VOLCANOES IN OUR BACKYARD

The West Potrillo Volcanic field is located about 40 miles west of El Paso in the state of New Mexico. It is an area of such diverse and interesting volcanic features that all the astronauts that traveled to the moon visited the area before their missions. I was privileged to be a part of one of those training mission when the Apollo 17 astronauts, Eugene Cernan and Harrison Schmidt, came to the area. The area is easily accessible by most high terrain vehicles such as trucks and SUVs.

Today we are going to take a field trip to those volcanoes. If you look off to the west from the top of Trans Mountain Road in El Paso, you will see on the horizon a line of low hills. The most prominent and highest of these hills is Mt Cox and Mt Riley, and just to the right of these peaks lay approximately 160 volcanoes and associated lava flows, which make up the West Potrillo Volcanic field.

The lava flows and volcanoes were formed in a structural feature called the Rio Grande Rift. A rift is a long linear trough that occurs when the crust of the Earth is stretched and pulled apart so that the center of the tough is lower than either side. The Rio Grande rift lays in a north-south direction, with extends from south of El Paso into Mexico and north into Colorado. The crust that is normally about 35 km thick, thinned, this allowed magma from the mantle, the layer of rock beneath the crust to move upward. This magma was then erupted from faults and fissures formed by the rifting. Eruptions continued intermittently from about 20,000 years ago to 900,000 years ago.

In most areas the rising magma encountered groundwater creating violent explosions. The falling, disintegrated rock fragments formed cinders, and cinder cones such as we will see at Black Mountain were formed. In other areas, the explosions were so violent that large amounts of ash and soil were blown out, collapse of the ground over the vent occurred, and large circular depressions, such as those we will see at Kilbourne’s Hole were formed. In many areas along the faults, basaltic lava erupted forming smooth billowy or ropy flow surfaces. Pahoehoe is the Hawaiian term used for these types of flow features.

Another type of volcano that we will see today is Aden volcano. Aden is a small shield volcano, which formed not by cinders but by a succession
of lava flows, built one upon the other around a central vent. In the center of Aden is a lava lake, which filled the crater almost to the rim. We will see each of these types of volcanoes today and the many interesting features associated with them.

Another complexity concerning evolution of the Rio Grande rift is that it occurs in an area in which considerable Mesozoic and Cenozoic tectonic activity preceded rifting. For example, this differs from the Baikal and East African rift systems which experienced long periods of tectonic stability prior to rifting. Thus, to understand evolution of the Rio Grande rift, an appreciation of the series of Cenozoic events affecting the Rio Grande rift region is required. These events include Laramide (Late Cretaceous-Paleogene) compression or transpression, extensive Paleogene subduction-related volcanism, and finally extension. Basins in the rift commonly include a significant thickness of sediments deposited in Laramide foreland-style basins, mid-Tertiary volcanics, and sometimes earlier sedimentary rocks (e.g., Lozinsky, 1994). Similarly, the rift-bounding faults often have experienced complex poly-stage movements that are difficult to unravel, making it difficult to determine the purely rift-related offset. Understanding the composite history of these events is thus all-important in the context of the formation of the rift basins and their sediments.

The basins of the Rio Grande rift are perhaps its most distinctive characteristic. The sediments filling these basins are well-exposed because of Neogene uplift and erosion, providing detailed information about the timing of events during the evolution of the rift. A considerable amount of seismic-reflection data is presented in Keller and Cather (1994), and these data and drilling results show that

Figure 1. Regional location map for the Rio Grande rift. Major late Cenozoic normal faults are shown as dark lines (modified from Keller et al., 1991). DMVF = Datil-Mogollon volcanic field.
What to do in this heat experiment:

You will need:
- Food coloring
- A large glass bottle
- Hot water
- Cold water
- A small glass bottle
- About 3/4 full glass jar
- A long piece of string
- Scissors

What happens:
- The bottle looks good
- The jar turns red
- The water feels hot
- The water looks flat
- The water looks flat
- The water feels hot
- The water feels hot

Why:
- The molecules move more quickly when they are hot.
- The molecules move more slowly when they are cold.
- The heat of the bottle
- The heat of the water
- The heat of the bottle
- The heat of the water
- The heat of the bottle
- The heat of the water

Kaboom
Hot Stuff

101 Cool Science Experiments
movement is sideways (side by side) or parallel. The action of a strike slip fault. In this type of fault, the two sides of the fault are forced up or down. The movement is up or down, not sideways. Examples of strike slip faults include the San Andreas fault. This type of fault, the books that rest on the table move. Hold them together or spread them apart. With the books slightly open, hold them to your chest. Then move them away from each other. The different movements of the books resemble earthquake faults. Why? How do earthquakes produce earthquake faults? How does this help? These breaks are called faults, and movement along the fault, which in turn, break and crack the Earth's crust. The pressures within the Earth cause great forces. Deformity Not Your Fault Earthquakes: They're Simple Earth Science Experiments with Everyday Materials.
Lifter

PROBLEM
How does intrusive volcanism (movement beneath the earth’s surface) change the shape of the earth’s crust?

Materials
scissors
10-ounce (300-ml) clear plastic cup
large tube of toothpaste (remove the cap)
½ cup (125 ml) soil
adult helper

Procedure
1. Ask an adult to prepare the cup by following these steps:
   • From inside the cup, use a sharp instrument to make a small hole in the bottom of the cup.
   • On the outside of the cup, insert one blade of the scissors in the hole and rotate the blade to make the hole large enough to accommodate the mouth of the toothpaste tube.
2. Cover the hole with your finger while you pour the soil into the cup.
3. Insert the mouth of the toothpaste tube into the hole.
4. Ask your helper to hold the cup while you press against the tube to force the toothpaste into the cup.
5. Observe the contents of the cup as the toothpaste enters. Pay special attention to the surface of the soil.

Results
As the toothpaste rises in the cup, the soil is pushed upward, forming a dome-shaped rise in the soil’s surface.
Why?

Liquid rock beneath the earth’s surface is called magma. Pressure on pools of magma deep within the earth forces it toward the surface. Magma that has reached the earth’s surface is called lava. This movement of magma within the earth is referred to as intrusive volcanism. Intrusive volcanism is responsible for different types of intrusions (flows of magma that cool and harden before they reach the surface). Intrusions have many shapes because magma hardens in many positions as it cools. Hardened or solidified magma forms igneous rock. A dome-shaped intrusion is called a laccolith, formed when magma pushes overlying rock upward. The toothpaste simulates the formation of a laccolith. The mushroom-shaped paste pushes the overlying contents of the cup upward, producing a mound on the soil’s surface.

LET’S EXPLORE

What would happen if rock layers restricted the upward movement of the magma? Repeat the experiment, adding rocks to the soil mixture and inserting an empty plastic cup in the cup of soil. Ask your helper to push down on the empty cup to restrict the movement of soil as you force toothpaste into the cup of soil. Science Fair Hint: Use the descriptions in Show Time! to identify the type of intrusion formed. Label and display drawings of the models from this and the original experiment.

SHOW TIME!

1. Bodies of intrusive igneous rock are classified according to their shape and relationship to surrounding rock. Use the description of each type of rock structure and the diagram to build a clay model showing the rock structures formed by intrusive activities. This model can be used as part of a project display.

- Batholiths: Large intrusions below the earth’s surface
- Dikes: Narrow, vertical intrusions that rise and break through horizontal rock layers.
- Laccoliths: Mushroom- or dome-shaped intrusions that push up the overlying rock layers.
- Sills: Thin, horizontal intrusions sandwiched between other rock layers.
- Stocks: Intrusions below the earth’s surface that are smaller than batholiths.

2. Granite is the most common type of intrusive igneous rock. The composition of granite can vary depending on the kinds and proportions of minerals present in the magma that formed it. Purchase different samples of granite at a rock shop, or collect your own samples. Use these as part of a display showing the different shapes of intrusions and their composition.

CHECK IT OUT!

Domed mountains, such as the Henry Mountains of southern Utah or the Black Hills of South Dakota, are broad, circular mountains formed when layers of rock are lifted. Find out more about the surface landforms created by intrusions. What is the surface like in areas where the different intrusions are exposed when rocks around them are worn away by erosion? Examples of exposed batholiths are the Sierra Nevada mountains of California. Identify other exposed areas created by intrusions.
Theropod tracks - Carnivores

Ornithopod tracks - herbivores

Ankylosaur tracks - herbivores
Dividing the North American Continent was the Cretaceous Interior Seaway also known as “an epieric sea”. An epieric sea is a shallow sea that rests upon continental (granitic) crust, whereas oceans rest upon oceanic (basaltic) crust. The seas extended from the Gulf of Mexico all the way to the Arctic. (http://www.scn.org/~bh162/maas.html)

http://en.wikipedia.org/wiki/Cretaceous_Seaway
LOWER CRETACEOUS DINOSAUR FOOTPRINTS AT CERRO DE CRISTO REY, SUNLAND PARK, NEW MEXICO, AND THE FRANKLIN MOUNTAINS, EL PASO, TEXAS

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INTRODUCTION

Dinosaur tracks and swimming traces have been discovered at many localities in the latest Albian Sarten Member of the Mojado Formation, Bisbee Group (Anapra Sandstone), at Cerro de Cristo Rey in Sunland Park, southernmost Doña Ana County, New Mexico, and in the Franklin Mountains, El Paso, Texas. These localities preserve footprints of ornithopod (Carichnium sp.) and theropod (Magnaovipes sp.) dinosaurs, reptilian(?) swimming traces and several traces of ankylosaurian dinosaurs. The Sarten Member is of latest Albian age, so the Cerro de Cristo Rey tracks are similar in age to the well known late Albian track sites of northeastern New Mexico (e Clayton Lake, Mosquero Creek). Within the Cristo Rey tracksite, the dominance of ornithopod tracks and absence of sauropod tracks fits regional patterns of late Albian-early Cenomanian track populations and distribution. The tide dominated, deltate depositional setting of the Sarten Member is also remarkably similar to the track-bearing late Albian-Cenomanian sandstones of NE New Mexico, Oklahoma, Nebraska and SE Colorado, which also have tetrapod footprint ichnofacies dominated by ornithopod (Carichnium) and theropod (Magnaovipes) tracks throughout the so-called “dinosaur freeway.”

The Cerro de Cristo Rey uplift has long been a field trip destination for classes and researchers in the El Paso region. In May of 2002, during a mapping exercise for summer field class at the University of Texas at El Paso (UTEP), and on subsequent excursions, several dinosaur tracksites were discovered by the author in the latest Albian “Anapra Sandstone,” which is exposed around most of the Cristo Rey trachyandesite intrusion in New Mexico and in Cd. Juarez, Mexico (Lovejoy, 1976), as well as along the western boundary fault of the Franklin Mountains (Lucas et al., 1998). Tracks have also been discovered in Cd. Juarez and are presently being researched by the author. Identifiable ichnotaxa present in the Cristo Rey tracksite are Carichnium and Magnaovipes. Swimming traces in the form of linear scratch marks and grooves are also present, most likely from reptiles. Also, several pentadactyl and tetradactyl impressions and one large undertrack have been found, and are attributed to ankylosaurs, but have not yet been assigned to an ichnospecies. This paper presents a preliminary report on the provenance and descriptions of three of these tracksites present at Cerro de Cristo Rey, as well as in the Franklin Mountains, including a general description of the stratigraphy (at Cristo Rey) and ichnotaxa (at each site). These sites are representative of all the recent tracksite discoveries made by the author in the Paso del Norte region (Kappus et al., 2003; Kappus and Cornell, 2003).

STRATIGRAPHY

Lower Cretaceous strata are known well exposed around the Cerro de Cristo Rey uplift (Fig. 1), which occurs in Sunland Park, New Mexico (southernmost Doña Ana County) and Cd. Juarez, Chihuahua, Mexico, just west of the Rio Grande and the city of El Paso (Boos, 1910; Lovejoy, 1976; Lucas et al., 1998). Also, Cretaceous strata of the same age can be found adjacent to the western boundary fault zone of the Franklin Mountains, at the eastern end of Festival drive. Of the Lower Cretaceous strata, exposures of the Sarten Member (formerly called the Anapra Sandstone) cover the largest surface area around the Cristo Rey intrusion (Lovejoy, 1976). Lucas and Estep (1998) suggested that the name Anapra Sandstone be abandoned and replaced with Sarten Member, and this is followed here (also see Kappus et al., 2003). The Sarten Member can be assigned to the Pleistocurtites brazeoiunx ammonite zone (Lucas and Estep, 1998). Thus, the latest Albian Sarten Member correlates with part of the Dakota Sandstone, so it broadly correlates stratigraphically to the “dinosaur freeway” of Lockley et al. (1992).
INTRODUCTION

LOWER CRETAceans DINOSAUR FOOTPRINTS AT CERRO DE CASTRO

FRANKLIN MOUNTAINS EL PASO, TEXAS

REPUBLIC OF EL PASO, NEW MEXICO, AND THE UNIVERSITY OF TEXAS AT EL PASO

DEPARTMENT OF GEOLOGY, UNIVERSITY OF TEXAS AT EL PASO, EL PASO, TEXAS 79968, USA

By L. R. S. & J. H. H. BRAUNER

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At Cristo Rey, the Sarten Member is ~52 m thick and overlies the marine Mesilla Valley Shale (Kappus et al., 2003; Böse, 1910; Strain, 1976). At this locality, the Sarten Member can be divided into units of sandstone and shale (Fig. 1). The sandstones are massive, or thinly interbedded with the shale, show crossbedding, trough cross strata, climbing ripples, and often extensive bioturbation (pedoturbation and Liesegang banding. The shales are gray and commonly have a rusty, mottled appearance. The mesoscale and microscale with interbedded sandstones of the Sarten Member are of terrestrial, coastal delta and coastalplain origin (Lucas et al., 1998; R. Langford, personal communication, 2002; Kappus et al., 2003). This level is consistent with the presence of dinosaur tracks. The Sarten Member paleocoastline was the western margin of the Cretaceous interior seaway in the El Paso area at the end of the Early Cretaceous (Kappus et al., 2003). To the northeast "Franklin Island" was visible, as evidenced by local stratigraphy (Lucas et al., 1998).

**TRACKSITE DESCRIPTIONS**

The first two tracksites described herein are exposed in two east/west-striking shale quarries adjacent to each other, and are designated NMMNH localities 5291 and 5292 from west to east (Kappus et al., 2003). These are linear quarries exposing two near vertical, track-bearing beds ~9 m apart stratigraphically in the uppermost shale and sandstone units of the Sarten Member (Fig. 1). The beds in these two quarries are...
strike at 090° and dip 80° to the north, and can be traced over a strike distance of ~750 m. There are approximately 350 individual footprints exposed in these two quarries.

The westernmost quarry, which is NMMNH locality 5291, is approximately 100 m long on strike and 9 m wide. The lower bed of this locality preserves at least 11 undertracks in convex hyporelief. These tracks vary in length from 14 cm to 60 cm, and have long, narrow, pointed toes with wide divarication angles (Fig. 2, after Kappus and Cornell, 2003). These tracks have been assigned to the ichnogenus *Magnoavipes* (Kappus and Cornell, 2003; Kappus et al., 2003; also see Lee, 1997; Lockley et al., 2001). This bed also preserves what appear to be large undertracks and "subsurface compression shapes," but these are poorly preserved and have not yet been assigned to an ichnotaxon.

The upper bed of this locality preserves many undertracks in convex hyporelief (Fig. 3A), including linear scratch marks, drag marks, and tridactyl underprints. The scratch marks and drag marks are swimming traces, probably from reptiles. The tridactyl underprints have broad and blunt digit impressions, bilobate heels, and the central digit impression (digit II) is not significantly longer than the side digits (Fig. 3A). These undertracks are all ~30-40 cm long. Kappus et al. (2003) assigned these tracks to the ichnotaxon *Carrichnium leonardii* because of their morphology, and because all North American *Carrichnium* tracks fall under this classification (Hunt and Lucas, 1998). *Carrichnium leonardii* tracks show a sub-circular (crest-shaped) manus impression much smaller than the medial pes digit impression. Although not always preserved, this manus impression is adjacent to digit impressions III and IV. There is also one large undertrack at this locality (Fig. 3B) that is ~75 cm long, appears to be pentadactyl, and may be an ankylosaur pes undertrack. This requires further study as it may simply be overprinted, an effect of trampling of previous tracks.

The second locality, NMMNH 5292, is separated from the adjacent quarry by a few small transverse faults and a divider of bedrock. This tracksite preserves large *Carrichnium leonardii* undertracks in concave relief with small manus impressions in a hematized, bioturbated sandstone. The tridactyl pes impressions are all between 45 and 65 cm long, with square, bilobate heels and digit sizes characteristic of the ichnogenus *Carrichnium*. The undertracks of this lower bed are almost all associated with sediment bulges, rings or "sand crescents" (term used by Lockley and Hunt, 1995 for sand dune facies tracks), indicating a paleolake dipping in a present-day westerly direction. This lower bed also preserves theropod underprints (tridactyl, pointed, tapering toes), as well as at least one trackway left by an ankylosaur. The theropod tracks have pointed, tapering toes, with evident claw marks, and wide digit divarication angles. Digit II of these tracks is significantly longer than digits II and IV. The trackmaker also walked in a digitigrade fashion, with heel prints mostly absent. All of these morphological characteristics justify an assignment to the ichnogenus *Magnoavipes* (see Kappus and Cornell, 2003; Kappus et al., 2003; Lockley et al., 2001). The ankylosaur tracks are quadrupedal, with manus prints having 4 digits, and pes prints having 5 digits. These tracks have a peculiar shape which is hard to recognize, and the tracks of the pes commonly overprint the tracks of the manus. This is described by Brown (1999) as a "direct register" of the pes onto the manus, and gives a remarkable clue as to the progression of ankylosaurs. Also, scratch marks and body traces cross cut undertracks on the lower bed, suggesting a subaqueous environment for track formation. The upper bed of this locality also preserves *Carrichnium* undertracks in convex hyporelief as well as several swimming traces, possibly reptilian. There are also scratch marks and other parallel, linear grooves as well as body traces.

Adjacent to NMMNH 5292, there are several large blocks of sandstone from the quarries that preserve undertracks, and these can be found scattered around the area, as well as on the Mexican side of the border. One of these blocks adjacent to NMMNH 5292 preserves a small pentadactyl undertrack with an associated smaller tetradactyl partial underprint (Fig. 4). These prints are isolated, and so are difficult to assign to an ichnotaxa due to lack of data. The larger pentadactyl track is ~37 cm long and has short, blunt toes 7 to 10 cm long, with wide divarication angles. This undertrack appears to be the pes track of an ankylosaur. The smaller adjacent undertrack also has short, blunt toes 5 to 7 cm long, with toes facing in the same apparent direction of travel. This smaller undertrack is also partially overprinted by the larger pentadactyl undertrack (Kappus et al., 2003). This pair of tracks, as well as other purported ankylosaur tracks in the Crasto Rey tracksite, strongly resembles drawings of ankylosaur tracks illustrated by Thulborn (1990) and Whyte and Romano (2001). It is likely that these two tracks represent a manus/pes pair produced by an ankylosaur. Several other isolated tracks attributable to ankylosaurs have been found in Cd. Juarez on the property of the Productos de Barro Industrializado brick plant and also along the western boundary fault of the Franklin Mountains.
NMMNH locality 5293 is separated stratigraphically from the other Cristo Rey sites mentioned as well as geographically by about 800 m. This tracksite is preserved in the lowermost sandstone unit of the Sarten Member, about 9 m above its basal contact with the underlying Mesilla Valley Shale (Fig. 1). The site reveals many underprints (more than 400) of the ichnogenus *Caririchnium*, but also includes several ankylosaur tracks and theropod tracks, possibly *Magnoavipes*, which are all preserved in concave-relief on top of a hematized, bioturbated (dinoturbated) sandstone (Figs. 5A and B). Also preserved are several undertracks of the ichnogenus *Caririchnium* exposed in cross section by a small fault that cuts across the tracksite. The exposure is approximately 400 m², although an additional ~150 m² is partially covered by erosional debris and overburden. The tracks at this site are tridactyl, relatively large (up to 65 cm total length), have wide, blunt toes, and a square bilobate heel, once again characteristic of the ichnogenus *Caririchnium* (Fig. 5B). Manus impressions are preserved as well as pes impressions. The tracksite itself has a moderate to heavy dinoturbation index (see Leckley, 1991). Sediment bulges are also visible at this site, indicating a paleoslope dipping in a present-day easterly direction.

The dinosaur tracks exposed in the Franklin Mountains are on posted private property in a canyon east to the East of Festival drive. The area has been surveyed and marked for construction of a gated community as is most of the western boundary of Franklin Mountains State Park. In this canyon east of Festival drive, several Cretaceous units are exposed, with the largest, most competent exposure being the Sarten Member of the Mojado Formation (Lucas et al., 1998). Bedforms in the Sarten Member at this location differ
Figure 5. Upper track bearing area at MMNH 85291. A) Overview showing Cartorhinus, Erasto scratch marks, and a large purported Ankylosaur track to the bottom right of the photo. B) Close-up of purported Ankylosaur track.
sandstones present in the same unit at Cristo Rey, several kilometers to the southwest. There are no shale interbeds, and the beds are either massive or persistently laminar, dipping in a present day easterly direction. However, rotation of beds back to their assumed original position shows a slight dip to the west/southwest. This supports the beach interpretation of Lucas et al. (1998), and not the tidal interpretation of Cerro de Cristo Rey. Dinosaur tracks are present only as undertracks at this locality (Figs. 6A and B), and are randomly distributed. Approximately 10 tracks are present at this locality.

**DISCUSSION**

The deltaic/coastal plain depositional setting of the Sarten Member is remarkably similar to the track-bearing late Albian-Cenomanian sandstones of northeastern New Mexico, Oklahoma, Nebraska and southeastern Colorado (Dakota Group), which also have a tetrapod footprint ichnofacies dominated by ornithopod (*Caririchnium*) tracks (Kappus et al., 2003; Lockley et al., 1992; Lockley and Hunt, 1995; Lockley et al., 2000; Jeeckel et al. 2001). Comparison of Cristo Rey dinosaur track outlines with previously published drawings of *Caririchnium* show several similarities, including size, bilobate heels, wide, blunt toes, and pes size, shape, and placement of manus in relation to pes (Kappus et al., 2003; Lockley and Hunt, 1995). Theropod tracks found at Cristo Rey (Fig. 2) show several similarities to the ichnogenus *Magnoavipes*, including the long, narrow, pointed toes, and wide divarication angles (Kappus and Cornell, 2003; Lee, 1997; Lockley et al., 2001).
Figure 5. NMMNH locality #5293. A) Overview facing southwest, with Dr. Adrian Hunt for scale; B) Close-up of a plantigrade Carinrichnium print, also showing a digitigrade Magnoavipes print progressing to the bottom right of the photo.
Figure 6. Franklin Mountains State Park footprints located near Festival drive. A) Closeup of concave undertrack of *Caririchnium*, B) Pentadactyl ankylosaur track.
According to Matsukawa et al. (1999) and Lockley (2001), the size range for Caririchnium tracks is 12.6-55 cm. This is consistent with the observations made at the Cerro de Cristo Rey tracksites, which suggest a size range of 14-60 cm. However, the large size of the theropod (Magnosauropus) tracks at Cerro de Cristo Rey is somewhat anomalous in comparison with size ranges of previous reports (Lee 1997; Lockley et al., 2001), which suggest an average length of 21.4 cm with a possible maximum of 38 cm (Kappus et al., 2003).

Using the present day orientation of these beds, sand crescents show that the dinosaurs at Cristo Rey walked on a west-dipping paleoslope at the western sites (NMNMH localities 5291 and 5292), and on an east-dipping paleoslope at the largest site (NMNMH locality 5293). Cross cutting sinuous and body traces, as well as fining upward sequences of sandstones to shales, strongly suggests subaqueous trackmaking.

Tracks in the Franklin Mountains differ from other tracks in preservation style and in stratigraphy. The bedforms of the Sarten Member at Festival drive indicate a beach environment, showing evidence of wave motion. Most tracks would most likely not be preserved, and what tracks are preserved would be spotty. This is the case at this locality.

Further interpretation of this tracksite will require a more detailed study of the stratigraphy and structure of the area. A comparison of the Cristo Rey tracksite with other coastal/deltaic tracksites of similar age is presently underway and is the topic of the senior author’s master’s thesis.

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