Terraces of Douglas Creek, northwestern Colorado:

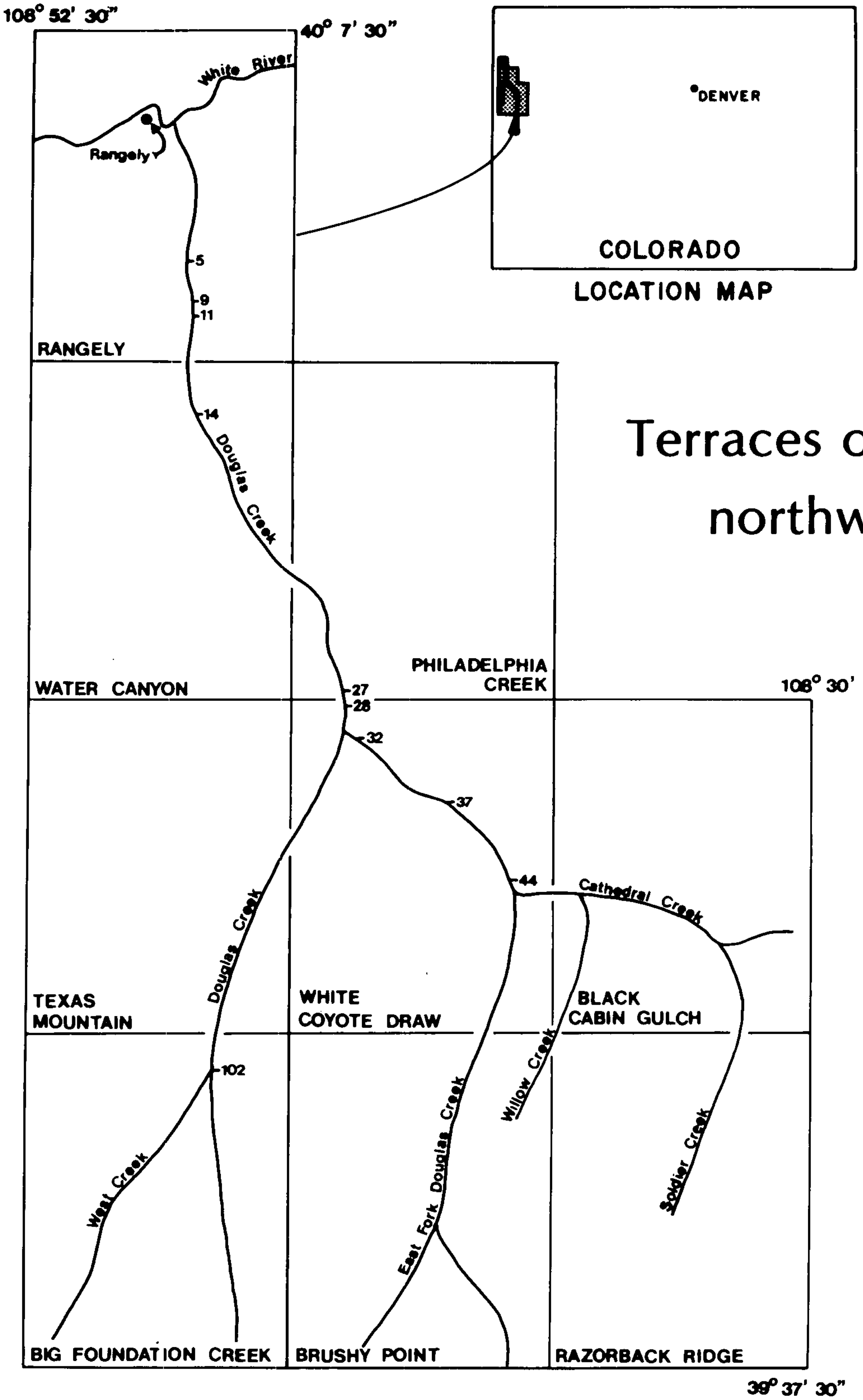

Figure 1. Index map of Douglas Creek. Numbered locations are study sites mentioned in text. Titles of U.S. Geological Survey topographic maps are provided.

ABSTRACT

Channel incision began after 1880 in Douglas Creek, a tributary of the White River in northwestern Colorado. This modern erosion produced a complex series of discontinuous, unpaired terraces below the 1880 valley floor. As many as four of these surfaces were formed below the level of the old valley floor by a process of discontinuous downcutting that apparently was not related to changes of base level, climate, or land use, although the initial incision was probably due to the introduction of large numbers of livestock.

The progress of incision was impeded as large quantities of sediment were flushed from steep tributary valleys into the main channel. Temporary storage and flushing of the sediment by episodic erosion produced a complex post-1900 terrace sequence. This phenomenon may be expected following rejuvenation of areas of high relief and high sediment production, and episodic incision may be a normal part of the erosional evolution of such areas.

An example of episodic erosion

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INTRODUCTION

The incision of a flood plain produces a terrace. Terraces border most channels, and the influence of climate, base-level, and tectonic change on terrace formation is reasonably well understood. Most major river terraces that can be correlated regionally are due to such causes. Terraces provide an important record of the dynamic changes that have taken place in a drainage basin, and, if the record is complete, the information provided may be of great value for prediction of channel response to man-induced or natural rejuvenation.

A major problem associated with an investigation of river change is that the response time is generally too slow for documentation of total river adjustment. For example, the instability of alluvial channels in the valleys of the southwestern United States has been a major environmental problem since about 1880. In a relatively short period of time many ephemeral stream channels in the Southwest were incised; alluvial valley floors were dissected, and today there are deep arroyos where broad, flat-floored, grassy valleys were found 90 yr ago. Dissection and lowering of the water table, which resulted in loss of grazing land and irrigation water, virtually destroyed agricultural productivity in many valleys. Obviously, the behavior of these streams is of practical as well as scientific concern. However, in spite of the interest of geomorphologists, archaeologists, and soil conservationists in this phenomenon, little is known about the progress of erosion in these valleys.

Many valleys have experienced several cycles of alluviation and erosion during Holocene time; these cycles are represented by alluvial deposits and terraces. The alternations of erosion and deposition have been correlated regionally, and they are usually explained either as the result of climatic fluctuations (Bryan, 1940; Hack, 1942; Leopold and Miller, 1954) or as the result of changing land use and overgrazing (Bailey, 1935; Thornthwaite and others, 1942).

Figure 2. Building, probably a root cellar, constructed about 1900 on floor of Douglas Creek valley at location 32.

An unusual opportunity to investigate the sequence of erosional events in one such valley came about when it was recognized that multiple unpaired terraces exist in the Douglas Creek valley of Colorado (Fig. 1). The presence of a small building at the edge of the arroyo (Fig. 2) suggested that the multiple surfaces, which occur below the surface on which the building was constructed, postdate arroyo cutting and settlement of the area. If this were found to be true, then the recent erosional history of this valley would provide information on the mechanics of the valley incision process that might not be available elsewhere.

The major objective of the investigation, therefore, was to find a cause for the apparently discontinuous downcutting that formed these surfaces. If all of the surfaces

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formed during the past 100 yr, then tectonic, climatic, and land-use changes would probably be insufficient to account for them, and the cause or causes would have to be related to the morphology of the basin and its response to rejuvenation.

DESCRIPTION

Douglas Creek is a tributary of the White River in northwestern Colorado (Fig. 1). It flows north toward Rangely from its headwaters in the Cathedral Bluffs, draining an area of approximately 1,070 km^2 that is underlain by sedimentary rocks of Cretaceous and Tertiary age.

Although there are no weather stations within the basin, precipitation is about 250 mm at the basin mouth near Rangely, and it increases to about 635 mm at higher elevations (Bureau of Land Management, 1974). Basin relief is about 1,000 m, and tributaries are very steep. Data collected by the Bureau of Land Management (1974) since 1962 show that the mean annual sediment yield from the basin is 175,276 m^3. A bedrock control near the mouth of the creek provides a local base level, which eliminates any influence of the White River on the Douglas Creek channel.

The terraces bordering Douglas Creek vary in number at any location from one to seven, including the highest surface or valley floor upon which the old building rests (Fig. 2). The lower surfaces are small (2 to 20 m wide and 10 to 150 m long), discontinuous, and, for the most part, unpaired, but they provide a unique record of channel behavior in this valley. The terraces are cut into older alluvium that is composed of channel, flood-plain, and tributary deposits (Womack, 1975). Several periods of deposition are indicated by the nature of the sediments, but nothing was found that provided a date for this alluvial complex.

EROSIONAL HISTORY

The first European to see Douglas Creek valley was Escalante (Crampton, 1952). He entered the East Fork valley from the south in 1776 and then followed an "easy trail" along the East Fork and Douglas Creek to its confluence with White River. If the present meandering condition of the arroyo had existed then, it would have forced travelers to cross Douglas Creek a number of times as they proceeded downvalley. If the valley floor had been deeply dissected during Escalante's visit, each crossing would have required detours and hard work, which certainly would have been mentioned, judging by the detail of the rest of Escalante's narrative.

James Rector, the first settler in the valley, described it as it was in 1882 as follows: "It was the best cattle country you ever seen [*sic*] . . . no brush and deep gullies like today, but lush grass up to the stirrups of a horse. The creek was right on top of the ground. You could dip out water with a bucket" (Kirby, 1972). Rector's homestead (Fig. 1, loc. 102) is now cut by a vertical-walled arroyo 10 m deep, and the stream is intermittent. Apparently, then, the modern arroyo began to form after 1882. According to Soil Conservation Service records, 27,000 cattle were brought into the valley from Texas in 1885, and the resultant overgrazing undoubtedly contributed to erosion and arroyo development in the valley.

The old building (Fig. 2) is all that remains of a homestead that was built in about 1900 near the confluence of East and West Forks (Fig. 1, loc. 32). Aerial photographs show that the main buildings were still standing in 1937, but they were being threatened by lateral migration of the East Fork arroyo. Apparently, when the buildings were constructed adjacent to East Fork near the end of the 19th century, erosion had not progressed up the valley to that point.

A large cottonwood tree is believed to be the oldest tree growing on any of the terraces. It germinated in 1900, as determined by a tree-ring count. Its position below the valley floor on East Fork indicates that almost 5 m of incision had occurred at that point by 1900. Therefore, the arroyo and terraces are certainly post-1882, but most of the erosion probably occurred after 1900.

Evidence for the age of terraces at several locations is provided by trees. For instance, in the cross section of Figure 3, tree-ring dating techniques indicate that a box elder at the fourth terrace level, about 6 m above the present channel, germinated around 1907. The stream subsequently deposited 2 m of fill at that point, partly burying several trees. Rector's 1882 valley floor and a lower surface, which was a flood plain, are composed of the oldest alluvium, and they form two terraces (T5 and T6) above terrace 4, indicating that after 1882 and before 1907 approximately 1.6 m of incision occurred at this point. By 1937 the channel eroded to a level 3 to 4 m above the present channel (the base of the third terrace level), as shown on aerial photographs taken then. A salt cedar growing on this surface has been partially buried. Aerial photographs taken in 1961 show that the stream at that time was at the level of the first terrace, about 2 m above the present channel; therefore, between 1937 and 1961 the second terrace (T2) formed. After 1961 the channel cut off and abandoned a large meander loop at the first terrace level, and it was incised to its present level. The rapid but discontinuous progress of erosion in the Douglas Creek valley is illustrated by the dated surfaces at location 5 (Fig. 3) and is clear evidence for episodic erosion in the Douglas Creek valley.

The cross sections along Douglas

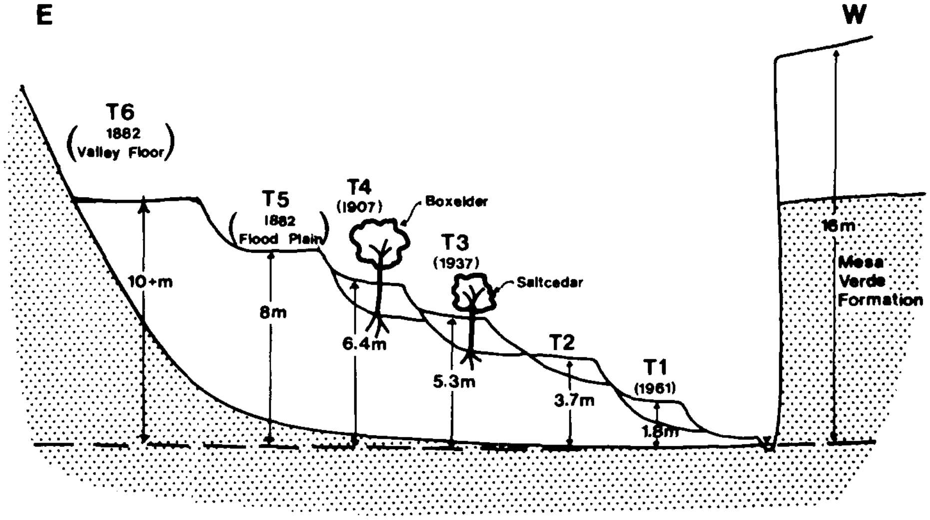

Figure 3. Cross section of Douglas Creek valley at location 5. Terraces 5 and 6 represent pre-1882 valley floor and probably flood plain of Douglas Creek. Terraces 1 through 4 were formed after 1900.

Creek vary greatly, indicating a different erosional-depositional history at various locations in the valley. These differences may be due partially to destruction of some terraces by lateral erosion, but, nevertheless, the variations are so great that it is impossible to identify periods of cutting and filling that affected the entire valley at one time.

Figure 4 illustrates some of the combinations of erosion and deposition that have occurred at various places in the valley since major erosion began after 1882. At locations 9 and 27, three depositional and four erosional periods are represented. At locations 11 and 32, two depositional and three erosional periods are represented. At location 14, one depositional and three erosional periods are represented. Some cross sections of Douglas Creek have as many as seven terraces, but most terrace levels can be identified for only short reaches along the stream, and, therefore, the numbers assigned to the terraces in Figures 3 and 4 do not mean that they have been correlated.

Examination of terrace stratigraphy reveals that the modern deposits that form the upper part of the terraces (Fig. 3) are composed of a number of fining-upward deposits. They vary somewhat in texture, but generally consist of fine gravels fining up to silt or fine sand. Each of the fining-upward cycles represents accumulation of flood deposits during a depositional event (whether the annual spring runoff caused by melting or winter snow in the headwaters) or a flood event caused by a thunderstorm. For instance, at location 28 (Fig. 1), two sequences of deposition, each composed of six fining-upward units, form the alluvial tops of two post-1882 terraces.

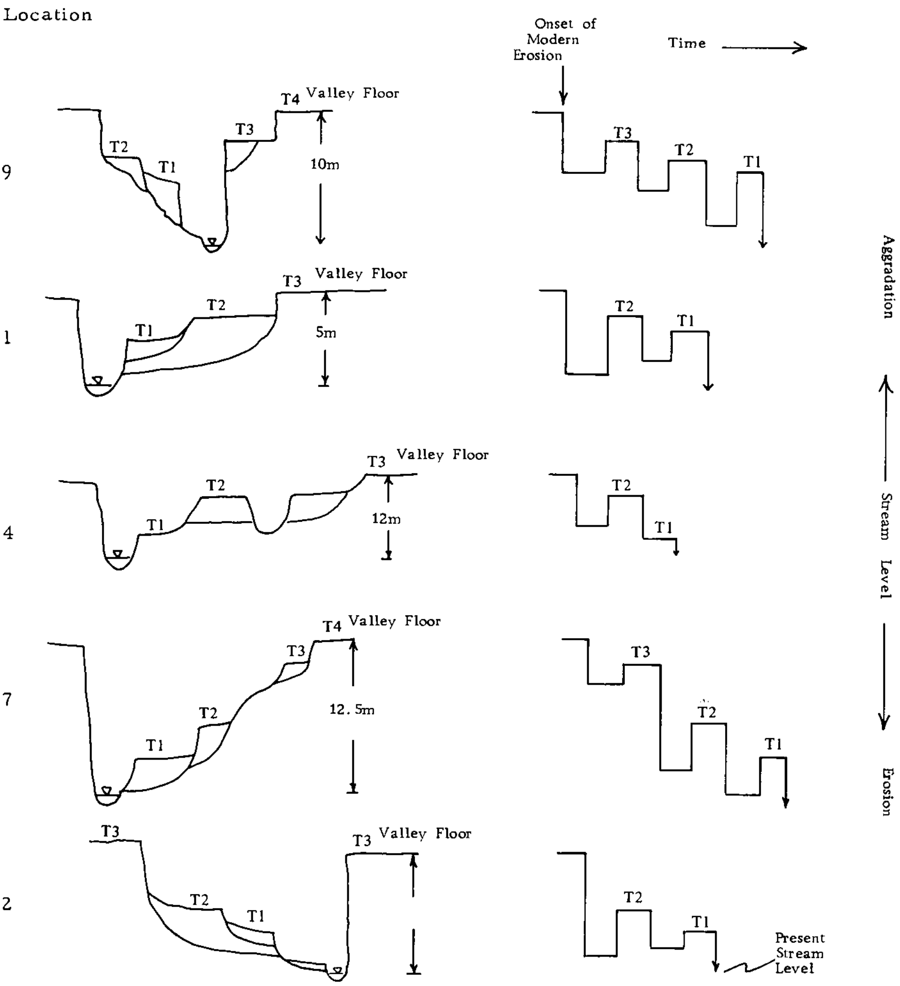

Figure 4. Diagrammatic cross sections of Douglas Creek terraces. Sections are not drawn to scale. To right of each is a representation of depositional and erosional history at each location as deduced from cross sections; that is, stream level is related to passage of time in a very general way. Note that terraces are numbered from lowest to highest at each location; therefore, 1882 valley floor is assigned a different number depending on number of terraces at each locality.

DISCUSSION

The rejuvenation of a drainage basin may initiate a complex sequence of events that reflects the response of a complex morphologic system to change. Experimental studies of drainage basin evolution reveal that high sediment loads produced by channel incision in turn cause aggradation, which is, in turn, followed by renewed incision as sediment production decreases. Thus, a single rejuvenation may produce incision and a terrace, aggradation and alluvial fill, and finally renewed incision to produce a second terrace (Schumm and Parker, 1973). This has been described as the complex response of a fluvial system (Schumm, 1973), and it is an explanation of the out-of-phase epicycles of erosion and deposition that characterize the Holocene record in the drier parts of the world (Kottlowski and others, 1965) and modern cut-and-fill episodes in agricultural areas (Daniels and Jordan, 1966).

Because of the relatively short period of time during which incision and terrace formation have occurred in Douglas Creek valley, the fact that the terraces are discontinuous and unpaired and cannot be readily traced throughout the valley, plus the lack of similar terraces in adjacent valleys, indicates to us that following the initial incision, the sequence of events in Douglas Creek cannot be attributed to influences such as climate, land-use, or base-level change. Certainly the three depositional and three erosional events that occurred at locations 9 and 27 (Fig. 4) since incision of the valley floor would require a very complex series of climatic fluctuations. Therefore, it appears that the controls are inherent to the Douglas Creek geomorphic system, although the initial period of erosion was likely the result of overgrazing in the 1880s.

The explanation of the post-1900 multiple terraces in Douglas Creek appears to be a modification of the complex response sequence (Schumm and Parker, 1973). In a typical complex response, incision occurs to some level, and this is followed by aggradation and then renewed incision. In Douglas Creek, the incision was episodic and probably resulted from the very large quantities of sediment delivered from the steep tributaries, which temporarily overwhelmed the channel's ability to transport the sediment.

The large quantities of sediment entering Douglas Creek from rejuvenated tributaries caused local deposition and oversteepening of the valley floor. Such accumulations, when repeatedly trenched, produced the flights of terraces, which persist for only short distances along the stream. However, some variation in the number of terraces was also observed, even along reaches dominated by the influence of a single major tributary, so that tributary influence alone cannot explain every episode of deposition and erosion. Adding complexity to the situation are meander cutoffs, which cause local steepening and channel scour, with consequent downstream deposition.

It appears that the post-1900, unpaired, discontinuous terraces of Douglas Creek have been formed through a complex response of the watershed to initial arroyo cutting and perhaps to local events, including flood deposition and erosion, meander cutoffs, and rejuvenation of tributaries. Because lateral erosion by the channel will gradually destroy these terrace remnants, it is possible that many of the post-1890 terraces will soon be destroyed. As it exists today, however, Douglas Creek provides a good example of the short-term channel adjustment to high sediment loads produced by rejuvenation. If this is the case, then perhaps the flights of terraces that form where large quantities of stored glacial and alluvial sediments are being removed from a valley (Davis, 1902) are also the result of the complex response or episodic erosion mechanism (Howard, 1960, p. 91; Alden, 1953, p. 181, 188) rather than a response to climatic fluctuations and so forth.

The Douglas Creek situation appears to conform to the observations of Born and Ritter (1970) who have mapped six discontinuous and unpaired terraces at the mouth of the Truckee River, where it enters Pyramid Lake in Nevada. A reduction of the water level in Pyramid Lake reduced the base level of the lower Truckee River, but instead of simple downcutting commensurate with the lowering of the base level, the channel in fact paused as many as six times. In addition, Gage (1970) cited an example of rapid deposition that caused aggradation of from 10 to 80 ft in the Waiho River of New Zealand. This glacier-fed river then proceeded to clear the deposited sediment over a period of a few weeks. The erosion produced a flight of 10-ft terraces. Gage attributed this and similar events to 10-yr weather patterns, and he cautioned that if some of these terraces were preserved they could easily be mistaken for surfaces of considerable antiquity.

Other examples of multiple terraces can be cited that may have formed as a result of rapid but episodic incision similar to that which occurred in the Douglas Creek valley (Thornthwaite and others, 1942, p. 90; Small, 1973); in fact, this process was observed during experimental studies when a major lowering of base level forced deep incision and canyon cutting at the lower end of a small 9- by 15-m experimental watershed (Weaver and Schumm, 1975).

Although the Douglas Creek area may be unusual in the number of terraces preserved, the events in this watershed have significant geomorphic implications. For example, episodic erosion may be the normal course of events in areas of high sediment production, and, in fact, it is possible that the early stages of the erosional evolution of all but the most resistant rocks will be characterized by interruptions of valley incision (Schumm, 1976). Further, variability of the terrace sequence within Douglas Creek indicates the danger of attempting terrace correlations on the basis of limited observations. For example, it is possible to find three surfaces in the Douglas Creek arroyo that could be correlated, by position alone, with the Hack (1942) and Leopold and Miller (1954) sequence (Fig. 3, locs. 11, 32). Further, if such channel behavior is common during incision, great variations in sediment yield from such a drainage basin may prevent the development of statistical relations between sediment yield and drainage basin morphology. This, in fact, may explain in part the high degree of variability of many long sediment-yield records and even part of the sedimentologic variability of ancient fluvial deposits.

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