OBSERVATIONS OF FOSSIL MATERIAL AND CHARCOALIZED WOOD IN THE DAKOTA FORMATION IN COLORADO AND WYOMING

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Abstract

The plant and trace fossils at Dinosaur Ridge, Morrison, Colorado, are given further descriptions. Most of the plant fossils in this outcrop of the Dakota Formation are in the form of broken pieces of charcoal or as casts, which often record the wood grain. Charcoal fragments mixed within the sand are interpreted as being deposited under catastrophic conditions. Rocks containing the charcoal along bedding planes are interpreted as being deposited under conditions slow enough to allow buoyancy to separate the plant matter from the rock detritus.

Charcoal fragments were also present in the upper third of the Dakota Formation in the local region near Dinosaur Ridge, at Canon City, Montrose, and Fort Collins, Colorado, and at Newcastle, Wyoming. The charcoal appears to be catastrophically deposited in the region of Dinosaur Ridge and at Newcastle. Further observations and research may fit these widespread deposits into the middle to upper part of Flood strata.

Introduction

Holroyd (1992) described the fossil deposits in the Morrison and Dakota Formations at Dinosaur Ridge, a hogback ridge between Morrison and Golden, Colorado. Deposits of large dinosaurs bones were discovered there in 1877. The hogback strata are exposed by stream cuts in the area and by the road cuts of Interstate-70 and West Alameda Parkway. Interpretive signs, following a uniformitarian framework, are at both road cuts to aid self-guided tours. Holroyd (1992) provided a map of the area as his Figure 1.

The Friends of Dinosaur Ridge have been conducting, for the general public, guided tours of this same Alameda Parkway exposure once each month from April to October since 1990. Lately they have been offering guided tours for groups from public, private, and home schools. Most tours are given from the evolution / uniformitarian viewpoint but a few are presented from the creation / young-earth viewpoint.

MacKenzie (1972) provided an excellent description of part of the Alameda Parkway exposure. He included detailed diagrams and photographs of the upper 100 feet of the Dakota Formation there and interpreted the sequence as from tidal sand flat deposits. He estimated current directions from the orientations and asymmetries of ripples preserved in the rocks. Comparisons were made with modern formations elsewhere in the world. He indicated that the scarcity of muds in the sequence argues against the deposit being from a shoal water delta.

Holroyd (1992) argued that the mere presence of dinosaur fossils and footprints required rapid sedimentation rates. Otherwise the animals would have decayed or have been scavenged and unavailable for fossilization. Footprints are even more delicate and would suffer destruction with the next wave, tide, rain, or other disturbance. He described the plant fossil material as impressions of broken pieces of charcoal mixed with sand in a thick cross-bedded deposit. Nearly all plant material is fragmented beyond recognition.

Holroyd (1992) also examined the 1989 Sugarloaf Mountain forest fire site two years later. Charcoal and sand were still accumulating in the creek bed of Black Tiger Gulch. Small trenches were dug into numerous sandbars formed since the fire, in an attempt to locate a charcoal and sand mixture similar to that found at Dinosaur Ridge. All sand deposits examined were free from charcoal except scattered pieces on the surface. Density differences between the sand (quartz grain density 2.65) and plant matter (density 0.2 to 1.1, depending on waterlogging) indicate that in a normal depositional environment with abundant water and agitation the two materials would strongly segregate.

Figure 1. This is the only Dinosaur Ridge rock sample found by the author that appears to have an identifiable plant impression, that of an *Equisetum sp.* stem. The finger indicates the scale of the broad stem.

Holroyd previously suggested that the mixing of sand and charcoal at the Dinosaur Ridge plant fossil deposit indicated a catastrophic mud flow. Within a debris or mud flow there may be sufficient water to move the material but not enough to completely separate the various composing materials by buoyant forces. Such a flow deposit could occur in a matter of minutes. The lack of disruptive biological activity in this mud flow deposit in the form of large plant roots, animal burrows, or soil formation, limits the time for the formation of the entire deposit (tens of meters).

Combining the necessary deposition rates indicated by the charcoal mixture with those needed for burial of dinosaurs and preservation of their footprints, Holroyd (1992) suggested minimum rates of meters per year. Conventional geology assigns 50 million years for

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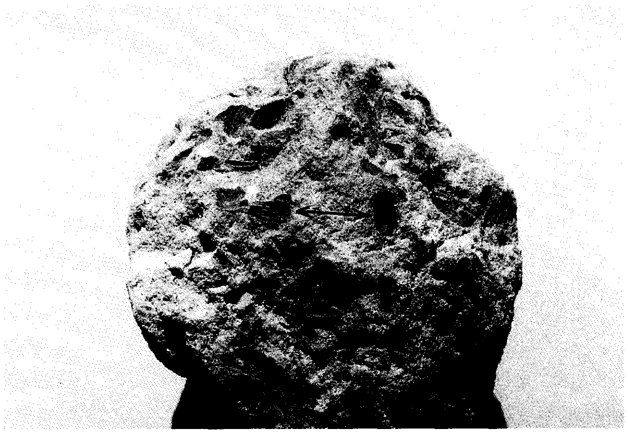

Figure 2. The dark hematite has served to preserve the wood grain orientation (shown by the arrow direction for the fragments to the left and right of the arrow). Some of the wood fragments found within this layer have sharp fractures perpendicular to the wood grain, indicating that they are likely to be derived from charcoalized wood and not green wood.

the 200 meters of rock in the combined Morrison and Dakota Formations at Dinosaur Ridge. Strict uniformitarianism would thus give an average net deposition rate of four micrometers per year. I made no attempt to fit all of the Dinosaur Ridge strata deposition into the single year of the Genesis Flood. Additional work is required to make this determination.

In an attempt to better understand the sand / charcoal mixing relationship, Holroyd (1996) examined a debris and mud flow from another forest fire site. I found that the mud had buoyant charcoal and plant matter mixed throughout two core samples. I found that the charcoal resided along bedding planes for deposits at the end of catastrophic flows and under normal, slow deposition conditions. I suggested that the two different occurrences of broken charcoal in the stratigraphic record can be used to partition a deposit into catastrophic (charcoal mixed within the matrix of sand and mud) and slow (charcoal along bedding planes) deposition.

Additional Dinosaur Ridge Observations

Identified Plant Debris— Holroyd (1992) described the plant material at Dinosaur Ridge as being broken beyond recognition. Subsequently, the author has found a stem impression, shown in Figure 1. Its surface features are somewhat indistinct and require rotating the specimen in directional illumination for highlighting the ridges. The cast's longitudinal striations and an apparent collar (between the arrows) match the patterns at joints of *Equisetum sp.*, a plant (horsetail, scouring rush) commonly found today along mid-latitude stream beds. This plant is also abundant in the fossil record. This is the only identifiable plant fragment I have found there to date.

Wood Grain— Additional samples of the plant fragments at Dinosaur Ridge have been found with excellent surface detail preserved. These are present where hematite concretion material has been deposited against the wood fragments. The fragment casts have a durable reddish brown surface. Casts without the hematite have a coarser, sandy surface with and without black colorations. The remarkable feature of the hematite

Figure 3. An aerial view of a portion of Dinosaur Ridge with north at the top. Dinosaur bones are to the right of the A. Invertebrate trace fossils are at B and E. Most of the plant fossils are at C and some at D. The 120 meter interval between C and D contains some symmetric long-crested ripples. A few dinosaur footprints are located between A and B and hundreds of prints are just north of E.

coatings is that they preserve the wood grain direction of the fragment, making it visible to the naked eye. Some wood fragments, shown in Figure 2, have sharp fracture surfaces perpendicular to the wood grain. The dark patches to the right and left of the central double-headed arrow have the grain in the direction of that arrow. The separation of their nearest edges is 19 mm. Holroyd (1992) claimed that green wood broken to such small pieces should have frayed and irregular ends perpendicular to the grain. It can be easily verified at a campfire that charcoal pieces can have sharp fractures perpendicular to the grain or stem direction. Semi-rotten wood might have either end style, depending on the degree of decomposition. The presence of this wood grain detail and fracture pattern, together with the abundant carbon in the other casts, generally confirms that the plant material at Dinosaur-Ridge is mostly of broken charcoal. Other scientists, hearing this description, have pointed out that bacteria, worms, and insect larvae will not usually consume charcoal. giving it a longer opportunity for preservation than green or rotten plant matter.

Fecal Pellets— On April 10, 1993, during a briefing tour for guides of Friends of Dinosaur Ridge, I found a rock at the cliff base near the middle of the left part of the panorama of Holroyd (1992, Figure 2, p. 8). It had fallen to the base of the channel sandstone deposit, to the lower left of the "C" in the aerial photograph of Figure 3. The rock, shown in Figure 4, is now stored at the Morrison Natural History Museum. It contained a detailed surface of grains resembling boiled rice along with some tubular structures (trace fossils) in adjacent layers. These grains have been interpreted as fecal pellets by several people who have examined them, including a scientist from the Denver Museum of Natural History who wanted the rock given to his museum. The pellets probably resulted from the excretions of

Figure 4. This rock surface is interpreted to represent fecal pellets and traces probably resulting from invertebrate animals (insects. worms, etc.). These animals may have fed on the organic matter in the Dinosaur Ridge deposits that was not deposited as charcoal. The ruler numbers the millimeters every centimeter.

small invertebrate animals feeding on the substrate debris after deposition but before its lithification. A passage of time would be indicated by the fecal pellets and the other trace fossils in the rock, but they provide no support for million-year interpretations of the Dakota Formation deposit. The use of trace fossils within the framework of the young-earth Flood model has been discussed in Cowart and Froede (1994).

Other Trace Fossils— At the west end of the road cut (extreme right in Holroyd (1992) Figure 2 and at the lower left of the "B" in Figure 3) the sandstone has an abundance of 2 to 5 mm diameter holes, interpreted as traces of invertebrate animals grazing on buried plant matter. The plant matter itself did not leave visible traces and was probably not charcoal. A few thin carbonaceous shales are between some sandstone strata and a few centimeters of volcanic ash are above the sequence.

Dakota layers higher in section and closer to the dinosaur footprints, at the "E" in Figure 3, have some excellent invertebrate traces, described in MacKenzie (1972) and interpreted as U-shaped vertical tubes *(Diplocraterion)* in sandstone. The original environment was interpreted as having been a marine shore with unconsolidated sand at the time of animal presence. Bioturbation of these original sands represents a limited passage of time easily compatible with a young earth time scale. Theoretically, an abundance of time for burrowing could homogenize the layer and could make the final burrows indistinct. Hence, the preservation of these U-shaped tubes suggests that the creatures were buried rapidly. That the layer is not homogenized suggests that the substrate was still in the early stage of being colonized.

Local Geographic Extents

The upper third of the Dakota Formation containing the fossil plant material (charcoal fragments) extends over a greater area at the Alameda Parkway site than previously indicated by Holroyd (1992). The charcoal fragment presence starts adjacent to the base of a 3.5 m thick channel sandstone (at "C" in Figure 3) at the Alameda Parkway road cut and extends to a thickness

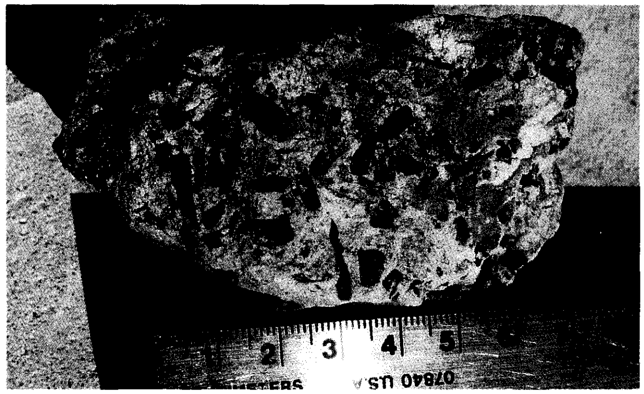

Figure 5. This rock from the Morrison Road cut through Dinosaur Ridge has an abundance of intact charcoal fragments, some showing wood grain direction. The scale numbers the centimeters of length.

of about 11 m on the south side of the cut and about 16 m on the north side. The thickness could easily exceed 20 m when additional layers near the trail ramp (at "D" in Figure 3) are added. Near the top of this section are exposures of long-crested ripples, interpreted by MacKenzie (1972) as forming under subaqueous conditions. Crest separations are mostly about 5 cm, but some 10 cm spacings are present. Some crests have a slight asymmetry, indicating oscillating water with a minor current flow of less than $1\ m\ s^{-1}$ (Collinson and Thompson, 1989, p. 68). They could have been formed in a variety of sheltered environments including in ponds, lakes, or lagoons. The Dakota Formation is suggested to represent the shore line deposit of a westward moving marine Zuni Sea (illustrated in Froede, 1995), extending across the interior of North America between the present Arctic Ocean and the Gulf of Mexico. Such an environment would be expected to have some locations conducive to the formation of ripples.

It is important to know the extent of the deposits of charcoal fragments and sand within the Dakota Formation to see if it is local or widespread. The lateral extent, measured from the Alameda Parkway road cut, of the charcoal presence was checked at other road cuts and stream notches of the area. At Interstate-70, 3.1 km to the north, the charcoal fragments are present in vertically tilted cross-bedded strata. Black coloration in the cavities is lacking, but the shapes are similar to those at Alameda Parkway. The largest fragments are lowest in section (i.e., westward) and contain bark and branch impressions. The fragments generally become smaller moving up section (i.e., eastward) to the top of the formation. The deposits have the fragments along bedding planes and also mixed within the sandstone. Thick layers of carbonaceous shale and cross-bedded sandstone separate the numerous layers with the plant fragment casts. Some layers also exhibit ripple marks.

The rock sample shown in Figure 5 contains an abundance of charcoal fragments. It was found at the Morrison Road notch through the ridge, 2.6 km to the south. The amount of carbon is comparable to that shown in Holroyd (1992) Figure 5, but the fragment size is smaller. The wood grain direction is clear in many pieces of charcoal of this sample. The charcoal is mixed throughout the rock rather than confined to a bedding plane.

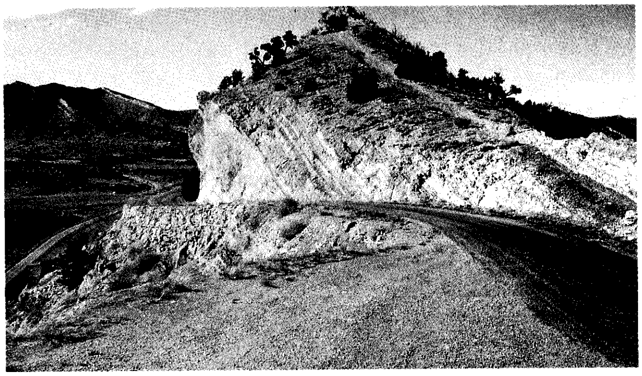

Figure 6. A view northward along the crest of the Dakota Hogback and Skyline Drive. The plant fossils were found along the left side just above the road.

The route 285 road cut, 4.8 km to the south, has been recently widened on the north side. The fresh decomposition of the shale is coating the rock surfaces with mud, obscuring the rock details. Some fallen rocks show a bold black and off-white pattern with centimeter-scale undulations. It appears that this route 285 exposure is a massive dump of powdered carbon and mud that combined to form carbonaceous shale. The undulations may have resulted from flowing, settling, and dewatering after initial deposition. The charcoal fragment angularity appears to be lacking in the rock fragments examined at the base of this new cliff.

At Belleview Avenue, 6.3 km to the south, only natural exposures are available for examination. A few layers of charcoal fragments were found. They were mostly along bedding planes and were seldomly within the bulk sandstone.

The evidence of the plant fragments, as casts and charcoal, therefore appears to extend at least 10 km along the Dakota Formation hogback near Dinosaur Ridge. There are significant variations in the style of the deposit among the exposures, ranging in particle size from bark and branch fragments to black powder, and from unblackened cavities to bulk carbon, with some cavities being lined with hematite. It therefore appears that the deposit is more complex and extends across an area broader than might be expected from a local creek bed or minor delta.

Remote Geographic Extents

Previous findings of the charcoal occurred about two-thirds of the way up through the Dakota Formation near Dinosaur Ridge. The same stratum was therefore examined at that level along Skyline Drive, on the hogback ridge on the west side of Canon City, Colorado, about 140 km south of Dinosaur Ridge. A much thinner (up to 20 cm) deposit of apparent charcoal and plant fragments (some large bark pieces) of the usual texture was found on the west side of the ridge north of where the road reaches the crest (at the road cut to the left side of Figure 6). The layer itself was a bedding plane in the context of the much thicker adjacent layers of sand, but the plant fragments were mixed with sand throughout that thin layer. Adjacent layers of sand had cross bedding and some coarse sand up to small pebble sizes.

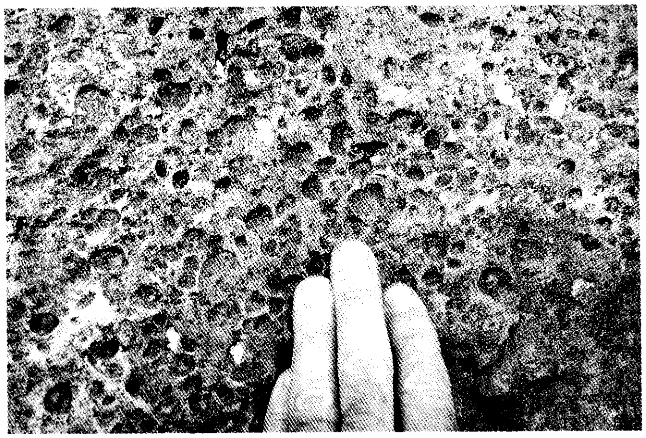

Figure 7. These hollow depressions in the Dakota Formation on the east side of the ridge at Canon City appear to be from balls of light-colored clay and not broken plant matter.

A layer with invertebrate trace fossils exists on the east side of the ridge. It is much thicker than at Dinosaur Ridge ("E" in Figure 3), but of a similar character. Also on the east side near the bottom of Skyline Drive are some layers with centimeter-sized *rounded* cavities in sandstone. At first glance they appear to have the plant fragment texture. Closer examination, as in Figure 7, shows that a few are filled with a pale tan clay. These impressions therefore seem to be the preservation of balls of rolled clay, indicative of a water current environment, and are not plant fragment impressions. This serves as a warning that care is needed in classifying the indistinct cavities in sandstone.

At Fort Collins, Colorado, about 90 km north of Dinosaur Ridge, the Dakota hogback forms the eastern boundary of Horsetooth Reservoir. At the southern end (Spring Canyon Dam) many black bedding plane layers of charcoal were found in light colored sandstone with relative crossbedding dips (with respect to the regionally strong tilt of the strata) of up to 40°. No examples of charcoal in bulk mixtures were found in this deposit of several meters thickness.

At Newcastle, Wyoming, about 460 km north of Dinosaur Ridge, and about a half kilometer north of the intersection of routes 16 and 85, the road cut has exposed the Dakota Formation dipping westward away from the Black Hills. The upper third of the Formation at this location has an abundance of cross-bedded sandstone and some carbonaceous shale. Large charcoal pieces are present in bedding plane style and are also mixed throughout the sandstone. Weathering has dislodged some charcoal pieces and they have joined in the flow of erosional debris moving down the steep slope. A sample of 32 pieces, chosen for being large, had maximum dimensions of 1.5 ±.5 cm and a width perpendicular to that of 1.2 ±.5 cm. The third dimension was smallest. The pieces were of very light density, sometimes showed wood grain directions, and crushed to black powder in the same manner that modern charcoal can be crushed between one's fingers. There are also a few examples of hematite deposits about the plant fragments and some black-lined casts. This deposit therefore is similar to that found at Dinosaur Ridge.

Discussion and Conclusions

The mapping of the possible extent of the charcoal fragments in the upper third of the Dakota Formation should continue, especially into other states. Formation names and structure will change with region. Drilling cores can be examined for locations at which there are no outcrops of the Dakota formation. Hundreds of rock cores from the Dakota Formation are available at the USGS Core Research Center, Building 810, Denver Federal Center, for direct viewing and / or as core photographs. The porosity of the Dakota sandstones makes them of great economic value for petroleum and water reservoir rock. A future examination of the cores for charcoal mixed sediments appears to be a worthwhile undertaking. The study should note whether the charcoal is mixed into the sand and silt (catastrophic burial) or is found only along bedding planes (slow deposition) or both.

Holroyd (1992) has previously identified these same types of charcoal fragments from 300 km to the southwest near Montrose. The Canon City finding now puts them about 140 km to the south. The Newcastle deposit extends their range to about 460 km to the north. These charcoal deposits are found in state-sized dimensions. We need to determine if there might be continuity between the sites and if the phenomenon points to a catastrophic deposit of multi-state extent. This comprehensive investigation might eventually indicate the source region of the charcoal, which has yet to be determined, and the nature of the event that transported the sand and charcoal.

The deposits containing charcoal mixed within them are interpreted by this author as reflecting catastrophic deposits at Dinosaur Ridge. The bedded deposits of charcoal along the top surfaces of the flows reflect brief interludes before the next catastrophic flow. The lack of biological disturbances of the strata (animal burrows, tree roots, soil formation) emphasizes that little time lapse occurred between the catastrophic flows. Some physical processes generated ripple patterns within the upper part of this Dakota series.

This interpretation, however, has possible difficulties. What charcoal source is sufficient to provide debris to cover an area of at least two states? Where was the source located and how was that debris transported? Charcoal can come from fires ignited by lightning or volcanic activity, both of which were presumably abundant during the Flood year. Yet large fires with such an abundance of water seems questionable. Perhaps the wood was turned to charcoal while buried in hot volcanic ash, then eroded and redeposited elsewhere after being separated from the ash and its subsequent clays.

The forest fire site examples are in rugged mountains, not on flat plains. The Dakota depositional environment was supposed to be near a generally flat north-south marine shore line with sandy beaches. Higher terrain was thought to be in central Utah and western Wyoming. The topography of the depositional area should therefore be similar to the Gulf coast of Texas or the coasts of the southeastern Atlantic states from northern Florida to the Carolinas. We certainly need to examine those coastal areas to see what happens to charcoal debris. It would be expected to occur along bedding planes when buried. It would not be expected as mixed with the sand except by catastrophic actions, like the passage of a hurricane or tsunami. Furthermore, I expect burials of charcoal fragments there to be accompanied by a greater amount of coastal mud than is found at Dinosaur Ridge. I welcome the observations of readers who have access to such environments. Surely there have been forest fires in coastal regions that contribute sand and charcoal to sedimentary deposits towards the coasts. However, catastrophic flows should be unlikely.

Southern California, however, also has fires that contribute charcoal and sand to deposits. We read frequently of earth movements destroying houses after fires have denuded the higher terrain. I expect that deposits like those of Dinosaur Ridge and Storm King Mountain will be located there. The key is found in the elevation of the terrain. California and western Colorado have sufficient slopes to generate catastrophic flows with simply an abundance of rain. Gulf and Atlantic coastal areas have mostly gentle slopes by comparison that would strongly limit catastrophic events.

If this interpretation is true, then what happened at Dinosaur Ridge and Newcastle? The nearby topographic highs should not have been sufficient to generate the energy of catastrophic flows. The high ground was more than 500 km away. What kind of event is energetic enough in shallow coastal lowlands to produce catastrophic flows capable of mixing sand and charcoal? What kind of catastrophic event is gentle enough to avoid pulverizing all charcoal fragments?

Ordinarily, one would expect the same process to have operated at each of the charcoal deposition sites, but not necessarily at the same point in time. Yet in an energetic environment consistent with the last stages of a global Flood, rapid sea floor subduction (earthquakes and tsunamis), a hot ocean and cold cloudy atmosphere (torrential rains and strong winds), there could be many causes of catastrophic debris flows.

Charcoal is also found in other layers of the geologic record. The Dakota Formation discussed here is considered to be lower Cretaceous on the uniformitarian time scale. Upper Cretaceous charcoal from the Big Bend area of Texas was studied by Williams and Howe (1993) and Williams et al. (1993). Readers are encouraged to note charcoal fossils in regions familiar to them. The widespread production of charcoal is not necessarily an expectation from a direct reading of scriptures relating to the Flood. It should provide an interesting study topic to discover how the observed charcoal was produced and buried during a short time period with abundant water from rain and flooding. While volcanism was apparently associated with the Big Bend deposits, it is only a trace component of the Dakota Formation.

Acknowledgments

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LETTERS TO THE EDITOR

Tropical Storm Alberto, 1994: Some Catastrophic Geologic Consequences in Georgia

Introduction

Tropical storm Alberto moved northward out of the Gulf of Mexico and struck the Florida panhandle on July 3, 1994. The storm continued on its northeast trek and on the following day, it collided with a cold front moving from the northwest into southwestern Georgia. After meeting the cold front, the tropical storm retraced its path southward toward the Gulf. This combination of atmospheric conditions produced prolonged thunder showers with heavy precipitation over middle and southwestern Georgia.

Figure 1. Map of the state of Georgia showing the course of the Flint River with its headwaters slightly south of Atlanta. The river flows southward through Albany which suffered major flood damage. Drawing by Thomas Bruce.

The maximum rainfall recorded in Georgia as a result of Alberto occurred during the period of July 3-7. The amount of precipitation varied from 3.00 inches in Atlanta to 27.06 inches in Americus.* Twenty-four inches of rain were recorded in Americus on July 6. Many regions of south central Georgia received 12-15 inches of rainfall in a 24-hour period. The Flint River (Figure 1) handled most of the runoff from the intense rainfall. Flooding that resulted from tropical storm Alberto was likely the worst natural disaster to occur in the history of the state.

Dam Breaching and Erosional Activity

Under such heavy rainfall during this tropical storm, soils and unconsolidated sediments were rapidly saturated, becoming unstable. Many farm ponds impounded behind earthen dams in the southwestern portion of the state were breached during the July 3-7 rainfall. Normally when a dam is breached, a "wall of water" is released causing extensive erosion and destruction below the dam. Local officials in Sumter County claimed that 15 people were killed in that county as a result of dam breaching episodes in July, 1994.

Two dams on the Flint River, one impounding Lake Blackshear and the other impounding Lake Worth above Albany, Georgia suffered damage during the flooding. These dams, constructed primarily for electrical power generation, are considered "run-of-the-river" dams with very little capacity to store large quantities of water above normal operating levels. At the Lake Blackshear dam site, earthen embankments are located on the north and south sides of the dam structure. The 3,000 foot-long northern embankment with a crest of approximately 11 feet above normal pool level was breached on July 9. The erosive power of the moving water initially developed a 500-foot wide breach which by the conclusion of the flood had expanded to about 800 feet with a depth of 10 to 20 feet. The Lake Worth dam was overtopped on July 7 (Figures 2a, b, c). This dam, rather than forming a 1,400 acre reservoir, was under the water of an 8,000 acre "lake" during the height of the flooding.

In the highway system of central and southwestern Georgia, approximately 1,600 bridges and culverts experienced washouts as a result of the surging flood waters (Figure 3). The authors will furnish more information on the locations of the various sites discussed in this letter to interested individuals.

*Americus, in Sumter County, is 37 miles north of Albany, Georgia.