THE FORMATION OF SANTA ELENA CANYON, BIG BEND NATIONAL PARK: ORIGIN SPECULATIONS

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Abstract

The formation of Santa Elena Canyon located in Big Bend National Park, Trans-Pecos Texas is discussed. All speculations are developed within a young-earth Flood model. Two phases of canyon formation are suggested. One period of extensive erosion occurred during the time of exiting Flood water and another period of considerable erosion occurred during a post-Flood warm ice age to form the canyon.

Introduction

Acceptance of a recent Creation and Flood model of earth history implies that many natural events, such as canyon formation, are assumed to have occurred quickly. Involved in rapid canyon formation is rapid erosion, a topic often discussed in the Quarterly. For instance, three articles (Williams, Meyer and Wolfrom, 1991, 1992a, 1992b) presented various views of the formation of the Grand Canyon of the Colorado River. (Also see Austin 1984a, 1984b, 1986, 1994a, 1994b; Brown 1989; Oard 1993; Williams 1993a.) An introductory study on the erosion of Pine Creek Gorge in Pennsylvania has been published (Williams, Chaffin, Goette and Meyer, 1994). A discussion of the formation of Bangs Canyon, Colorado was given by Holroyd (1994). The rapid erosion and canyon formation caused by the 1993 Midwest floods was graphically illustrated by Wolfrom (1994). In a 10-year study at Providence Canyon, Georgia, Williams (1995) outlined the effects of recent catastrophic erosion. This treatise on Santa Elena Canyon in Big Bend National Park, Texas (Figures 1 and 2) is another introductory study reflecting the continuing field work of the Society on the topics of rapid erosion and canyon formation, important aspects of Flood geology. A glossary of geological terms used in this paper is provided after the acknowledgments.

Canyon Location

The Rio Grande courses through three principal canyons, Boquillas, Mariscal and Santa Elena, in Big Bend National Park on its way to the Gulf of Mexico. Santa Elena is the western-most canyon and the first one that the river enters in the park. Its location is shown in Figure 2. The canyon is approximately 18 miles long, beginning near Lajitas at the northwest corner of the park. The lower seven-mile section of the canyon is narrow with steep walls (Figure 3). The walls of the canyon are approximately 1700 ft (520 m) high and in the lower seven-mile portion, the walls are often no more than 30 ft (9 m) apart in places (Figures 4a and 4b). The impressive mouth of the canyon (Figures 5 and 6) can be seen in the Park from an overlook about 32 miles (51.5 km) southwest from the intersection of the Ross Maxwell Scenic Drive and the main park road. It is also possible to walk along a trail across Terlingua Creek into the mouth of the canyon for a short distance. The Rio Grande enters the lower seven-mile stretch (11.3 km) of the canyon about 11 miles (17.7 km) southwest of Lajitas. This entrance into the high-walled, narrow section is not as impressive (Figure 7) as the mouth of the canyon.

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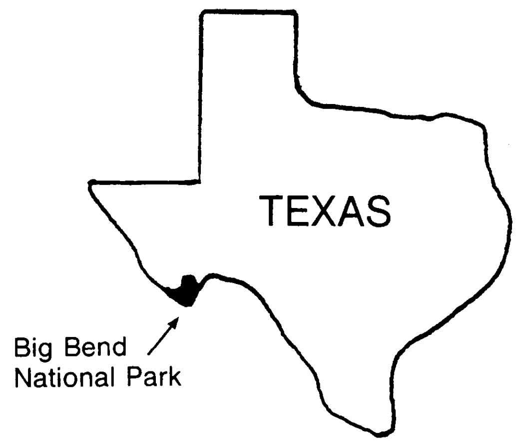

Figure 1 Location of Big Bend National Park in the state of Texas.

Stratigraphy at the Mouth of the Canyon

Rusch (1988) and Williams (1988) wrote brief letters for the Quarterly concerning Santa Elena Canyon. Rusch presented a stratigraphic column of the canyon. Maxwell (1968, p. 87) state that ". . . the canyon walls show the best cross section of the Lower Cretaceous formations exposed in the Park." Table I details the exposed stratigraphic column at the mouth of the canyon. Also see Figure 6. A general stratigraphy for Big Bend National Park is given in Williams and Howe (1993).

Origin of the Canyon-Various Concepts

Most uniformitarian scientists consider that the Rio Grande formed Santa Elena Canyon. The different theories involve various quantities of water, i.e., generally small amounts of water flowing over long periods of time or larger amounts of water flowing over shorter periods of time. The various origin concepts will be reviewed and then our hypothesis of canyon origin within a young earth-Flood model will be presented.

Antecedent Stream View

Probably the first known published suggestion of how Santa Elena Canyon formed was written by Udden (1907) [as documented by Maxwell, Lonsdale, Hazzard and Wilson (1967. p. 20)]. In discussing the Rio Grande, the following statement was made by Udden, Baker and Böse (1916, pp. 21, 22):

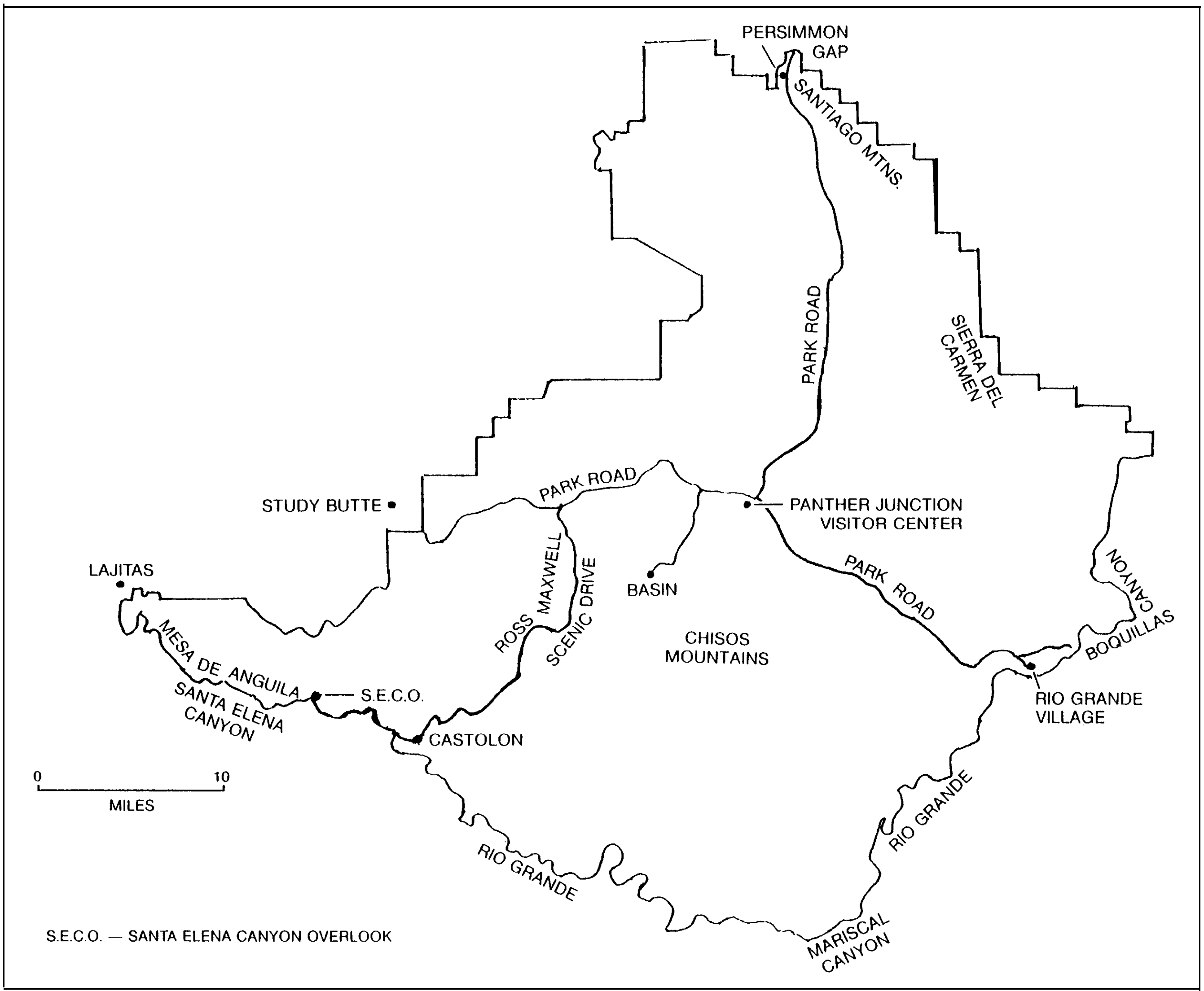

Figure 2 Simplified map of Big Bend National Park.

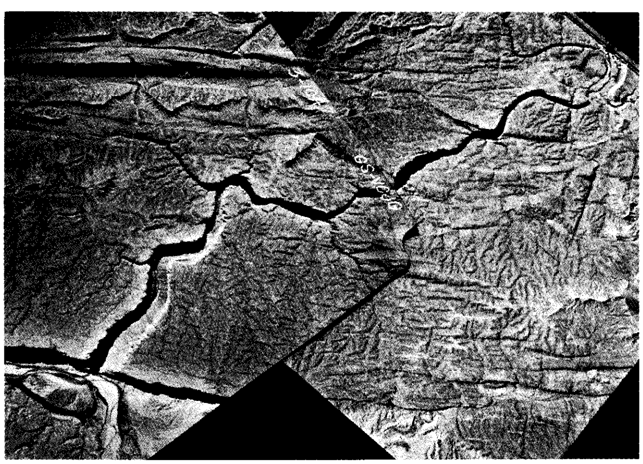

Figure 3a Composite of U.S. Geologic Survey high altitude photographs of Santa Elena Canyon through Mesa de Anguila (right) and Sierra Ponce (left) by Robert L. Goette. Sierra Ponce is in Mexico whereas Mesa de Anguila is in the United States. Rio Grande flows from right to left.

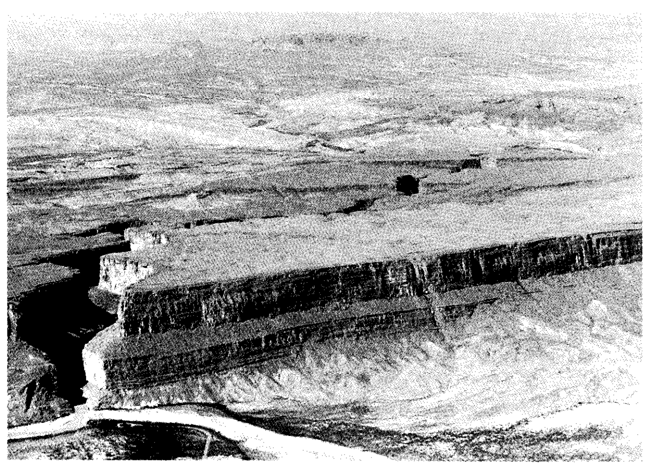

Figure 3b Oblique aerial photograph of Santa Elena Canyon (lower seven-mile length) through Mesa de Anguila (right) and Sierra Ponce (left). Rio Grande turns to the left as it exits the funnel-shaped mouth of the canyon. Terlingua Creek is seen entering the Rio Grande at the mouth of the canyon. Photograph by Robert L. Goette.

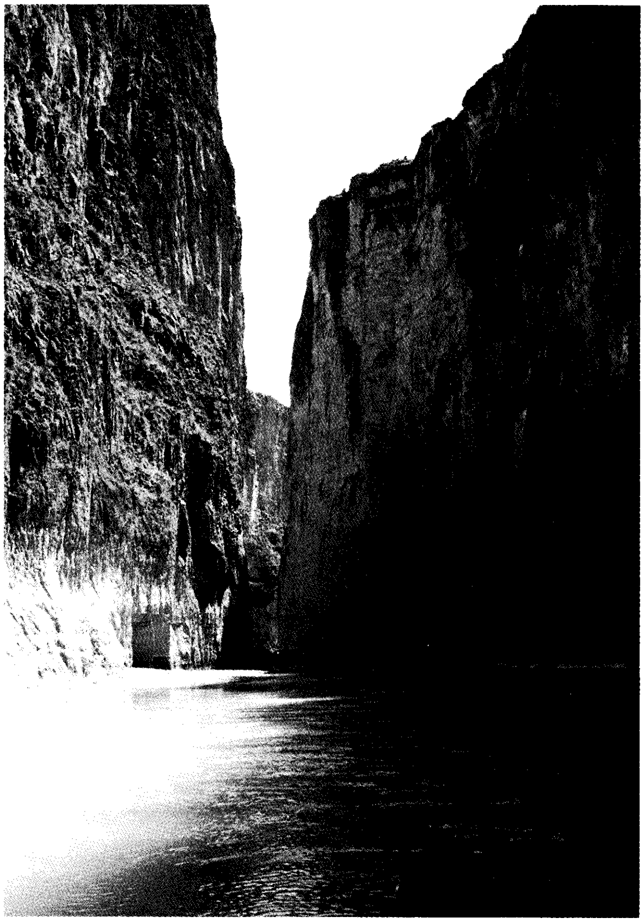

Figure 4a Note the high walls and narrow canyon width from water level as one floats the Rio Grande through Santa Elena Canyon. Photograph by Emmett L. Williams.

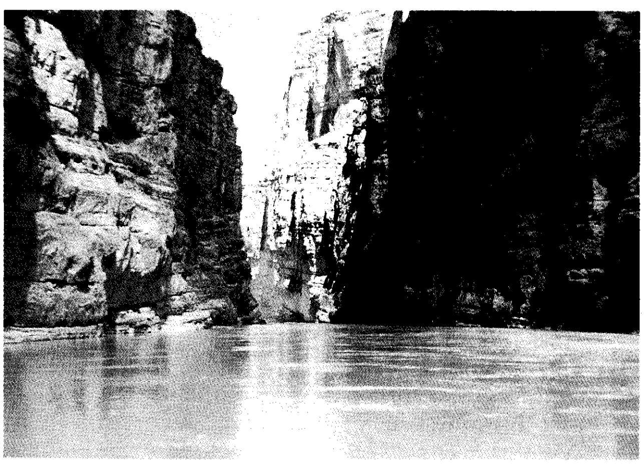

Figure 4b The tilted strata inside Santa Elena Canyon create an optical illusion giving the appearance that one is floating down an incline toward the mouth of the canyon. Photograph by Emmett L. Williams.

Figure 5 The funnel-shaped mouth of Santa Elena Canyon as seen from the air. Terlingua Creek empties into the Rio Grande as the river exits the mouth of the canyon; left-Sierra Ponce, right-Mesa de Anguila. Photograph by Robert L. Goette.

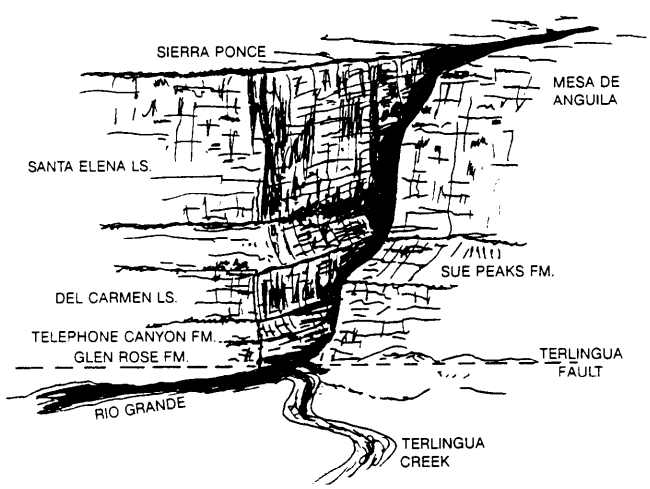

Figure 6 Drawing of the mouth of Santa Elena Canyon with the superposition of the various formations noted. The Terlingua fault line runs along the base of Mesa de Anguila and Sierra Ponce (after Stevens and Stevens, 1990, p. 49).

At a time which we cannot as yet definitely state, but either at the end of the Tertiary (late Pliocene) or early in the Quaternary (Pleistocene) the mountain ranges of West Texas were uplifted athwart its course. The river was able to cut down as fast as the mountains rose, and so today its course through the mountains is marked by a series of canyons.

Figure 7 The Rio Grande enters the lower section of Santa Elena Canyon about 11 miles (17.7 km) southwest of Lajitas. Photograph by Emmett L. Williams.

Possibly Udden was influenced by the ideas of John Wesley Powell (1961, pp. 89, 90) and his antecedent stream views of the formation of the Grand Canyon by the Colorado River—see Williams, Meyer and Wolfrom (1991). The gist of the antecedent stream view of canyon formation is that as the river runs along its course over a region where a canyon is "destined" to form, this course is established and the river will continue this path during and after canyon formation. It is speculated that the land along the path of the river uplifted slowly. As the slow uplift occurred, the erosive forces of the flowing water cut into the uplifted rock as rapidly as it rose. Thus the river continued along its original course during the entire uplift process and a canyon formed through the uplift. This view of canyon formation was very popular in the late 1890's and early 1900's. Many geologists still adhere to the antecedent stream view for the formation of many canyons. For instance Spearing (1991) believes that the Rio Grande is antecedent to Santa Elena Canyon:

> An obvious question is why the Rio Grande cuts across this massive uplifted block of limestone-why doesn't the Rio Grande just go around it on the way to the Gulf of Mexico? The answer is that the Rio Grande (or its ancestor) was here before the block uplifted! And, as the block rose along the fault in earthquake increments of a few inches to a few feet at a time, the river simply downcut a little faster to accommodate the small change in slope caused by the last earthquake and uplift. Now, repeat this process many, many times over several million years, and you can see how the river cut Santa Elena Canyon little by little, inch by inch-nothing dramatic, just small effects multiplied over millions of years (p. 321).

Earthquakes can cause uplift and thrusting of inch proportions as noted by Howe (1972). Allowing millions of years of time and assuming many small uplifts, the river would erode such a rising landscape as rapidly as it lifted, and the river would continue along the same path as a canyon forms. Belcher, in discussing the geomorphic evolution of the Rio Grande, appeared to favor the antecedent stream view for the formation of canyons along the Rio Grande in West Texas (1975, pp. 15, 16, 22-34). Nelson (1992, p. 47) briefly outlined the

Table I Santa Elena Canyon-Exposed Stratigraphic Colunn. Modified from Stevens and Stevens (1990, p. 50).

Formation	Thickness (feet)	Lithology
Santa Elena	740 (226 m)	Massive, thick-bedded, dense, cherty, ledge-forming limestone with thin-bedded marly limestone near base
Sue Peaks	275 (84 m)	Shale, marl and thin marly, nodular limestone ledges
Del Carmen	465 (142 m)	Massive, heavy-bedded, dense, cherty, ledge-forming limestone
Telephone Canyon	145 (44 m)	Thin, nodular, marly limestone and marl
Glen Rose	~100 (31 m)	Dense limestone interbedded with calcerous shale, erodes to form step-like benches, conglomerate and coarse sandstone at base

antecedent stream theory for the formation of Santa Elena Canyon.

> . . . the ancestral Rio Grande established its course prior to Basin and Range faulting. As it slowly cut its channel deeper into the massive limestones the uplift of one fault block continued. The end result was a magnificent steep-walled canyon.

Views of C. L. Baker—
Lake Formation and Superimposed Stream Theory

Possibly the first published view of the origin of Santa Elena Canyon that differed from that of the antecedent theory was written by C. L. Baker (1927, pp. 37, 38):

> The uplifting of the present mountain ranges destroyed in large part pre-existing drainage lines . . . The basin of the Rio Grande, all the way from its source to the Boquillas Cañons at the eastern side of the Big Bend syncline (this area includes Santa Elena Canyon which is west of Boquillas Canyon) was dammed and a lake or a series of lakes was formed along the present valley of the river (Parenthesis ours).

Maxwell, et al. (1967, pp. 20, 21) in discussing an unpublished manuscript of Baker (1934) claimed that he postulated the existence of a lake in the lowland ". . . between the Santiago-Sierra del Carmen ranges on the east and Mesa de Anguila on the west . . ." The lake may have had an elevation of 4000 ft (1219 m) and covered the Mesa de Anguila leaving only the highest peaks in the Chisos and Sierra del Carmen Mountains above water. Baker offered two suggestions as to how the Rio Grande attained its present course (Maxwell et al., 1967, p. 21):

> . . . (1) superimposition from ancient lake deposits which entirely buried some of the uplifts so that when erosion reached the base of the lake beds, the river cut downward into the massive limestone, or (2) the original Rio Grande channel was underground and the canyons were formed by collapse of the rocks of the solution channels.

Figure 8 Did a lake once cover this region of Trans-Pecos Texas? View at Persimmon Gap, Big Bend National Park looking westward into Chalk Draw Graben. Photograph by Emmett L. Williams.

It is easy to imagine that the present desert basins in Big Bend National Park once were covered by a lake or lakes (Figure 8). However the actual depth of any postulated lake or of any lake-deposited (lacustrine) material is a matter of speculation (Scheubel and Mruk, 1994, pp. 62, 66).

View of P. B. King-
Superimposed Stream Theory, Basin Fill and Overflow

In discussing the late "Cenozoic," King (1935, p. 259) dismissed the antecedent stream concept of the formation of Trans-Pecos Texas canyons along the Rio Grande by stating:

> There is no evidence that these areas were connected by any large streams . . . It is probable that the Rio Grande did not take its course across New Mexico and western Texas until long after the first time of faulting and after the time of basin filling.

King (1935) proposed that during a sequence of erosion, intermontane basins (possibly shallow lakes or playas) were filled with erosional debris which was derived from adjacent mountains. The basins were filled to considerable heights and the pediment was cut so deeply into the encircling mountains that many of the valleys became connected to other basins. As the basins filled, water sought the lowest outlet and overflowed into a lower valley in a continuing process. The Rio Grande became superimposed on this type of topography. The river likely transported abrasive material (possibly a water-particulate slurry) which cut canyons into many uplifted blocks of sediment. King felt that much water was available during this period of erosion as he compared the development of the Rio Grande to that of the Colorado River (1935, p. 260):

> Much water must have been shed off toward the south and southwest, filling near-by desert basins to their rims, overflowing into adjacent lower basins, and eventually establishing through-flowing drainage to the sea. One such through-flowing stream was the Colorado, another the Rio Grande.

King (p. 261) graciously acknowledged his indebtedness to C. L. Baker as to the similarity of their interpretations concerning stream development in Trans-Pecos Texas.

The superimposed stream concept of canyon formation along the Rio Grande was briefly explained by Nelson (1992, p. 47).

> . . . the ancestral Rio Grande was located on the coastal plain east of the present Sierra del Carmen and the Santiago Mountains while the Basin and Range faulting was taking place. The closed basins formed by the faulting slowly filled with sediment eroded from the Chisos Mountains and from the up turned edges of the fault blocks. Each basin then overflowed into the next lower basin until finally a single large basin formed centered in northern Mexico. As the mountains rose during the Pliocene and as the Pleistocene began, precipitation increased. The basin then overflowed the Sierra del Carmen at a structurally low point and flowed into the ancestral Rio Grande on the coastal plain.

With this scenario Boquillas Canyon in the southeastern end of the park was formed first, then Mariscal Canyon and then Santa Elena Canyon.

Maxwell (1968, pp. 91, 92) supported the superimposed stream theory for the Rio Grande canyons. Muehlberger and Dickerson (1989, p. 48) stated that:

> Throughout its course the river occupies the structurally lowest areas, and in only a few places has it been superposed across Laramide or younger structures. In those areas it flows through narrow canyons orientations of which were influenced by fractures formed during Laramide deformation and enhanced during later episodes.

DeCamp (1985, pp. 127-135), in an excellent treatise on the structural geology of Mesa de Anguila, noted that in the Post-Laramide period the mesa was subjected to extension causing vertical displacements along the Terlingua and Anguila fault zones (Figure 9). He stated:

> Closed basins in these fault zones accumulated thick sections of bolson fill. When these bolsons were breached, the Rio Grande, or its ancestor incised the fill. The present eccentric course of the Rio Grande in this region was probably caused predominantly by superposition of the river through the fill onto jostled fault blocks (p. 133).

The official park handbook for Big Bend (1983) offers the superimposed stream theory origin for the canyons on the Rio Grande as does a park explanatory sign at the Santa Elena Canyon overlook.

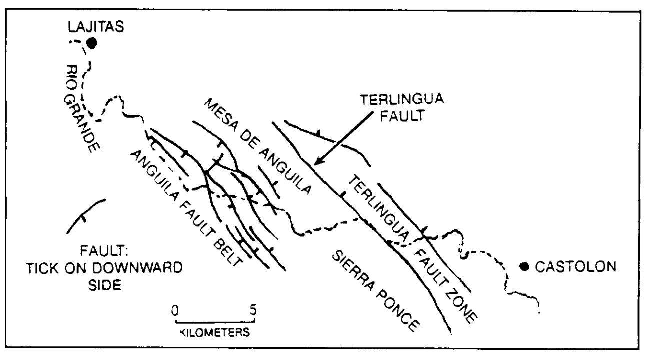

Figure 9 Representation of some of the faults in the Terlingua fault zone and Anguila fault belt. See DeCamp (1985, p. 127). Dotted line—trace of Rio Grande.

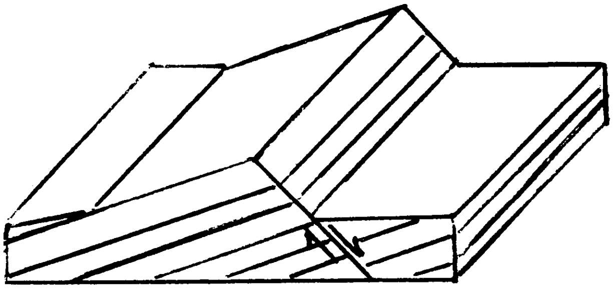

Figure 10 Representation of the development of a fault-block mountain. Arrows indicate the direction of movement of the strata.

Scheubel and Mruk (1994) explain the superimposed stream concept for canyon formation in Trans-Pecos Texas as follows:

> Uplift in the Southwest during mid-Cenozoic time formed many fault-block mountains and intermontane basins. The basins received their debris from the mountains. In some of them there was not through drainage and they probably contained lakes . . . As the closed basins were filled with debris, the lower ranges were probably buried. Basin waters naturally drained through the lowest outlet into a lower basin. When the second basin was filled, the water flowed into a still lower depression. In time, through-flowing drainage was established . . . and most of the basins contained great thicknesses of rock debris . . . Once drainage was established on the valley-fill deposits, the river was trapped. When it encountered hard underlying bedrock there was no alternate but to cut a canyon (pp. 62, 66).

As has been shown, various workers who support the superimposed stream hypothesis for the Trans-Pecos Texas canyons along the Rio Grande differ on the details of the process.

Prior Creationist Canyon Formation Speculations-Big Bend National Park

The Society has sponsored several teams of scientists to do field work in Big Bend National Park. Some of the work has been reported in the Quarterly—Froede, 1994a, 1995a; Howe and Williams, 1990; Rusch, 1988; Williams, 1988, 1993b, 1993c, 1994; Williams and Howe, 1993; Williams and White, 1992; Williams and Wolfrom, 1993; Williams, Howe and White, 1991; Williams, Howe, Matzko, White and Stark, 1995; Williams, Matzko, Howe, White and Stark, 1993. Also some unpublished manuscripts and informal field notes have contained sections on the formation of Santa Elena Canyon (Howe, 1990; Waisgerber, 1990).

Waisgerber, influenced by Pause and Spears (1986, pp. 9-13), envisioned the formation of lakes over bolson sites in Trans-Pecos Texas. When the dam of a particular lake was breached, possibly by piping, the escaping lake water containing considerable abrasive material could have cut the canyons along the Rio Grande in a brief period of time. Also Howe (1990) supported the concept of the breaching of dams along bolsons releasing water filled with abrasive particles which scoured canyons in Trans-Pecos Texas. He speculated that during the Basin and Range extension, zones of weakness along fault-block mountains (Figure 10) and in dams impounding the bolsons would have been created by the faulting. This tectonic activity may have generated preferred paths for flowing water through dams and fault-block mountains.

Current Creationist Speculations on Formation of Santa Elena Canyon

The purpose of this article, besides reviewing the various suggestions for the formation of Santa Elena Canyon, is to update the creationist model for the origin of the Canyon. The postulated model will be developed within a young earth-Flood framework.

The "Cretaceous" formations which form the walls of Santa Elena Canyon were deposited during the latter stages of the Flood.* Later as Flood water exited the continental United States and Mexico, much erosion would have occurred in Trans-Pecos Texas. Tectonic and volcanic activity would have created highlands and basins. Water moving along the highlands and into the basins would have caused tremendous erosion. Many basins would become closed either by the collection of erosional debris from the highlands, landslide blockage or uplift forming dams. Dam breaching would occur in this period as the trapped water sought lower elevations causing continued vast erosion. Possibly extreme water pressure on the unstable dams as well as piping through the weak obstruction would lead to dam failure releasing walls of water which would scour rock and soil in their path. (See Williams, 1993a.)

At the onset of a post-Flood warm ice age** as suggested by Oard (1990) this erosional process would continue as increased precipitation in Trans-Pecos Texas would provide abundant water. (While there was no glaciation in Trans-Pecos, Texas, increased precipitation would fall upon the region during a warm ice age.) Continued tectonic activity could produce uplift, again blocking the flow of water from higher to lower elevations. Bolsons would form again and dam breaching would be possible, generating more erosional action. In this stage considerable faulting likely was occurring along Sierra Ponce and Mesa de Anguila (Figure 9) creating zones of weakness encouraging the low of water through narrow faults. As the ice age abated, the Trans-Pecos Texas region became arid (Lammerts, 1971; Wells, 1985; Howe, 1996) as the supply water decreased. A "path" had been scoured for the Rio Grande to follow by the sequence of basin fill and dam breaching. The last seven miles of Santa Elena with high walls and narrow width also could have resulted from the solution of the limestone by water and subsequent collapse of the material above the solution cavity. A rapidly decreasing water supply as ice age conditions diminished could have lessened the opportunity for lateral erosion and this portion of the canyon retained its narrow width while downcutting proceeded.

Conclusions

All of the events suggested for the formation of Santa Elena Canyon from a Flood, post-Flood perspective are considered to have happened rapidly within a

***See Froede, 1995b for a discussion of the "Cretaceous Seaway" as possibly retreating Floodwater on the North American continent.**

****It is suggested that these two periods need not have occurred sequentially. There could have been a drying period between the time of exiting Flood water and the ice age stage.**

young-earth framework. The erosion of Santa Elena Canyon may have encompassed two separate time frames, a period of exiting Flood water and a period of increased precipitation during a warm ice age. Erosion was substantial in Trans-Pecos Texas during both periods. Tectonic and volcanic activity in the region caused the development of highlands and basins in both time frames. Erosion of the highlands, landslides and uplift blocked the flow of water out of many basins forming bolsons. Breaching of the natural dams generated considerable erosion below the dams.

Santa Elena Canyon was essentially completely formed at the end of the ice age. The curious path of the Rio Grande developed during the two erosional phases and particularly during the last phase of the ice age. The last seven miles of Santa Elena Canyon could have developed by the formation of solution cavities in the uplifted limestone blocks and subsequent collapse of overlying sediments or by the flow of water through narrow fault zones created during the waning stages of the ice age as the water supply rapidly diminished in Trans-Pecos Texas.***

The breaching of dams in debris-filled bolsons releasing large quantities of water containing considerable abrasive matter caused the major erosional action to form Santa Elena Canyon and possibly other canyons in Trans-Pecos Texas. These suggestions are tentative and are to be considered speculative.

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Glossary

Antecedent Stream—A stream that was established before local uplift began and incised its channel at the same rate the land was rising. A stream that existed prior to the present topography.

Bolson—An extensive flat alluvium-floored depression into which drainage from the surrounding mountains flows. An interior or closed basin with internal drainage.

Downcutting—Stream erosion in which the cutting action is directed in a downward direction.

Fault-block Mountain—A mountain that is formed by block faulting.

Faulting—The process of fracturing and displacement that produces a fault.

Lacustrine—Pertaining to or produced by lakes.

Lateral Erosion—The erosion of a canyon or gully walls by water action and gravitational forces causing the canyon to widen.

Lithology—The physical character of a rock.

Pediment-A broad, gently-sloping erosion surface typically developed by running water in an arid or semiarid region at the base of an abrupt and receding mountain front.

Piping—A process causing catastrophic failure of natural and man-made dams in which water enlarges tunnels through the dam.

Playa—A dry, barren area in the lowest part of an undrained desert basin. A shallow, intermittent lake in an arid region.

Superimposed Stream—A stream that was established on a new surface and that maintained its course despite different lithologies and structures encountered as it eroded downward into the underlying rocks.

Uplift—A structurally high area in the crust produced by movement that raised the rocks.

***For a discussion of the possible formation of channels in limestone in conjunction with a lowering groundwater level, see Froede, 1994b.

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