CONFIRMATION FROM A DEBRIS FLOW AT A FOREST FIRE SITE

EDMOND W. HOLROYD, III*

Received 28 October 1995; Revised 22 January 1996

Abstract

The previously reported plant fossils at Dinosaur Ridge, Morrison, Colorado, are a mixture of broken charcoal pieces and their impressions, silt and sand. Normal sedimentation processes at a forest fire site indicated that buoyancy differences should strongly limit the mixing of sand and charcoal. Catastrophic mud or debris flows were suggested as the appropriate mechanism for much of the Dinosaur Ridge plant fossil deposit.

The contents of a catastrophic debris flow from the Storm King Mountain forest fire site at Glenwood Springs, Colorado, were examined to determine any similarities with the Dinosaur Ridge site. Charcoal fragments were found mixed throughout two cores taken from the mud flow component of the deposit. Two cores from other areas which experienced normal sedimentation conditions showed no mixing of sand and charcoal. These differing depositional frameworks are suggested as a basis for distinguishing between slow and catastrophic sedimentation rates.

Introduction

Holroyd (1992) described the plant fossil deposits in the Dakota Formation at Dinosaur Ridge, a hogback between Morrison and Golden, Colorado. He interpreted them as impressions of broken pieces of charcoal mixed with sand in a thick cross-bedded deposit. Nearly all plant material is fragmented beyond recognition.

He also examined the Sugarloaf Mountain forest fire site two years after the 1989 fire. Charcoal and sand were still accumulating in the creek bed of Black Tiger Gulch. Small trenches were dug in numerous sandbars formed since the fire, searching for 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. Buoyancy 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 be strongly separated.

He 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 enough water to move the material but not enough water to completely separate the various composing materials by buoyancy. Such a flow deposit would occur in several minutes. The lack of disruptive biological activity in the fossil 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) to a fraction of a year up to decades at most.

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

An opportunity to confirm the scenario of a catastrophic deposit within the upper Dakota Formation at Dinosaur Ridge arose during the Summer of 1994. A major forest fire occurred on July 6 on Storm King Mountain, west of Glenwood Springs in central Colorado. The fire made national news by killing 14 fire fighters when a sudden wind shift blew the flames over them. During the evening of September 1 a thunderstorm initiated a debris flow on the southern slopes of the mountain. The mud and debris crossed both lanes of Interstate-70 (I-70) on its way to the Colorado River, blocking travel until the evening of September 4. The author visited the site, taking photographs and core samples of the mud (still damp but exhibiting shrinkage cracks) on the afternoon of September 4. Aerial photography of the scene was obtained on the morning of September 6.

Core Analyses

Cores of the deposits at Sugarloaf and Storm King Mountains were obtained by pressing jars and cans into the mud and sand. Fingers were forced under the containers before removal to retain the sample within. The three Storm King Mountain cores were gently baked at approximately 90 °C for 2.5 hours to kill bacteria. A limited growth of white mold occurred thereafter on the exposed surface of one core during the 3.5 months before analysis. A small core (#l) in a metal can was carefully rewetted and moved to a glass jar in December, causing a slight contamination of the charcoal layer with sand. The single Sugarloaf Mountain core was analyzed immediately.

The Storm King cores, two still in their original containers, each had a nail taped to the container walls with the point of the nail indicating the downward direction. A medical X-ray unit was used to provide images of the cores along three mutually perpendicular axes.

A set of soil sieves was borrowed for sorting the various sizes of particles within the cores. Table I gives the characteristics of the sieve set. Intermediate sieves sizes exist but were not available in this set. The sieve number indicates the number of wires per inch. The sequence numbers will be used for referencing in the text and figures to follow.

Samples before and after sieving were weighed on a beam balance with a resolution of 0.01 g. Most samples were weighed together with a previously weighed container or sheet of paper. Wet sieving samples were drained of excess water on sheets of typing paper in an

*Edmond W. Holroyd, III, Ph.D., 8905 W. 63rd Ave., Arvada, CO 80004-3103.

Table I. The characteristics of the sieves used for sample sorting.

Sequence number	Sieve number	Opening inch	Opening mm	Size retained
1	4	.187	4.76	pebble
2	10	.0787	2.00	granule
3	40	.0165	.420	coarse sand
4	200	.0029	.074	fine, medium sand
5	270	.0021	.053	coarse silt
6	pan	none	none	silt, mud
7	–	–	–	rinse water contents

attempt to return to near initial dampness before weighing. The smooth paper surface permitted the removal with a putty knife of the damp sample with only small losses. A few samples were completely air dried. The procedures introduced measurement errors depending mostly on the amount of draining and drying. Core #3 had a slight excess of water and the others a deficit resulting from drying of some of the original moisture. Muddy rinse water carried away some of the finest sediments, contributing to a weight deficit.

Samples were moved through and around the sieves during wet sieving by water from a spray bottle. They were then removed from the rim of the sieves with a putty knife. That process minimized mechanical actions that might fragment the organic contents of the cores. Dry samples were moved through the sieves by shaking, tapping, and limited stirring. Dry samples were poured into weighing media and sometimes onto an intermediate sheet of paper. During these processes there was always some loss of damp sample material to drainage papers. Unrecoverable material from one sieve was washed into the next to minimize losses during wet sieving.

A portion of each core was analyzed using the sieves. The X-ray images were used to guide a knife away from major stones. Those parts were subdivided vertically so that variations with depth at about centimeter resolution could be determined. The Storm King cores had been kept moist, so no grinding was necessary for breakup. They were washed through the sieves after initial weighing. A deficit from moisture evaporation occurred with the Sugarloaf samples even though no water was used during the sieving.

For comparison, two Dinosaur Ridge fallen stones having indistinct plant impressions were crushed between a hammer and a steel plate to break them into grains. The resulting powder was then sieved for a size distribution. As a check on the possible destruction of original rock grains, a sample of the Sugarloaf quartz sand was crushed with comparable vigor. Sizes were indeed reduced by about a half to one sieve size interval.

Sugarloaf Mountain Sample

By utilizing a 12.5 cm diameter plastic can, a 14 cm deep core was taken from Black Tiger Gulch at Sugarloaf Mountain on December 24, 1994, 5.5 years after the fire. The location was probably within a meter of the site of Figure 7 in Holroyd (1992). Its lower layers contained fine living rootlets from nearby herbs and grasses. Charred bark and twigs were gathered from the surface within 2 meters of the core. The nearby perennial stream was about 2 meters away and about 10 cm lower than the surface. The surface was therefore highly vulnerable to stream overflow. The surface characteristics indicated a depositional environment during overflow rather than erosional. The sand was unconsolidated and coarse. Its cohesion was provided by residual moisture rather than by mud or silt.

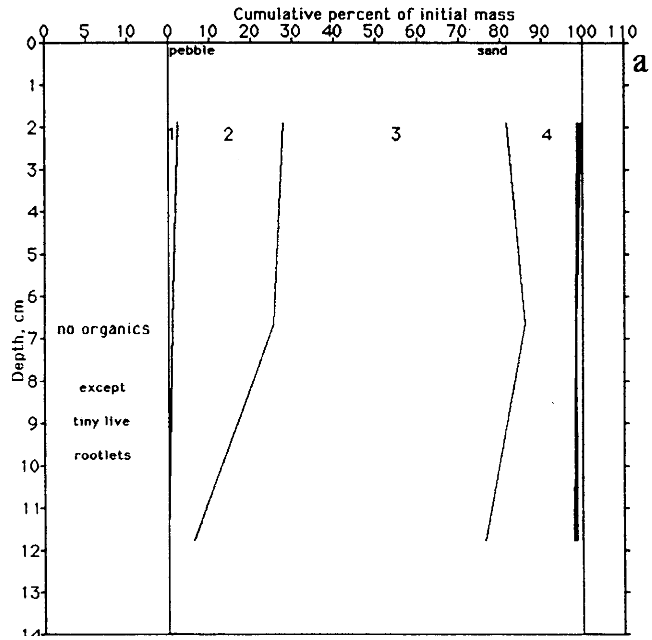

Figure 1. The size distribution, with depth, of the Sugarloaf Mountain core. It shows essentially pure, coarse sand and no charcoal.

The initial core was resampled by forcing a thin-walled steel tube of 2.8 cm internal diameter vertically through the sample. The general uniformity of the core prompted its division into only three vertical layers as it was extruded from the tube. The size distribution is shown in Figure 1 in a format nearly identical with subsequent figures for other cores. The vertical axis is depth from the surface. The horizontal axis is cumulative percent of the initial mass. The scale extends to 110 percent because some samples (particularly core #3) contained extra water from the wet sieving. The left portion of the figure has an expanded scale for the two largest sizes further partitioned into organic matter and rock detritus. No organic matter, other than new living rootlets, was found in the sieved samples from the Sugarloaf Mountain site, in agreement with the previous report by Holroyd (1992). The numbers 1 to 4 in the main part of the figure indicate the sieve sequence number containing the sample subset. The nearly vertical lines connect the vertical midpoints of the three sample partitions. The core actually extends from the surface through 14 cm. The Sugarloaf core contained mostly fine to coarse sand and larger granules. There was very little silt. Losses of residual soil moisture were minor (light shading at the right).

The products of sieving were placed in a partitioned display tray shown in Figure 2. The scale and the horizontal Plexiglas partitions indicate the vertical boundaries of the core subsamples. The vertical partitions separate the various sizes, from 4 to 1. The bins

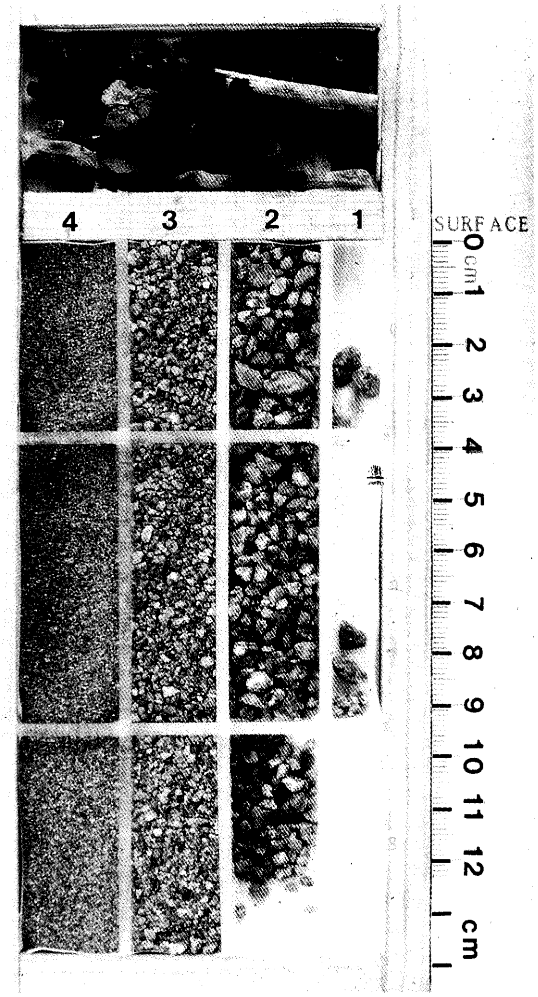

Figure 2. A tray containing the sieved samples of the Sugarloaf core, for sieves 4 to 1. At the top are samples of charred bark and twigs that were still present only on the surface within 2 meters of the core, 5.5 years after the fire.

were loaded with as much of the sieved material as possible. Some bins are therefore full. Others contain everything available. A few bins at the largest sizes in similar figures may not exhibit particles that were too big to fit. At the top of Figure 2 are some of the pieces of charred bark and twigs that were, lying on the surface nearby the core location. They emphasize that the fire products are still available for mixing but buoyancy keeps them out of the sand.

Storm King Mountain Samples

Figure 3 shows an aerial view of the debris flow site on the south side of Storm King Mountain. North is at the top. The drainage, which crosses the westbound lane of Interstate-70 at 39° 33’ 39” N, 107° 23’ 11” W, is not named on the topographic map. The extent of the contrasting reddish mud is evident in the original color image. It is traced in part b, labeled with “M” symbols, and annotated with observation sites, “P” for photographs and “C” for cores. Chronic (1980, p. 203) indicates that the source rocks are of the Permian Maroon Formation and that mud slides are common in the Glenwood Springs area.

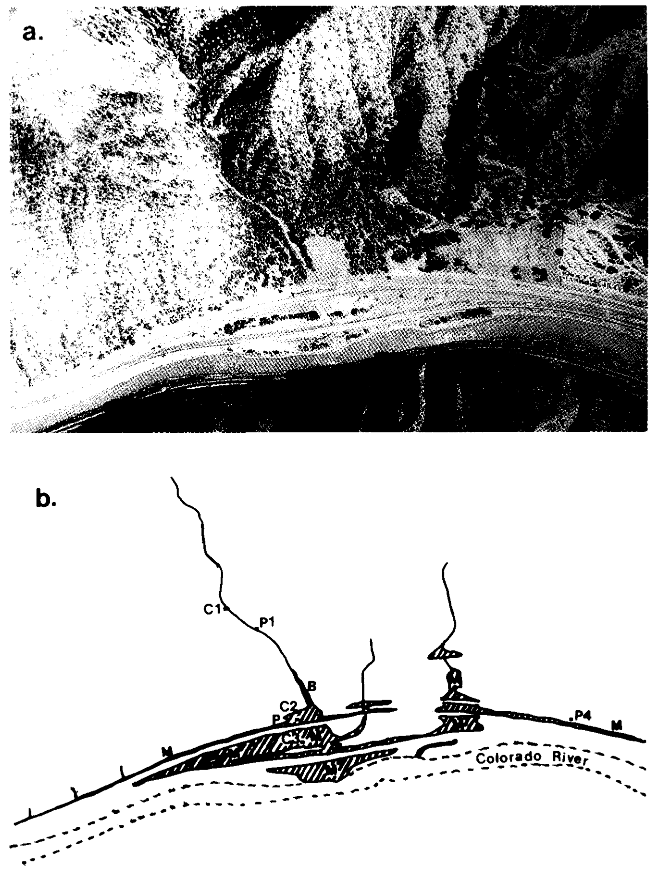

Figure 3. a. An aerial view of the Storm King Mountain debris flow site about 4.5 days after the flow. The dark conifer trees and the Interstate highway lanes indicate the scale. b. A tracing showing the extent of the mud flow (M) and indicating the positions of core samples (C) and photographs (P).

The residual mud and scour patterns in the creek bed north of the highway, as shown in Figure 4 and taken looking upstream from “Pl” in Figure 3b, indicated that the flow was about 2 meters deep there. It climbed higher on the outside edges of turns and lower on the inside edges from flow dynamics. From such elevation differences and the radius of curvature of the turns a flow speed could be calculated using energy conservation equations. Data for such estimates were not gathered during the site visit.

Core #l—Core #l was obtained by pressing a steel can of 7.0 cm internal diameter, 10 cm depth, into a drained settling pool in the scoured creek bed. The core was taken near point “Cl” in Figure 3b, a location in the rear of Figure 4. Figure 5 shows before and after views of the core site. The ruler, which appears in the before picture, has a width of 3.2 m. The surface was covered with charcoal debris. Only 5.3 cm of the deposit could be penetrated by the can. A plastic lid was then placed on the can to retain the contents and moisture. Essentially all moisture escaped before analysis, making the clays powdery. Water was added to the contents in mid-December. A thin mylar sheet was forced along the can edges and extracted with the core during transfer to a glass jar for X-ray analysis. The top mat (about 5 mm deep) of wet charcoal debris did not come out of the bottom of the can with the core. It was

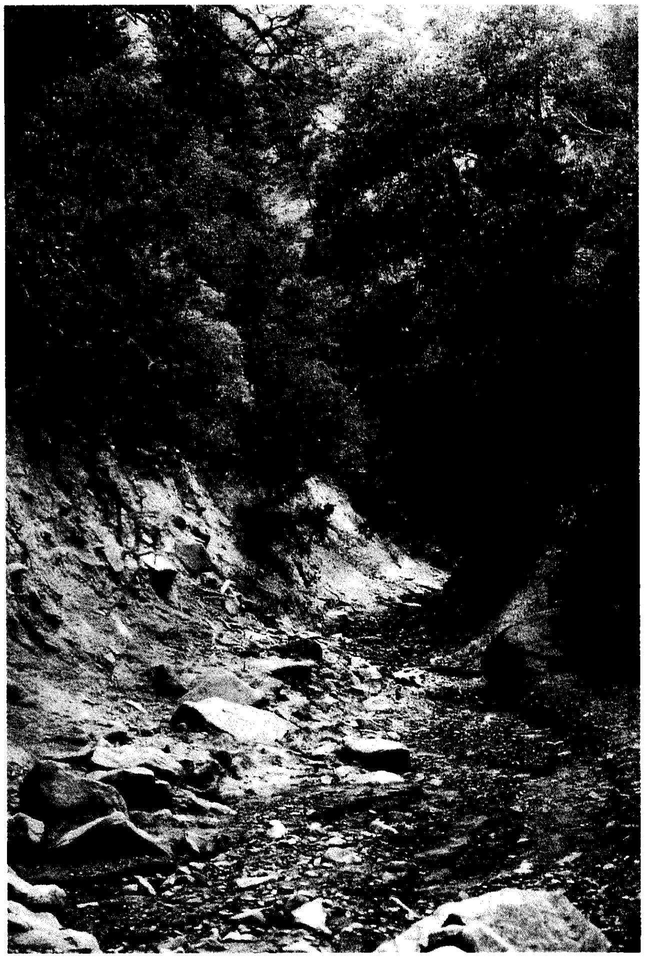

Figure 4. A view looking upstream at the channel scoured by the 2 meter high debris flow. Figure 5 and core #1 were taken somewhere in the left side of the creek bed towards the rear of the view.

scraped out and pasted on the core end. During sieve analysis it again had to be scraped out of the container. The rewetting and extraction processes thereby contaminated this nearly pure vegetative layer with silt and sand.

The X-ray images of core #l are shown in Figure 6 along with a scale. The glass container and nail are also visible. The top of the core shows black in the image because it is nearly transparent to the X rays. The core becomes progressively lighter towards the bottom and brightest at a large pebble. This results from a great amount of stratification of material with the densest material of the settling pool on the bottom of the core. Buoyancy kept the plant matter at the top of the core. This stratification is confirmed in the size distribution graph of Figure 7. The largest rock detritus sizes are at the bottom of the core with fine sand and silt in the middle. The top of the core was nearly all organic debris except for contamination. The second sublayer from the top retained a great amount of water from the sieving operation. It was therefore air dried for about an hour and lost more than half its original mass of apparently rewetting water.

Figure 8 shows the display tray of core #l materials by depth. From left to right are the unsorted core, then sieve contents 4, 3, 2v-vegetative matter, and 2s-sand and stones. Organic material dominated all but the smallest sizes at the top of the core. Even the fine sizes are dark compared to the bottom of the core (ignoring the top contamination). Rock granules are present at the bottom where there is no vegetative debris. The loose texture of the top debris may be visible in the unsorted core, while in the lower left is a pebble.

Core #l is therefore interpreted as the product of normal sedimentation processes after the scouring passage of the debris flow. There was sufficient water and time for buoyancy forces to operate. The most dense materials are at the bottom and the least at the top, in accord with buoyancy expectations.

Core #2-Figure 9 shows the site of core #2, labeled “C2” in Figure 3b. The picture was taken just southwest of the core location at a point labeled “P.” It is slightly downstream from where the gradient lessens and where there is a long deposit of boulders, labeled “B” in Figure 3b. Some boulders are visible on the right in Figure 9 above the foreground tire tracks and below the rear grassy field. A bright stone is in the center left of the picture in front of the tree shadow. As shown in Figure 10, core #2 was taken in the adjacent deep mud. A broken log and stick are to the right in the before picture and a 38.1 cm ruler is lying against the rock. In the after picture are the core hole, my footprints, and a drying crack in the mud. The container for the core was a glass jar with 7.5 m internal diameter opening, widening to 8.0 cm diameter inside. The jar was 10 cm deep and was sealed with a metal lid. The contents settled into the jar to a depth of 8.1 cm before analysis. No depth corrections extrapolating back to 10 cm were made, but that does not affect the conclusions.

The X-ray images of core #2 in Figure 11 show a mottled appearance of lights (stones) and darks (organics). There is no general stratification of this texture. The size distribution of Figure 12 shows slight variations with depth and only a minor trend for coarsening downward. The exception is at the enlargement at the left, where the fraction of pebbles from sieve 1 (no shading) has two major lobes while the dark shaded organics of the same size have no strong variation. Shaded zone 7 indicates the weight of initial dampness that was lost during processing. The third layer from the top was subjected to total air drying. As in Figure 1, the vertical lines connect the depth midpoints of the subsamples. The core analysis extended from the surface to 8.1 cm, though it settled from an original thickness of 10 cm.

Figure 13 shows the display tray of the contents of the sieving operation along with a piece of the unsorted core. Though probably not visible in the reproduction, the raw core shows pebbles, charcoal chunks, and needles amongst the sand and silt. In the partitions, the left two columns are from sieves 4 and 3. Sieve 3 contents are an obvious mix of coarse red sand and black charcoal fragments. The black specks in the Sieve 4 contents are less obvious but were visible during wet sieving by tending to float to the top of the fine sand. Muscovite mica was abundant in both core #2 and core #3. Dark biotite mica may have been present but was not obvious. A few mineral grains were dark, challenging visual separation from charcoal grains. A strong magnet passed over the dried samples did not

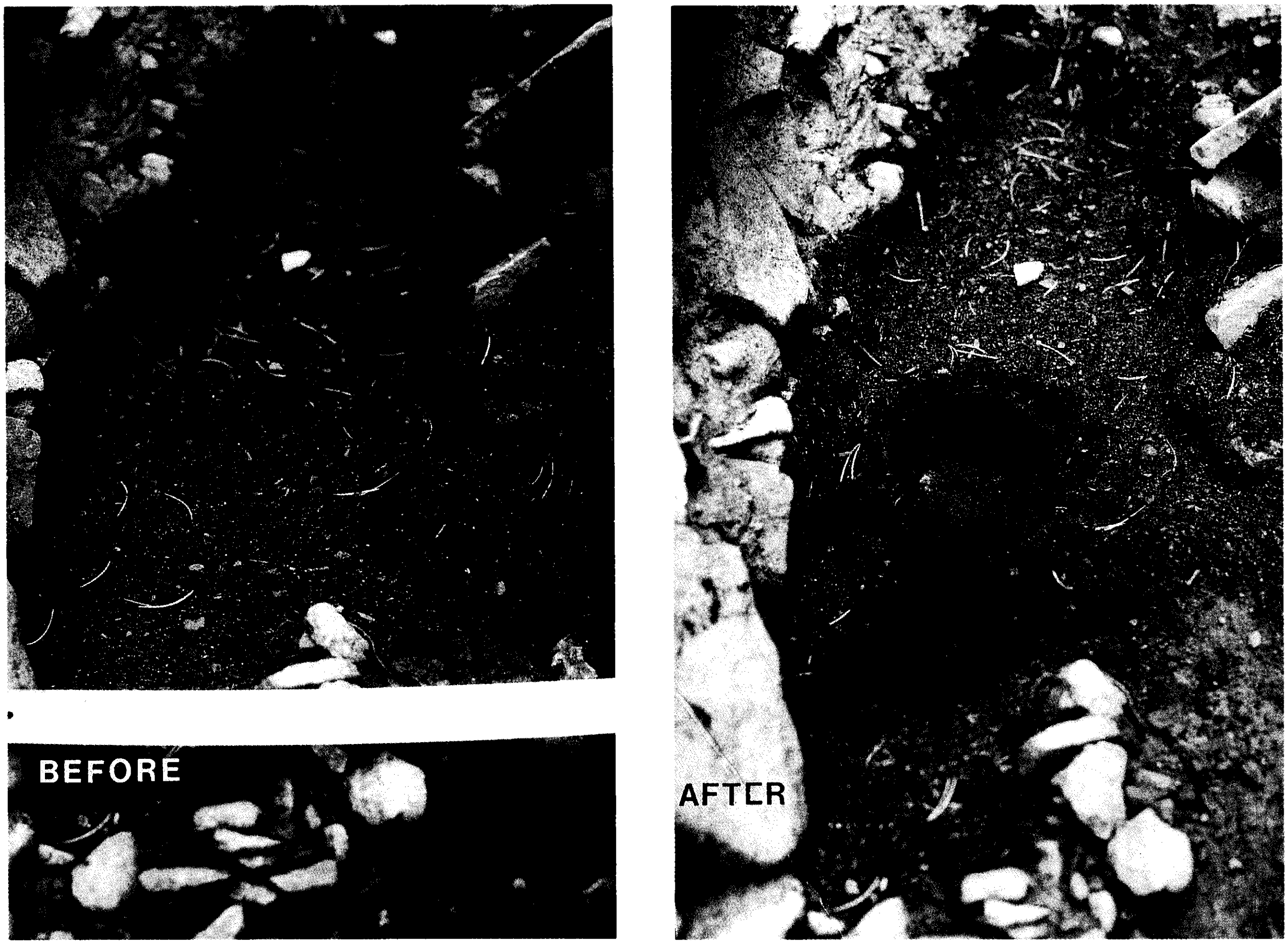

Figure 5. Views before and after a can was pressed into the drained debris of a settling pool. The top surface is essentially all charcoal and other plant fragments.

attract any black magnetite. The middle columns contain the organic (2v) and sand and stone (2s) fractions from sieve 2. The organic contents were essentially uniform with depth but the stone fragments varied with depth. Similar depth variation shows in the right two columns of organics (1v) and stones (1s) from sieve 1. Large charcoal chunks were found at the top, middle, and bottom, with needles and bark throughout.

Core #2 is therefore interpreted as from a turbulent (well-mixed) catastrophic dump from a debris or mud flow. The mud was too thick for buoyancy forces to overcome viscous restraints. Charcoal is therefore found throughout the core at all sizes and depths.

Core #3—The site of core #3 is shown in the photograph of Figure 14, looking across (to the south of) the westbound lanes of Interstate-70 from about the same location ("P" in Figure 3b) as Figure 9. By the time of the photograph the left lane was open but the right lane and shoulder were still being cleaned. Freshly brightened boulders were deposited across the highway to the left of the car. In front of the far trees is a large uprooted tree trunk with broken roots. Core #3 was taken just to the right of it in a deep (estimated at about 0.5 meter) deposit of mud at location "C3" in Figure 3b. There was an abundance of large charred wood fragments on the surface. Looking the other way (north) in Figure 15 is a view of the coring site before and after disturbance. The view shows several thick branch fragments, some shrinkage cracks, and the 38.1 cm (15 inch) long ruler in the center. The after picture shows a pair of my deep toe prints in the center left with the core hole beyond. The container was a plastic can of the same dimensions as at Sugarloaf Mountain. Though nearly 14 cm of material was gathered into the can, it settled to 11.5 cm before analysis due to loss of water. Again, no correction for shrinkage was calculated.

Figure 16 shows the X-ray images of core #3. The patterns are less distinct because of the core thickness. As with core #2, they do not show any stratification of the mottling with depth. This indicates that the organic material is mixed throughout its depth. Figure 17 shows the size distribution. Shaded area 7 indicates that the processing left excess water in the samples after sieving, except for the bottom layer. There is only a slight tendency for a coarsening of the sand with depth, as in Figure 12. The mass distributions of the two largest sizes are more uniform for both organics and stones than in core #2. The greater uniformity of core #3 may come from larger sample

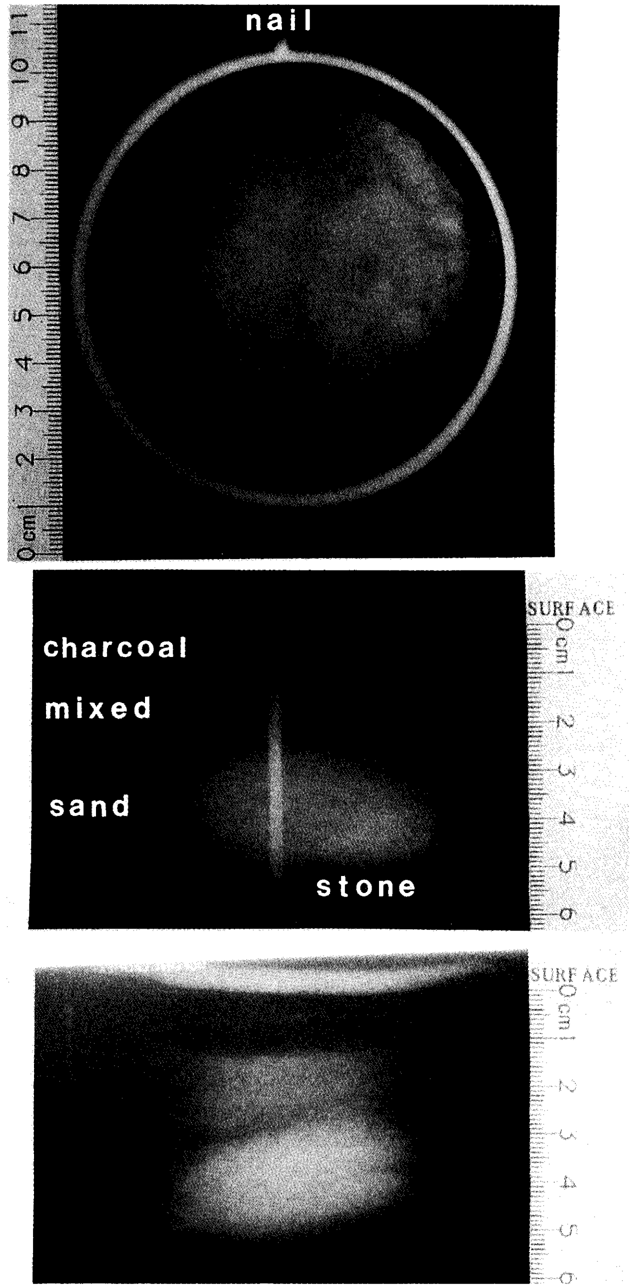

Figure 6. The three mutually perpendicular X-ray images of core #l show it to be highly stratified, with a large pebble (light) on the bottom, sand an silt in the middle, and less dense (dark) vegetative matter at the top.

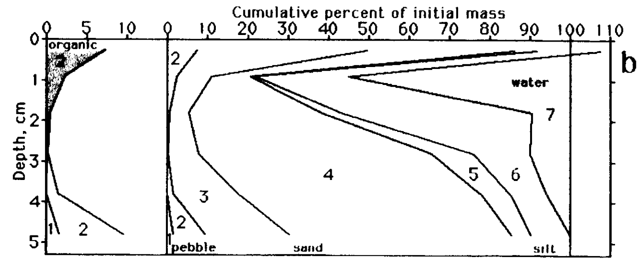

Figure 7. The size distribution of core #l with depth. The very top layer was contaminated with sand and silt during processing. The next layer down was soggy vegetative matter that lost most of its weight during drying. Sand sizes increase with depth. Buoyancy during settling produced highly stratified material in this core, particularly for sieve size 2, enlarged at the left and shaded for the organic portion.

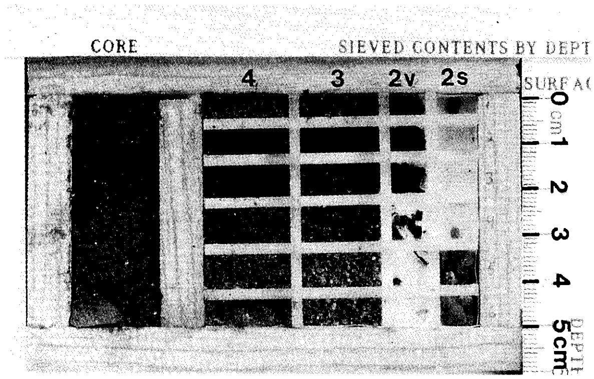

Figure 8. A tray containing a piece of the unsorted core #l (left) and sieved samples (right partitions) from sieves 4 to 2. Those of sieve 2 are further separated into vegetative matter and rock detritus. The organic matter shades the fine samples dark while the rock materials shade them reddish.

Figure 9. A view of the site of core #2, looking northeast. The debris with boulders flowed toward the right from between the trees. The mud to the left had few boulders.

sizes. Only quarters of cores #2 and #3 were sieved but core #3 had a larger diameter.

The tray of sieved contents of core #3 is shown in Figure 18 in the same format as Figure 14. Less variation is seen in all columns. Charcoal fragments were found at all sizes and depths. Core #3 is therefore given the same interpretation as core #2.

Other Storm King Mountain Observations

Throughout the wet sieving of cores #2 and #3 there was a distinct tendency for the black component of the sieve contents to remain distinct and on top of the red sand portion. This illustrates the buoyancy separation claimed for the Sugar-loaf site. The sieving operation gave the sample enough extra water and time to perform the separation.

The debris flow showed two directions of movement when it encountered the interstate. The boulder-loaded flow simply crossed the highway and continued to the Colorado River. The interstate gutters, however, filled with the mud component of the debris flow and ex-

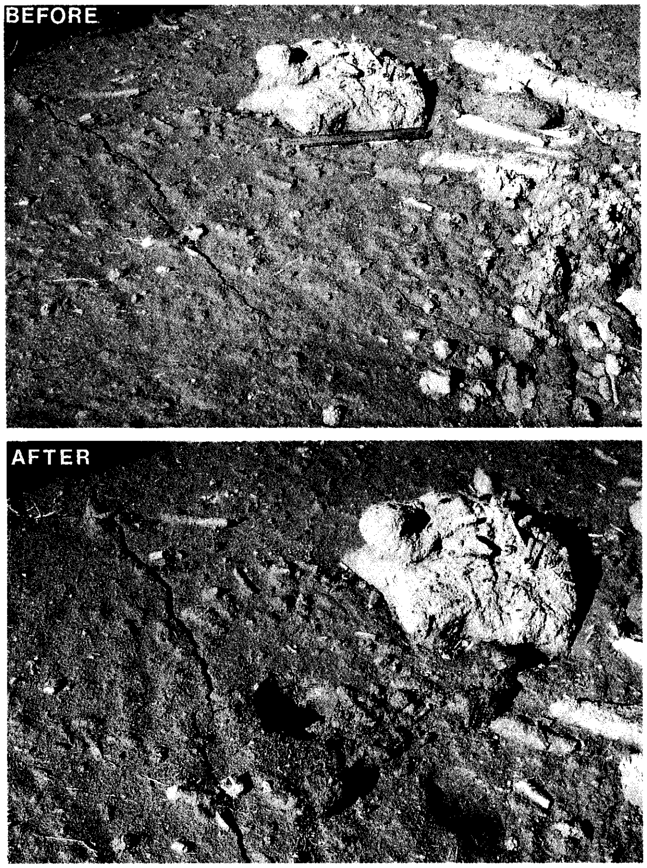

Figure 10. The before picture shows the pool of mud, sticks and stones before coring along with a 38.1 cm (15 inch) ruler. The after picture shows the core hole, footprints and drying crack in the deep mud.

tended parallel to the highway to distances 10 times as great, as shown in Figure 3b. The mud was less viscous and could flow far across a lesser gradient. This gutter flow of mud is illustrated in Figure 19, taken from location "P4" in Figure 3b, and contrasts with the boulder flow in parts of Figures 9 and 14.

When I was walking in the soft mud at the Storm King Mountain debris flow site I was leaving footprints, some of which are visible in Figures 10 and 15. About a week later Dr. Martin Lockley stopped at the site as he was passing by on a trip unsuccessfully looking elsewhere for dinosaur footprints. He told me that he saw footprints of deer and humans (some presumably mine) at the I-70 flow. Though no study was made of those footprints, it might have been an interesting one. How long would the footprints have remained? That would depend on the rates of baking of the mud versus the occurrence of the next showers of rain. Presumably, the best preservation would be for the mud to bake hard and then be overlaid by another mud flow before water had a chance to soften the mud that I walked upon. If rain softened the footprints before preservation then they would be damaged or destroyed. The study likely would have shown that catastrophic processes (rapid deposition) are usually necessary for the preservation of footprints in the geologic record.

The next series of mud flows across I-70 began on 31 May 1995 as a result of snow melt and abundant rains.

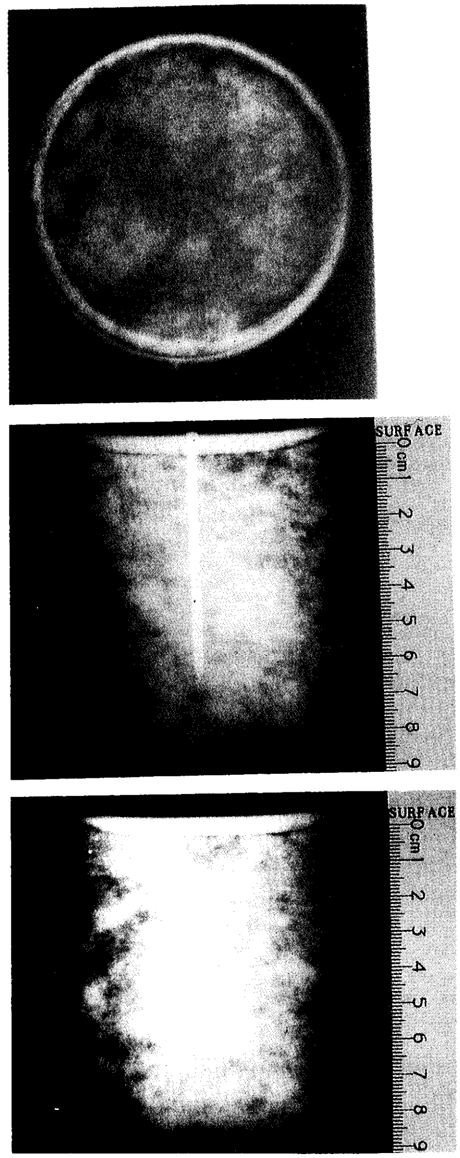

Figure 11. The three mutually perpendicular X-ray images of core #2 show a highly varying texture of brights (stones) and darks (vegetative matter) that are generally well mixed with depth.

Depths of 4 feet were reported. All autumn footprints should have been destroyed by then.

Dinosaur Ridge Sizes

Two small fallen rocks were gathered from the area of the plant fossils at Dinosaur Ridge. One was tan with cavities where the plant material had been. The other was gray with black staining at the cavities and elsewhere within the rock. Both were crushed to reduce them to powder comparable to their original grain sizes. A similar crushing of Sugarloaf site sand showed that the process fractured the original grains to a measurable extent. Figure 20 shows the spectra of the crushed samples along with the original average spectrum of Figure 1. The Sugarloaf sieve 2 granules were all reduced to sieve 3 sizes. Those in turn had half shifted to sieve 4 sizes. So the grinding process is highly likely to have affected the coarser sizes in the

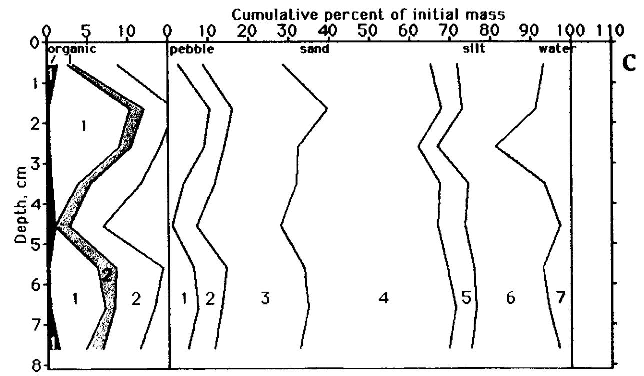

Figure 12. The size distribution of core #2 with depth. Most of the mass is sand with only slight size variations with depth, except for sieve #1 pebbles. The organic content of the largest two sizes extends throughout the core.

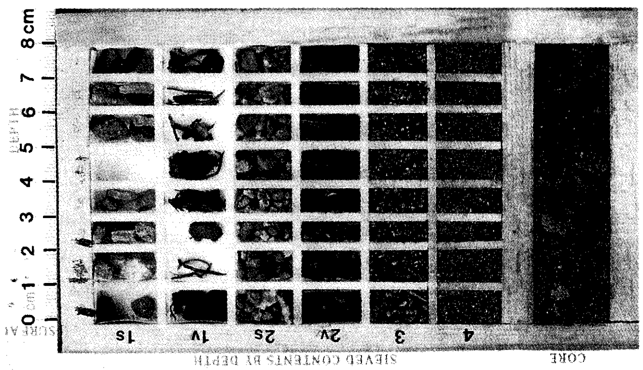

Figure 13. A tray containing a piece of the unsorted core #2 (left) and sieved samples (right partitions) from sieves 4 to 1. The rocky contents of sieves 1 and 2 are in the first and third columns at the right while the organic contents are in the second and fourth columns. The largest size bins show that both stones and organics vary somewhat in concentration with depth but with no general trend in this catastrophic deposit.

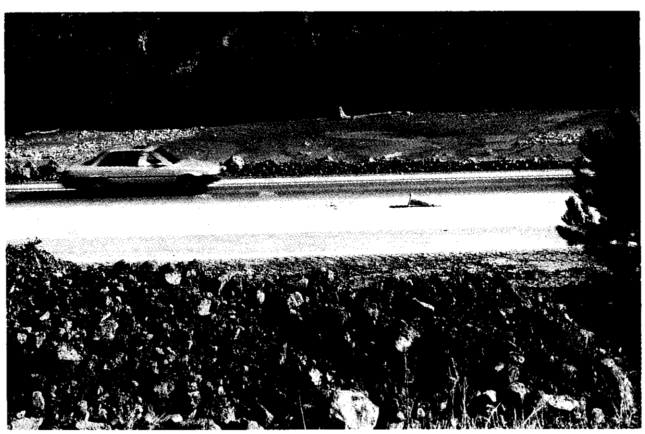

Figure 14. A view to the south, across the Interstate-70 westbound lane. Coring site #3 is in the pool of mud in front of the trees just to the right of center.

rock samples. The tan rock spectrum is plotted in the center of Figure 20, bounded with simple vertical lines for visibility. The results of crushing were nearly all of sieve 4 sizes. That range, 74 to 420 micrometers (Table I) generously spans the 200 to 300 micrometers from microscope examinations reported by Holroyd (1992)

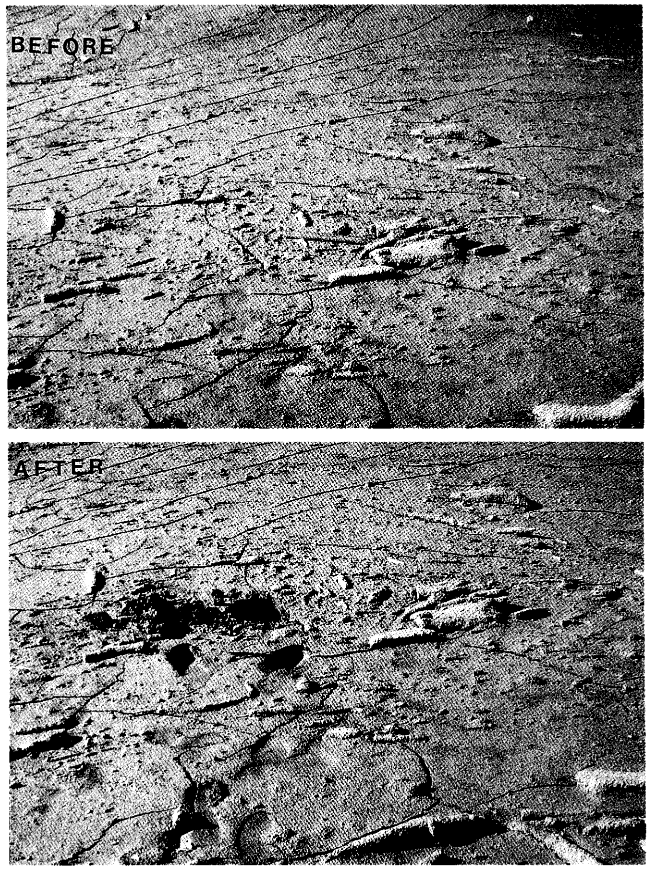

Figure 15. The before picture shows the site of core 13, broken branches, mud cracks, and a ruler before disturbance. The after picture shows deep toe prints and the core hole just to the left of center.

for the large grains in a similar tan rock sample. He also found lesser amounts of small sizes. The gray rock (bottom) has considerably finer sand and silt materials. These smaller sizes are less susceptible to further crushing by the crude technique applied and so are likely to represent true sizes of the Dinosaur Ridge grain spectra with reasonable accuracy. The median sizes of the tan rock grains match those of all Storm King cores. The size range of the Dinosaur Ridge tan rock lacks both the larger grains and silt sizes found at Storm King. The grains of the gray rock are smaller than those of both fire sites.

Discussion and Conclusions

The sediments from two forest fire sites were examined in detail and compared with the deposits at Dinosaur Ridge that contain impressions of plant fragments. The Sugarloaf Mountain site showed no mixing of sand and charcoal at either 2 or 5.5 years after the fire. The depositional flows are presumed to have an abundance of water and agitation. Those normal conditions give buoyant forces the opportunity to separate the two materials and keep them from further mixing.

The Storm King Mountain debris flow contained median sand grain sizes nearly identical to those in the tan rocks at Dinosaur Ridge but had a broader range of sizes. Presumably, a greater transport distance for

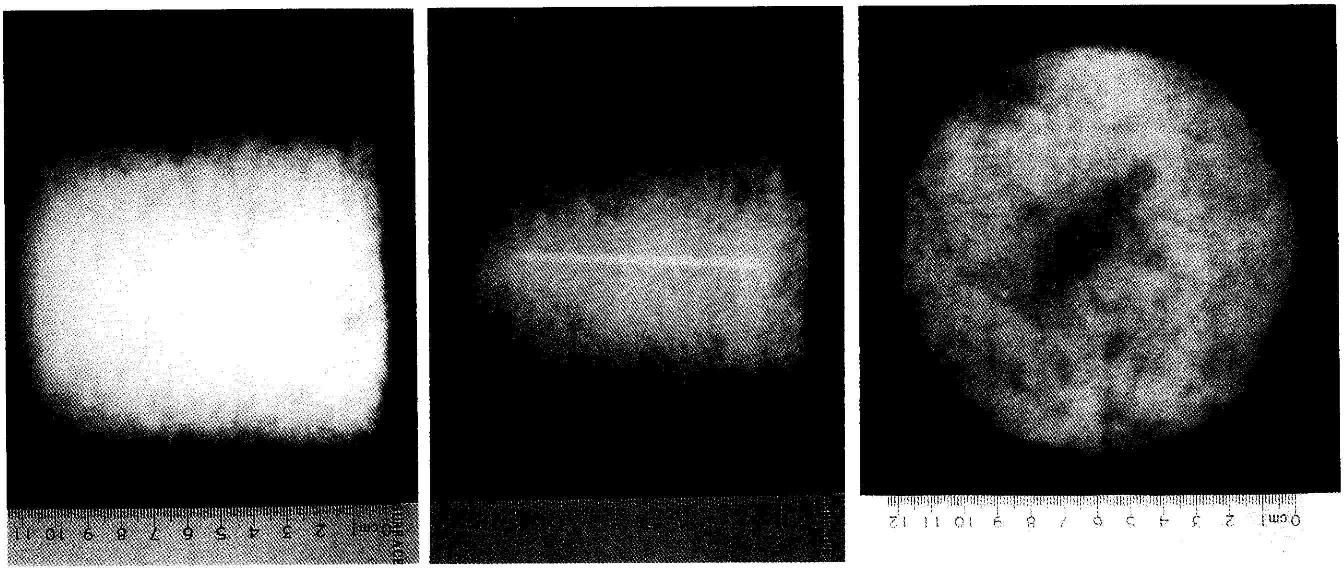

Figure 16. The three mutually perpendicular X-ray images of core #3 show nearly uniform mottling of shades like core #2 but the thickness makes the patterns less distinct. There is no general trend with depth in the images.

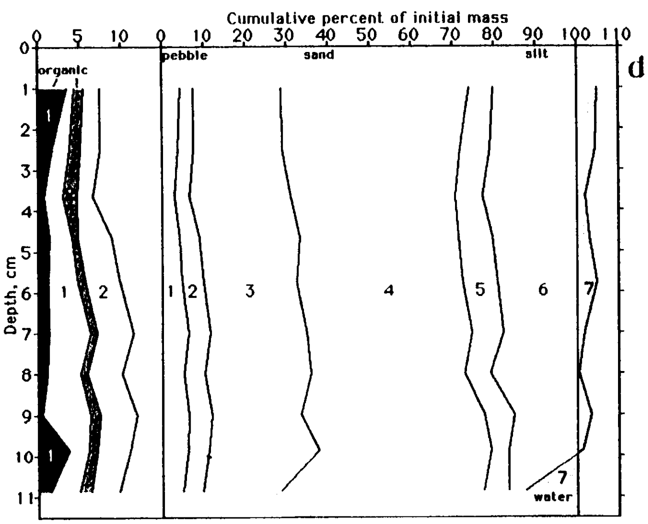

Figure 17. The size distribution of core #3 with depth. The pattern is like that of Figure 12, core #2, except for greater uniformity of the largest sizes (left) and excess water from processing. The large organic pieces are found throughout the core.

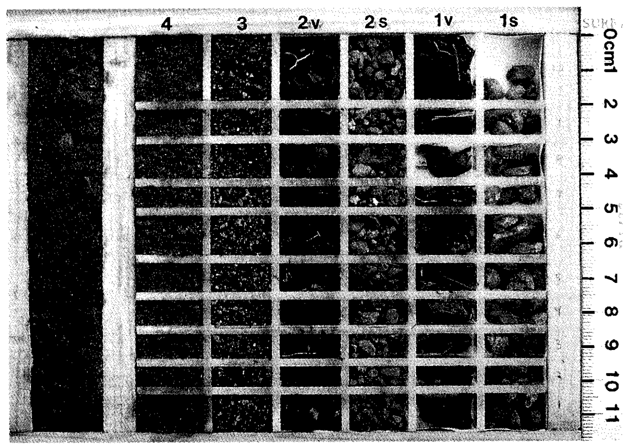

Figure 18. A tray containing a piece of the unsorted core #3 (left) and sieved samples (right partitions) from sieves 4 to 1 in the same sequence as Figure 13. There is less variation of large charcoal pieces with depth in the second column at the right. Charcoal fragments are also at all depths and sizes in core #3.

the Dinosaur Ridge materials caused a narrowing of the range of sizes.

More importantly, the Storm King cores showed the relative effects of buoyancy and viscosity. In core #l the materials settled by density after the passage of the catastrophic debris flow. Larger sand grains were therefore on the bottom and nearly pure plant debris was on the top. This, like the Sugarloaf deposit, represents normal sedimentary conditions. Cores #2 and #3, however, contained charcoal and other vegetative fragments throughout their depths and at all resolvable sizes. This matches some of the distributions found at Dinosaur Ridge. There the plant deposits are of two types. In some samples, Holroyd (1996), Figures 2 and 5, the charcoal is mixed throughout the sand similar to cores #2 and #3. In others, like those shown at the left side of Holroyd (1992) Figure 4, there is a bedding surface on the cross-stratifications that contains a higher concentration of charcoal fragments. This matches the stratification pattern of core #l and somewhat at Sugarloaf Mountain.

The different depositional frameworks are interpreted as follows and sketched in Figure 21. Plant deposits along bedding planes usually represent normal depositional processes strongly influenced by buoyancy, as at Sugarloaf Mountain. Materials between the bedding planes that have no inclusions of charcoal might be deposited either from slow or catastrophic processes, depending in part on whether or not charcoal was available for mixing into the strata. For most of the stratigraphic record it was apparently not available. The deposits with charcoal mixed throughout are those from catastrophic flows, whereby there is enough water for transport but not for separation. Those that have a

Figure 19. Much of the mud component diverted to the highway gutters, as shown here, and traveled farther across a lesser gradient than the boulder flow that crossed the Interstate on its way to the Colorado River.

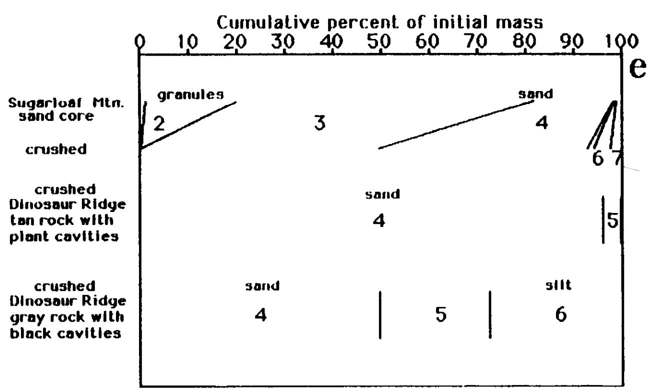

Figure 20. The size spectra of original and crushed Sugarloaf Mountain sand and two crushed rocks from Dinosaur Ridge that contained plant fragment impressions. Crushing reduced the sizes of the Sugarloaf grains but probably had a lesser effect on the finer Dinosaur Ridge grains.

higher concentration of charcoal at bedding surfaces than between them represent the aftermath of a catastrophic mud or debris flow, as in core #l.

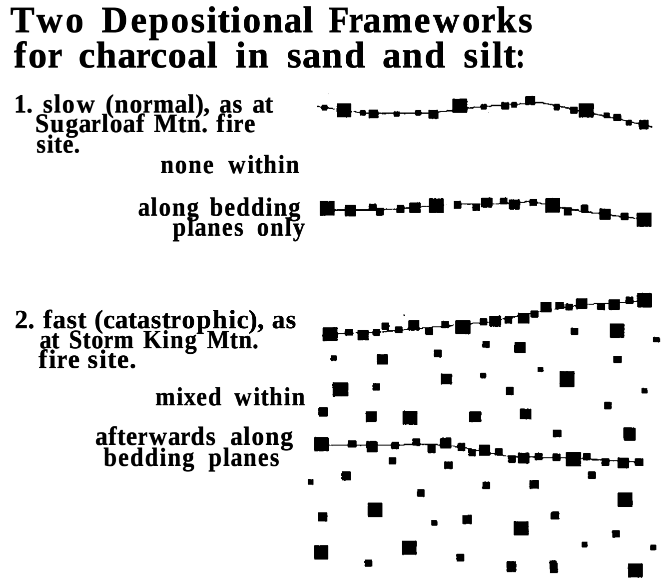

Figure 21. A sketch of the deposition frameworks of charcoal in sand and silt.

Just as the surfaces of the Storm King debris and mud flow deposits have a high concentration of large plant matter (as in Figure 10-after), so the bedding planes are the recipients of matter separated by buoyant forces. The concentrated lighter fragments are vulnerable to being swept away by normal stream flow or washed away by rainfall. However, if the deposit can dry sufficiently before the next flow of water or debris, then the fragments might become firmly attached to the bedding surface and less vulnerable to future displacement. The charcoal fragments cannot, however, remain exposed to weathering conditions for periods of hundreds or thousands of years in a uniformitarian scenario. They would oxidize or fragment to dust and become unavailable for preservation.

Therefore, the deposits containing charcoal mixed within them are interpreted 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 occurred between the catastrophic flows. Some physical processes generated ripple patterns within the upper part of this Dakota series.

The style of study presented here is not difficult. The measurements can presumably be done by students with sieves, scales and some household items. The X-ray and aerial photographs are helpful primarily for illustration but are not critical. This low cost study addresses some important questions. Further research on mixed deposits of sand and charcoal therefore will have important implications for the distinction between catastrophic and uniformitarian depositional environments. More observations on the presence and absence of broken charcoal in recent and in fossil conditions are needed for a meaningful discussion. A discussion of the geographic extents of the charcoal and sand mixture in the upper Dakota Formation is presented in Holroyd (1996).

Acknowledgments

The aerial photographs were provided by Denny Donahue of Donahue Aerial Surveying, Centennial Airport, Englewood, Colorado. The X-ray photographs were provided by Karen Morgan of Union Square Radiology, Lakewood, Colorado. The set of soil sieves were loaned by the Natural Resources Conservation Service Metro Office, Lakewood, Colorado. The balance was loaned by Faith Christian Academy, Arvada, Colorado. Software used for drafting some of the figures was partly provided by a grant from the Creation Research Laboratory Fund for which donations are greatly appreciated. Reviews by Carl R. Froede, Jr., and Jack B. Cowart of some of this material in another manuscript were helpful in refining this text.

References

Chronic, Halka, 1980. Roadside Geology of Colorado. Mountain Press Publishing. Missoula. MT.

Holroyd, Edmond W., III, 1992. Comments on the fossils of Dinosaur Ridge. *Creation Research Society Quarterly* 29:6-13.

Holroyd, Edmond W., III, 1996. Observations of fossil material and charcoalized wood in the Dakota Formation in Colorado and Wyoming. *Creation Research Society Quarterly* 33: in press.

BOOK REVIEW

Genesis and the Big Bang, by Gerald L. Schroeder, Ph.D. 1990. Bantam Doubleday Dell. New York. 212 pages. $11.95.

Reviewed by Eugene F. Chaffin*

How do you reconcile the findings of modern science with the findings of theology? Readers of the *Creation Research Society Quarterly* are familiar with the paradigms, models, and theories being considered by young-earth creationists. However, in this book we learn about how a physicist, oceanographer, and Jewish scholar views the creation. The author describes how the book resulted, in part, from discussions with his son. The son was educated in some conservative Jewish institutions while the father was educated in liberal western institutions. This led to discussions which resulted in this book.

The book accepts the Standard Model of cosmology, the Big Bang Model, as well as other branches of evolutionism such as punctuated equilibria. Interestingly, Jewish scholars and sources such as Maimonides, Nahmanides, and *The Babylonian Talmud* are quoted extensively. The opinions of these ancient sources are given equal weight to those of modern science, and viewed as having impeccable authority in matters of interpretation of the Pentateuch. For example, Nahmanides, the author of *Commentary on Genesis,* is given credit for referring to mass-energy duality (p. 40). However, Nahmanides lived in 1194 to 1270 A.D., over 600 years before Einstein. The theory of relativity is accepted without question and is referred to as the "law of relativity" (p. 34).

All of this would indicate a boring book, but there are some conclusions in the book which are not common among evolutionists today. The most exciting such conclusion deals with the nature of the first man, Adam.

> It is only at the instant when God places in Adam this breath (in Hebrew the *neshamah),* that both the created and Creator become inseparably linked . . . In the jargon of relativistic physics, it was at the moment of Adam's appearance that the part of the universe where man dwells started to operate in the same space-time reference frame as its Creator. (p. 52)

The book goes on to postulate that before Adam was created, the literal days of creation were 24-hour days according to God's reference frame. The book accepts 15 billion years for the time elapsed in the Earth's reference frame, following the Standard Model.

Other interesting departures from evolutionary dogma include the statement that the probability that life could arise by chance is negligible even if 15 billion years are available (p. 159). Another concerns recognizing gaps in the fossil record. The Niles Eldredge statement: "The pattern [in the fossil record] that we were told to find for the last one hundred and twenty years does not exist." is quoted three times (pp. 25, 129, and 134). A third concerns acceptance of the extraordinary longevity of the Antediluvian patriarchs (p. 138).

On the negative side, the author accepts human evolution to have occurred starting from stardust and leading to Adam, the solar system evolved from a cloud of gas, dust, and rocks, and the inflationary epoch of the universe occurred within the first fractions of a second after the Big Bang singularity. On p. 28 it is stated that the Genesis Flood was so brief a period that "firm archaeological evidence may never be found."

I find that the book places too much credence in modern radiometric dating methods and other findings of modern science. Also, it is understandable that the Jewish scholars should be venerated, especially by an author who is Jewish, but I again find that too much is read into what they wrote. For instance, on p. 136 we find the statement: "The Talmud describes a swamp-like interface between earth and water as the place of origin of animal life." However, the Talmud does not carry the same weight as Scripture (Isaiah 29:13).

*715 Tazewell Ave., Bluefield, VA 24605.