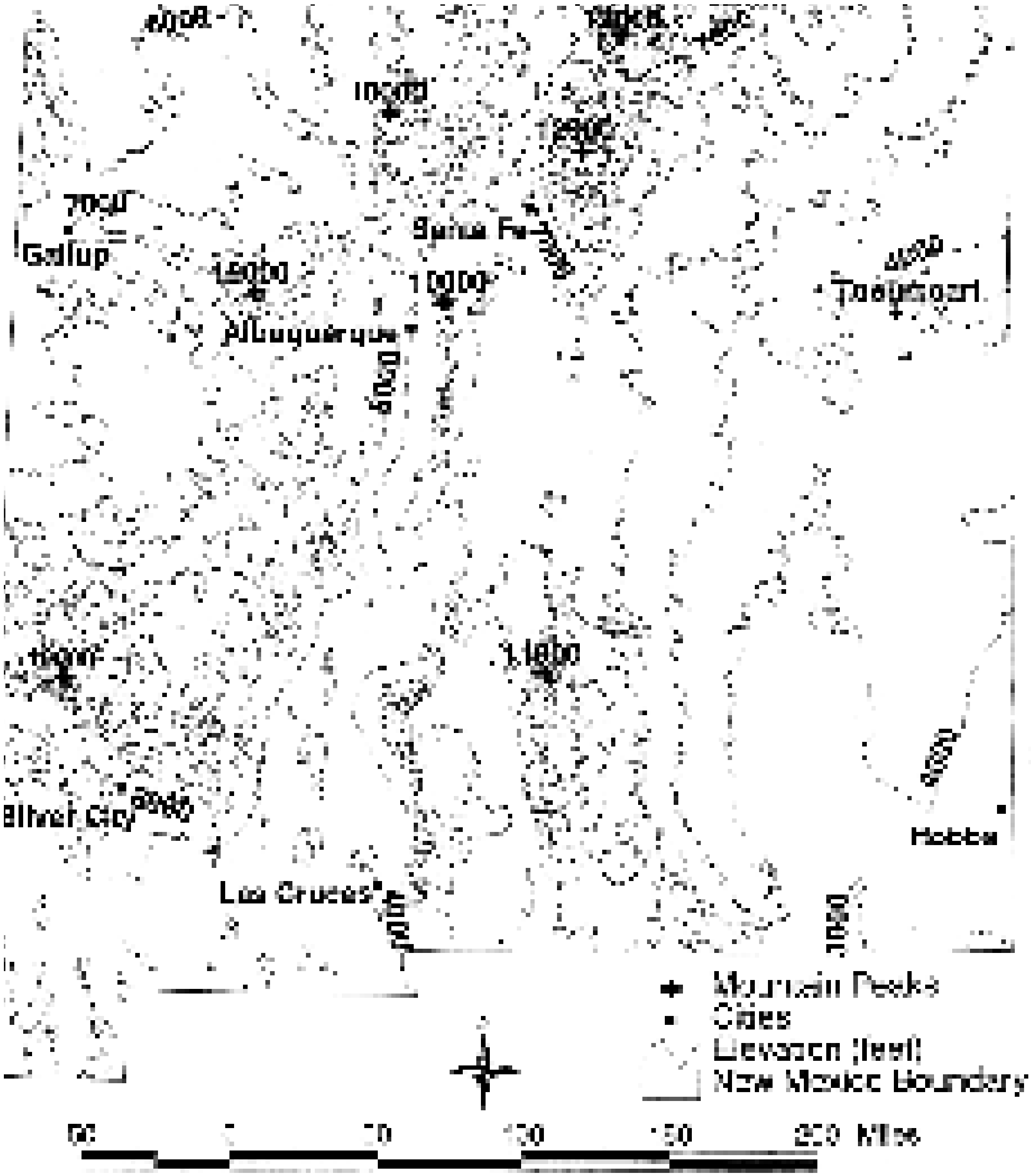
1,000-foot Elevation Contours



Geologic History of the Rio Grande Rift

By Jayne Aubele

New Mexico is unique in many ways. One of the little-known reasons that it is unique is that it is the site of the Rio Grande Rift which extends from southern Colorado (the San Luis Valley) down the center of our state and into northern Mexico* (see map and diagram on following pages). Much of the landscape, geology, and vegetation of New Mexico is related to the development and location of the rift. The Rio Grande exists because of the rift. Without the rift, there would have been no Rio Grande and no Rio Grande bosque.

Imagine a New Mexico without the Rio Grande, without the mountains that today border the Rio Grande and without the young volcanoes that today parallel the river. This was New Mexico near the end of the Mesozoic Era (65 million years ago [mya]). How did New Mexico get from there to here? How did the Rio Grande Rift and the Rio Grande form?

Pushing and Pulling

The Earth's crust is actually made up of many huge, separate pieces; geologists call these plates. Plates cover the Earth much like giant puzzle pieces, but they are not static. They move in relation to each other. Two plates can slide past each other, move toward each other causing mountain building or volcanism, or move apart from each other. New Mexico lies within a single plate, the North American plate, but our state has been affected by the movement of plates far away, along the western edge of the continent.

At the end of the Mesozoic Era, many small plates apparently began to crash into the western margin of the North American plate. These plates caused the continent to ripple like a rug being pushed from the edge. Geologists call this type of movement compression. The "ripples" became the modern Rocky Mountains, extending from Canada into northern New Mexico. The Sangre de Cristo Mountains in New Mexico are the southernmost expression of the modern Rocky Mountains.

As plates continued to crash into the western edge of the continent, some pieces of plates attached to the edge of the continent. What we now call California was added to this edge. Apparently, at least one plate actually began to move beneath the continent. As this plate traveled from west to east beneath the continent, a wave of volcanic eruptions occurred throughout what would become the western U.S.

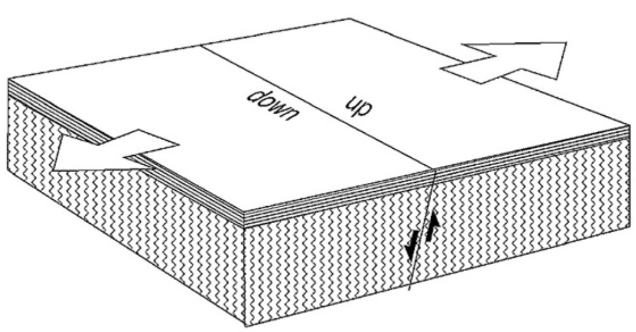
* There are only five known young (active or recently active) continental rifts in the world, and the Rio Grande Rift is one of them. A continental rift is a linear area where the crust within a continent is thinning and pulling apart. It is not the boundary of two separate plates, but instead it forms within a plate. It can with time develop into a plate boundary. The other young active continental rifts in the world are: (1) the East African Rift; (2) the Rhine Valley in Germany; (3) the Baikal Rift in Russia; and (4) a recently identified rift beneath the ice in Antarctica.

These volcanic eruptions occurred from 60 to 20 mya and formed the Superstition Mountains in Arizona and the San Juan Mountains in Colorado. In southern New Mexico, dozens of enormous caldera eruptions formed what are today the Mogollon Mountains, the Black Range, Magdalena and Socorro mountains and the Organ Mountains. The Organ caldera eruption occurred about 36 mya to form the rocks of the Organs; later, after the rift began to form, the Organ Mountains were lifted up as part of the marginal rift mountain chain and eroded into their organ-pipe shape. At this same time, Sierra Blanca, the large composite volcano, or strato volcano (a combination of lave and hot ash), just north of the Sacramento Mountains, and a volcano that eventually was eroded partially away to form Shiprock also erupted. The "Age of Volcanoes" in New Mexico began during this period and has continued to today.

It's All California's Fault!

About 20 mya something happened to the movement of the North American and Pacific plates. There may have been a redistribution or reorientation of their movements, as occasionally happens, and the compression of the North American continent ended. Instead of pushing the continent into mountainous "ripples," the plate bounding the western edge of the continent began to slide northward along the edge of the continent. This movement continues today and is the cause of the San Andreas fault zone in California. This sliding motion began to tear or pull apart the southwestern region of North America. Geologists call this type of movement tension or shear. As this movement continued, it caused the pulling apart of what is now the southwestern U.S. A series of roughly parallel, north-trending, deep, elongated valleys with intervening mountain ranges were created by this pulling apart of the continent. If you drive through southern Arizona or Nevada today, you see these parallel valleys and mountains in what is called the Basin and Range Province.

During this time, something strange happened in the Four Corners area of northwestern New Mexico, northeastern Arizona, southeastern Utah and southwestern Colorado. This region, which geologists named the Colorado Plateau, was a shallow circular valley during the Mesozoic Era (Triassic, Jurassic and Cretaceous Periods) and had layer upon layer of rock units deposited on it in a flat layer-cake sequence. At the end of the Mesozoic Era, when the Rocky Mountains were uplifted, and during the Tertiary Period (60–20 mya), when the extensive volcanism was occurring in the western U.S., very little seemed to affect this region. When the continent began to pull apart 20 mya, the Colorado Plateau still was not affected. It stayed as a stable, layered piece of continental crust, while the rest of the continent broke apart into a series of valleys around it. If you pin a piece of paper to a bulletin board with a single pin and then



1. Rio Grande Rift 20 million years ago (see key p. 202)

pull on that piece of paper from one direction, the paper will begin to rotate and tear around the pin. That is what happened to the southwestern North American continent. As the continent began to pull apart and rotate around the Colorado Plateau, valleys were created to the south and west of the plateau (part of the Basin and Range), and a large valley began to form east of it. This "valley" is the Rio Grande Rift.

Like Pizza Dough . . .

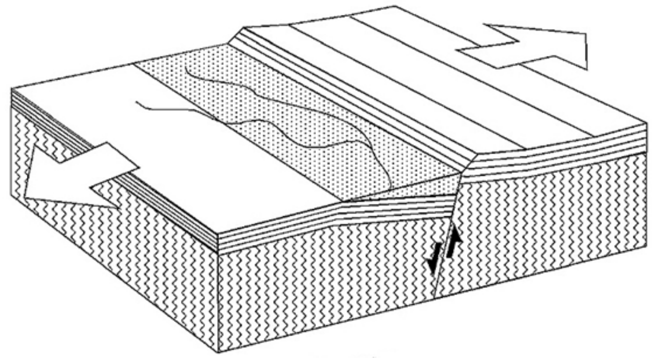
A geological rift forms by the pulling apart and thinning of the Earth's crust. You can think about it as though it was pie crust or pizza dough rolled out with a rolling pin and then pulling apart from both sides. If you have ever done this with dough, you know that it does not break in a straight line down the center. Instead, it breaks apart in a series of oval openings that occur as you continue to pull and the dough thins and breaks. This is exactly the way the Earth's crust responds to tension. In fact, the Rio Grande Rift has formed as a series of oval basins or depressions, outlined by faults, that extend in a slightly offset line from southern Colorado to northern Mexico. The northern Rio Grande rift is composed of three major basins; from north to south they are the San Luis, Espanola and Albuquerque–Belen basins.

The boundary between the northern and southern segments of the rift occurs north of Socorro. The southern segment, from Socorro to El Paso, began operating earlier than the northern rift (as early as 30 mya) and has opened into a much wider area of several parallel basins extending from just west of the Florida Mountains to the Sacramento Mountains. The two major basins of the southern rift are the Jornada del Muerto Basin (between the Caballo Mountains and the San Andres) and the Tularosa Basin (between the San Andres and Sacramento mountains). The rift south of Las Cruces is called the Mesilla Basin, and the area southeast of Deming is the Mimbres Basin. Between the Caballo Mountains and the Black Range is the Palomas–San Marcial Basin.

As the basins began to form, the continental crust thinned and dropped down to form low areas. Thinner crust meant that it was easier for magma to reach the surface, so volcanoes began to erupt in the center of the rift. Volcanoes from Taos to Carrizozo erupted. The Jornado del Muerto Basin is named for the volcanic badland in the northern part of the basin. Nearby, within the Jornada and Palomas–San Marcial basins, are other volcanoes: east of the Rio Grande at Elephant Butte Reservoir and to the northwest near San Marcial. Southwest of Las Cruces, the Potrillo Mountains are a large area of volcanoes and volcanic flows, including unusual maar volcanoes produced by the interaction of magma and water.

In the northern Tularosa Basin, the Carrizozo Volcanic Field contains the second-youngest lava flow in New Mexico: the Valley of Fires, dated at around 5,000 mya.

The series of cracks in the crust at the edges of the rift, called boundary faults, became very complex. Some of the margins of the rift began to be uplifted into the modern central mountains of New Mexico, including the Fra Cristobal and Caballo Mountains. Northwest of Las Cruces, the Robledo Mountains are composed mostly of



2. Rio Grande Rift 10 million years ago

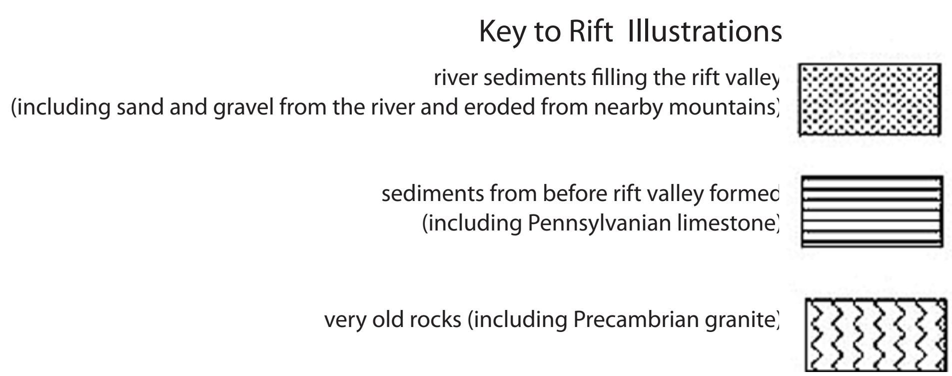
Permian rock that was originally deposited as a lowland river floodplain. They contain one of the most extensive early reptile trackways in the world.

The San Andres Mountains are formed of layers of rock that were originally deposited as the floor of a shallow Paleozoic sea (see Geologic Time Line) and have been lifted up as block and tilted to the west; they form the western margin of the Tularosa Basin. Forming the eastern margin, the Sacramento Mountains contain the same rock layers, but these have been lifted up and tilted to the east. At Bingham, the Sierra Oscura or Dark Mountains are an eastward-tilted block of rock layers (from bottom to top: Precambrian, Ordovician, Pennsylvanian and Permian) that have been lifted up along the fault that separates the Tularosa Valley from the Jornada del Muerto.

These mountains contain very old rock layers. In fact, the mountains of south-central New Mexico, such as the San Andres, are the only places where rocks from the early Paleozoic Era (Ordovician, Silurian and Devonian periods) exist in our state. While the rocks are old, the mountain ranges themselves are geologically young; they probably began to rise perhaps around 10 mya. These mountains were lifted up as a block of rock layers, and therefore geologists call them fault-block mountains. For example, the Oscura-San Andres-Organ-Franklin uplift separates the two major basins of the southern rift. Many of the mountain ranges that occur on the east and west sides of the Rio Grande in southern New Mexico are fault block ranges.

The Rio Grande Rift and the mountains that form the rift's margins continue to be geologically active today.

The series of rift basins, with uplifted margins, formed a perfect low area for water to flow. As water runoff began to form in northern mountains, such as the San Juans, the water began to integrate into a permanent through-going river that took



advantage of the low area. Most geologists believe that the ancestral Rio Grande began about 4 mya and that the modern river formed as a major river 1–2 mya. Most river valleys are eroded or cut by the rivers that flow within them. Unlike most rivers, the ancestral Rio Grande did not erode the broad, flat valley through which it now flows; it simply took advantage of this linked series of basins or low areas.

The modern river, of course, has eroded the small channel that you see today. In the Taos area, it eroded the Rio Grande Gorge, cutting down through the layered basalts filling that basin. The ancestral Rio Grande (broad and shallow) probably moved back and forth between the Sierra de Las Uvas and the San Andres. At least ouce it flowed through Fillmore Pass between the Organ and Franklin Mountains and into the Tularosa Basin. It did not, however, flow to the Gulf of Mexico; it emptied into a shallow lake near El Paso. About 2 mya the upper and lower Rio Grande drainages connected to form the single river from Colorado to the Gulf.

From Albuquerque south, the river fluctuated between cutting a channel and depositing silt and sand carried down the river. It slowly carved an entrenched and wide valley and left behind earlier, higher valley floors such as the Jornada plain near Upham and the west mesa between Sunland Park and Las Cruces. At the end of the last ice age (12,000 years ago) when there was abundant water in the Southwest, the river probably eroded a deeper river channel than we see today. During the past 10,000 years, the river probably deposited material, in general, and actually filled in what was once a deeper, wider river channel. As the modern river flow rate and volume changes, the river bed can be slightly eroded or raised.

The Rio Grande is the Gift of the Rift

In New Mexico, more than in many other places, the landscape is directly related to and produced by dynamic, on-going geology. The rift has provided New Mexico with much of its beautiful landscape, its young mountains and its volcanoes. The rift has also given us the gift of a major river, unusual in our semi-arid region. As a result, the rift and the river have provided a home for a biologically diverse population of plants and animals, recognized today as the Rio Grande bosque.

The rift has also produced a landscape unique to New Mexico. The Tularosa is a closed basin, with no external drainage. Late in the Ice Ages (late Pleistocene) a giant lake later named Lake Otero filled the area north of the Jarilla Mountains. The lake water contained salt and gypsum dissolved and carried by rainwater passing through the Paleozoic limestone layers in the San Andres Mountains. At the end of the Ice Ages the lake began to evaporate, and gypsum was concentrated and precipitated out of the water. There is still a remnant of that lake, called Lake Lucero, which may contain water during the rainy season. It also contains large crystals of gypsum. The wind blows dominantly from the southwest here, and over the past few thousand years it has picked up and carried sand-sized pieces of gypsum from Lake Lucero toward the center of the basin to form the largest gypsum dune field in the world, preserved as the White Sands National Monument. The White Sands are still forming, and the dunes move about 10 feet (3 meters) per year.

25. Time Line Activity

One way to help students understand the concept of geologic time is to have them make a time line. Using this time line, choose items that are most interesting, with one for each student. Have the students make separate index cards for each one of the items. They can list the item or event and the time when it occurred or they can draw a picture. You then choose a unit of measure for each unit of time. For example, if you choose one centimeter = one million years then the age of the Sandia granite: 1.5 billion = 1,500 million = 1500/100 cm (and million years) per meter = 15 meters of string! If you go back to the beginning of the Earth at 4.6 billion years ago: 4.6 billion = 4,600 million = 4,600/100 cm per meter = 46 meters of string! If you used 1 millimeter for each million years and go back to the formation of the Earth, you will need only 4.6 meters of string.

Have the students stand up with their cards and arrange themselves in order from most recent item or event to oldest. Go down the line and have them state to the class what they are and the time. Then pull out the string and have them measure where they belong on the time line. You can pre-mark the string at each meter/100 million years. The students should then stand at the proper place along the string.

A Few Questions for Discussion

Were the Sacramento or San Andres mountains here when dinosaurs lived here?
The dinosaurs went extinct 66 million years ago. The rocks that make up these mountains had been formed, but they did not rise into mountains until 10 million years ago.

Is the lava flow of the Valley of Fires relatively old or relatively young?
It is very young in relation to the geologic history of the Earth.

What things do we see together today that formed at very different times?
The rocks of the central mountains are very old, but the mountains themselves are geologically young.

What happened early in Earth's history? Why have we lost much of the record of it?
There has been erosion, mountain building and volcanism to change the surface of the Earth; we have a much better record of more recent events.

Geologic Time Line

ya=years ago; mya=millions of years ago; bya=billions of years ago

Era	Period		
CENOZOIC	QUATERNARY	12,000 ya	oldest known people in North America; Lake Lucero begins to contribute gypsum; White Sands begin to form
		30–40,000 ya	modern humans first evolved: *Homo sapiens;* Lake Otero forms
		150,000–1 mya	first bison in N. America
		1.1–1.6 mya	San Augustin Plain is a lake
		1.6 mya	
	TERTIARY	1.5–2.5 mya	first mammoths in North America; Rio Grande becomes a river that flows from Colorado to the Gulf of Mexico
		10–20 mya	first bears; Caballo, Fra Cristobal, Animas, Oscura-San Andres-Organ-Franklin and Sacramento mountains begin to lift up
		20–30 mya	first camels; Rio Grande Rift begins to form; Organ Mountains erupt
		35-55 mya	first grasses; first horses; Sierra Blanca erupts; Mogollon, Black Range, Socorro and Magdalena mountains erupt
		60 mya	first primates; primitive mammals
		65 mya	
MESOZOIC			extinction of dinosaurs, other species at Tertiary–Cretaceous boundary
		67–66 mya	rise and fall of *Tyrannosaurus*
	CRETACEOUS	70–90 mya	mosasaur, *Albertosaurus*, *Pentaceratops;* most of New Mexico covered by ocean; Clayton Lake trackway formed along ocean beach
		100 mya	first flowers; ammonites abundant
		145 mya	
	JURASSIC	150 mya	NM a muddy floodplain (Late Jurassic); first bird, *Archaeopteryx; Stegosaurus, Allosaurus, Camarasaurus, Seismosaurus*
		170 mya	NM a "sand sea" similar to the Sahara (Middle Jurassic),
		200 mya	
	TRIASSIC		*Coelophysis* (NM state fossil); first mammals and dinosaurs; phytosaurs, aetosaurs, *Placerias*
		250 mya	
PALEOZOIC	PERMIAN		*Dimetrodon;* red sandstone mud on sea floor will become San Andres limestone with reptile tracks preserved, will become Robledo Mountains; great reef formed in ocean, will become Guadalupe Mountains
		290 mya	
	PENNSYLVANIAN		first reptiles; first seed plants; Crinoids (sea lillies); rock layers deposited, will become rocks in San Andres and Sacramento mountains
		320 mya	
	MISSISSIPPIAN		Crinoids proliferate; shallow reefs cover New Mexico
		355 mya	
	DEVONIAN		first amphibians; rock layers deposited, will become rocks in mountains
		415 mya	
	SILURIAN		first insects; first land plants and land animals; scorpions; rock layers deposited, will become rocks in mountains
		440 mya	
	ORDOVICIAN		early jawless fishes; rock layers deposited, will become limestone on San Andres and other mountains
		495 mya	
	CAMBRIAN		first fish; trilobites and brachiopods
		545 mya	
PRECAM-BRIAN	PRECAM-BRIAN	1.5–2 bya	formation of granite that will be uplifted as southern mountains form
		3.2–3.8 bya	oldest known rocks on Earth; oldest known fossils
		4.6 bya	Earth and other planets in our solar system formed