EVIDENCES OF CATASTROPHIC SUBAQUEOUS PROCESSES AT GOAT MOUNTAIN, IN BIG BEND NATIONAL PARK, TEXAS, U.S.A.

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Abstract

Today many geologists are more willing to consider catastrophic physical processes than in the past. However, these catastrophic events are postulated as having occurred over the millions of years necessary to validate the uniformitarian model. One such site where catastrophic physical processes have been proposed is at Goat Mountain in Big Bend National Park, Texas. This site has undergone significant volcanic deposition and erosion. All the volcanic sedimentation is viewed as having occurred rapidly and subaerially, with the intervening erosion being slow and uniformitarian. Tentatively, it appears that the evidence from the stratigraphic section exposed at Goat Mountain fails to support the present uniformitarian interpretation. Rather it appears to better fit subaqueous emplacement and subsequent massive erosion within a short timeframe. The author interprets the Goat Mountain exposure as having formed predominantly during the Flood (i.e., Middle to Upper Flood Event Timeframe).

Introduction

Today the science of geology is at a crossroads. Many geoscientists are starting to embrace the idea that catastrophic physical processes have occurred in earth's past (e.g., Ager, 1993a; 1993b; Fraser, 1989; Einsele, Ricken and Seilacher, 1991; Dott, 1983; Goodwin and Anderson, 1985; Yulsman, 1994). The acceptance of this concept, as simple as it seems on the surface, holds great promise for diluvial geologists (i.e., young-earth catastrophists). In the past, the idea of worldwide catastrophes was scorned and ridiculed. However, today catastrophes are viewed as recurring throughout geologic history. Many of our uniformitarian associates now consider the possibility of global catastrophes (e.g., K/T boundary, Permian crisis, Frasnian-Famennian boundary, etc.). However, the difference for many young-earth catastrophists is that these events are viewed as occurring predominantly during the Flood Event Timeframe and not as multiple events occurring over millions of years.

An outcrop of volcanic rock exposed in cross-section, in Big Bend National Park, provides one such example for a young-earth catastrophist interpretation. The outcrop is exposed at Goat Mountain and is located approximately 14 miles south of the turn-off from the Study Butte/Panther Junction road along the Ross Maxwell Scenic Drive (Figure 1). This exposure provides an opportunity to examine large scale historic geologic events. This paper suggests that the duration of the events which formed and shaped this mountain were brief and occurred during the Flood (i.e., Middle to Upper Flood Event Timeframe [Froede, 1995a]).

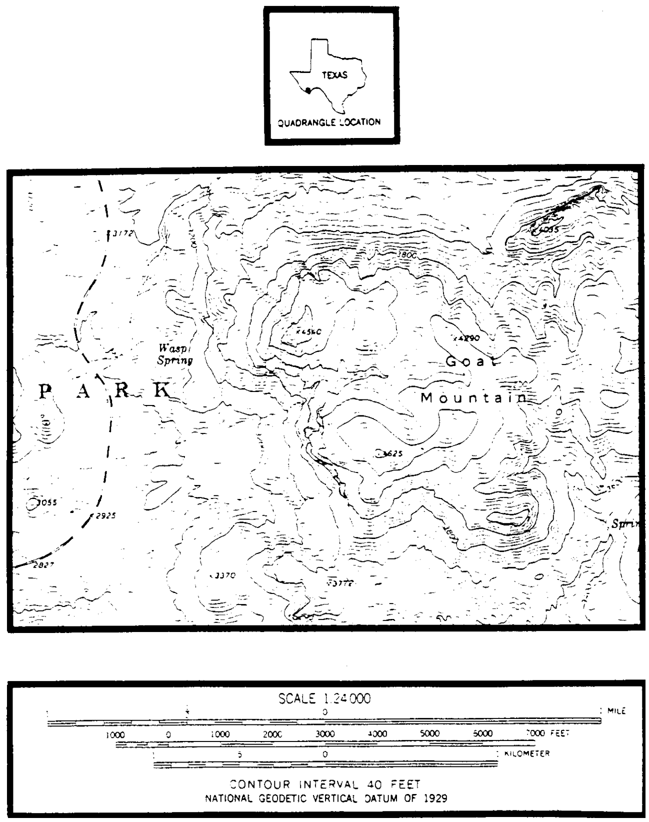

Figure 1. U.S. Geological Survey. 1971. Cerro Castellan, Texas. 7.5 Minute Series. Topographic Quadrangle Sheet. Scale: 1:24,000.

Previous Investigations

In their now classic work, Maxwell, Lonsdale, Hazzard and Wilson (1967) extensively studied the sediments and stratigraphy which compose the geologic section found at Big Bend National Park in Texas. Various creationist investigators have also reported on aspects of this most interesting park from a catastrophic viewpoint (e.g., Williams and Howe, 1993; Williams, 1993a; 1993b; Williams, Matzko, Howe, White and Stark, 1993; Froede, 1995b).

It was Maxwell, et al., (1967, p. 139) who first discussed and interpreted the Goat Mountain exposure. Subsequent investigations of the Goat Mountain outcrop, by various investigators, have served to verify the previous work (e.g., Maxwell, 1968; Pause and Spears, 1986; Henry, Price, Parker, and Wolff, 1989; Dickerson, Stevens and Stevens, 1990; Spearing, 1991).

The formation of the Goat Mountain exposure has been described, within the uniformitarian framework, as starting with subaerial volcanic eruptions from nearby calderas, which resulted in the outpouring of various lavas and the fallout of considerable quantities of ash

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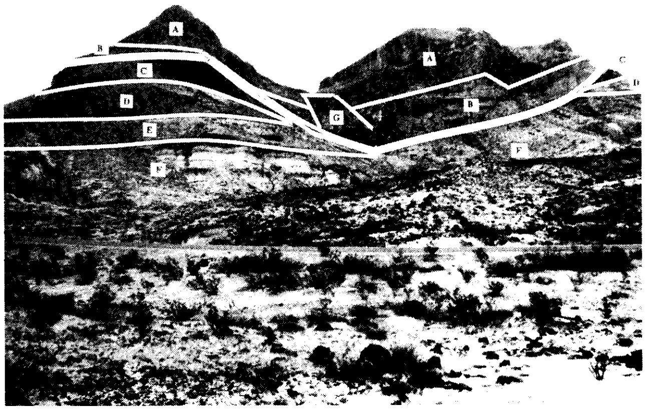

Figure 2a. Cross-section of Goat Mountain exposure with formations and members. A. South Rim Formation-Burro Mesa Riebeckite Rhyolite Member. B. South Rim Formation-Wasp Spring Flow Breccia Member. (Unconformity-double white line) C. Chisos Formation—Tule Mountain Trachyandesite Member. D. Chisos Formation—Tuff beds. E. Chisos Formation-Bee Mountain Basalt Member. F. Chisos Formation—Tuff beds. G. Spine-like intrusion of the Riebeckite rhyolite. The unconformity served as the canyon river channel, according to Maxwell et al., 1967, p. 139. Modified from Maxwell et al., 1967, p. 139, and Pause and Spears, 1986, p. 35: p. 224.

(Upper Eocene). At some later time an ancient stream flowing southwestward toward Castolon, cut a canyon about 900 feet deep (Upper Eocene/Lower Oligocene). This stream is suggested as having flowed for approximately eight million years (abbreviated Ma). Later still, additional subaerial calderan eruptions filled the canyon and surrounding area with additional volcanic deposits [Lower Oligocene] (from Maxwell et al., 1967, pp. 133,137-138; Pause and Spears, 1986, p. 223; Spearing, 1991, p. 316) [Figures 2a and b].

Using the uniformitarian timeframe, all of these formations and their associated events which formed, shaped and eroded them, occurred over millions of years during the Tertiary Period, specifically the Upper Eocene to Lower Oligocene (approximately eight Ma). There has been some difficulty with the radiometric dating of these rocks (Maxwell et al., 1967, p. 137). Additionally, the sparsity of fossils found in the multi-layered volcanics and sedimentary rocks do not aid in determining an age of the volcanic deposits (Maxwell et al., 1967, p. 136). Hence the exact ages of some of the volcanic rocks remains speculative. However, dating of these volcaniclastics has been performed using lateral contacts, superpositions, and the limited fossils found in certain sections of the Park.

Volcanology

Today we know that volcanic eruptions and their associated pyroclastic materials can be deposited and eroded rapidly (e.g., Mount St. Helens). The uniformitarian explanation to account for the occurrence of volcanic deposits is one of sporadic volcanic activity spanning millions of years, resulting in the occurrence of vast sections of volcanic materials. Today, the science of volcanology has advanced to the point where the physical processes and systems are understood well enough to evaluate rates and processes affecting the deposition of pyroclastic rocks and to compare those rates against time. However, Uniformitarians still use

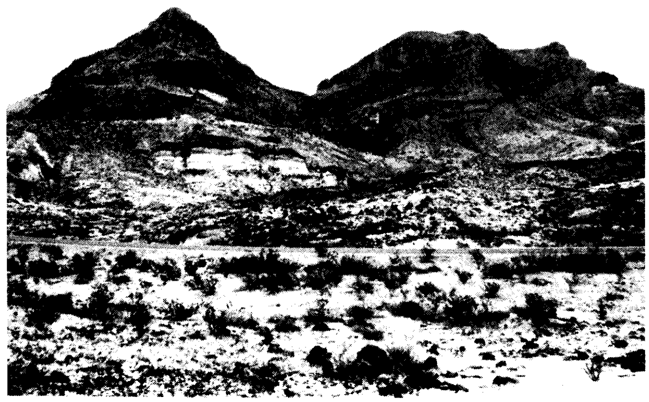

Figure 2b. Cross-section of Goat Mountain exposure without formations and members highlighted.

millions of years when describing the deposition and erosion of volcaniclastics, even when cumulative deposition and erosion could have occurred in much shorter time frames.

Emplacement of Ash-flow Tuffs

Ash-flow tuffs compose much of the extrusive volcanic stratigraphic section found in Big Bend National Park, and several are exposed at Goat Mountain. Much research has been performed on the origins and emplacement of ash-flow tuffs (e.g., Smith, 1960; Ross and Smith, 1961; Chapin and Elston, 1979; Fisher and Schmincke, 1984; Cas and Wright, 1987; Cas and Busby-Spera, 1991; Fisher and Smith, 1991) and while considerable research remains to be done, a clearer picture is emerging regarding its formation. Additional information specifically about ash flow-tuffs can be found in Appendix I.

It has always been accepted that ash-flow tuffs form in a subaerial setting. However, recently it has been suggested that ash-flow tuffs can also form in a subaqueous setting (e.g., Cas, 1978; Fisher and Schmincke, 1984, pp. 293-296; Fisher, 1984, p. 18; Yamada, 1984; Howells, Reedman, and Campbell, 1986; Reedman, Howells, Orton, and Campbell, 1987; Kano, 1990; Ayres, Van Wagoner, Ferreira, 1991, pp. 183-184; Einsele, 1992, pp. 69-71; Lajoie and Stix, 1992). Cas and Wright (1987; 1991) have identified differences between welded subaqueous volcaniclastic (i.e., pyroclastic) deposits and subaqueous consolidated or epiclastic debris (ash-flow tuffs included), and the reader should consult these references to clarify the many dissimilarities between them. Additionally, the depth of subaqueous emplacement is still unresolved for locations suggested as reflecting possible deep water environments (e.g., Orton, 1987). Even as late-as January 1995, Gregg and Fink report the current lack of understanding in subaqueous lava flows in terms of both volume and resulting types (i.e., pillow, lobate, or sheets).

The heat generated within a subaerial ash flow is generally accepted as providing enough energy to weld the ash together to form the tuff (Smith, 1960, p. 151; Ross and Smith, 1961, pp. 41-44), although higher temperatures would be required to weld the ash subaqueously (Fisher and Schmincke, 1984, p. 295). Where sufficient heat was not available it would result in an unwelded or unconsolidated deposit (Fiske, 1963; Fiske and Matsuda, 1964; Niem, 1977; Cas, 1979; Wright and Mutti, 1981; Sparks, Brazier, Huang, and Muerdter, 1983; Heiken and Wohletz, 1985; Stix, 1991). To ensure complete preservation of the entire volcaniclastic deposit the top must be quickly covered or subsequent erosion could remove it (Ross and Smith, 1961, p. 24). Smith (1960, pp. 154-155) identified three zones of welding (i.e., no welding, partial welding, and dense welding) which directly relate to the original emplacement temperature of the ash flow, and which result in the variation of ash flow deposits. His work further revealed that the variables (i.e., temperature, thickness, composition of the ash, amount and composition of volatile constituents, and the ratio of pumice fragments to shards) can result in zonal variations in texture, color, and other features, such that essentially no two ash deposits are alike and a single deposit will show lateral (albeit slight) variation (Smith, 1960, pp. 153-154).

Welded tuffs are reported from many locales. Sidwell and Renfroe (1943, p. 17) reference volcanic tuffs, from nearby Chihuahua, Mexico, which they believed were deposited in water; however, they failed to explain how they would have become welded. Other geologists have reported welded tuffs stratified with marine sediments and have proposed that they were deposited subaqueously (see Cas, Allen, Bull, Clifford, and Wright, 1990; Schneider, Fourquin, and Paicheler, 1992: Fritz and Howells, 1991; Orton, 1991; Kokelaar, Bevins, and Roach, 1985; Dolozi and Ayres, 1991; Howells, Reedman, and Campbell, 1986; Fisher, 1984; Yamada, 1984; Fernandez, 1969; Sparks, Sigurdsson, and Carey, 1980a; Howells, Leveridge, and Evans, 1973; Francis and Howells, 1973; Kato, Muroi, Yamazaki, and Abe, 1971; Yamazaki, Kato, Muroi and Abe, 1973). However, not all subaqueously emplaced ash flow deposits contained sufficient heat to result in welding. For example Sparks, Sigurdsson, and Care (1980b) discuss the formation of subaqueous pyroclastic flows (i.e., epiclastics) which they discovered off the coast of Dominica, Lesser Antilles. Their research revealed unconsolidated pyroclastic rocks which were transported approximately 8.1 miles from Dominica in waters as deep as 1.1 miles (Sparks, Sigurdsson, and Carey, 1980b, pp. 94-95).

Thus the reader now understands that the welding of ash flow deposits can occur underwater. There are special requirements for this type of condition, but evidences supplied by various welded ash flows appear to support their formation in a subaqueous environment.

Goat Mountain Stratigraphic Section

The Tertiary stratigraphic units of interest for this report (i.e., specifically for Goat Mountain) include the Chisos Formation-Upper Eocene/Lower Oligocene (moving from bottom to top-a layer of unnamed tuff beds, the Bee Mountain Basalt Member, the Tule Mountain Member, and the Mule Ear Spring Tuff Member) and South Rim Formation-Lower Oligocene (moving from bottom to top-Wasp Spring Flow Breccia Member and the uppermost Burro Mesa Riebeckite Rhyolite Member) [Pause and Spears, 1986, pp. 34-35; pp. 223-224; Dickerson et al., 1990, pp. 42-43] (Figures 2a and b).

The author suggests that the Chisos Formation was deposited subaqueously. This interpretation is based on the occurrence of fossilized mammal bones, turtle remains, fresh water snails and wood (Maxwell et al., 1967, p. 136) sporadically contained within inter-bedded sedimentary deposits (i.e., clay and mudstone, tuffaceous clay and mudstone, tuffaceous sandstone, coarse massive conglomerate, very thick lenses of fanglomerate, and some freshwater limestones [Maxwell et. al., 1967, p. 112]) between the welded and consolidated volcanic strata of the Chisos Formation.

The overlying South Rim Formation contains neither fossils nor significant non-volcanic sedimentary deposits (Maxwell, et al., 1967, pp. 137-151). The author believes that the majority of the South Rim Formation was probably also deposited subaqueously. However, questions remain regarding the uppermost member (i.e., the Burro Mesa Riebeckite Rhyolite) and additional studies are necessary in any attempt to determine the original environment of its emplacement.

The Goat Mountain section described by Dickerson et al. (1990, p. 42), provides information which supports the author's hypothesis of subaqueous deposition of volcaniclastics, due to the inter-bedding of sedimentary deposits between the welded and consolidated volcanic units:

> The lower part of Goat Mountain is composed of the Chisos Formation (moving up in section): tilted Goat Mountain Member (informal; Stevens, 1969) constructive volcanic apron sediments **(diluted by some non-volcanic sediments),** now much zeolitized, are overlain by Bee Mountain (basalt), and Mule Ear Spring (welded ash-flow tuff; ignimbrite) members; **these in turn are overlain by a thin unit of sedimentary tuffs,** and Tule Mountain Member (coarsely, sometimes very coarsely porphyritic brown trachyandesite). (emphasis mine)

Dickerson et al., (1990, p. 42) have proposed that the Pine Canyon caldera created conditions (i.e., doming) which resulted in the erosion, via fluvial processes, and formation of the canyon seen exposed at Goat Mountain. However, Henry et al. (1989), interprets the area as being subject to many calderas and they do not provide an explanation as to the origin or cause of the channel exposed at Goat Mountain. The overlying South Rim Formation is described (Dickerson et al., 1990, p. 42) as: "Wasp Spring Member **(poorly welded ash flow breccia and minor sedimentary beds)** overlain by three thick, columnar-jointed cooling units of the Burro Mesa Member." (emphasis mine)

The author interprets the poorly welded Wasp Spring Member (South Rim Formation) as probably also having been deposited in a subaqueous environment. In support of this position, Maxwell et al., (1967, p. 140) state that a paleomagnetic study was performed on the Wasp Spring Member and the results indicated that some differential movement occurred in a "fluid" material at temperatures below the average Curie point temperature for the entire mass. Additionally, as the Wasp Spring Member moves away from the Chisos Mountain source area, the lava component decreases and the flow breccia increases (Maxwell et al., 1967, p. 140). With the loss of sufficient heat to weld the subaqueous flow together, the further away the material flows from the heat source the less likely that it would be welded together, and the greater the chances of the deposit being eroded. Hence the ash-flow tuff would grade from more "lava" to more "breccia" in direct relationship to the distance from the heat source (see Sparks et al., 1980a).

The Burro Mesa Rhyolite Member caps Goat Mountain as well as many other sections of Big Bend National Park. It is described by Maxwell et al., (1967, pp. 141-142) as:

> . . . a highly siliceous, medium-grained, gray rhyolite with quartz phenocrysts in a riebeckyte matrix. The base is finely crystalline to glassy; flow structure is most evident in the basal 50 feet where platy riebeckite crystals form bands parallel to the flow structure.
>
> The lava of the Burro Mesa Riebeckite Rhyolite Member probably came from several vents, but the vent or vents have not been located. The major riebeckite-bearing intrusive masses now exposed in the Chisos Mountains probably came from the same magma source as the extrusive rock in most of the South Rim Formation, but the vent or vents from which the extrusive rocks were erupted were **obliterated by erosion** or by the younger intrusives. (emphasis mine)

It should be clear to the reader that these volcanic deposits provide evidence of a complex original depositional environment. The exposure of these volcanic strata is due to the extensive erosion which has occurred across the Park. Much time (e.g., millions of years) has been postulated as passing between each of these volcanic depositional events.

Subaqueous Caldera Volcaniclastics

The author suggests that the original Trans-Pecos/Big Bend region existed along the western edge of a slowly withdrawing epeiric sea (i.e., receding Flood waters) [Froede 1995c]. This area remained submerged due to the slow rate of accommodation space provided for the epeiric waters as the oceanic crust slowly cooled and sank (see Schopf, 1980, p. 48). Plumes of magma rose to the Earth's surface beneath the Trans-Pecos Region associated with tectonic forces (rifting, uplift, and downwarping) in effect during this time frame. This tectonic movement coupled with deep-seated rising magma resulted in the subaqueous eruption of calderas throughout the region. The subaqueous caldera eruptions postulated for this region are analogous to those proposed by Busby-Spera (1984; 1986) for the subaqueous caldera eruptions at Mineral King in the southern Sierra Nevada, California. The reader is encouraged to review these two references along with the others cited for further information regarding the subaqueous eruption of calderas and the formation of volcanic strata in that environment.

The author proposes multiple subaqueous eruption events from the various caldera sources across the Trans-Pecos region, including Big Bend. These subaqueous eruptions resulted in the generation of massive volumes of volcaniclastic rock. It is proposed that the calderas would rise and erupt subaqueously releasing various volcaniclastics into the overlying waters (probably very shallow in the immediate area of uplift-see Orton, 1991) and then collapse back into themselves and be buried in their own extruded volcanic deposits. This would explain why many of the source calderas cannot be found today. The volcaniclastics extruded from the caldera source areas would thin with distance from those sources. This is reflected in the thickness of the volcanic deposits (intracaldera versus extracaldera) seen across the Park (see Busby-Spera, 1984, p. 8421; and her Figure 4, p. 8422).

It is this author's opinion that the majority of the volcaniclastics found in the region (i.e., Trans-Pecos) and specifically at Big Bend National Park represent subaqueously deposited caldera volcaniclastics. Additional discussion is welcome in an attempt to determine any criteria which might further serve to clarify the possible original volcanic (i.e., caldera) environment.

Paleosols

Extensive investigations have been conducted on a number of the Upper Cretaceous (Maastrichtian) and Lower Tertiary formations in Big Bend National Park to determine the number and type of paleosols which have developed (e.g., Lehman, 1989; 1990). The author is unaware of any reported paleosol analysis performed on any of the Chisos or South Rim Formations across the Park. The issue of paleosol analysis is discussed because physical and chemical processes start breaking rock down as soon as it becomes exposed at the surface. Once sufficient soil is developed plant life would attempt to establish itself. This has been clearly demonstrated at Mount St. Helens following the May 18, 1980, eruption (see Tilling, Topinka and Swanson, 1990, p. 51; Austin, 1991). Studies by Smith (1991), showed that overland flow of water would be reduced (up to 30%) following the reestablishment of a full ground cover (requiring approximately 15 to 20 years) on volcanic sediments. Soil scientists have identified the Andisol as a soil which develops in volcanic ejecta (such as volcanic ash, pumice, cinders, and lava) and/or in volcanic materials, with short-range-order minerals (amorphous) or Al-humus complexes dominating the colloidal fraction (Daniels and Hammer, 1992, p. 115). In some cases the Andisol can be used to separate various volcanic layers and serve as a marker and mappable horizon (Campbell, 1986, pp. 222-224; Ward, 1967). If approximately 8 Ma were available for soil development, then there should be some evidence (somewhere in the whole Park!) that the Chisos and South Rim Formations developed vegetation or at minimum a soil capable of sustaining plant life. At this time no paleosol is recognized in the Chisos or South Rim Formations exposed at Goat Mountain.

Fluvial Deposits

Maxwell, et al. (1967, pp. 139-140) proposed that following the deposition of the Tule Mountain Trachyandesite (Chisos Fm.—upper Eocene), a stream cut a canyon that flowed southwest. According to Spearing (1991, p. 316), the ancient stream carved the canyon 900 feet deep as it flowed southwest toward Castolon. Today the evidences for this canyon only exist around the Goat Mountain exposure. While it is postulated to have flowed toward Castolon, no physical evidences of the paleo-river remain to verify this proposal. Following several millions of years of inactivity, the canyon

Figure 3. Rio Grande River flows from the ton center to bottom left of this photograph. This is the way that Goat Mountain is suggested to have appeared over the 8 Ma that the stream flowed through the area. The Rio Grande has cut down through volcaniclastics. The author speculates that the original Rio Grande channel might have started with the draining of the Flood waters. Note the wide river canyon. This could represent a period of time when the Rio Grande flowed at much higher-rates with greater water volumes than present.

was subsequently filled with South Rim Formation volcanic deposits (i.e., tuffs, lava, and breccia) which eventually overflowed the top of the canyon (Spearing, 1991, p. 316).

If a stream or river did in fact exist over the millions of years suggested by the previously cited authors. then some evidence should remain in the form of fluvial deposits. However, if the erosion of the Tule Mountain Trachyandesite occurred rapidly, followed by the emplacement of the Wasp Spring Member and Burro Mesa Rhyolite Member there should be little to no record of channel deposits (i.e., fluvial deposits) found at the Goat Mountain outcrop.

An exposure along the present day Rio Grande provides an excellent analogy (Figure 3). This specific locale which is located approximately 13 miles northwest of Lajitas, on Texas Highway 170 along the Rio Grande, reveals an exposure created by the incision of the river into a rhyolite (Figure 4). The sidewalls are shear and do not exhibit any indication of fluvial weathering or deposits. However, the bottom of the canyon contains typical fluvial deposits (i.e., sands, silts and clays). If the Rio Grande were not present, these fluvial deposits would provide evidence that a stream or river once flowed here.

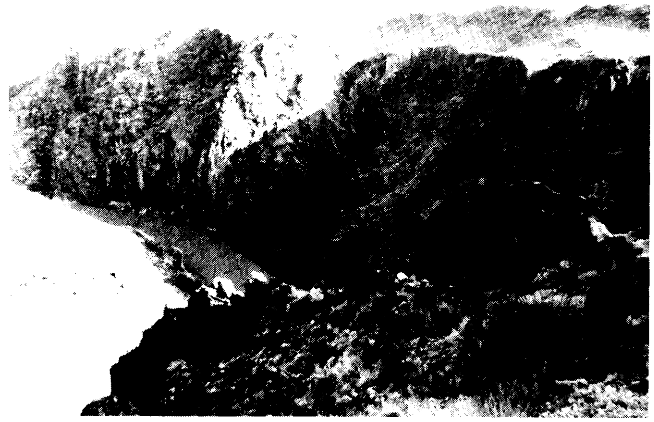

Figure 4. Rio Grande River flows toward the left side of the photograph. The side walls of this canyon are composed of rhyolite which has been eroded by the Rio Grande River. This location is approximately 13 miles northwest of Lajitas on Texas Highway 170.

An exposure at the top of this canyon of the Rio Grande reveals fluvial channel deposits (Figures 5 and 6) which are capped by rhyolite. This suggests that the rhyolite was deposited while the paleo-Rio Grande was already in existence and that following the emplacement of the rhyolite, the river subsequently eroded through it. The proof exists that a paleo-Rio Grande existed in the past not only because the river is present today, but fluvial deposits are exposed alongside the river, albeit 450 feet above the present Rio Grande river channel.

The Goat Mountain exposure has been interpreted as having had a river channel cut through 900 feet of volcanic rock. If a stream flowed through this exposure

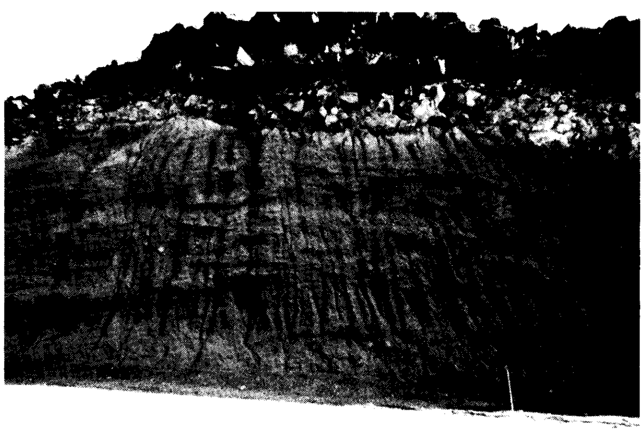

Figure 5. Twenty feet of fluvial deposits exposed approximately 450 feet above the present day Rio Grande, approximately 13 miles northwest of Lajitas on Texas Highway 170. Note rhyolite cap above the fluvial deposits. If the canyon at Goat Mountain once contained a stream or river and if it carved the canyon over the millions of years proposed. then there should be some evidence of its existence (i.e., fluvial deposits). No fluvial deposits have been reported at the Goat Mountain exposure!

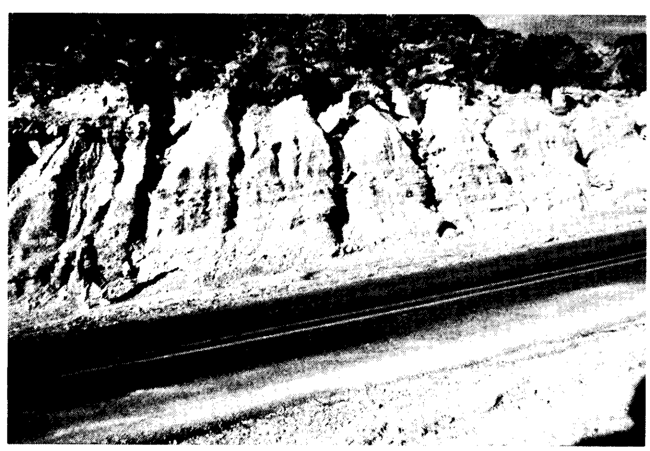

Figure 6. Fifteen feet of fluvial deposits exposed approximately 450 feet above the present day Rio Grande approximately 13 miles northwest of Lajitas on Texas Highway 170. Note rhyolite cap above the fluvial deposits. These deposits provide physical evidence of a nearby river or stream, in this case the Rio Grande. These fluvial deposits are missing at the Goat Mountain exposure.

for several million years then there should be some indication (i.e., fluvial deposits) which confirm that it did exist. The author has not found any reference which identifies fluvial deposits at Goat Mountain! Additionally, none of the photographs taken by the author reveal fluvial deposits such as are presently observed along the Rio Grande River valley.

Paleontology

The paleontology of any site should be considered when performing paleoecological reconstructions. Certain sections of the Chisos Formation (Tertiary age) have been found to contain vertebrate fossils (See Maxwell et al., 1967, pp. 136-137). The fossiliferous sections are very minor when compared to the entire Chisos Formation, and are reported from the approximate middle of the exposed sections (e.g., West of Round Mountain—19 feet of a 2200 foot section; Western slope of Cerro Castellan—22 feet of a 1500 foot section; Northwest side of Casa Grande—25 feet and 3 feet of a 999 foot section) [data from Maxwell, et al., 1967, pp. 130-136]. These fossils, if they do reflect an actual paleoenvironmental setting, appear to have been transported for some distances due to the conditions (i.e., worn and abraded) in which they have been found. **However, no fossils have been reported from the Chisos at the Goat Mountain exposure.**

Additionally, fossils are also commonly found in the unlithified volcanically derived deposits of the Upper Cretaceous (i.e., Aguja and Javelina Formations) and in surficial alluvial deposits (dated from the Miocene to recent). Most of the fossils found in Big Bend National Park, from these deposits, are disarticulated bits and pieces of bone or teeth from a variety of terrestrial creatures. Very few whole (i.e., articulated) fossilized animals have been found in any of the Tertiary volcanics in the Park.

Currently these Tertiary volcanic deposits are interpreted as being Post-Flood by some creationists Williams and Howe, 1993; Williams, 1993). It has been proposed that following the Flood, animals dispersed from the Ark and rapidly spread into the North American continent using land bridges created as a result of the accumulation of exotic terranes and uplift associated with the Laramide Orogeny (the last major orogeny to occur on the North American Continent). Flood waters were no longer in the Big Bend area and fresh water lakes are believed to have abounded during this time (see Oard, 1990, pp. 78-80).

While the author generally agrees with this interpretation, further refinement is necessary because fossils are found in at least two different types of strata (i.e., in sedimentary deposits inter-bedded between welded and consolidated volcanic rocks, and also in unlithified re-worked volcanically derived fluvial deposits). The uniformitarian paleoenvironmental reconstruction of these two volcanic paleontological settings as well as others found throughout the Park are open to personal interpretation of the data, and in no way infer a specific setting. For example Maxwell (1968, p. 20) has suggested that the Upper Cretaceous formations (i.e., the Aguja and Javelina Formations) reflect a coastal swamp environment:

> . . . associated with dinosaur bones, are fossil stumps of agatized wood, the roots of which are still emplaced in the sandy lagoon deposits in which they grew **(this is based on finding several trees stumps in this condition; however, the majority of the trees exist as trunks which lie prone and are in various stages of disintegration).** In some places, groups of fossil logs suggest "log jams" that were covered with mud and preserved. Fossil turtles have been found in the same rocks, and this association of dinosaur bones, wood, and turtles suggests that the ancient environment was similar to the present-day bayou environment of East Texas and Louisiana. (parenthesis and emphasis mine)

Regarding the fossilized dinosaur bone remains found within these same deposits (i.e., the Aguja and Javelina Formations), Maxwell (1968, p. 20) states:

> The skeletal remains of the duckbill dinosaur, ceratopsian bones (similar to the familiar Triceratops), and some of the large carnivorous types have been discovered, but only a few bones of the bird-like reptiles have been found. Jawbone fragments and teeth of swimming reptiles are also present.

One can quickly see that any paleoenvironmental reconstruction of the Upper Cretaceous deposits and associated fossils yields many possible interpretations. These Cretaceous deposits were volcanically derived and contain a mixture of both terrestrial and marine fossils. This mixed assemblage should alert the interpreter to seriously question any paleoenvironment reconstruction. Hence, great caution must be exercised by the young-earth Flood modeler in any attempt to recreate a depositional environment. The original information used to reconstruct the suggested environment might be based on only a portion of the facts presented as physical evidence, because the interpreter has a bias toward a specific environmental setting.

Several scientists have proposed a tropical fluvial volcanic environment for the original Goat Mountain area (again based on fossilized pieces of bone, teeth, snails and wood found in the Chisos Fm., collected from various sections of the Park). This environmental setting is interpreted as being violently destroyed in the eruptions of one (Henry and Price, 1984; Barker, Henry and McDowell, 1986; Dickerson et al., 1990, p. 42) or more (Henry et al., 1989) calderas located in the area. These caldera eruptions served to fill and even overtop the former Goat Mountain river valley. It is suggested that the plants and animals, living near these calderas, were also rapidly buried under **hundreds** of feet of volcanic deposits. This is the postulated environment proposed by both Uniformitarians (using millions of years) and some creationists (using several hundreds of years) who cite Nevins (1974) work (see Appendix II) in support of their interpretation.

It should also be noted that uniformitarian paleontologists recognize the concept of climatic zones and many are not willing to speculate as to compare the type of climate and associated flora and fauna found in one area versus another (see Frazier and Schwimmer, 1987, p. 634; Cox and Moore, 1985; Middlemiss, Rawson, and Newall, 1971). It is generally accepted that different types of animals lived in different climatic settings during different times within the Cenozoic. The author suggests that the upper Cenozoic rocks found across the Park correlate to the young-earth Upper Flood to Ice Age Timeframes when Flood waters continued to recede from the continents and plant and animal life sought to reestablish themselves on the continental landmasses following their migration into new areas. However, any paleoenvironmental reconstruction, within the framework of the young earth Flood model, remains speculative until enough is known about specific species of both plants and animals to determine if migration has occurred or if the fossils represent creatures buried in the Flood.

Creationist Paleoecology of Big Bend and Goat Mountain

As previously stated, the issue of depositional environments, based squarely on the paleontology found in Big Bend, suggests a warm, humid, tropical type of climate. This is true whether examining the fossils contained within the sedimentary deposits inter-bedded in the welded and consolidated volcanic deposits or the fossils within the volcanically derived non-lithified fluvial deposits. The past climatological conditions have been modeled using air flow patterns believed to have been in existence during the Upper Flood through Ice Age Timeframes (see Oard, 1990, pp. 78-91; Vardiman, 1994). The fossilized animal bone, snail shells, and petrified wood found within the sedimentary deposits inter-bedded between welded and consolidated volcanic rocks of the Chisos Formation (Maxwell et al., 1967, p. 136-137) represent species of animals which were believed to have lived in a tropical environment (note the potential for circular reasoning based on the types of fossilized wood and animal remains-one serves to reinforce the other and yet both may be wrong). These fossils along with climatic modeling do not solve the possible paleoenvironment for Big Bend Park, they only suggest a possible interpretation.

Another point of contention is possible based on the amount of time following the Flood event in which the area was repopulated by migrating species of animals. These animals moved from the Ark through Asia, across the Bering Strait land bridge, and into the North American continent, with some species ultimately residing near or in what is now Big Bend (do not forget the freshwater? snails). Eventually these animals met their demise when exploding calderas erupted massive volcanic deposits (i.e., several hundreds of feet of volcaniclastics across hundreds of square miles) which served to bury and preserve them. Oard (1990, p. 84) and Lammerts (1988) have both expressed concern with the animal repopulation of the North American continent following the Flood event. This author agrees! Additional studies need to be performed to determine population dynamics and dispersion as related to the migration and population of the North American continent by animals, following the Flood. However, a rapid population scenario would seem to be required to explain the occurrence of fossils within the sedimentary deposits between the welded and consolidated volcaniclastics of the Chisos Formation.

The animal, snail, and wood fossils found within the welded and consolidated volcanics would appear to suggest that a specific paleoenvironment was in existence when the volcanic eruptions occurred. However, if life were present and the environment was as postulated then evidence of that environment should exist outside the local Big Bend Area in the form of paleosols (both exposed and buried) and buried animal communities. Chronostratigraphically equivalent (i.e., time equivalent) formations, exposed to the east, across the Texas Gulf Coastal Plain, contain sedimentary deposits which reflect a marine environment (Spearing, 1991, pp. 10-11; Renfro, Feray and King, 1973; Plummer, 1932, pp. 803-805). Time equivalent fossils found to the west in the Rocky Mountains are believed (by Uniformitarians) to date to the Laramide Orogeny, and consist of vertebrates and fish (Frazier and Schwimmer, 1987, pp. 634-649). So it would appear that time equivalent rocks associated with the Rocky Mountains more closely compare with those found in the unlithified re-worked volcanic fluvial deposits than they do with the fossils found inter-bedded in the sedimentary deposits between the welded and consolidated volcanic rocks of the Chisos Formation. This interpretation is based solely on paleontology and no creationist work has been performed to date the Laramide Orogeny to a specific period within the creationist timeframe (e.g., Flood Event, Ice Age, or Present Age Timeframes). Again the subject of paleoenvironmental reconstruction, based on limited fossil evidence from two types of settings, remains speculative.

Additional analyses and investigations are necessary to further define and refine the paleosols and fossilized remains found at Big Bend Park within a Creationist Geologic Timescale (Froede, 1995a; Walker, 1994).

Discussion

The Goat Mountain exposure shows that volcanic materials have been deposited, were subsequently eroded, and additional volcaniclastics were deposited again, filling and overflowing the area. The rock record remains unchanged, only the interpretation will vary. The interpretation should be based on the facts as presented by the volcaniclastics exposed at the Goat Mountain outcrop. If millions of years were available for the deposition and erosion of the formations exposed at Goat Mountain, then evidence should be present to support that model. Likewise, if a much shorter timespan were used to explain the rock record then the evidence should exist to support that interpretation also.

Many of the volcaniclastics found at the Goat Mountain exposure were all deposited rapidly, or they would not be welded. This is true whether they were deposited in air or water. If the volcanic materials were deposited in air, they would then be subject to the rigors of chemical and mechanical weathering. This weathering would result in the formation of a soil. With sufficient time plant life would establish itself and further decompose the volcanic rock. If millions of years were available for weathering then at least some, albeit slight, layer of soil should have developed. No soil or paleosol is described or reported at Goat Mountain. Is it possible that every volcanic event destroyed every paleosol horizon before depositing the next layer of volcanic rock? The author believes that to evoke this concept would serve as an ad hoc explanation to justify why no paleosols are found, and this is would not be acceptable within either the uniformitarian or young-earth Flood models.

If the volcaniclastics were deposited rapidly (i.e., subaqueously), and if subsequent erosion occurred due to tectonics and water currents in effect at the time of deposition (i.e., closing stages of the Flood), then no soil would form, there would be abundant missing lateral rock section, and any remaining volcaniclastics would exhibit sharp lithologic contacts. These sharp contacts have been noted at Goat Mountain (Barker et al., 1986, p. 274). The time interval between successive lava flows would be brief and would be limited in lateral extent. If the subaqueous depositional conditions proposed are correct, then the volcanic ash flow tuff deposits would vary with distance and welding would be reduced with distances from the original source area. Each successive layer of welded or consolidated volcanic rock would be rapidly emplaced above the previous layer. The subaqueous environment could have had highly erosive conditions due to possible scouring by water laden volcaniclastics (i.e., epiclastics) coupled with nearby uplift associated with other volcanic features (i.e., the Pine Canyon Caldera and other calderas in the immediate area). The inter-bedded sedimentary deposits could have been washed in from the nearby North American Continent, with the draining of the epeiric sea (i.e., Flood waters) from its surface. The rock sections previously described tend to support this position (i.e., fossil containing sedimentary layers between welded and consolidated volcanic layers, in the Chisos Formation).

However, if the current uniformitarian model is correct in assuming that a stream or river flowed southwest from the Pine Canyon Caldera toward Castolon, carving a channel 900 feet deep, then there should be some physical evidences at the outcrop (e.g., fluvial deposits) which support such an interpretation. None have been described in any of the investigations performed at the Goat Mountain exposure, nor were any observed by the writer. The canyon exposure along the Rio Grande provides a model which should be observed at the Goat Mountain outcrop if a stream or river did in fact flow and carve the canyon seen in cross section.

The sharp contact between the Tule Mountain Trachyandesite (Chisos Formation) and the Wasp Spring Member (South Rim Formation) clearly reflect that nothing developed (e.g., paleosols) or was deposited (e.g., fluvial deposits) between them (Figures 2a and b).

The author proposes that the scouring of the channel possibly resulted as erupting subaqueous calderas generated water-laden volcanics which moved in currents directed by tectonic forces. These water-laden volcanic rock slurries (i.e., volcanic turbidites) served to rapidly erode the 900 feet deep canyon during the Flood Middle to Upper Flood Event Timeframe). An additional possibility could be that the channel was scoured by the Wasp Spring as it flowed subaqueously from its caldera source across the Tule Mountain Trachyandesite. That no fluvial deposits are found can best be explained coupling the erosion with rapid in-filling of the canyon with the Wasp Spring Member (subaqueously) and subsequent Burro Mesa Rhyolite. The rapid erosion, suggested for the subaqueous environment, would not have allowed for the development of typical fluvial deposits. Evidence of the hypothetical river channel (to Castolon) could also have been easily removed along with all the other missing (i.e., eroded) volcaniclastic deposits (e.g., Tule Mountain Trachyandesite, Wasp Spring member, etc.) during this subaqueous period (i.e., Middle to Upper Flood Event).

Fisher (1977) originally proposed a base-surge mechanism for the formation of some U-shaped erosional channels (see also Cas and Wright, 1988, p. 124). The author agrees that the U-shape erosional channel observed at Goat Mountain is a result of erosion. However, it is unknown if this feature formed due to any base-surge mechanism(s). Additional study is required to further investigate this possibility. The U-shaped channels closely resemble typical stream profiles (Fisher, 1977, p. 1295), and the author suggests that the early investigations of the Goat Mountain exposure assumed that the U-shaped cross-section was created by a stream channel. Subsequent investigations have also made the same assumptions, without the physical evidence (i.e., fluvial deposits) to substantiate the original proposal.

While this young-earth Flood model proposal appears to best fit with the evidences seen at this locale, additional investigation of the Goat Mountain outcrop is required to further determine the physical forces and resulting deposits which occurred forming this exposure.

Conclusion

The exposure of the volcanic sequence at Goat Mountain testifies to the power of incredible physical forces in both creating and destroying large amounts of volcanic rock. The defense of either the uniformitarian or young-earth Flood model should fit with the physical evidences observed at the Goat Mountain exposure. The author believes that the Goat Mountain exposure readily lends itself to a catastrophic interpretation and that it can best be explained within the time constraints and physical energy requirements of the young-earth catastrophist Flood model. Deposits necessary to defend the current uniformitarian model and the suggested paleoenvironment (i.e., paleosols, fluvial deposits, and paleontology) are either not present or fail to support the proposed setting.

The author proposes that (within the young-earth Flood model) the Goat Mountain area underwent subaqueous eruption of volcaniclastics which mixed with sedimentary deposits. These deposits were then subject to massive erosion, all of this occurring during the Middle to Upper Flood Event. Volcaniclastics erupted from nearby source areas (i.e., subaqueous calderas) and flowed outward, forming both welded and consolidated deposits. Tectonic forces created water currents which caused massive erosion of the newly deposited volcaniclastics. As a result Big Bend National Park has undergone complex volcanic and sedimentary deposition and massive erosion. The erosion which has occurred across the Park has served to create excellent outcrops of the volcanic deposits (e.g., Williams, 1993b).

The question as to what happened to all the missing volcanic rock remains unanswered. However, the author suggests that it was transported, in whole or in part, toward the Gulf of Mexico with the receding of the Flood waters. Holroyd (1987; 1990; 1994) has pointed to the “missing talus” at other western U.S. sites as being indicators of intense weathering and this author supports that premise and believes that the missing volcanic rock reinforces the highly erosive conditions (i.e., Middle to Upper Flood Event) under which these volcanic sediments were deposited and subsequently eroded. The present exposures observed across the park are interpreted, by this author, to reflect subaqueous conditions for both emplacement and erosion during the closing stages of the Flood event. Additional erosion occurred throughout the Ice Age Time frame; however, at greatly reduced levels (Froede, 1995b). Only additional research can substantiate this interpretation within the young-earth Flood model. The author welcomes other possible interpretations specifically for the Goat Mountain exposure and for the Big Bend National Park.

APPENDIX I
Ash-Flow Tuff

According to Fisher and Schmincke (1984, p. 91):

> Volcanic ash is composed of various proportions of vitric, crystal or lithic particles of juvenile, cognate or accidental origin forming 75 volume percent or more of an aggregate. Tuff is the **consolidated** (i.e., welded-either from the original heat within the mass or subsequent due to diagenesis or tectonic forces) equivalent of ash and is subdivided into fine- and coarse-grained varieties according to the size of component particles. Further classification is made according to environment of deposition (lacustrine tuff, submarine tuff, subaerial tuff) or manner of transport (fallout tuff, ash-flow tuff). Reworked ash is commonly named according to the transport agent (fluvial tuff, aeolian tuff, etc.) [emphasis and parentheses mine].

APPENDIX II
Previous Work by Nevins in a Subaerial Volcanic Terrain

Nevins (1974) has postulated the assemblage of volcanic rock containing mammalian fossils in the John Day Country of Northeast Oregon as dating to the Post-Flood time frame. His justification for this position is presented in “seven points” (Nevins, 1974, pp. 246-248). Some of these points and their relevancy to Big Bend Park, specifically for the Goat Mountain exposure were suggested by reviewers as being appropriate for comparison and are now addressed.

Subaerial Versus Subaqueous Deposition of Basalt

The basalts found in Big Bend, and specifically at Goat Mountain, are for the most part scoriaceous and highly vesicular (see Maxwell et al., 1967, [e.g., Bee Mountain Basalt Member-pp. 132-133]). These physical features would tend to support rapid cooling where escaping gases emitted from the extruded basalts were quick-cooled resulting in vesicular/scoriaceous rocks. The author proposes the possibility of subaqueous deposition for these scoriaceous basalts. No pillow structures have been found; however, the basalts have undergone extensive erosion and these features may not be as readily apparent due to their weathered condition. The author also admits that these basalts could have been extruded into a hypothetical lake (suggested by some) associated with the Post-Flood/Ice Age timeframe; however, the erosion which has occurred in the area is believed to be better explained using the highly erosive conditions associated with the Flood event (Middle to Upper Flood Event).

Subaerial Versus Subaqueous Deposition of Volcanic Ash

Previously cited works (especially Busby-Spera, 1984; 1986) have now firmly established that subaqueous welded ash flows can and do occur. Volcanic ash moving and welding subaqueously involves all fractional sizes, including very fine-grained ash and pumice (see Fiske, 1969; Yamazaki, Kato, Muroi, and Abe, 1973, p. 235; Yamada, 1973).

The author proposes that calderas erupted subaqueously in the Trans-Pecos Area and across the western sections of Big Bend National Park, creating the volcanic strata presently found and interpreted by uniformitarians as being subaerial. The subaqueous setting is believed to be justified based on the types of volcaniclastics found across the Park (and region), and the erosional energy associated with the Flood Event Timeframe. The author does not believe that the Ice Age Timeframe would provide both the volcanic and subsequent erosional energy necessary to explain the hundreds of square miles of volcanic material deposited and then eroded from the Trans-Pecos Region, and more specifically Big Bend National Park.

Local Versus Distant Transport of Volcanic Material

The geochemistry of the volcanic rocks found in the area surrounding Goat Mountain has led scientists to believe that one (Barker, Henry and McDowell, 1986; Dickerson et al., 1990, p. 42) or more (Henry et al., 1999, pp. 259-261) local calderas are responsible for the massive volcanic deposits found at Big Bend. Some of these welded and consolidated volcanic formations contain inter-bedded layers of sedimentary deposits and fossils. This author proposes that these fossils represent creatures which were killed and buried during the Flood. These fossil creatures are NOT paleo-indicators for Big Bend National Park.

Vertebrate fossils are also found in unlithified volcanically derived fluvial deposits in certain areas of the Park. However, these fossil containing formations do **not** consistently yield fossils across the Park, rather the types and amount of fossils found vary from outcrop to outcrop. This author suggests that many of the fossils found in these fluvial deposits represent local fauna, recently migrated into the area (Middle to Upper Ice Age Timeframe), which were probably killed as a result of ongoing but lessening volcanic activity. Hence these fossils were not derived from great distances, but rather locally.

Features Which Suggest a Possible Paleoenvironment

Nevins (1974, pp. 239-240) presents information regarding “upright trees” in the Clarno Formation which he suggests indicate a fossil forest (Post-Flood) which was buried rapidly. However, Austin (1991, pp. 20-23) has shown that upright trees in a volcanic setting might not reflect fossil forests, rather they might reflect water-saturated trees which sank in a vertical orientation and were subsequently buried under additional volcanic sediments. Additionally, Nevins (1974, p. 226, p. 239) cites specific “warm” weather trees, plants and nuts along with terrestrial vertebrates as indicating a "Mt. Vesuvius" type of eruption which buried and preserved all of this material within one narrow zone of the Clarno Formation. However, Nevins (1974, p. 239) is forced to state that the "mixed" assemblage of fossilized vertebrates do not fit together ecologically. Baldwin (1976, p. 94) stated that the vertebrates found in the Clarno vertebrate locality (near the town of Clarno) represent: ". . . crocodile, fish, horse, tapir, large swamp dwelling rhinoceros, small running rhinoceros, oreodont, and titanothere, **but practically no small animals."** (emphasis mine)

If this were a Post-Flood deposit, as has been suggested, and if small plant material such as fruits and nuts were found preserved in those deposits and this was a real ecological setting, then where are the smaller vertebrates which are normally associated with this type of community? Could they have not made the trip across the land-bridge or were they just not preserved? Do these fossils (both plant and animal) really represent a Post-Flood environment? It is interesting to note that Specimen Ridge in Yellowstone National Park also contains a mixture of non-ecologically related trees and that this area is interpreted as reflecting buried upright trees derived from a floating log mat generated during the Flood (Austin, 1991; Morris, 1995).

The overlying John Day Formation also contains an interesting mix of extinct vertebrate and plant fossils, with most of the larger vertebrates identified being grassland inhabitants, living in a temperate and wet climate (Baldwin, 1976, pp. 96-97). The John Day Formation fossils are found in deposits described as "badlands" (Stock, 1946, p. 59). Nevins (1974) provides his interpretation of Post-Flood paleoenvironment based on paleontological assemblage and upright trees; however, a closer examination could suggest other possible interpretations.

Frazier and Schwimmer (1987, p. 634) state that, by the Upper Oligocene, floras found in the John Day Basin resembled those found in the Northwest today. This would appear to confirm the change in climate conditions associated with the closing of the Ice Age, and the beginnings of our modern "uniformitarian" climatic setting. Based on the similarity of past (i.e., Upper Oligocene) to present environments, the author could support the possible interpretation of a Post-Flood setting for the existence and possible burial of the plants and animals found in some of Nevin's John Day Country. However, additional work in the John Day Country could help to resolve these issues, especially in the light of new information gained from the eruptions of Mount St. Helens and volcanic stratigraphy (e.g. Lipman and Mullineaux, 1981; Fisher and Schmincke, 1984; Cas and Wright, 1987: Scott, 1988; Fisher and Smith, 1991).

No upright trees or any other sort of geopetal structures have been identified in the volcaniclastic deposits associated with Goat Mountain, in Big Bend National Park. Nothing found (i.e., fossils) appears to indicate any sort of paleoenvironment. Rather only fossilized broken bits and pieces of bone and wood, along with what are believed to have **been** fresh water snail shells (these snail shells resemble present day species of fresh water snails) are used to reconstruct what the environment might have been like in the Big Bend area.

Fossils found within the unlithified volcanically derived fluvial deposits date to a lower energy environment, which this author suggests would reflect a Middle to Upper Ice Age Timeframe. Volcanic eruptions, associate with the many calderas found both in the region, as well as in the Park, probably continued throughout much if not all of the Ice Age Timeframe. These volcanic releases probably supplied much of the clastics, currently not identified as volcanically derived, on the Gulf Coastal Plain. Additionally, these altered volcaniclastics served to bury and preserve many of the terrestrial environments found in the Cenozoic age deposits.

The author acknowledges that great differences exist between the Nevins (1974) John Day Country strata and its suggested subaerial depositional environment (see Robinson, Brem, and McKee, 1984), and that which is found and suggested as being subaqueously deposited, by this author, at Big Bend National Park (specifically at Goat Mountain). The Trans-Pecos / Big Bend Park region contains hundreds of vertical feet of volcanic deposits spread out over hundreds of square miles, which were subsequently eroded to the point where, in many cases, only buttes and mesas remain. The author suggests that the energy levels necessary to both deposit and subsequently erode all of these volcaniclastic deposits would only be available during the Flood event (i.e., Middle to Upper Flood Event Timeframes).

In recent studies of the various volcanic environments found worldwide, many uniformitarian scientists now recognize and suggest subaqueous eruptional settings. This depositional setting has opened the opportunity to investigate volcanic environments which might have been deposited during the Flood event (e.g., Trans-Pecos, Big Bend, and specifically Goat Mountain). This concept now adds options to the young-earth Flood scientist which allows the possible volcanic site reconstruction within the timeframes and energy levels necessary to support the young-earth Flood model.

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PANORAMA NOTES

Creation Law Debated in Tennessee

In the 1996 session, the General Assembly of the State of Tennessee debated and finally defeated a bill which would have required teachers to treat evolution as a theory rather than a fact. Senate Bill 3229, introduced by Senator Tommy Burks, a Democrat whose home district is 45 miles northwest of Dayton, stated in part:

> No teacher or administrator in a local education agency shall teach the theory of evolution except as a scientific theory. Any teacher or administrator teaching such theory as fact commits insubordination, . . . and shall be dismissed or suspended . . .

When it was debated in early March, the Senate voted 19-13 to send it back to committee for consideration of numerous proposed amendments. The debate also received coverage in the national media. An Associated Press article (Brown, 1996) stated that the bill was originally expected to pass "despite an attorney general's opinion it violates the constitutional separation of church and state."

Historical studies (Barton, 1992) show that the concept of separation of church and state is not in the