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EROSION OF THE GRAND CANYON OF THE COLORADO RIVER PART I — Review of Antecedent River Hypothesis and the Postulation of Large Quantities of Rapidly Flowing Water as the Primary Agent of Erosion

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Received 10 April 1991; Revised 20 June 1991

Abstract

One interpretation of the erosion of the Grand Canyon is reviewed—the antecedent view of the Colorado River cutting through the rising landscape. It is postulated that rapidly flowing water laden with abrasive particles moving from higher regions into lower areas was the main erosive agent in the formation of the Grand Canyon and that this erosion occurred rapidly within recent times.

Introduction

The Grand Canyon defies description because of its immensity and barren beauty. Even more so its history and the origin of the Colorado River that runs through it have led to considerable speculation and many differences of opinion. When one sees different portions of the Canyon, one can understand why there is so much variation of interpretation. If one has seen only the eastern end of the Canyon at the visitor centers, he is in for a shock when he visits the western portions of the Canyon. (See Figures 1-4.) Such was the authors' reaction. In many aspects it is similar to viewing two different canyons. It takes hours of walking to reach the Colorado River in the eastern Canyon. Likewise trying to reach the Shiva Saddle from the North Rim with a limited supply of water in extremely hot weather is very difficult (Meyer, 1987; Meyer and Howe, 1988). By contrast, you can drive down into the western Grand Canyon through Peach Springs Canyon. One feels as if not enough energy has been expended to achieve the goal or he has not placed himself at sufficient risk!

Because of the barrenness of the region, (Figure 5) the geology of the various formations can be examined in detail if one can reach the area of study. This differs from so many areas in the eastern United States when only an occasional window (fenster) can be found to study the arrangement of the geological formations. Thus the Colorado Plateau has attracted many people to do geological work because of the abundance of opportunities for observation. Uniformitarian scientists as well as catastrophist scientists have studied the area. We review one of the interpretations as to how the Grand Canyon formed and postulate the major causative agent for erosion—rapidly flowing water. Later papers will discuss other interpretations of formation as well as other processes involved in the formation of the Canyon. In mentioning time estimates, the authors are quoting the opinions of various workers involved. We do not subscribe to the geologic timetable.

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John Wesley Powell's Views

The first widely accepted explanation of how the Grand Canyon originated was elucidated by Major Powell, a one-armed Civil War veteran who led an expedition by boat down the Colorado River in 1869. As Collier (1980, p. 34) claimed:

> Powell advanced the notion that the Kaibab Plateau rose against an already established Colorado River. The River would have cut through the Plateau like a stationary saw cuts through a rising log.

Or in Powell's own words (1961, pp. 89,90),

> . . . Over the entire region limestones, shales, and sandstones were deposited through long periods of geologic time to the thickness of many thousands of feet; then the country was uplifted and tilted toward the north; but the Colorado River was flowing when the tilting commenced and the upheaval was very slow, so that the river cleared away the obstruction to its channel as fast as it was presented, and this is the Grand Canyon.

Thus Powell believed that the Colorado River existed prior to the uplift [antecedent to the structures in the Grand Canyon area] (McKee, et al., 1967, p. v) originating as far back as Tertiary times (Blackwelder, 1934, p. 554). As Nations and Stump (1981, p. 88) state, ". . . Powell the first to run the Colorado River through the Grand Canyon . . . claimed that the river was there first and merely maintained its course as the Kaibab Uplift rose beneath it." Also this antecedent view was held by Dutton (1882). Likewise Usinger (1967, p. 187) seemed to support this view:

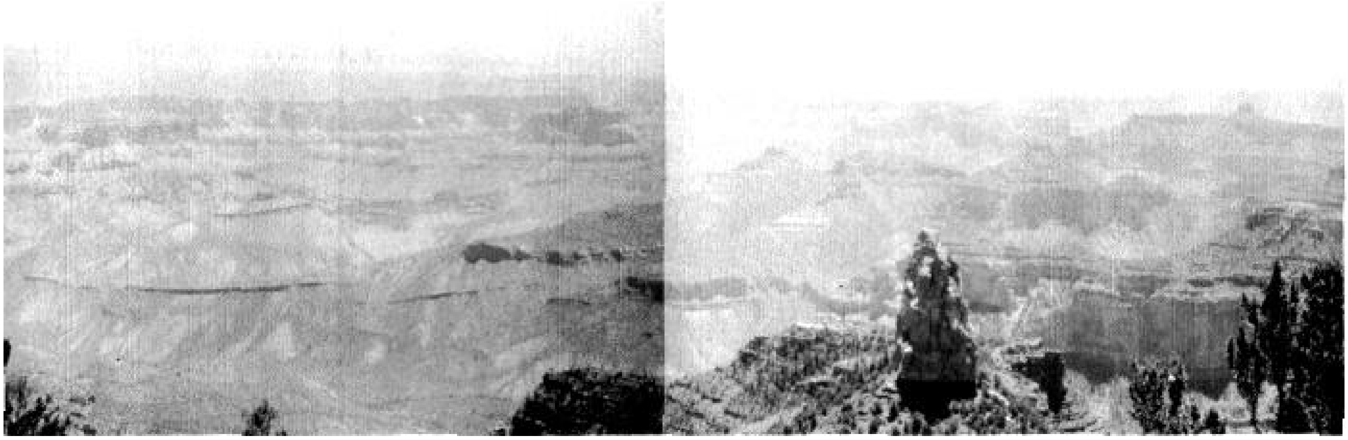


Figure 1. Panoramic view from Point Imperial Vista, North Rim, eastern Grand Canyon. Photographs by Glen Wolfrom

> . . . the site now occupied by the canyon (Grand Canyon) was a wide level plain traversed by a river that probably looked relatively placid. But then, as a result of a shifting of the earth's crust, the plain began to arch upward into a dome. As the land gradually rose higher and higher, the river cut constantly downward, carving a narrow ever-deepening scar in the earth.

Inherent in this view of the formation of the canyons of the Colorado River is the assumption that rapidly moving water when laden with abrasive substances can extensively erode consolidated sediments. This view needs to be explored and will be considered at this point.

Flowing Water, Erosion and the Grand Canyon

Powell, having risked his life exploring the various canyons through which the Colorado flowed, likely was impressed by the power of moving water as are all who have taken a boat trip upon the rapidly flowing stream. He (1961, pp. 390, 393) graphically stated:

> The carving of the Grand Canyon is the work of rains and rivers. The vast labyrinth of canyon by which the plateau region drained by the Colorado is dissected is also the work of waters. Every river has excavated its own gorge and every creek has excavated its gorge. When a shower comes in the land, the rills carve canyons—but a little at each storm and though storms are far apart and the heavens above are cloudless for most of the days of the year, still, years are plenty in the ages, and an intermittent rill called to life by a shower can do much work in centuries of centuries.

Powell discussed the erosive power of rapidly moving large quantities of water available from melting snows and infrequent rain storms in the arid climate of the Colorado Plateau in other places in his treatise (1961, pp. 28, 29, 46, 221, 223). Basically, given *enough time* the erosion caused by the flowing water containing silt and other abrasive material could carve the Grand Canyon. As Stokes (1989, p. 28) noted:

> It is not uncommon to hear a tourist give expression to the thought that the Grand Canyon is a fault or giant crack, opened by a great upheaval. But most persons with a little reflection can be convinced that everyday erosion, given enough time, could do the job.

Interestingly, Longwell, Knopf and Flint (1946, p. 68) mentioned as Stokes did that ". . . those who first speculated on its (Grand Canyon) history thought that the river had found a low-level course already prepared for it by a great gash or rift earlier opened by some cataclysm in the Earth's crust." However they attributed the erosive power of the vast amount of sediment carried by the Colorado River as the key to the formation of the Canyon (p. 68). They stated that the River carried 11,000 tons/hour of material past a given point as it drained an area of 230,000 mi^2. ". . . we find that the whole surface of this 230,000 mi^2 of country is being lowered at the average rate of one inch every 440 years" (p. 68). Stokes (1966, p. 42) estimated that the area of drainage by the Colorado River was 244,000 mi^2. Because of the large amount of sediment carried by the River, he conjectured that an estimated 142 million tons of sediment settled in Lake Mead every year until 1964 (p. 42). Since the construction of Glen Canyon Dam near Page, Arizona, the flow of the Colorado through the Grand Canyon has been reduced (Hamblin and Rigby, 1982, p. 8).

McKee (1985, p. 36), after noting that the average person often cannot comprehend the erosive power of running water, explained that:

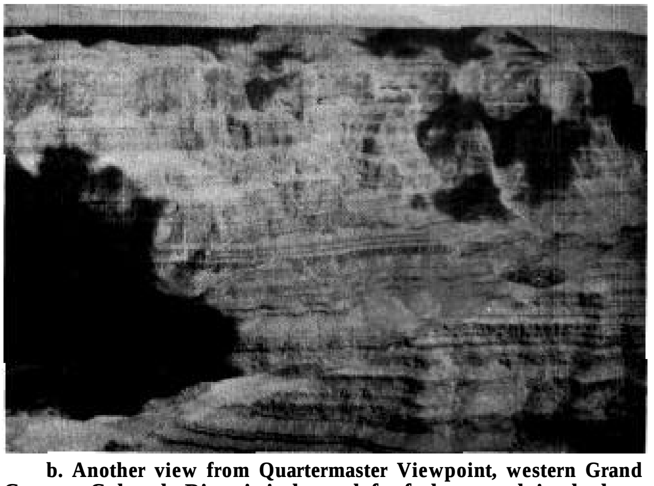
> The vast Grand Canyon, however, an extreme example of erosion, seems a bit too large—too wide and deep—to be attributed alone to the power of any river such as exists today. But the Grand Canyon—the greatest of chasms—is nothing more than the result of the work of running water over a long period of history.

McKee, who spent much of his professional career studying the geology of the Canyon region, felt that the arid climate and the very rapid down-cutting of the river had caused the development of the Canyon profile (1985, p. 37).

Rapid Erosion Possible

Morris, a hydraulic engineer, presented many examples of the destructive power of river water, particularly in flood conditions, including an instance observed

Figure 2. a. View from Quartermaster Viewpoint, western Grand Canyon, looking north. Colorado River can be seen in lower center of photograph. Photograph by Glen Wolfrom



b. Another view from Quartermaster Viewpoint, western Grand Canyon, Colorado River is in lower left of photograph in shadow. Photograph by Glen Wolfrom

c. Same view as b except reduced to illustrate distance between Viewpoint and Colorado River. Photograph by Emmett Williams

in the Colorado River (Whitcomb and Morris, 1963, pp. 259-261). Also Austin (1984, pp. 179-180) discussed the formation of two extensive gorges in a Colorado River flood of 1905. Particular examples of rapid erosion and the catastrophic results have been noted in the Quarterly. Morris (1966, p. 53) mentioned the amount of sediment transported by the Mississippi River per year which relates to the erosive power of moving water. The "antecedent bed" of the Mississippi River, the transportation of gravel and the significance of deltaic subsidence in relation to the movement of large quantities of water was considered by Allen (1972, pp. 96-114). Also see Mehlert, 1988, pp. 121-123 for another discussion of the erosion and deposition capabilities of a large river. Burdick discussed (1970, pp. 143-144) the effects of flooding in the scablands of eastern Washington. Also see Allen, Burns and Sargent, 1986. The alteration of a cave during the flooding associated with hurricane Camille in 1969 in Virginia was noted briefly by Armstrong (1972, pp. 135-136). Also see Austin, 1984, p. 178. The unbelievable damage caused by 30 to 40 inches of rain in Nelson County, Virginia (a county of many narrow valleys surrounded by steep ridges) within a six-hour period was related by eyewitnesses (Williams, 1986, pp. 62-63). A team of geologists recorded the damage and stated:

> Erosion resulted mainly from debris avalanches down the mountain-sides and channel scour along streams and headwater tributaries. Total amounts of sediment yield from certain mountainous areas in Nelson County were about 2-4.6 million cubic feet per square mile, probably the equivalent of several thousand years of normal denudation. . . . For drainage basins ranging up to about 1.5 square miles, the estimated storm-average sediment-transportation rates varied from practically nothing to as much as 172,000 pounds per second (7.4 million tons per day) [Williams and Guy, 1973, p. 1].

Compton, in discussing the James River system, also mentioned this remarkable flood damage in 1969 in Virginia (1977, pp. 23-46). This catastrophe could possibly be compared to what might have happened in the Grand Canyon area during its early erosion cycle when copious quantities of water cascaded down higher elevations into lower regions.

Lammerts (1974, pp. 101-103) conducted some field studies on the rapid formation of beaches and rounded stones by wave action at San Luis reservoir. Such erosional processes do not require long periods of time to grind and smooth even hard stones. See Austin (1984, pp. 180, 182, 184) for the erosion and other damage caused by catastrophic wave action. The horrible erosive action in Tsunamis (seismic sea waves), particularly in shallow water, was vividly described by D'Armond (1980, pp. 95-98). He conjectured on the possible erosion effects in the emerging stages of continents in the late stages of the Flood (or possibly

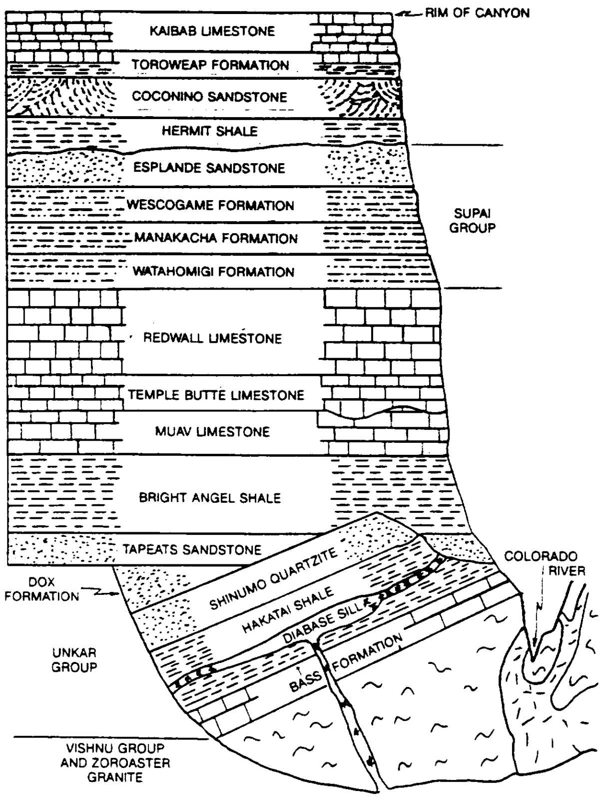


Figure 3. Idealized geologic cross section of the eastern Grand Canyon (after Breed, 1975).

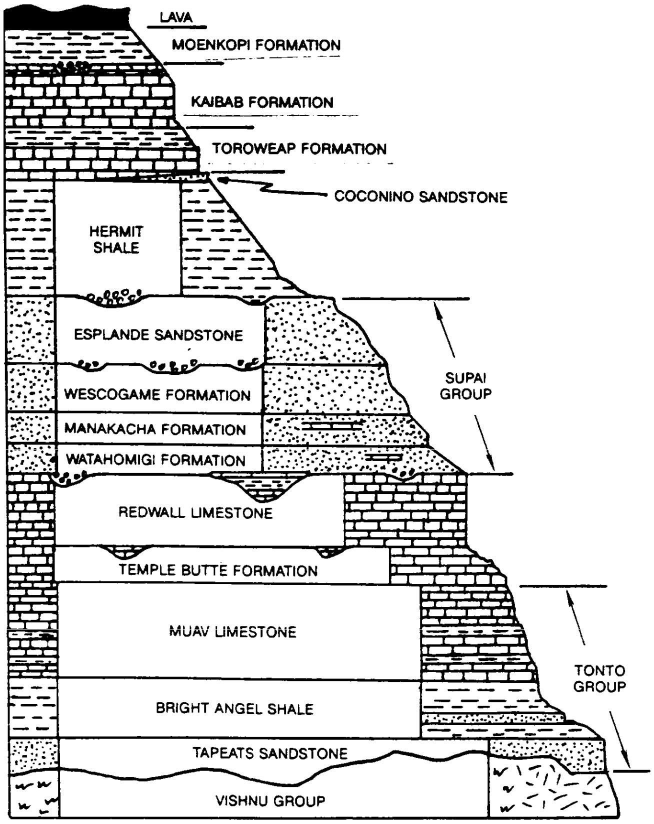


Figure 4. Idealized geologic cross section of the western Grand Canyon (after Billingsley and Breed, 1980).

as aftereffects of the Flood). For damage done by some tsunamis, see Austin (1984, pp. 181-185, 189).

The effect of floods on the filling of Yosemite Valley, including the erosion damage, was presented by Lammerts (1975, pp. 3-4). Water-action erosion of the Sierra Nevada mountain chain was discussed in a reprinted article (1978, pp. 164-165) by J. D. Whitney, California State Geologist from 1865-1882. Ur of the Chaldees was a seaport before rivers brought in considerable delta deposits "and left Ur high and dry in the desert" (Heinze, 1977, p. 87). Erosion by rivers was necessary to bring in such an enormous amount of sediment. Cox (1979, pp. 26-27) briefly elucidated the erosion of the Great Lakes basins, the Niagara Escarpment and the Finger Lakes of New York by the possible action of rapid currents of water. The rapid erosion of the Niagara Falls escarpment and St. Davids Gorge was carefully discussed by Daly (1974, pp. 177-181). Likewise Daly noted that Columbia Canyon probably was formed recently (pp. 181-182). It would be instructive to refer to Corliss' discussion (1988, pp. 136-138) on erosion of the Columbia River Plateau. Cox (1979, pp. 154-162) felt that the erosive action of rapid currents formed drumlins and was responsible for the shaping of recently deposited sediments. Also see Corliss (1988, pp. 132-136) for a discussion of drumlin anomalies.

In an important series, Holroyd (1990a, b) discussed the actual damage to reinforced concrete structures by rapidly moving water due to the process of cavitation. Large volumes of water rushing through tunnels to a lower level caused considerable damage to the concrete and adjacent sandstone. Such a phenomenon can develop in any rapidly moving water system. The author, in postulating damage potential for a Grand Canyon simulation made the following observation (1990b, p. 54):

> However, the harnesses of the rocks during the carving of the Grand Canyon might have been similar to those observed today and reflected in the present erosion profile. A catastrophic flow of water, such as might result during the capture of the Colorado River through the Kaibab uplift, might encounter similar profiles. The computer simulation shows that there are indeed locations for cavitation processes to greatly accelerate the removal of rock.

In a brief note Williams (1990, p. 96) mentioned two examples of rapid erosion. The Duna River excavated 2250 cubic meters of material in 24 hours and the granite pavement in a tunnel had to be replaced within a year because of erosion. Austin (1984) cataloged some other rapid erosional effects resulting from water catastrophes:

> The geological effects of hurricane Donna in south Florida, 1961 (pp. 175-176, 187)
> The geological effects of hurricane Cindy in Texas, 1963 (pp. 176-178)
> Erosion on Surtsey Island, 1967/68 (pp. 193-194)

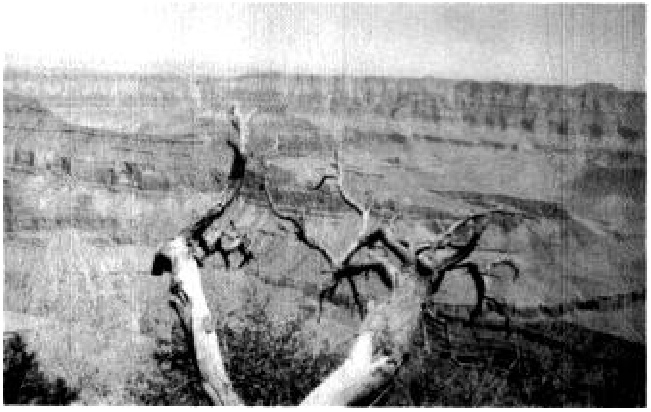


Figure 5. Barrenness of the region allows geologists to study the various formations in detail. View from Cape Royal Vista, North Rim, eastern Grand Canyon. Photograph by Glen Wolfrom

Erosion along Waiho River, New Zealand, 1965 (p. 194)
Overnight valley formation, San Nicolau, Brazil, 1974 (p. 195)
Rapid gulley erosion, Mount St. Helens, 1980 (pp. 196-197)

Frederick Dellenbaugh was a member of the team that accompanied Powell down the Colorado River on the second expedition (1871-1872). Acting as artist and assistant topographer, Dellenbaugh did quite a bit of exploring throughout the canyon country. He recorded (1988, p. 180) an example of rapid erosion near Kanab, Utah:

> While camped below Kanab, Clem and I in walking one day saw a place where the creek which flowed on a level with the surroundings suddenly plunged into a deep mud canyon. This canyon had been cut back from below by the undermining action of the falling water, and it was plain to see that it would continue its retrogression till it eventually reached the mouth of the great canyon several miles above, but I did not dream that it could accomplish this work as rapidly as it actually did years after. During a great flood it washed a canyon not only to Kanab but for miles up the gorge, sweeping away at one master stroke hundreds of acres of arable land and leaving a mud chasm forty feet deep.

Emmett Williams, George Howe and Norbert Smith, while doing some field work near the Grasslands Experiment Station in Oklahoma, observed a similar situation. A field of grain at Crowder Lake had been planted near a creek; however the edge of the field dropped abruptly approximately 30 feet to the creek bed. The grain was only about a few inches tall but an enormous gulley had been cut through the field about 25 feet deep by water draining across the field from a slightly higher elevation (Figure 6). The steep-sided gulley was quite wide and had destroyed about one-third of the grain field. This erosion developed by a drainage flow diversion when State Route 270 West was repaved. Any unconsolidated material is easily washed away by excessive water flowing over and through it when such a height gradient exists that increases the erosive power of the moving fluid.

Unless one has witnessed a rain storm in an arid climate, it is difficult to realize the potential damage capability of a "cloudburst." In July of 1990, Emmett Williams, George Howe and William Waisgerber were caught in a thunderstorm in the northwestern part of Big Bend National Park in the Chihuahua Desert. Deep streams developed rapidly in dry gullies actually

Figure 6. a. Looking down into steep-sided gulley near Crowder Lake, Oklahoma

b. Looking up from the base of steep-sided gulley. Photographs by George F. Howe

becoming raging torrents carrying abrasive materials from eroded deposits making roads immediately impassable. Considerable erosion is possible in a brief time span in such a situation. Thus in the Grand Canyon area in the past, large quantities of water moving over consolidated strata could have formed the various canyons *rapidly*. The literature cited in this section illustrates several possible mechanisms for quick erosion of both hardened and unconsolidated material. Powell was correct in his observations of the power of moving water but the time necessary to perform the canyon-cutting task was overestimated. Rapid erosion is possible as long as there is ample moving water available for the task. As in the formation of caverns in limestone (Williams and Herdklotz, 1977, pp. 197-198; 1978, p. 88), the critical factor is *large quantities* of water.

Austin, et al. (1992), in the finest creationist monograph in print on the subject of the Grand Canyon, devoted a chapter to the erosion of the area (pp. 69-91). Steve Austin who wrote this chapter pointed out the enormous amount of erosion that has occurred (pp. 69-70). Not only the canyon itself, but possibly 1000 feet of material on a vast plain that once was above the Canyon also may have been removed by erosion! He (pp. 79-81, 87-88) noted other catastrophic occurrences that illustrate the erosive power of large quantities of moving water—the failure of Teton Dam in 1976, the prehistoric Spokane flood and canyon formation in the Mount St. Helens area in 1980-1982. Austin (pp. 80-85) offered evidence for accelerated drainage in the past compared to the present water flow upstream from the Grand Canyon:

1. The present streams and rivers are "underfit."
2. Incised river meanders cut into hundreds of feet of sedimentary strata.

Austin (pp. 88-89) mentioned also cavitation, hydraulic plucking and hydraulic vortex action as possible mechanisms of rapid erosion in bedrock.

Although the erosive power of sediment-laden water probably is considered the most important factor in the formation of the Grand Canyon by uniformitarian geologists, other agents such as weathering, collapse, etc. will be discussed in a later article.

Geological evidence discovered in the first half of this century disproved Powell's antecedent view of the Colorado River on the Colorado Plateau. This evidence will be discussed in Part II.

Acknowledgement

The Research Committee of the Creation Research Society supplied funds for some of the field work involved in this research effort. This funding was made possible by donors to the Creation Research Society Laboratory Fund, interest from which was used. The authors appreciate this needed financial aid and thank everyone concerned.

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SYMPOSIUM ON VARIATION-XI**

VARIATION AND FIXITY AS SEEN IN CLIMATOLOGY

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Received 10 October 1990; Revised 22 January 1991

Abstract

The climate involves many interlocking feedback mechanisms. Their complexity raises questions about current forecasts of climate change. The case is presented that built-in design limits any major climate change.

Introduction

There has been considerable interest lately in the subject of global warming and the greenhouse theory of climatic change. Computer models called general circulation models have been written to predict the effect that an increasing concentration of carbon dioxide in the atmosphere will have on the future climate of the earth. These without exception predict that the earth's average temperature will increase, anywhere from 1 to 5°C. Climatologists are puzzled when they compare these predictions to reality. The greenhouse theory of climatic change is so believable and predictions based on it are so straightforward that scientists are hard pressed to see where the models based on it are failing. Yet a study of the weather records for the last century from all over the world suggests that most of the predictions are on the high side.

A search of the literature indicates that explanations given by climatologists as to why the predictions are high fall into five groups. One of the five groups of climatologists is, I believe, of special interest to creationists. This group believes that feedback mechanisms are built into nature so that the earth's climatic environment will not change drastically, if at all. They conclude that for every positive feedback there is also a negative feedback or set of negative feedbacks that keep the earths temperature in its present equilibrium. Therefore there will be little, if any, global warming. These climatologists do not publicly state that they are creationists nor should it be construed from this paper that they are creationists, but their research does fit into the creationist model of limited variations in a created environment that is approximated by the average conditions found on the earth today.

There are three kinds of feedbacks in the earth's atmospheric system: positive, negative, and thermostatic feedbacks. What follows is a brief description of each with an example or two taken from the study of climatology.

Feedback

Feedbacks are changes that may cause a spiraling or "vicious circle" effect. A positive temperature feedback causes the temperature to become hotter and hotter. A negative temperature feedback would cause the temperature to become colder and colder. For example, a doubling of the carbon dioxide concentration in the atmosphere increases the amount of energy incident on the earth's surface by 5 watt/meter! If it were not for two positive feedbacks, this 2% increase in energy at the earth's surface would not by itself raise the earth's temperature very much. The feedback processes which double the warming effect of the increased carbon dioxide are: (1) the ice-albedo feedback and (2) the water vapor feedback.

The first case follows: A snow and/or ice surface has a higher albedo or reflectivity than a ground or vegetation surface; thus the latter surfaces heat more than an ice or snow surface. This in turn heats the air. The snow/ground and ice/water boundary is an equilibrium position whose location depends on the mean global air temperature. If the earth experiences greenhouse warming; the snow/ground, ice/water boundary will move poleward, exposing more land and water. This will absorb more insolation, thus causing the earth to warm, causing the snow/land boundary to move further poleward causing more warming, etc. At first glance this appears to be a positive feedback mechanism which will continue to escalate until the earth warms to the point that there is no permanent snow or ice on the earth. This is, in fact, how this feedback is treated by most climatologists.

Ellsaesser (1984), however, believes the ice-albedo feedback is overestimated, if not actually of the wrong sign. In other words, he thinks the feedback may be negative rather than positive because ice and snow have a strong insulating effect. Therefore he reasons that an ice or snow cover reduces the wintertime loss of latent and sensible heat. This represents a warming for the earth. Thus global warming which would reduce the snow and ice cover would in the long run cool rather than warm the earth and be a negative feedback rather than a positive feedback.

There is a second feedback which is thought to double the warming effect of increased carbon dioxide. Water vapor in most instances is part of a positive feedback loop. The warmer the air, the more water will evaporate, This water vapor then absorbs terrestrial radiation which, through a chain of events, heats the air, which in turn causes more water to evaporate. When this positive feedback is built into general circulation models the estimated global warming is approxi-

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**Parts I-X are in *CRSQ* 27:144-153; 28:18-27, 50-59.