[AMERICAN JOURNAL OF SCIENCE, VOL. 262, FEBRUARY 1964, P. 249-258]

HISTORY AND CAUSES OF CHANNEL TRENCHING IN WESTERN FRESNO COUNTY, CALIFORNIA*

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ABSTRACT. Most of the recent channel trenching in western Fresno County, California, has occurred since 1855. Reports of early settlers, maps, and field evidence indicate two periods of accelerated erosion, one from about 1875 to 1895 and the other from about 1935 to 1945.

Many channels have been deepened a total of 25 to 40 feet. During the period of erosion that started about 1935, many streams cut deeper, leaving the previous channel bottoms as terraces.

The amount and rate of stream-channel erosion are partly controlled by periods of above normal stream flow caused by large rainfall. Rainfall data from five stations in the Coast Ranges and Central Valley of California show two periods of very large annual rainfall, one from about 1875 to 1895 and the other from about 1935 to 1945. These periods of large annual rainfall were also periods of high frequency of large daily rainfall and about average frequency of small daily rainfall.

INTRODUCTION

Stream-channel trenching, or arroyo cutting, is common in the southwestern and western states. Much of the literature about the accelerated erosion that has occurred in the past century describes areas in New Mexico, Arizona, and Utah. The purpose of this article is to describe in detail the history and causes of the channel trenching in western Fresno County, California.

The area discussed in this article includes about 1400 square miles of the west side of the San Joaquin Valley (the southern half of the Central Valley of California) and the adjacent Coast Ranges. The northern boundary of the area is the north edge of the Little Panoche Creek fan, and the southern boundary is the south side of the drainage basin of Domengine Creek (fig. 1).

The eastern edge of the area studied is marked by the flood plains of the San Joaquin River and Fresno Slough. Between the flood plains and the foothills to the southwest is a strip of gently sloping coalescing alluvial fans 12 to 19 miles wide. Much of the channel trenching has occurred on the upper half of these fans. Areas are now being eroded that were being aggraded a century ago.

The Diablo Range in the southwestern part of the area consists of several groups of foothills fringing the San Joaquin Valley and the main Diablo Range, which is generally about 10 to 15 miles from the San Joaquin Valley. The larger foothill groups have maximum altitudes of about 2700 to 3400 feet, and the main Diablo Range has several peaks higher than 5000 feet.

The core of the Diablo Range consists of deformed and slightly metamorphosed shale and graywacke. The east flank of the range consists of a thick sequence of mudstone, shale, and sandstone that dips to the east. Soft marine and continental sediments are common in the foothill belt.

The channel entrenchment extends several miles upstream from the fans, but is not readily noticeable in headwater areas that do not have well developed flood plains.

* Publication authorized by the Director, U. S. Geological Survey. Prepared in cooperation with the California Department of Water Resources.

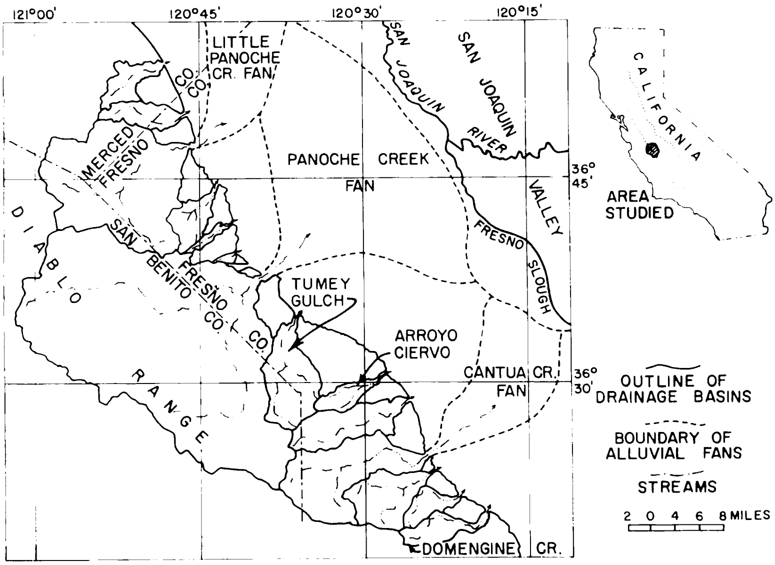


Fig. 1. Larger alluvial fans and drainage basins in western Fresno County, California.

The average annual rainfall is 8 to 20 inches for the Diablo Range and 6½ to 8 inches for the San Joaquin Valley. Daily amounts of rainfall of 3 to 4 inches have been recorded in both the mountains and the San Joaquin Valley.

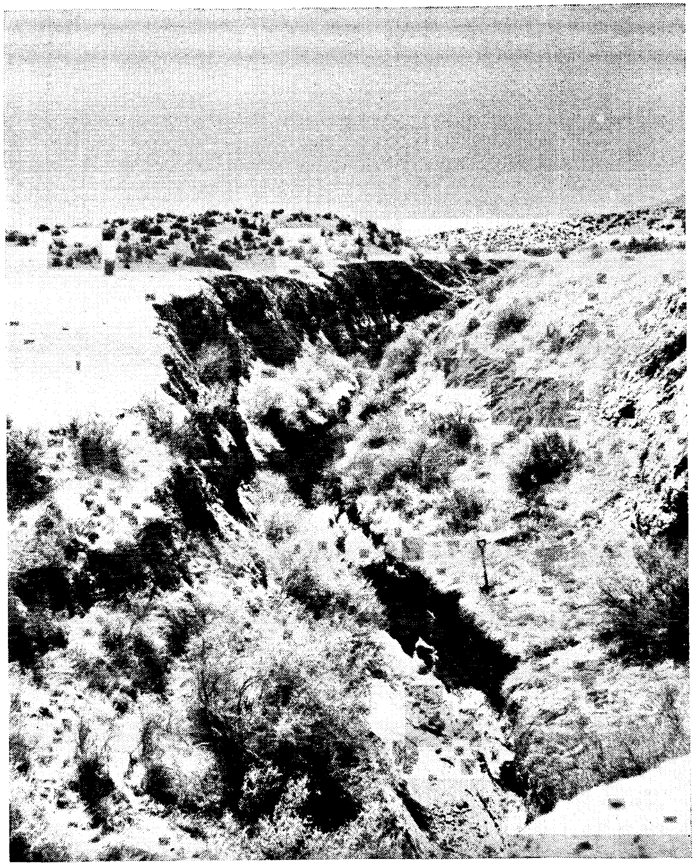
The vegetative density of the drainage basins in the foothill belt is sparse. For example, hoop tests and estimates indicate that the Arroyo Ciervo basin has an estimated vegetative density of 350 pounds per acre. Shadscale is a very common shrub, and the grasses are short types such as downy chess and redstem filaree. Other areas in the United States that have thicker growths of grass and bushes have vegetative densities ranging from 900 to 6000 pounds per acre (Langbein and Schumm, 1958, p. 1082).

Precipitation is too low and drainage basins are too small to support perennial streams. Little Panoche, Panoche, and Cantua Creeks are intermittent streams which receive enough ground water to flow along their entire lengths for a few weeks after most winter rainy seasons. The channels of the ephemeral streams of the foothill belt are always above the water table; therefore, they flow only in direct response to rainfall.

The ephemeral streams usually have a flashy type of flow. The type of flow is controlled by areal distribution, intensity, and duration of rainfall, and by the vegetative cover, lithology, and slopes of the drainage basin. The resulting flow ranges from clear water to viscous mud.

The maps used in the study include the following: General Land Office plats and survey notes of 1853 to 1858, and 1879 to 1881; U. S. Geological Survey 7½ minute quadrangles, 1922 to 1931, scale 1:31,680, contour intervals 5 and 25 feet; and U. S. Geological Survey 7½ minute quadrangles, 1955 to 1956, scale 1:24,000, contour intervals 5, 10, 20, and 40 feet.

PLATE 1



A. Narrow terraces in the channel of Arroyo Ciervo.

B. Incised channel on the Tumey Gulch fan.

This paper has been prepared from elements of an investigation of deposits susceptible to near-surface land subsidence made between 1957 and 1960 by the U. S. Geological Survey in cooperation with the California Department of Water Resources. Stanley N. Davis and George A. Thompson of Stanford University gave advice on certain aspects of the article. Ranchers, sheepherders, farmers, and other people living in the area gave first hand accounts of the history of channel trenching. The author wishes to thank Joseph F. Poland of the U. S. Geological Survey for critically reviewing this article.

HISTORY OF CHANNEL TRENCHING

The stream channels in western Fresno County are entrenched into the upper part of their alluvial fans and into the valleys upstream from the fans. In general, the channels of the ephemeral streams are narrow and occur in clayey deposits, whereas the channels of the intermittent streams are wide and occur in sandy deposits. This relationship between channel shape and sediment type agrees with the results of detailed studies that Schumm (1960) has made. The sides of the incised channels in many places are nearly vertical. The depth of the main channel decreases away from the mountain front, and eventually it splits into several shallow distributary channels.

Entrenched streams are a natural feature of alluvial fans, and traces of abandoned gullies can be found on several fans. The present period of arroyo cutting already had started on some fans when the first land survey was made in the early 1850's. Later surveys and the accounts of some of the first settlers show that channel trenching started on other fans in the period between 1875 and 1885. This date is about the same as the time of the channel trenching in parts of Arizona, Utah, Colorado, and New Mexico (Bryan, 1925). Cattlemen and sheepherders who have lived 30 to 40 years in the area agree that much of the deepening of these channels has occurred since about 1935, although the channels on most of the fans had their present areal extent by 1930.

Many of the entrenched channels are terraced. Tumey Gulch has remnants of paired terraces, 7 to 20 feet above the present channel, and Arroyo Hondo has 3- to 5-foot terraces which are paired in some places. Paired terraces are excellently preserved in Arroyo Ciervo, where a narrow slot about 8 to 15 feet wide has been cut 5 to 9 feet deep into the floor of the former channel, to form the terraces (pl. 1-A). The channels of the large intermittent streams are flanked by broad terraces 3 to 10 feet above the present stream grade. Most terraces have been formed since 1935.

The channel of Tumey Gulch, a mile from the edge of the foothills, is shown in plate 1-B. At this point the channel is 37 feet below the surface of the fan. The bushes along one side of the channel indicate the location of a narrow terrace remnant. The original land surveys show that Tumey Gulch had the same extent and position in 1854 as it does today, but in 1854 the channel was shallow enough for the surveyors to walk across as they chained the section lines.

The changes in the depth of Tumey Gulch between 1921 and 1955 are shown in figure 2. The data are from topographic maps. Like other fans in western Fresno County (Bull, in press), the Tumey Gulch fan (Bull, 1961)

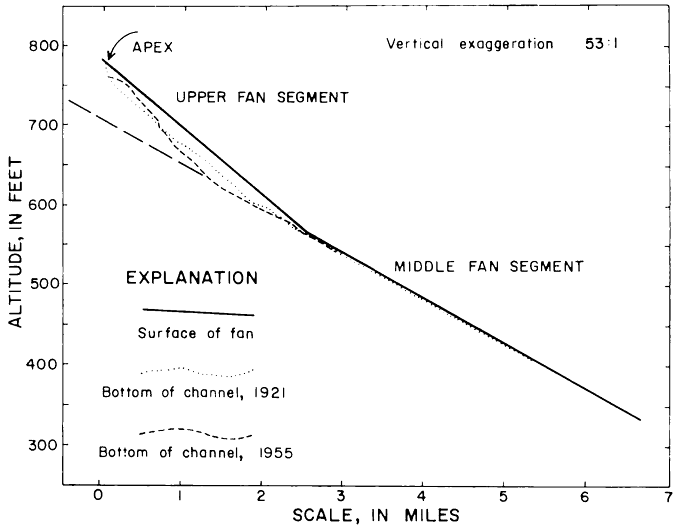


Fig. 2. Changes in channel depth on the Tumey Gulch fan, 1921-1955. Heavy dashed line represents a projection of the slope of the middle fan segment.

has a segmented radial profile. The depth of Tumey Gulch decreases abruptly at the downslope end of the upper fan segment. The shallow channel shown in the middle fan segment is one of several distributary channels. In 1921 the main channel was as much as 20 feet deep. By 1955 the upslope part of the channel was partly filled, but in places the channel was deeper than 30 feet, and the deepest part was moving upstream. More than a mile of the downslope end of the deepened 1955 channel is a continuation of the slope of the middle fan segment.

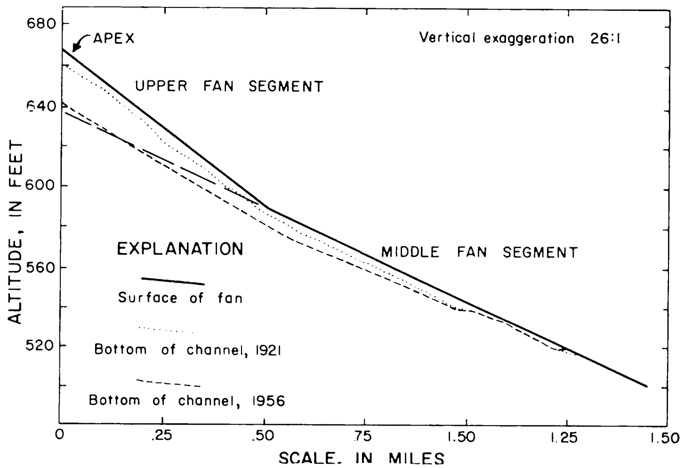


Fig. 3. Changes in channel depth on the Arroyo Ciervo fan, 1921-1956. Heavy dashed line represents a projection of the slope of the middle fan segment.

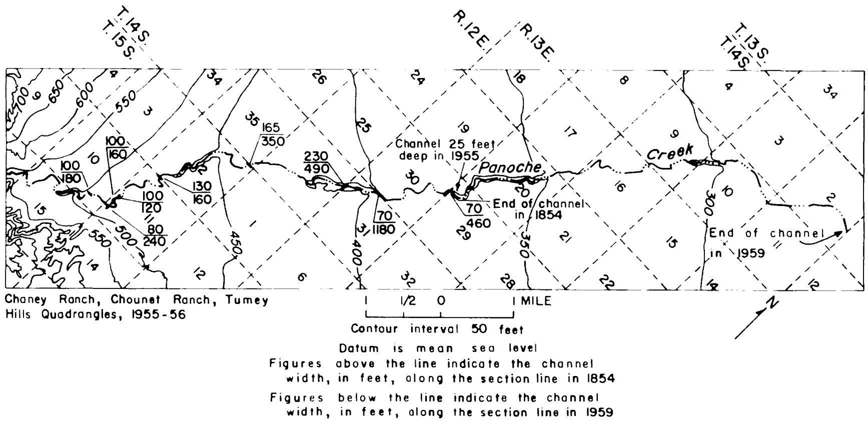


Fig. 4. Changes in channel width and length on the Panoche Creek Fan, 1854-1959.

Figure 3 shows the changes in the depth of Arroyo Ciervo between 1921 and 1956. The 1858 maps do not show a gully, but the 1880 mapping reveals that a gully extended to the downslope end of the upper fan segment. Topographic maps show the 1921 channel to be 4 to 6 feet deep and the 1955 channel to be as much as 26 feet deep. Most of the channel deepening between 1921 and 1956 occurred within the upper fan segment. The channel trenching of the Arroyo Ciervo fan differs from that of the Tumey Gulch fan, because trenching of 2 to 9 feet extends 0.6 mile downslope from the upper segment.

The channel widths of the intermittent streams have increased markedly during the past 100 years. The pairs of numbers in figure 4 show increases in the width of Panoche Creek from 20 to several hundred feet between 1854 and 1959. Many sections of the channel are from 2 to 6 times wider than they were in 1854. The lines of measurement along which the width was measured generally are not perpendicular to the stream channel because the surveyors in 1854 noted the channel widths between section corners; therefore the 1959 measurements also were made along section lines.

The length and depth of the channel of Panoche Creek also have changed since 1854. The channel extended into the San Joaquin Valley for 5 miles in 1854 and for 10 miles in 1959, and the channel has been deepened by erosion in some places as much as 25 feet.

CAUSES OF THE CHANNEL TRENCHING

Channel trenching has been ascribed by most writers to periods of increased runoff during which floods deepened stream channels. The increased runoff has been attributed to the removal of vegetation by overgrazing and to climatic fluctuations.

Accelerated erosion in the southwestern states was ascribed to overgrazing by Rich (1911), Bailey (1935), and Thornthwaite, Sharpe, and Dosch (1942). On the other hand, Gregory (1917, p. 132) says that some parts of Arizona not used for grazing present the same features as the areas that were overgrazed. Leopold (1951a) studied the vegetation of several areas in the south-

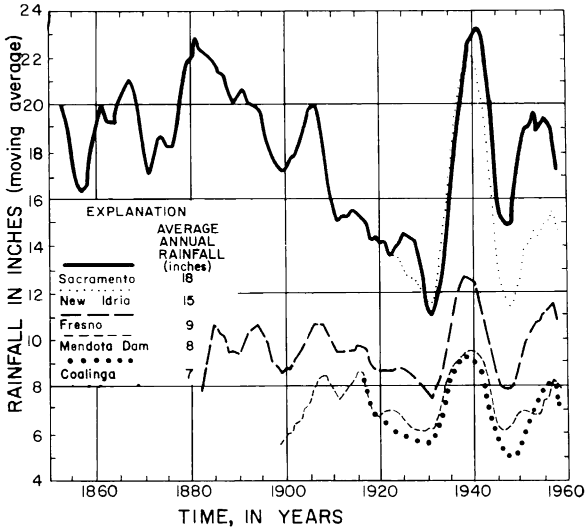


Fig. 5. Trends of annual rainfall for five stations in California, 1853-1958. Three year moving average of a five year moving average. Weather Bureau climatic year, July 1-June 30.

west that had been photographed between 1895 and 1903, and again between 1937 and 1946. He concluded that better quality forage might have been available in some spots at the turn of the century, but his general impression was that there has been little change in the volume of growth during the 50-year interval, and therefore that grazing was not a primary cause of arroyo cutting.

It is unlikely that overgrazing was the dominant factor in starting the channel trenching in western Fresno County, because traces of older gullies on some fans indicate that entrenched channels existed before sheep were brought into California in 1853 and before large-scale cattle ranching was introduced in western Fresno County.

Severe reduction in the vegetative cover might increase the runoff to the streams, and perhaps Bryan (1928, p. 281) was close to the truth when he said that " . . . the introduction of livestock and the ensuing overgrazing should be regarded as a mere trigger pull which timed a change about to take place".

Variation in the intensity and amount of rainfall is one possible regional cause for the channel trenching. Richardson (1945, p. 17) and Antevs (1952, p. 382) state that the vegetative cover is the immediate factor controlling erosion which in turn is controlled by precipitation.

The precipitation records of five U. S. Weather Bureau stations were examined to determine if climatic trends coincided with the time of channel trenching. These weather stations are: New Idria in the Diablo Range; Coalinga in a sheltered valley adjacent to the San Joaquin Valley; Mendota Dam station in the trough of the San Joaquin Valley; Fresno on the east side of the San Joaquin Valley; and Sacramento in the southern Sacramento Valley.

The trends of the annual rainfall (Weather Bureau climatic year July 1 to June 30) at the five stations are shown in figure 5; second order moving averages were used for all control points to remove minor irregularities in the curves. The patterns of rainfall at the stations are similar despite the variety of physiographic settings and the distances between stations. This similarity suggests that the cyclonic storms that move southeastward across the Pacific Coast are a common source of rainfall for all the stations. Annual rainfall decreases generally from north to south and increases with an increase in altitude. The New Idria station, at an altitude of 2650 feet, receives only slightly less rain than the Sacramento station, 150 miles to the north at an altitude of 35 feet.

The period of highest rainfall, well defined at all the stations, was between 1935 and 1945. Although several peaks of excessive rainfall between 1850 and 1910 are shown on the Sacramento record, the broadest, highest peak occurred in the general period 1875 to 1895. The Fresno record shows highs during the same time interval. These intervals appear to coincide with the two periods of channel trenching reported since 1854. This conclusion contrasts with the work of Thornthwaite, Sharpe, and Dosch (1942) and Leopold (1951b) who, in their discussions of accelerated erosion in the Southwest, have suggested that there is no significant relationship between annual precipitation and periods of arroyo cutting.

Leopold (1951b) pointed out that the New Mexico records show significant trends in the number of rains of a given size group. He shows that between 1850 and 1870 there was a decrease in the annual number of rains of 0.01 to 0.49 inch in a day and points out that this decrease would weaken

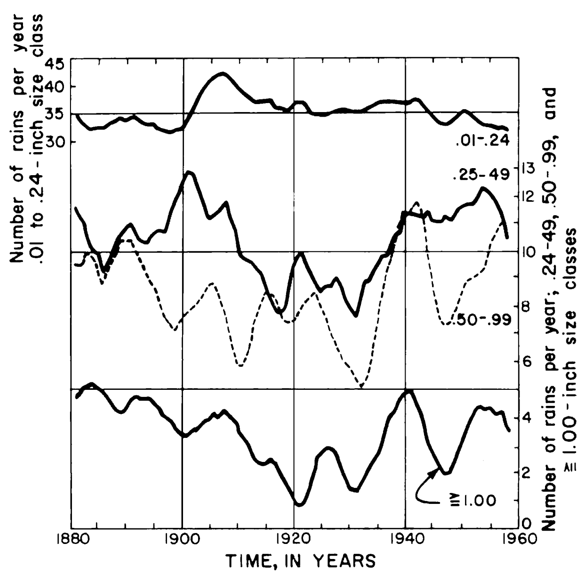


Fig. 6. Trends of daily rainfall size classes, 1881-1958, Sacramento, California. Three year moving average of a five year moving average.

protective vegetation, such as summer grasses. This combined with a high frequency of large rains at some stations apparently contributed to the accelerated erosion. The trends of the daily rainfall size classes of California stations were analyzed in about the same way as Leopold treated the New Mexico data.

Figure 6 shows the trends of some daily rainfall size classes at Sacramento. Rainfall of 0.01 to 0.24 inch per day would promote the growth of grasses but would provide little runoff. The number of rains in this size class was at its lowest level for the years between 1881 and 1900 and about average between 1930 and 1945. But between 1875 and 1895 and 1935 and 1945 the number of days of rainfall of more than 0.50 inch were among the highest on record. These heavy rains would produce more runoff to erode the stream channels. Again, the years that had a high frequency of large daily rainfall coincide in general with the times of known arroyo cutting in western Fresno County. A comparison of figures 5 and 6 shows that periods of large annual rainfall were also periods of more than the usual number of large daily rainfalls. This suggests that in this region years of high annual rainfall coincide with years of an abnormally large number of large daily rainfalls.

Mendota Dam is the only station in western Fresno County for which daily rainfall records are available as far back as 1900. The trend in the amounts of daily rainfall are shown in figure 7. Daily rainfalls greater than 0.50 inch are not as common at Mendota Dam as at Sacramento. However, the

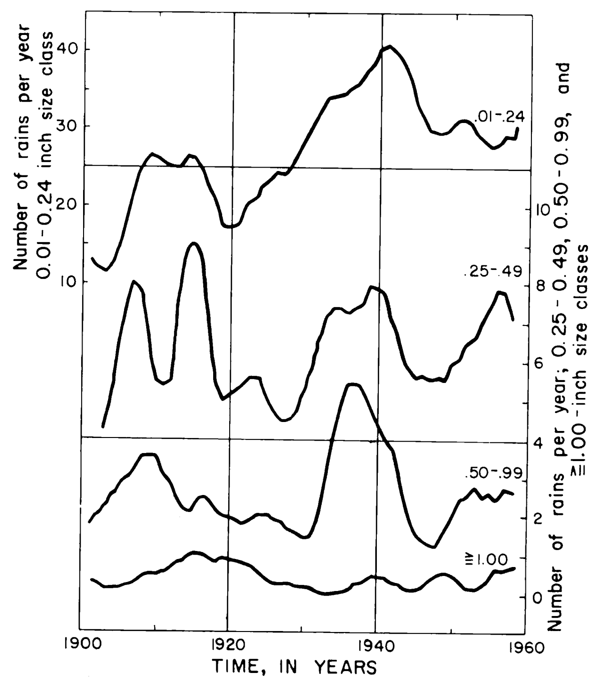


Fig. 7. Trends of daily rainfall size classes, 1901-1958, Mendota Dam, California. Three year moving average of a five year moving average.

period between 1930 and 1945 shows the same general characteristics as the Sacramento record, except that there was a high frequency of daily rainfalls in the 0.01 to 0.24 inch size class as well as a marked increase in the 0.50 to 0.99 size class. The pronounced peak in the 0.50 to 0.99 size class coincides with the period of high annual rainfall and with the time at which channel deepening was known to have occurred.

The rainfall analyses offer a reason for the arroyo cutting that began on some streams about 1880. The periods of most of the arroyo cutting (1875 to 1895, 1935 to 1945) also were periods of above normal daily and annual rainfall. A combination of high frequency of the large rainfalls and a low frequency of the small rainfalls coincided to produce above normal runoff, thus allowing the above normal runoff to erode the stream channels. Once started, channels probably became semipermanent although they may have been partly filled during dry periods such as 1920 to 1935 and 1945 to 1952. Figures 6 and 7 show a low frequency of large rainfalls during dry-year periods and therefore few large runoffs to keep the channels scoured of the material deposited in them by small amounts of runoff. About 1935 the channels began to be deepened again, coincident with another period of high frequency of large daily rainfalls. Renewal of channel entrenchment made the low terraces within the channels.

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