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ART. XXVII.—*Recent Stream Trenching in the Semi-arid Portion of Southwestern New Mexico, a Result of Removal of Vegetation Cover* ;* by JOHN LYON RICH.

A CONSPICUOUS development of recent stream trenches in the valleys of many of the temporary streams of the western states is a feature of such widespread and common occurrence that it cannot be assigned to accidental causes, but calls for an explanation which shall have more than a local application. This trenching is particularly well developed in portions of southwestern New Mexico. Here it is apparently an effect of the removal of vegetation cover by excessive grazing. A brief description of the nature of the trenching and a statement of the evidence on which the above explanation of the phenomenon is based is the purpose of the following discussion.

The portion of New Mexico on which our study is particularly based is included within the Silver City quadrangle in the southwestern part of the state. The quadrangle may be roughly divided into two physiographic units, a mountainous portion and a desert plain formed by the accumulation of gravels derived from the mountains. Of the whole area of the quadrangle, about one-third is covered by these desert accumulations.

The climate is semi-arid, with an average rainfall in the neighborhood of 18 inches in the mountainous parts, and considerably less in the lower, desert portions. The precipitation comes mostly in the form of showers during the hot summer months, from about the middle of June until the latter part of September. General rains are not of common occurrence. As a result of these climatic conditions there are no permanent streams in the area outside the higher mountains, and even in

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the mountains, the permanent streams are of small consequence except when swollen by the summer rains.

In the following discussion when we speak of streams we would be understood as referring to the temporary streams which carry water only during, or immediately after, a storm.

A conspicuous feature of the topography of the Silver City quadrangle, outside the more rugged mountains, is a pronounced stream trenching in all the valleys; a trenching of recent date which is evidently still in progress. Along the steep-walled mountain gorges this feature is, of course, not evident, but outside of the higher mountains it would be difficult

FIG. 1.

FIG. 1. View showing typical features along the course of the Cane Spring Canyon stream across the piedmont fan. The photograph shows recent trench in the foreground cut into alluvial valley filling, piedmont gravels in the middle distance along the sides of the valley, and mountains at source of the stream in background. Note the bowlders and flood débris spread out over the surface of the alluvial flat.

to name a valley in which it is not conspicuous. The features shown in different parts of the quadrangle are so similar that a description of one of the most typical valleys will serve as a characterization of the general conditions throughout the area, and as a basis for a discussion of the causes of the trenching. For such a description the valley called Cane Spring Canyon, along which some of the accompanying photographs were taken, will admirably serve our purpose.

The stream, which is a temporary one, flowing only in times of flood, heads with several branches in a region of rocky hills of moderate height. Within the hills it has a drainage area of

about seven square miles. After leaving the hills the stream flows with an average slope of 120 feet per mile for about 5 miles across a dissected piedmont gravel accumulation to the Mangas, a larger temporary stream which, about 15 miles below, empties into the Gila, a good-sized permanent stream.

The salient features of the Cane Spring valley in its course across the piedmont gravels are well shown in the accompanying photograph (fig. 1). There are first the steep-sided valley walls of partly cemented desert conglomerate from 50 to 150 feet high; then, forming the valley floor, comes an alluvial flat, nearly level in cross section; and finally, cutting sharply

FIG. 2.

FIG. 2. Recent stream trench working back into the still undissected flat of a small tributary of Cane Spring Canyon. This picture was taken near the site of fig. 1.

into the material of this flat, is the recent stream trench from 50 to 200 feet in width and from 2 to 15 feet in depth, and bounded, as a rule, by vertical walls of alluvium.

The history of the valley as revealed by its cross section may be briefly summarized as follows: The valley was initiated on the surface of the piedmont desert fan. For some reason—an uplift of the land or a change in climatic conditions—the stream began cutting through the fan. This cutting continued until a valley from one-eighth to one-fourth mile in width and locally over 150 feet in depth had been formed. Following this period of cutting came one of filling, during which the alluvial flats in the valley were formed. Lastly, the streams began cutting again, forming the trenches whose origin we are

seeking. These trenches are still working their way up the tributary valleys by headwater recession and sapping. This is well illustrated by fig. 2, which shows the trench working back into the still undissected flat of a small tributary.

The alluvial flats are composed of fine sandy loam and gravel. The latter occurs in the form of irregular lenses interspersed through the loam. Its component pebbles range in size up to 5, 6, or 8 inches in diameter, but seldom larger, and even these sizes are uncommon. Two or three inches in diameter would represent a fair average for the coarser gravel. From this there is every gradation down to fine sand. The stratification is indistinct, but may usually be made out. In characteristic exposure the material stands up in vertical bluffs. From its general make-up and composition there can be no doubt that it is a stream deposit of the type formed by aggrading temporary streams.

Fairly uniform conditions of deposition are shown by the nature of the sediment. That heavy floods were not common during the time of deposition is indicated by the lack of heavy boulders in the deposit. The valley filling is not an ordinary flood plain such as may be formed along permanent streams, for, in the first place, the slope of the valley bottom, 120 feet per mile, is too great for the formation of a flood plain so wide and flat as the one we are considering; and in the second place, the surface of the flat is not a graded slope along the stream course. Alluvial fans from the valley sides form an integral part of the valley filling. Their prominence, and their effect in breaking the normal valley profile, indicate that a large proportion of the filling came from the sides down the short steep tributaries rather than down the main valley.

On the whole, then, the character of the valley filling indicates accumulation under conditions such that there was no permanent stream in the main valley, and such that accumulations from the sides were as important as those from the main stream. These conditions would be realized under an arid or semi-arid climate during the time of filling.

In the bottoms of the trenches and sometimes spread out over the surface of the flats above, there is *coarse* stream gravel with boulders ranging up to two feet in diameter, and much of it evidently of very recent deposition. This coarse material presents a marked and significant contrast to the fine textured alluvial valley filling revealed in the side walls of the trenches. The significance lies in the fact that its transportation must have required a volume of water much greater than that of the finer alluvial material on which it rests. Its presence overlying the finer material and the fact that it is associated with flood débris in such a manner as to prove its

deposition within a very few years at most, clearly indicates that, in recent times, the maximum volume of water coming down the valley in times of flood has been greater than while the alluvium was accumulating.

On the basis of such evidence of the increased volume of flood waters, we are justified in suspecting that the waters of these floods may have been responsible for the cutting of the stream trenches in question. In an endeavor to explain the trenching it is, therefore, necessary to look for the cause of the increased volume of the flood waters.

Such an increase may be the result of one or the other of two conditions or a combination of both. These conditions are: either an increase in the amount of water by increased precipitation, or a more rapid run-off with no increase in precipitation. An analysis of the results of each of these two conditions taken separately may serve to indicate which is most probably the responsible one in the case at hand.

Taking first the condition of increased precipitation, we will start with a semi-arid climate, such that the streams are not permanent and are silting up their valleys—in other words, with conditions as we conceive them to have been at the time of the formation of the valley fill of Cane Spring Canyon and other valleys of the region. There would undoubtedly be some vegetation which might serve as a fairly efficient cover and constitute an important factor in the absence of heavy floods. With an increase in precipitation we should expect the vegetation to become more luxuriant and more effective as a protective covering; in this way perhaps equaling or overbalancing the tendency of the stream toward cutting, resulting from the increased volume of water. Even though the storms became heavier, the run-off would be slower, so that it is likely that, until the time that the precipitation became so great that the streams became permanent, there would be little, if any, increased tendency toward cutting.

Considering next the second factor; if we have a semi-arid climate favorable to the formation of a fairly efficient vegetation cover, and the balance between erosion and deposition is so adjusted that the streams are silting up with fine material; with considerable rainfall at certain times of the year, prevented, however, by the vegetation cover from forming heavy floods, and if by some means we remove the vegetation cover without changing the amount or distribution of the rainfall, marked results of a different nature will follow. The rain, still as heavy as before, will fall on a bare surface unprotected by vegetation and with little capacity to hold in reserve the excess precipitation. A rapid run-off in the form of floods must result. These floods, rushing down the valleys, will have

power to cut where before deposition was in progress. Good sized bowlders will be carried down and strewn along the stream courses and over the flats. The result of such floods would be manifest in the trenching of the valley bottoms and the spreading out over the flats of bowlders larger than those in the valley fill itself. They would produce conditions exactly the same as those we have described as characteristic of the valleys of the Silver City quadrangle.

Having been led to the belief that a removal of the vegetation cover would be competent to cause stream trenching, it becomes pertinent that we inquire whether there is evidence of such a removal of cover in the region under discussion. The answer is in the affirmative.

An efficient cause for the removal of such a vegetation cover is the excessive grazing to which the country has been subjected during the past few years. A good account of the former conditions of the region was given me by Mr. MacMillan, a rancher living in the Mangas valley, who has been a resident of the region since 1876. His statement of the early conditions is substantiated by that of all the old residents of the neighborhood with whom I had occasion to talk. According to him there was formerly much more timber than at present along the Mangas valley and on the piedmont desert fans, but probably never enough to modify materially the run-off of the water. More important than the timber, there was, along the valley bottoms, as well as on the hills and desert fans, a thick carpet of grass. This is reported to have been about knee high and quite thick. Along the valley bottoms it was thick enough to be cut for hay by the ranchers.

Such were the conditions in places where now scarcely a spear of grass can be found. The cattle, often forced to extremes of hunger so great that, sometimes, in a single season, as during the past year, they die by the hundreds of starvation alone, have kept the grass eaten so closely that there has been little opportunity for natural maturing and seeding, with the result that not only has the grass been kept closely cropped, but it has been to a large extent exterminated. The vegetation cover has been reduced from one of relatively high efficiency to almost nothing.

Coincident with the removal of the vegetation has come an increase in the violence of the floods. In the early days, according to MacMillan and others, heavy floods were rare. The storms were just as severe as now, but the run-off was slower. For instance, when a heavy storm occurred in the Burro Mountains, at the head waters of the Mangas, the water would continue to come down the valley for two or three days, whereas now it all comes at once in a single flood. When

overstocking had reduced the vegetation cover the first floods began to come, and have been coming with increased frequency and violence every year since.

Having found from an inductive study that the trenching and other conditions of the valleys might be explained by a removal of vegetation cover, and having found from the his-

FIG. 3.

FIG. 3. Typical recent stream trench in the Mangas valley. Note the flat alluvial valley filling in which the trench is cut.

FIG. 4.

FIG. 4. Another view showing characteristic recent stream trenching. This is near the head of a small valley, but the trench is well developed.

torical evidence that such a reduction has actually taken place, with an accompaniment of increased floods, we may further test the theory by inquiring whether the formation of the trenches corresponds in time with the removal of the vegetation. On this point the testimony of the settlers is unanimous that, in the early days, there were few, if any, trenches in the valley bottoms, and that trenching has followed the appearance of the heavy floods. The deep trenches in the Mangas, one of which is shown in the photograph (fig. 3), have practically all been formed within the past 20 or 30 years, and are still deepening. The town of Silver City is built partly on an alluvial flat, such as those we have described. Running through the town is a trench or gulley cut through the alluvial valley filling to a depth of at least 20 feet and with a width of about 100 feet. A little over 15 years ago the site of this trench was one of the main streets of the town. During a severe storm the street was partly washed out and the trench begun. This trench has been cut deeper every year until the present condition has been reached.

From physiographic evidence of this sort, and from the testimony of the early settlers, there is good proof that the trenching is of recent date, corresponding in time with the removal of the grass by too close pasturing.

Our own observations, in so far as we had opportunity to make them in the short space of one summer, bear out the statements of Mr. MacMillan and others as to the normal vegetation conditions. In certain portions of the Silver City quadrangle, which were so far removed from water that the cattle seldom visited them, we found a fairly good cover of grass. These portions were on rocky hills of lava, never, at the best, fitted to maintain a great amount of vegetation, so that in the more fertile valley bottoms and on the gravel plains one would expect a good growth of grass. Within the Fort Bayard military reservation there is a tract of land which has been kept fenced for several years, and has been subjected to very slight grazing. Within this area the grass grows thick and often knee high. There can be no doubt that this grass as a covering is efficient, both in preventing a rapid run-off, and, on account of the sod which is formed, directly hindering stream cutting. Mr. MacMillan reports that in a watershed which he has kept fenced for several years and has not allowed to be closely pastured, the stream trenches which had begun to form before the fencing are gradually filling up.

The conspicuous nature of the physiographic results of overstocking of a region, and the rapidity with which they are brought about are surprising, and afford a striking illustration of the influence of man on geologic processes. If the grazing

of a region for a period of 40 years, more or less, has produced so great results, it requires no great stretch of the imagination to picture the conditions in this section a few centuries hence if the same processes continue, as there is every reason to believe they will.

It is not alone within the area of the Silver City quadrangle that stream trenching is a conspicuous feature, for it is common in many parts of the west. In traveling through the states of New Mexico, Colorado and Wyoming, one finds that this trenched condition is widespread. The recency of the trenching is indicated by the fact that it is still in progress, and the gulleys are still working back towards the heads of the smaller tributaries.

In making a wider application of the principles of stream trenching which we have outlined, it is evident that, since the trenching is the result of the removal of vegetation cover, we will be likely to find it only in those regions whose normal climate is such that the normal vegetation would be luxuriant enough to become an important factor in the conservation of the rainfall, and in the protection of the valley bottoms from direct erosion. In such regions the overstocking, to which the west has been subjected, will have so reduced the cover as to cause increased floods with accompanying stream trenching. In regions normally too arid for the formation of an efficient vegetation cover the trenching should not be apparent.

Within the area of the Silver City quadrangle alone there is some evidence bearing on this point. The extreme southeastern corner of the sheet is lower and much more arid than the rest of the area, and it was noted that here the trenching is not so well developed as in the portions of the quadrangle which receive a greater precipitation. In order to thoroughly test the principle, comparison should be made between portions of the state, or of other states, which have climatic conditions similar to those of the Silver City region and other portions where climate is distinctly more arid, as, for instance, portions of southern New Mexico and Arizona.