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Texas Through Time: New Evidence on the Geological Prehistory of Texas and the American Southwest

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Where on Earth is Texas - In the "Southwest," on the "third coast" of the Gulf of Mexico, bordering the Rio Grande and the Chihuahua Desert? All of the above. The combination of these locations has molded the Lone Star State and its people. Where on Earth did Texas come from? That is a harder question to answer, one that takes us back more than one billion years in time, and to far flung parts of the world.

Present: Along the Gulf of Mexico and Rio Grande. It is the bedrock we all see, exposed in the Guadalupe and Chisos mountains, in the Colorado and Brazos river valleys, in the ancient cliffs of the canyons along the Rio Grande and the shores of the Highland Lakes, and in modern road cuts throughout the state, that tells the story of Texas through time.

That bedrock leads us back through a quarter of the history of the planet, and from southern North America where we live directly to three of the other five continents. South America, Africa and even part of Antarctica may all have been adjacent to what is now Texas at various times in the past. These former

continental connections teach us about the enormous changes in geography and the global environment that influenced evolving life. Global change has constantly reshaped Planet Earth since the birth of the solar system 4,550 million years ago. Only humankind's growing influence over the past few millenia is new.

Data acquired by a spacecraft in high Earth orbit shows our part of the Earth as if the oceans had been emptied of water. The region of southern North America that we call Texas, and home, faces northern South America across the Gulf of Mexico and Caribbean basins. North and South America are separated from Europe and Africa by the Atlantic basin, and from Asia and Australia across the far wider Pacific basin. Studies of the floors of the oceans have taught us that the Atlantic Ocean basin is comparatively young, a mere 180 million years old. The Gulf of Mexico and Caribbean basins were formed at about the same time, when North America separated from Europe, Africa and South America at the time dinosaurs dominated life on Earth. The first step back in time to appreciating the wanderings of Texas across the face of the planet leads us to Pangea, the supercontinent that incorporated all land on the planet prior to that separation.

Dinosaur days: The Pangea Supercontinent. The late astronomer Carl Sagan referred to Earth as the "pale blue dot" in space. He persuaded NASA to regard the "fly-by" of Earth by the spacecraft Galileo as a visit to an alien planet. Could life here be detected? The presence of oxygen suggests the presence of life, and the detection of modulated radio signals is a clue to the activities of intelligent life forms, but a visit a mere 200 years ago would not have detected such radio waves. Let us pretend that we are in a spacecraft visiting Earth not a mere 200, but 200 million years ago. What would the planet have looked like?

An equatorial orbit would take us over an enlarged Pacific Ocean between the eastern shore of Asia and the western shore of today's American continents. Then, passing right over the area that one distant day was to become the state of Texas, we would pass over the vast landmass of the supercontinent Pangea. There would be no Atlantic Ocean, no Indian Ocean, and no Southern Ocean isolating an Antarctic continent over the South Pole. There also would be no Gulf of Mexico. The area we know as Texas would be nestled against Yucatan and the northern coast of South America and would be very close to today's Africa. The newly evolved dinosaurs, if our spacecraft could detect them, would range widely. Fossil dinosaurs have been found over the length and breadth of Pangea.

If we stayed in Earth orbit long enough, we would see the familiar continental shapes emerge from the Pangean supercontinent. At about 180 million years before the present, the continental margins of northern South America and Texas would separate to form the embryonic Gulf of Mexico, with the Yucatan moving off to its present position within Central America. At about the same time, the Appalachian margin of North America would separate from West Africa.

All this happened because of the growth of a massive crack through the Pangean supercontinent, a crack driven by tensional forces generated in the

Earth's mantle more than 60 miles beneath the surface. The floors of new oceans form by upwelling of basaltic lava from the mantle as pressure is released along the line of the growing crack ‹ like the outpouring of a gaseous soft drink from a can when the tab is removed. As the new basins formed, ocean water from the encircling Pacific Ocean flowed into these cracks in Pangea, becoming the waters of the Gulf of Mexico and Atlantic Ocean.

The rate of lava outflow and hence the formation of new ocean floor varies over tens of millions of years. Between 110 and 85 million years before "Present", there was a period of particularly rapid outflow and ocean floor spreading. The hot young lava displaced water from the ocean basins and it spread over the low coasts of the bordering continents, including the Texas margin of the Gulf of Mexico. The warm ocean waters harbored a myriad of floating organisms. As they died, these organisms fell to the floors of the shallow seas, and when the pulse of rapid lava outflow ceased about 85 million years ago, towards the end of the interval of time known as the Cretaceous Period, the sea water retreated from the continents into the Gulf of Mexico and the ocean basins.

Left behind was a thin layer of white limestone known as chalk that forms the white cliffs of Dover in England, much of the landscape of the European lowlands, and the Hill Country of Central Texas. It was the soft limey mud that oozed up between the toes of the dinosaurs as they hunted and foraged along the primeval Texas waterways, leaving the footprints that we still see. We might think of the limestone that we drive past in the road cuts of Loop 360 skirting the west side of Austin, and along other highways of the Hill Country, as the "bathtub ring" of the Gulf of Mexico and world ocean during this period of intense volcanic activity and fast growth of the ocean basins. This was one of the main intervals when oil was generated from decaying organic remains.

One of the most exciting events since the early days of the planet took place 65 million years before Present. Just as the dinosaurs were adjusting to the fragmentation of the Pangea supercontinent into our familiar continental entities, a comet about six miles in diameter entered the Earth's atmosphere and crashed into the shallow seas of the Yucatan Peninsula. The impact caused ejecta and tidal waves to rush out from ground zero in every direction, engulfing low-lying parts of islands in the Caribbean and sweeping up river valleys on the Gulf Coast of Texas. Chaotic tsunami deposits still can be seen along the banks of the Brazos river.

Recognition that the Cretaceous Period came to an end so abruptly has changed our views of the planet. It is still uncertain that this event was the direct cause of the demise of the dinosaurs. There was an almost simultaneous, and probably coincidental, massive outpouring of basaltic lava in northwestern India that must also have had a major effect on the global environment. Nonetheless, this impact in the immediate neighborhood of Texas has heightened awareness of the role played by extraterrestrial events in the history of the Earth ‹ and the possibility of other catastrophic encounters in the future.

Texan trilobites: The Argentine connection. Many people have the impression that the Pangea supercontinent was the original configuration of continents on

the surface of the planet ‹ far from it. That supercontinent was, however, the earliest one whose geography we can reconstruct with confidence.

Pangea is only the most recent supercontinent of several that formed since the earliest epoch of Earth history known as the Archean, 4,550 to 2,500 million years ago. That is the very ancient interval of time, immediately after the birth of our planet, during which the low density material forming the continents accumulated at the surface of the planet. It is perhaps a help in considering these immense numbers of years back in "deep time" to bear in mind that one year represents the time required for Earth to orbit the sun ‹ hence the planet has completed approximately 4,500 million orbits since the formation of the solar system.

Pangea itself amalgamated from earlier continental entities stitched together along a "suture" line of mountains extending from the Urals of Russia, through Central Europe, and along the Appalachian Mountains. In Alabama the suture turns west, and is represented by the Ouachita Mountains of Oklahoma and the hills that extend south from Marathon, Texas towards the Rio Grande. This semi-circular arrangement of ancient highlands reflects where the "bulge" of northern South America collided with southern North America before being pulled away again in the opening of the Gulf of Mexico, which I described above. It reflects the fact that there was an earlier embayment in the Texas margin, which geologists call the Ouachita embayment, a precursor of today's gulf and ‹ it turns out ‹ an important clue to reconstructing earlier supercontinents.

In northwestern Argentina, the easternmost mountain range of the mighty Andean Cordillera is known as the "Precordillera." The rocks forming this range, on which the Argentines develop their excellent vineyards, were once part of ancestral North America prior to the formation of Pangea. How do we know this? Principally because the ancient limestones of the Cambrian and Ordovician periods of Earth history, roughly 500 to 550 million years old, contain the fossil remains of bottom-dwelling arthropods called "trilobites" that are as strictly North American in character as is, say, today's bison. These particular trilobites could not swim, nor could their larvae have survived a long passage in ocean currents between North and South American continents. Rather, the present location of their fossils means that the rocks of the Argentine Precordillera are North American. Moreover, detailed analysis of those rocks by Dr. Ricardo Astini of the University of Cordoba in Argentina indicates they are closely related to those in the southern part of the Appalachian Mountains.

Dr. William Thomas of the University of Kentucky proposed several years ago that the Ouachita embayment was formed when a major fragment rifted from North America and drifted to some unknown location. Now we know where it is ‹ Argentina. But how did it get there? As a small microcontinent drifting free like Madagascar, as suggested by Dr. Thomas and Dr. Astini?

I believe instead that the presence of these rocks and their fossils from North America in southern South America reflects nothing less than a collision between the ancient Appalachian and Andean margins of the two continents approximately 450 million years ago during the Ordovician Period, perhaps

involving an offshore "Texas Plateau" now lost to Argentina. This means that the Precordillera is a sort of geological business card left behind by North America as it moved into the Northern Hemisphere. Its presence in Argentina says nothing less than: "North America was here 450 million years before Present." I refer to the supercontinent that existed fleetingly at the time of the suggested collision of North America with South America as "Artejia," reflecting the hypothesized origin of the rocks of Argentina and Texas.

Earlier collision with a southern neighbor: The Texas Himalayas. Half a billion years before its encounter with South America, the Texas continental margin of North America collided with something really big, and head-on, not just a side-swipe like the collision that transferred the Precordillera to South America! This has long been the opinion of my colleagues Dr. William Carlson and Dr. Sharon Mosher in the department of geological sciences, based on two sorts of evidence: temperatures and pressures required to generate minerals found in some of the oldest rocks of Texas around Llano that are exposed from beneath the Hill Country limestones, and the deformation that some of these rocks have suffered.

This head-on collision must have occurred between 1,150 and 1,120 million years ago, according to the results of isotopic analyses performed by students and faculty members in the UT Austin laboratory of Dr. James Connelly. From a Texas standpoint, we can identify the collider only as an "unknown southern continent," to use Dr. Mosher's term. Comparison with the geological history of southern Africa, and with the area of Antarctica south of Africa and the Atlantic Ocean, however, has led Dr. Mosher and myself to suggest that it was a continent comprising rocks of these two areas and referred to as Kalahari that collided with the ancestral Texas margin of North America. This continent formed a billion-year-old mountain range of what must have been Himalayan proportions.

Work done in the UT Austin paleomagnetic laboratory of Dr. Wulf Gose indicates that the Kalahari continent and Texas may have converged to within 600 miles of each other at that time. That is approximately the width of the present Himalayas. The rocks now exposed at Enchanted Rock State Park, for example, would have been the foundation of this huge mountain chain, long worn down by erosion to expose its deepest roots.

These studies have allowed us to refine the paleogeography of the hypothetical supercontinent of Rodinia, aptly named from the Russian language as the parent of all subsequent continents. The Pacific Ocean formed between Antarctica and Australia on the one side and North America on the other when Rodinia broke up at around 800 million years ago.

Time's abyss: Earth before Texas. A mere 200 years ago, a physician from my native Scotland broke out of the bonds that literal translation of the Scriptures imposed on thinking about the age of the Earth. A gentleman farmer, James Hutton realized that the soil-generating processes he observed on his land acted quite slowly. Relating them to rock formations, some of which had been uplifted and deformed in mountain building episodes, he wrote of the great antiquity of the planet and related it to other planets and the stars. Hutton has come to be known as the founder of modern geology. His

biographer, physics professor John Playfair of the University of Edinburgh, described how Hutton made the heads of his companions "Grow giddy, as we looked into the abyss of time."

Hutton concluded that he could discern: "No vestige of a beginning and no prospect of an end." With the help of modern isotope geochemistry we can now determine that the Earth has orbited the Sun approximately 4,550 million times since the birth of the solar system, and with the help of astronomic observations and calculations we can relate this to the birth of the universe.

As we look back into Playfair's "abyss of time" beyond that of the earliest supercontinent now reconstructed, albeit hypothetically, we contemplate an age on Earth when the land we know as Texas did not exist. The oldest rocks of the state were formed along the margin of the ancient core of the North American continent around 1,400 million years before Present, immediately (at least in geologic terms!) prior to the continent-continent collision that generated the "Texas Himalayas" whose roots are seen at Enchanted Rock. They were formed partly of juvenile material from the Earth's mantle that had never previously seen the light of the Sun, and partly from materials recycled from the continent's core. That core is exposed now in the Mojave Desert of California, in the mountain ranges of Wyoming and Montana, and in the low lying glaciated rock outcrops surrounding Lake Superior and the Great Slave Lake of Canada.

These ancient rocks, and others of comparable antiquity in Western Australia and Greenland, take over from the younger ones in places like Texas to tell us the story of our planet back to four billion years, almost to the time of the cessation of the heavy bombardment by meteorites that affected Earth, the Moon, and all the planets of the inner solar system immediately after its birth. Amazingly, the history of life on Earth can be traced back almost as far. The oldest fossils, of single celled organisms that lived in what is now Western Australia, date back more than 3.5 billion years. Astrophysicists have demonstrated, by comparison with other stars, that about five billion years into the future, our Sun will become a red giant and envelop its planets, including Earth, in a gaseous holocaust that must end all life remaining at that time.

We must therefore contemplate a time on Earth before 1,400 million years ago when there was no Texas, but also a time in the future after the planet has orbited the Sun five billion additional times, that it will become at best a lifeless cinder in space. Against that seemingly depressing thought, we can weigh a highly invigorating one. Humankind, from its most remote primate ancestors, evolved over a mere five million years. In these terms, we have virtually limitless time available to reach our full potential on this planet, and indeed perhaps to outlive our terrestrial home and realize a dream we cannot even imagine.