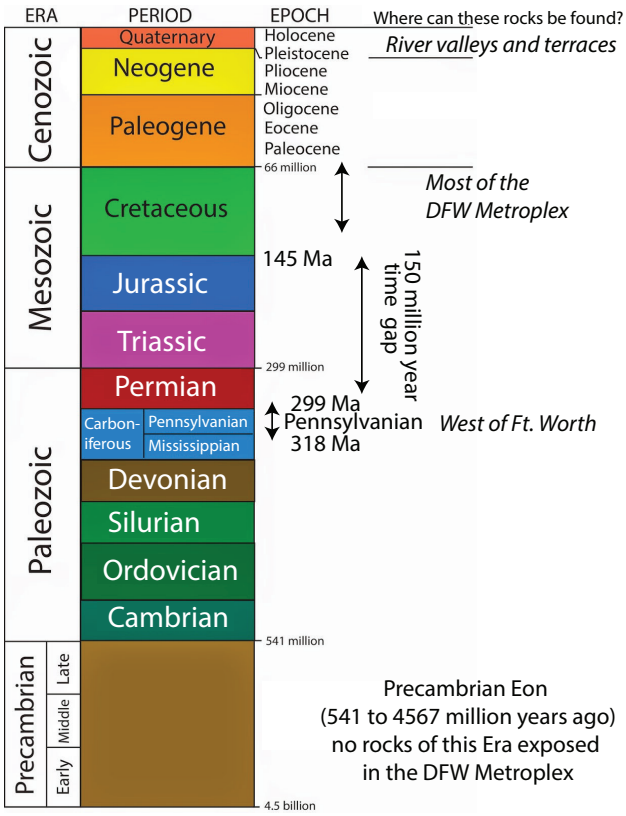

Figure 3 The Phanerozoic time scale, vertical axis is in millions of years before present (mega annum, Ma). Sedimentary rocks exposed in the DFW Metroplex include Pennsylvanian units in the far west, Paleocene units in the far SE, and a vast expanse of Cretaceous sediments in between. A time gap of about 150 million years between the Pennsylvanian and the Cretaceous is when our region was a mountainous uplift, subject to erosion. In fact, the oldest Cretaceous sediments are ~110 Ma, the gap encompasses almost 200 million years of Earth history. Figure by R. J. Stern.

over the last several millions of years. The eastern Metroplex is mostly underlain by shales—which easily break down into thick soils—but the western Metroplex is mostly underlain by limestones, which form poor soils. As a result, the post-Civil War economy around Dallas was founded on cotton, which grew well on the thick soils in the east. In contrast, the drier land around Fort Worth favored cattle drives and ranching. These economic realities of the last half of the 19th century are reflected in the saying that "The East stops at Dallas; the West starts at Fort Worth."

The solid Earth has three great compositional layers: the core, the mantle, and the crust. The crust is by far the smallest part, making up about 0.5% of Earth's mass, and is divided into thinner oceanic crust and thicker continental crust. The lightness and thickness of continental crust means that its upper surface is mostly above sea level, and this encouraged an incredible variety of plants and

air-breathing creatures to evolve on its surface, Texans included. The continental crust beneath southern Oklahoma and north central Texas is composed of Precambrian (about 1.4 billion year old) igneous and metamorphic rocks. These rocks are everywhere buried beneath sedimentary rocks in the Metroplex but can be seen in the Llano area west of Austin, for example in the granitic monolith of Enchanted Rock. Thick Paleozoic (541 to 252 million year old) sedimentary rocks lie on top of the crust, including the Mississippian (about 330 million year old) shales of the gas-rich Barnett Shale. Paleozoic sedimentary rocks are mostly buried beneath younger sediments in the Metroplex, but Pennsylvanian sedimentary rocks (about 300 million years old; Fig. 3) are exposed in the far northwest (Fig. 2). Thick sequences of Pennsylvanian sediments were shed from the east, where collision between the ancient continents of Laurussia and Gondwana made the super continent Pangea ("All Earth"), with a now-eroded mountain range marking where the collision occurred (although remnants of the Pennsylvanian mountain range are still exposed in the Ouachitas of SE Oklahoma and SW Arkansas). Places where Pennsylvanian sedimentary rocks can be enjoyed include Mineral Wells State Park, where some folks enjoy climbing cliffs of Pennsylvanian conglomerate. These conglomerates were shed westward from the mountains that used to rise where Dallas is today. Another fun destination is Mineral Wells Fossil Park, where you can hunt for Pennsylvanian marine fossils.[3] At this time, the ocean lay to the west. The economy of Fort Worth was transformed in 1917 when oil was discovered in Pennsylvanian sedimentary rocks near Ranger, about 90 miles to the west.[4]

Paleozoic sedimentary rocks of the Metroplex tilt gently west, so they get younger in that direction. Some of the youngest Paleozoic sedimentary rocks have thick layers of salt and the rivers that flow over these deposits can become quite salty and unpalatable, even nonpotable. One reason that population and economic activity in north central Texas focused on the Metroplex is because the Trinity River is short and does not flow over the salt deposits to the west. In contrast, longer rivers to the north (the Red River) and south (Brazos River) reached farther west and flowed over these salt deposits, making the water of these rivers too salty to use. The saltiness of the Red River is reflected in the fact that Striped Bass, a fish that normally lives in the ocean, thrives in Lake Texoma. (The largest was caught in 1984 by Terry Harber; it was 39 inches long and weighed 35 pounds.)[5] Thus, partly because of water quality, the regional economy—transportation, banking, et cetera—increasingly focused at communities built on the shorter Trinity River. The superior quality of Trinity River water—a gift of the river's shorter length—thus stimulated the growth of Dallas and Fort Worth over settlements on the longer Brazos and Red Rivers. Maintaining Trinity River water quality and quantity, increasingly supplemented by water from rivers to the east, is also a key for the

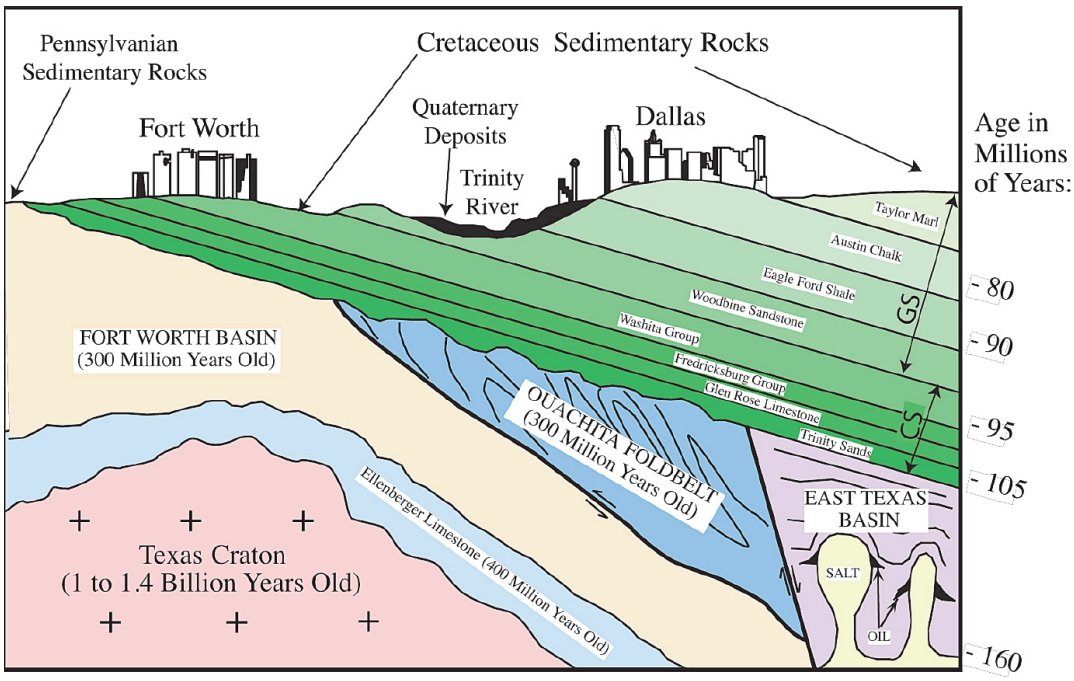

Figure 4 Simplified and exaggerated section across the DFW Metroplex. All that is exposed at the surface is Quaternary river terraces and Cretaceous and Pennsylvanian sedimentary rocks; older rocks are buried and only known from drilling. Note that about 200 million years of erosion separates Pennsylvanian and Cretaceous sediments. The Pennsylvanian sea retreated towards the Pacific, but the Cretaceous sea retreated to the SE. The Ouachita foldbelt is remnant of the mountains that once rose where Dallas is today. The Cretaceous is a gently (~1°) eastward dipping series of beach and river sands, limestones, shale, and chalk; CS = Early Cretaceous Comanche Series; GS = mostly Late Cretaceous Gulf Series. Note that the Cretaceous sediments overlie much older Pennsylvanian sediments above a major unconformity. Figure by R. J. Stern.

future of the region. The unpredictable effects of global climate change on rainfall in and around the Metroplex complicate planning for continued population growth.

The importance of Dallas and Fort Worth as regional centers was cemented when the railroads arrived after the Civil War. The north-south railroad arrived in Dallas 1873 with the Houston and Texas Central. A memory of this railroad is preserved in the name of Central Expressway, which follows the old tracks. The east-west Texas and Pacific Railway arrived the same year and established Dallas and Fort Worth as regional transportation hubs. The north-south freeways (IH-35E and 35W, and IH-45) and east-west freeways (IH-20 and 30) followed similar routes to and through the Metroplex.

Most of the Metroplex is underlain by Cretaceous sedimentary rocks. These sediments were deposited as sea level rose through the 79 million years of this time period, reaching the Metroplex about 110 million years ago. The sea expanded from the Gulf

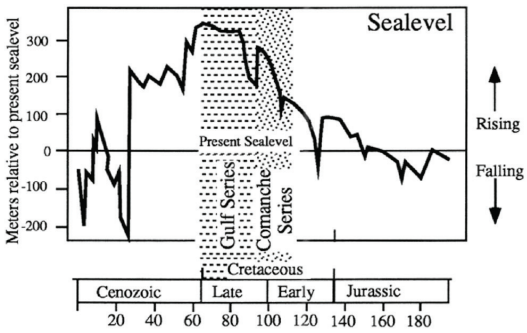

Figure 5 The great Cretaceous transgression and the Cretaceous interior seaway.

Left Sea level rose throughout Cretaceous time, eventually reaching the region now occupied by the DFW Metroplex towards the end of Early Cretaceous time, about 110 Ma. Sea level continued to rise, depositing the Early Cretaceous sediments of the Comanche Series (now exposed in the western Metroplex) followed by Late Cretaceous sediments of the Gulf Series (now exposed in the eastern Metroplex). Figure by R. J. Stern.

Right Artistic depiction of what the DFW Metroplex looked like during Late Cretaceous sealevel highstand ~80 Ma. © Denver Museum of Nature and Science.

of Mexico, a small ocean basin that formed when Pangea broke up about 165 million years ago. As sea level rose, the ocean flooded the land, which had been eroding for about 200 million years since the collision to form Pangea ended. The first deposits in the Metroplex were clean beach sands and shallow water limestones, now exposed west and south of Fort Worth. Dinosaurs cavorted in this shoreline environment. You can see their footprints at Dinosaur Valley State Park, near Glen Rose.[6] Sea level continued to rise slowly, depositing shallow marine limestones, which are well exposed in Tarrant County. This basal sand overlain by younger limestones makes up the Comanche Series (CS in Figure 4).

This shallow warm marine environment was interrupted about 100 million years ago, when crustal uplift to the northeast in what is now southeast Oklahoma and southwest Arkansas shed tremendous volumes of sediments to the south. These sediments outcrop in the mid-cities area, from Arlington north to Grapevine and beyond. One or more great rivers flowed south into the Metroplex region, forming a great delta with vast swamps. Dinosaurs returned to the area; their footprints are known from rock exposures near Lake Grapevine. Oak trees thrive on this sandy soil and in John Neely Bryan's time a forest of these defined the north-south strip known as the "Cross Timbers," separating the limestone scrub to the west from the blackland prairie to the east. You can get your hands dirty in the Woodbine, helping other volunteers dig for Cretaceous swamp creatures such as crocodiles and turtles at the Arlington Archosaur Site.[7]

Figure 6 The Austin Chalk. This Late Cretaceous marine sediment is made up of untold billions of Coccolithophorae, which are unicellular eukaryotic phytoplankton.

A Coccosphaera showing arrangement of calcite ($CaCO_3$) plates coccoliths in life position. This organism is 50-100 µm in diameter. B Loose coccolith plates deposited on seafloor. Compression turned this loose agglomeration of microfossil fragments into chalk. C, D Outcrops of Austin Chalk exposed by erosion on an outside bend of White Rock Creek, at Anderson-Bonner Park in North Dallas. Figures by R. J. Stern.

Tectonic movements to the north waned, the region subsided, and the great Woodbine river died. The sea invaded again, but this time it was a stagnant sea, with no oxygen below the shallow wind-mixed region, so that any animal that swam or sank into the oxygen-starved waters died instantly and was preserved in the black shales deposited on the seafloor, known as the Eagle Ford Shale. A slightly different variety of Eagle Ford Shale is a prolific producer of oil in south Texas. The Eagle Ford Shale in the Metroplex makes a poor soil and its swelling clays sometimes causes problems for construction.

Sealevel continued to rise and the stagnant Eagle Ford ocean was replaced by much more oxygenated waters (Fig. 5). The sea about 90 million years ago was deep enough to submerge all but the tallest skyscrapers in downtown Dallas.[8] In this clear, warm sea, far removed from muddy shorelines, single-celled phytoplankton called coccolithophorae thrived. These creatures were armored with hubcap-shaped calcite plates that sank to the seafloor when the coccoliths died,

accumulating on the seafloor as a gentle "snow" over millions of years to ultimately produce the 400-foot-thick Austin Chalk (Fig. 6). The Austin Chalk is the bedrock that Dallas is built on, from east of US-75 (Central Expressway) to west of the North Dallas Tollway. Austin Chalk outcrops generally stand a little above the more easily eroded Eagle Ford Shale to the west and the Taylor and Navarro shales to the east, which tend to form muddy river valleys (e.g. the Elm Fork and East Fork of the Trinity River). The north-south trending Austin Chalk outcrop belt makes a well-drained, modestly vegetated, high-standing ridge that can makes an excellent route for animals and people to move from San Antonio though Austin to Dallas. It was this firm substrate for overland travel and favorable river crossings that was followed by buffalo, Native Americans, John Neely Bryan, railroads, and IH-35.

The economy of Dallas was transformed when the gigantic East Texas oil field, a subterranean pool 42 miles long and 8 miles wide, was discovered 120 miles to the east in 1930.[9] This pool was found where the Woodbine sandstone was slightly tilted; the oil was cooked out of the organic-rich Eagle Ford Shale and sealed into place by a cap of Austin Chalk.

The youngest Cretaceous sediments underlie the easternmost Metroplex (Fig. 2), and farther east only Cenozoic sedimentary rocks, deposited in the last 66 million years, are exposed. The boundary between the youngest Cretaceous and oldest Cenozoic sedimentary rocks (Paleocene; Fig. 2,3) elsewhere preserves evidence of the large meteorite that struck Earth on what is now the Yucatan Peninsula of Mexico, disrupting climate and leading to the demise of the dinosaurs and other Cenozoic life. Such evidence has not yet been reported from this horizon in the Metroplex.

The final geologic time period represented in the Metroplex is the Quaternary, essentially the most recent two and a half million years of Earth history. This was a time known as the Ice Age. The great continental ice sheet that covered much of North America never reached south of Kansas and Missouri, but its effects on climate and especially rainfall were felt in the Metroplex region. The Trinity River and its tributaries received much more water and were much more vigorous streams than they are today. Coarse gravels were deposited and broad river terraces were cut by these bigger rivers. Giant mammals like mammoths dominated the animal life of the Metroplex. Occasional glimpses of these majestic beasts are sometimes seen when someone finds a buried tusk or tooth. A spectacular mass grave of these beasts can be seen at Waco Mammoth National Monument.[10]

I hope you enjoyed this brief overview of the rocks beneath the DFW Metroplex. Keep this history in mind when encounter some of the many rock exposures in roadcuts, construction sites, and along streams in the Metroplex. Pause and think about the environments in which these sediments were deposited. The rocks can be visited easily

enough on your own, or you can join one of the many fossil-collecting field trips offered by organizations like the Dallas Paleontological Society.[11] If you want to learn more about the geology of our region, take a look at Stern and Pujana (2016) .[12]

Our region enjoys significant natural advantages including buildable land extending in all directions and good water resources. Even some former disadvantages are no longer such: Not being near the seashore or on a great river means that the DFW Metroplex is protected from increasingly powerful storms and floods resulting from climate change. From Nature's hand, we only have to worry about flooding, droughts, tornadoes, and maybe earthquakes. Will we and our children and the many new people who will move to the Metroplex be wise enough to make the best use of and protect these advantages? .A

Endnotes

1 https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

2 https://www.youtube.com/watch?v=axtGS7KSAzo

3 https://www.mineralwellsfossilpark.com

4 http://fortworthtexas.gov/about/history

5 https://danbarnett.com/lake-texoma-fishing-records

6 https://tpwd.texas.gov/state-parks/dinosaur-valley

7 https://www.nbcdfw.com/news/local/Fossilized-Dinosaur-Tracks-Discovered-at-Lake-Grapevine-321509491.html

8 https://www.smu.edu/Dedman/Academics/InstitutesCenters/ISEM/OceanDallas (includes a nice downloadable guide to the units and fossils in Dallas County)

9 https://en.wikipedia.org/wiki/East_Texas_Oil_Field

10 https://www.nps.gov/waco

11 https://dallaspaleo.org

12 Robert J. Stern and Ignacio Pujana, "Stratigraphy of the Dallas Fort Worth Metroplex," in George Maxey and Roger Farish, eds. Guide to Fossil Collecting, Ivy Press (Dallas, 2016), 4-1 to 4-17. The Guide to Fossil Collecting by the Dallas Paleontological Society is best obtained at www.DallasPaleo.org; click on 'store'.