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SOIL AND WATER ECONOMY IN THE PUEBLO SOUTHWEST

II. Evaluation of Primitive Methods of Conservation

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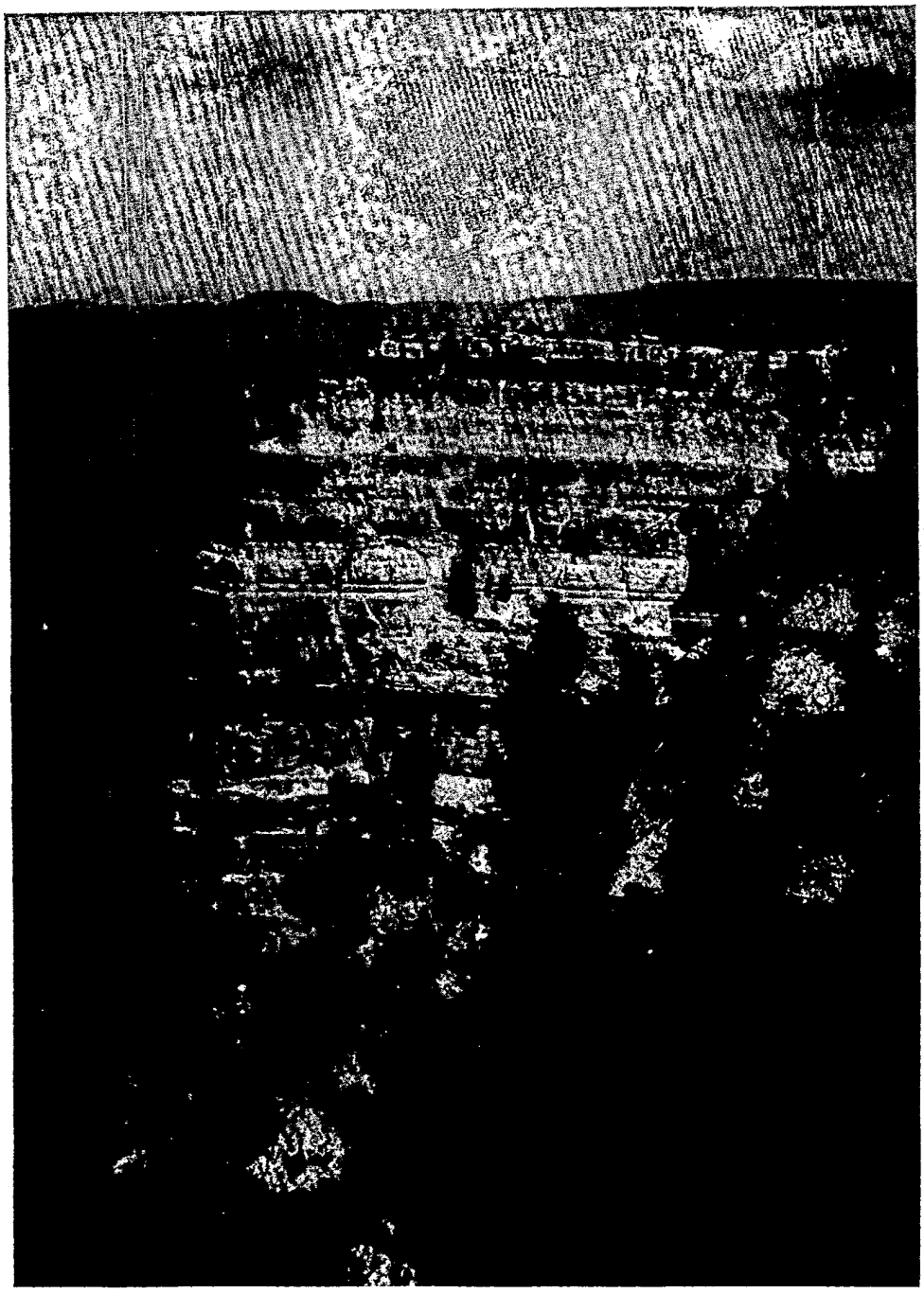
In the work carried out so far, we have found five principal types of conservation practice which were used by the early Pueblo farmers. The first of these consisted of boulder bench terraces which received local run-off from adjacent slopes, and so supplemented the rainfall by adding the precipitation from tracts several times as large as that on which the crop was planted. Many such plots were tiny in size, even 8 by 10 feet in area, but in most cases consisted of a series of two or three boulder checks which would have helped to retain run-off coming onto small gardens 75 to 100 feet long by 20 to 30 feet wide. The large terraced site on the Walhalla Plateau is an example of field scale water conservation upon this type of area, where local run-off was arrested. Very few terraces of this sort were on level land, and even with gradients no steeper than 2½ to 3 per cent. there has been a gradual loss of surface soil. In their simplest form boulder bench terraces merely reduced the velocity of flow of run-off water, thereby increasing the water intake into the soil. It is probable that this type of moisture- and soil-saving dam was first constructed after some early cultivator observed that water was retarded and soil retained by fallen tree trunks which lay across small drainage depressions. Where rocks supported and reinforced the tree branches or trunks it was found that the structure was likely to be more permanent. The natural occurrence of simple wood and rock water-arresting checks has often been observed by us at Mesa Verde and at other points in the Pueblo country, and such demonstrations could not have failed to attract the attention of a primitive cultivator.

The effectiveness of the ancient boulder and rock bench terraces depended on the steepness of the slope on which the structure was placed and on the care with which the boulder or rock wall was constructed. On slopes of 6 to 8 per cent. there was little retention of soil, but on gentle slopes, under 3 to 4 per cent., terraces of this class have effectively held soils of stable structure until the wall was broached by floods.

The use of land receiving local run-off in present-day Pueblo agriculture can be seen in the bean fields adjacent to the Hopi mesas or the corn fields at Nutria on the Zuni reservation, which are supplied with additional water from surrounding hill slopes.

A second group of conservation installations which can still be identified, both in the northern and southern portions of the Pueblo country, were the village check dam plots, placed in the upper part of any convenient watercourse where the grade was not too steep and the stream flow relatively gentle. In most cases, other than at Mesa Verde, these check dam gardens were on a slope of 4 to 6 per cent., so that the resulting plot had a moderate grade of 1½ to 3 per cent. When first installed these plots were probably effective devices to conserve soil and water as the soil was of moderate depth and surplus water filled the root zone after each rainfall which produced run-off. There was, however, some washing away of the sloping surface soil so the greater part of

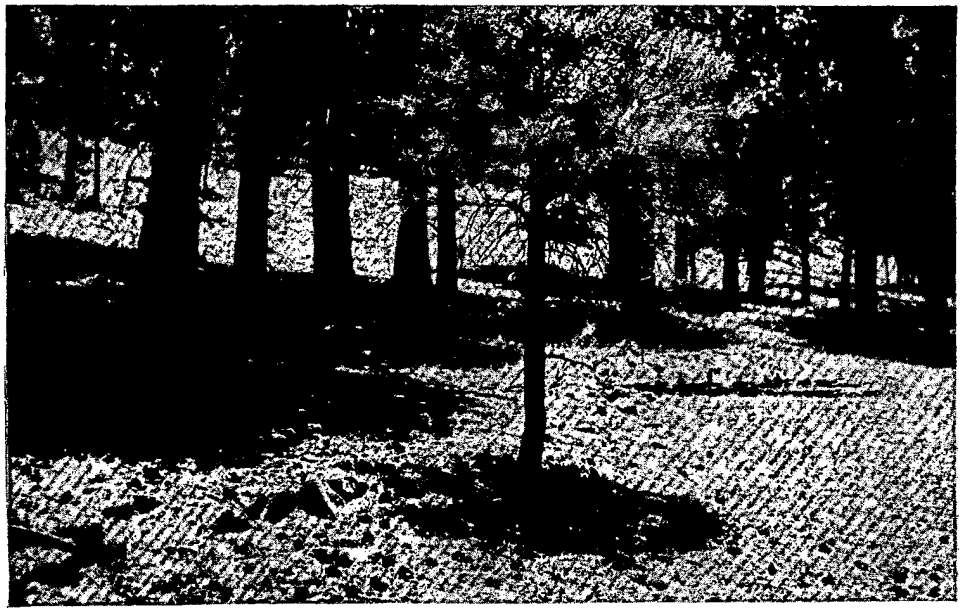


ANGELS WINDOW, NORTH RIM, GRAND CANYON, NEAR WALHALLA PLATEAU.

these installations could not be classed as a method of stabilizing a permanent system of agriculture. At Mesa Verde, this type of garden plot had the best development which we have discovered so far. A definite type of construction can be recognized, with the ends of the checks carefully tied in to the sides of the stream channel and the dam itself built up to a sufficient height so that a level plot resulted. The portions of these plots which now remain at the sides of the streams indicate that excellent small gardens were formed, with an adequate depth of soil for corn, beans or squash. While the dams were kept in repair the Mesa Verde type of garden check may be classed as a splendid installation well designed to conserve soil and utilize storm run-off for crop production.

A third type of conservation practice was the use of flood water distributing ditches to bring flash stream flow or surface run-off onto corn land or garden patches. This conservation measure had its greatest development in the widespread ditch system of the Salt River Valley, which one of us[1] has discussed previously. These ditches are often described as a system of irrigating ditches. From all the evidence of the general use of impounded flood water for crop production in the Southwest, it appears probable that the Salt River Valley system was a well-organized method of distributing and spreading flood flow.

The Mesa Verde flood water ditch is the only instance we have discovered so far of this method of handling water in the northern Pueblo country. The ditch trapped a large flow of run-off, both from the uplands and from ground immediately adjacent to it. Along the ditch there are remains of small field checks and recognizable areas of probable diversion onto corn land. These accessory methods of slowing up run-off, impounded soil and increased the penetration of water, thereby retaining a greater supply of moisture for plant growth.



BOULDER TERRACES OF SMALL ROCK

UPPER PART OF A LARGE TERRACED SITE ON THE WALHALLA PLATEAU, GRAND CANYON.

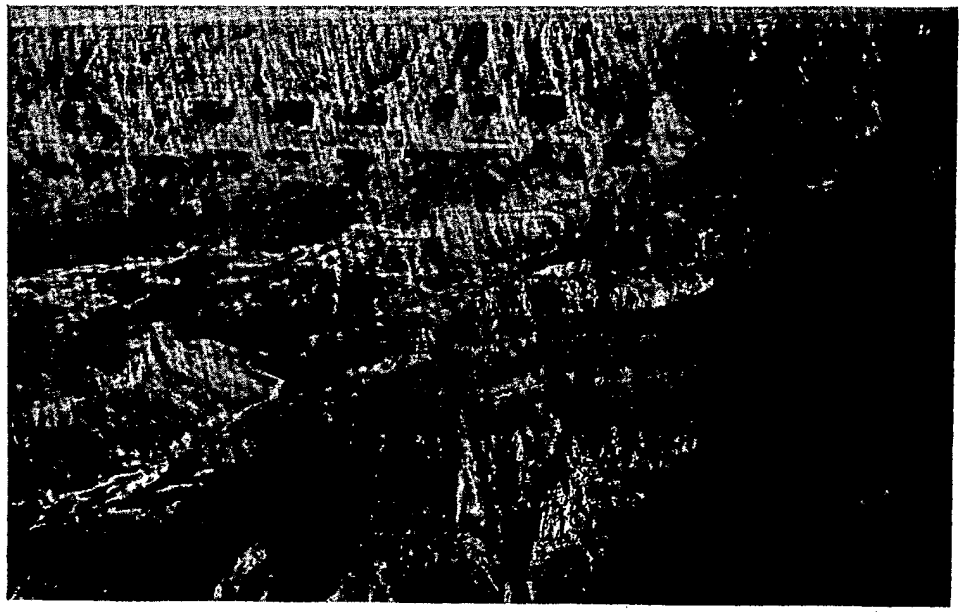
The wide, relatively flat channel of this ditch suggests that it may have been planted to corn in the same manner that natural flood waterways in modern Hopi or Zuni corn fields are still treated.

A fourth method of conservation of water was the use of springs or small, live streams for the irrigation of village garden plots. The Tohalena Gardens, near Navajo Mountain, were an example of a garden area, which was supplied with water, partly by run-off from the hills to the northeast and partly by flow from a live spring. The rainfall and spring flow were conserved by throwing up banks to surround the plots which were frequently built up on step-like terraces. Gardens of this type, which have been cultivated intensively by the Hopis since early days, can be seen at Hotevilla and Wipo Springs, and on a smaller scale wherever continuous flow of water was available adjacent to the Hopi villages.

The fifth and most important practice consisted in cropping the flood water fields where the principal corn crops of the villages were produced. By the use of temporary brush and soil dams, occasionally reinforced with rock, water from flash floods was diverted from its normal channel across adjacent fields where it could be impounded and absorbed into the soil. Strangely enough, even though these tracts were the largest areas of the crop land that was planted, they are often the most difficult primitive sites to recognize at the present day. This is because a relatively small amount of rock was used in the water-spreading dams which deflected the water across the corn land.

A typical flood plain field was almost level with a slight fall of about 1 per cent. so that it was easy to distribute the water over the entire area. Cushing[12] was one of the first to make detailed

[12] Frank H. Cushing, "Zuni Breadstuff," New York Museum of the American Indian, Heye Foundation, 1920.



VIEW OF THE NORTH RIM OF THE GRAND CANYON
NEAR ONE OF THE VILLAGE SITES ON THE WALHALLA PLATEAU.

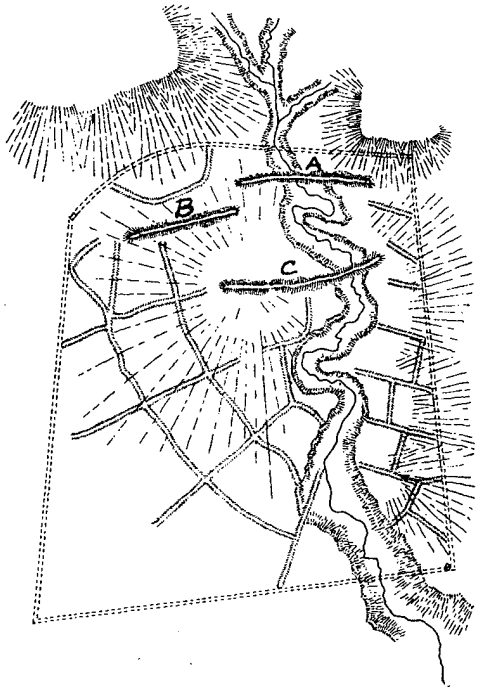


FIG. 4. PLAN OF ZUNI CORNFIELD IN 1884. AFTER CUSHING.

studies of flood water irrigation by Pueblo methods. In his residence at Zuni as a member of the tribe from 1880–85 he interested himself in all the agricultural operations, as well as in the ceremonial life of the tribe. The manner in which a Zuni cultivator handled the flood water flow on a field in 1884 is shown in Fig. 4. A dam of earth and brush was placed across the stream at the top of the field at A. This deflected the water over to the secondary spreader B, and as the water swept round B, the earth dikes were cut through and then closed to retain impounded water. An additional dam at C again kept the water from flowing down the main channel and helped to turn it over the balance of the field. Cushing notes that it was frequently possible to reclaim a sandy flood plain for agricultural use by turning silty flows out over the sandy land for a season or two until the water-holding capacity of the sandy soil had been improved.

Essentially the same process of flood irrigation can be seen on many of the Zuni fields now in use and a careful study was made of the methods followed on all the Zuni corn land during the season of 1940, through the cooperation of Melvin Helander, Zuni agent for the Indian Service. The manner of handling the corn land was discussed with a number of the older Zuni, who were all agreed that the practice of flood irrigation traced back to their ancestors. The principal change which has occurred recently has been the introduction of plowing, which is now causing modifications in the early planting technique described by one of us[1] previously. One of the larger fields examined in 1940 had a series of four dams across the stream channel to spread the flood water over the field. The secondary effect of the dams was to keep the stream bed on the same level as the field and prevent the development of gullies. By this method of treatment the stream channel did not always stay in one place, so the entire field, including the stream, was planted in its entirety. A heavy flood flow might alter the course of the main channel and wash out a strip of corn, but the loss was no greater than if the strip of land along the main stream bed had been left free from a crop. Planting corn in the stream also has aided in reducing the turbulence of the flood flow and was one of the few instances where we have seen the corn plant used as an accessory vegetative aid in the control of small flood flows.

The discussions with Zuni cultivators brought out several of the risks to which flood-water farming is subject. At times an excessive amount of sand may be deposited in, and adjacent to, the stream channel so that a part of the land will not retain water sufficiently to carry the crop through periods of drouth. The

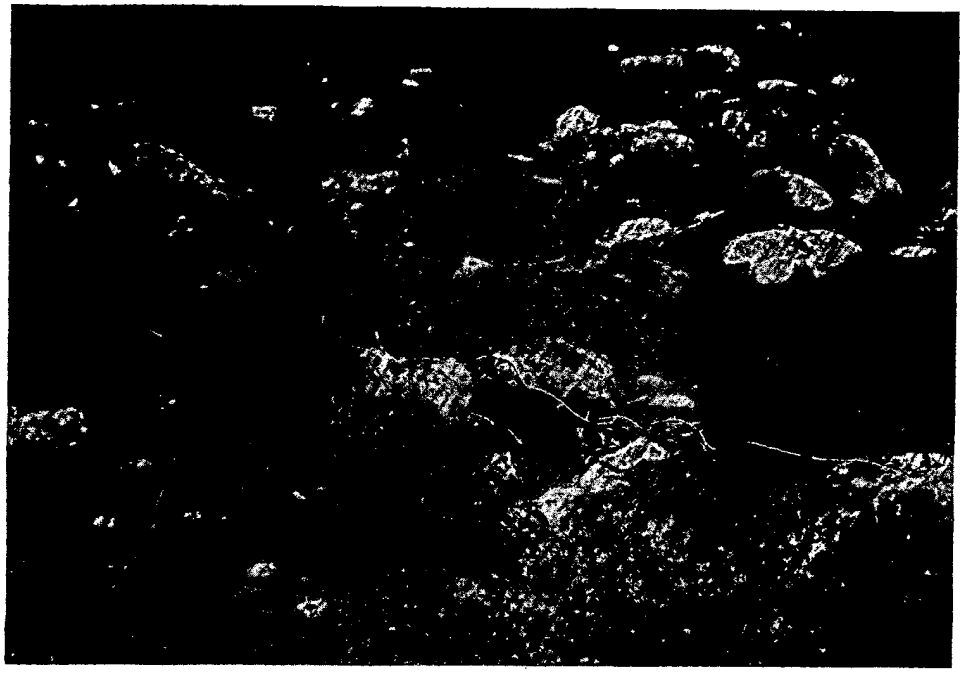
Zuni informants claimed, however, that this condition may be corrected by later flows in the season, but sometimes continues until more silt is deposited in the following year. An exceptionally heavy flood flow occasionally washes out portions of the planted crop, but the philosophic comment was made that the rest of the field would probably yield enough to make up for this loss, because of the extra supply of water received. The only thing which they felt permanently injured a flood-water field was deep trenching or gullying of the stream channel, which would make it impossible to turn water out on the land. Such gullying must be checked by preventive dams as soon as it began. Reagan[13] has indicated his belief in the importance of the filling in of valley flood-water fields in the Pueblo country as a preventive of serious erosion and gullying.

[13] Albert B. Reagan, "Stream Aggradation through Irrigation," *Pan-Am. Geologist*, Vol. 42, No. 5, pp. 335–344, 1924.

The fact that the evidences of the early use of land for flood-water fields is now often difficult to detect makes us urge that archeologists working in the Southwest devote more attention to reporting such information. Certainly a solution of the manner in which the primitive peoples of the Pueblo country lived and adapted themselves to their environment should be of interest to all scientists working in this portion of the country, and warrants a united attack by both agriculturists and archeologists. In the case of some sites, as of Chaco Canyon, the very location of the corn fields which would have supported the large communities residing there has been a matter of question. Several reports quoted by Hodge[14] have suggested that one or more primitive ditches were used to take water from the canyon and irrigate fields at

[14] F. W. Hodge, "Handbook of the American Indians North of Mexico." *Bull.* 30, Bureau Amer. Ethnology, Parts 1 and 2, Washington, 1907–1910. Section on Irrigation, p. 620.

STREAM CHECK DAM, BELOW RAINBOW LODGE, NAVAJO MOUNTAIN.



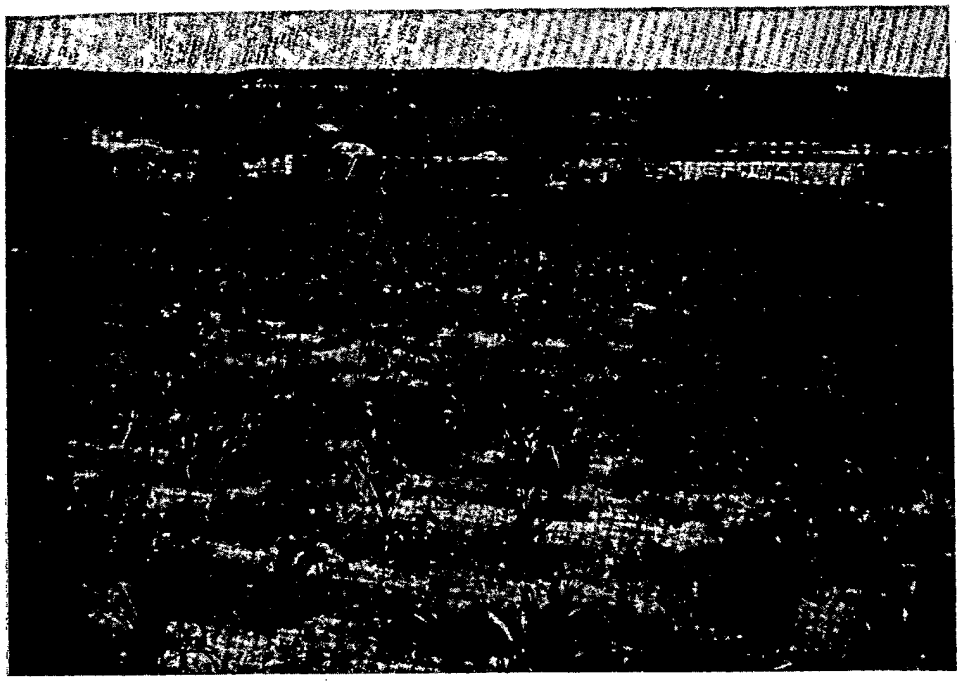
PRIMITIVE BOULDER FIELD CHECK AT TOHALENA GARDENS
ABOUT TWO MILES FROM NAVAJO MOUNTAIN.

some distance from the main villages. There has been some difference of opinion, however, whether these ditches described may not have been constructed by the Navajo during the early period of their residence in the country.

Through the cooperation of the Soil Conservation Service Office at Albuquerque, an examination of the entire area adjacent to Chaco Canyon was made from the air. No signs of a large system of diversion ditches, which would have watered corn land sufficient for the Chaco villages, could be detected. On the other hand, the aerial study of Chaco Canyon and the adjacent Escabada Wash suggested that these two streams had adequate areas of land suitable for flood-water corn fields in the canyon beds, themselves. The main gully running down Chaco Canyon has every appearance of being a channel cut in recent years. Were this channel not present, the stream flow could be spread in many places to form an excellent system of corn fields. When Simpson[15] passed through Chaco Canyon in 1849 he described conditions there in some detail and stated that the stream near his camp not far from Pueblo Wejiji had a width of 8 feet and a depth of 1½ feet and that occasional patches of excellent grama grass were located along the canyon. There was no mention of the deeply trenched gully that the stream now occupies, which apparently had not been cut out at the time of Simpson's visit.

The country surrounding Chaco Canyon is as heavily grazed as the areas we have examined adjacent to Navajo Mountain. It, therefore, seems probable that the rapidity of run-off has increased in modern times with consequent trench-

[15] James H. Simpson, "Report of an Expedition into the Navajo Country in 1849." In reports of the Secretary of War, Senate Ex. Doc. No. 64, 31st Cong., 1st Sess.



ZUNI CORN FIELD AND FARMSTEAD AT NUTRIA
CORN LAND RECEIVES RUN-OFF FROM ADJACENT HILLS.

ing of fields which could originally have been used as flood-water corn land. Even had there been no increase in the rate of run-off, the observations made at Zuni show that catastrophic gullying of corn land can occur in flood-water fields when diversion dams no longer stabilize the channel. Hence, disuse alone might have started the formation of a deep arroyo. It appears probable that reduction in vegetative cover after the time of Simpson's visit has intensified run-off and contributed to the destructive process.

All the ancient conservation installations that we have examined have undergone moderate to severe soil erosion. The period when this erosion took place is difficult to determine at the present day. If soil washing was occurring during the time of early settlement it might account for part of the shift in the prehistoric population. The Pueblo people had no livestock to reduce vegetative cover over a wide extent of surrounding country. They did have an appreciable need for firewood and timber for support of the upper floors of the houses. It is difficult to estimate whether wood and brush cutting would have been so complete that erosion might have been accelerated on the sloping village fields. Our examination of one large terraced site on the North Rim of the Grand Canyon indicated that erosion might have occurred at an early date. This is not the case for the region as a whole.

There is, in fact, considerable evidence that vegetative cover on at least part of the Pueblo country has decreased within historic times with a consequent increase in the susceptibility of appreciable areas to sheet erosion. This is shown in a series of reports of official expeditions made across portions of the Pueblo country in the period of 1846–1857. Lieu-

tenant Colonel Emory[16] accompanied the first United States military expedition into New Mexico in 1846. After the occupation of Sante Fe, Emory was a member of the army which proceeded down the lower Rio Grande, and then turned across the mountains until the Gila was reached and followed to the Colorado. At a number of places in his journal he described the typical vegetation on the lower Rio Grande, which included large patches of grama grass. Later, while crossing the table land enroute to the Gila, he commented on the great abundance of the winter grama grass. Occasional notes were made by Simpson[17] of the supply of grass for teams and stock in his report of the survey of the wagon route from Fort Smith, Arkansas, to Santa Fe, New Mexico, in 1849. Sitgreaves[18] made a journey from Zuni to the Colorado River in 1852, crossing the country below the San Francisco Mountains. In his report he mentioned the excellent grass cover found on the hills away from the stream. Whipple,[19] on his railway survey near the 35th parallel of latitude, crossed the Pueblo country in 1853 approximately along the route of the present Sante Fe Railroad and commented on the thick carpet of grama grass that covered the western hills.

[16] Lt. Col. W. H. Emory, "Notes of a Military Reconnaissance from Fort Leavenworth in Missouri to San Diego, California." (Made in 1846–7 with the advanced guard of the Army of the West). Thirtieth Cong., First Sess., Ex. Doc. No. 41, Feb. 9, 1848, pp. 1–614.

[17] James H. Simpson, U. S. Engineer Dept. Report from the Secretary of War Communicating the report and map of the route from Fort Smith, Arkansas to Santa Fe, N. M., Washington, 1850. U. S. 31st Cong., 1st Sess., Senate Ex. doc. No. 12, 25 pages, 4 maps.

[18] L. Sitgreaves, Report on an Expedition down the Zuni and Colorado Rivers, Senate, 32nd Cong., 2nd Sess., Ex. Doc. No. 59, pp. 1–190, with plates, Washington, 1853.

[19] Lt. A. W. Whipple, "Report of Explorations for a Railway Route near the Thirty-fifth Parallel of Latitude from the Mississippi River to the Pacific Ocean." 33rd Cong., 1st Sess., Ex. Doc. No. 129, pp. 1–154, 1854.

The most detailed report of vegetative growth, however, is that made by Beale[20] covering his survey of the wagon road from Fort Defiance to the Colorado River in 1857. As this route was intended for the use of emigrants to California he made detailed notes on the supply of grass and water for stock and wood for cooking. He summarized his observations as follows: "You will find by my journal that we encamped sometimes without wood and sometimes without water, but never without abundant grass." Recently Lockett[21] has followed the Beale Trail through the Navajo country and has shown photographically the great change which has occurred in loss of vegetative cover and resulting soil erosion at Beale's camp sites, except at a few locations where grazing has been controlled.

Probably the most eroded sites examined by us were those located on the slopes of Navajo Mountain, where the grazing by sheep in late years has been heavy. In addition, the soils at the mountain foot are largely sandy or gravelly in texture, showing poor resistance to erosion.

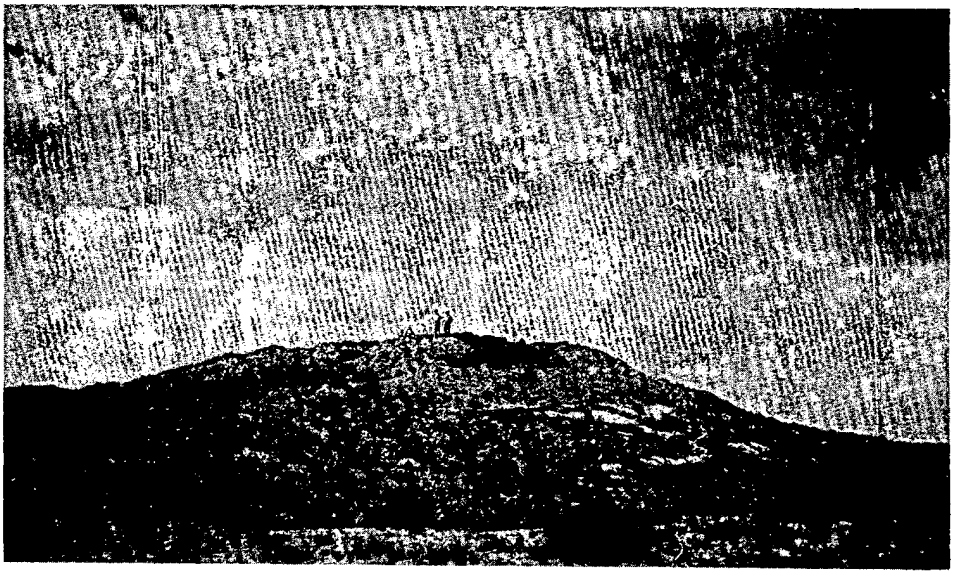
The land at Mesa Verde was grazed only moderately by cattle prior to 1906, and is now protected by better vegetative cover than is found around Navajo Mountain. The soils on most portions of Mesa Verde visited by us are loams or silt loams, which appear to be less erodible than the looser soils of the Navajo Mountain area so that a good portion of the surface horizons are still in place on the mesa.

In a careful review, Bryan[22] examined the records of early travelers and explorers in the Southwest in an endeavor

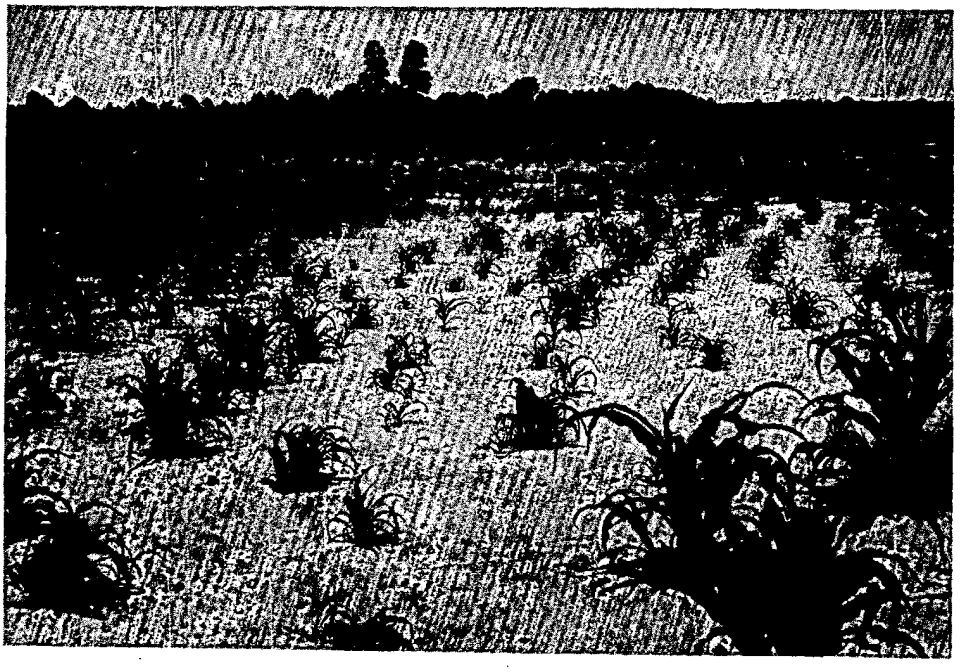
[20] E. F. Beale, "Wagon Road from Fort Defiance to the Colorado River." House of Representatives. Executive Doc. No. 124, 35th Cong., 1st Sess., Washington, 1858, pp. 1–87.

[21] H. C. Lockett, "Along the Beale Trail," Education Div., Office Indian Affairs, U. S. Dept. of Interior, 1939, pp. 1–56.

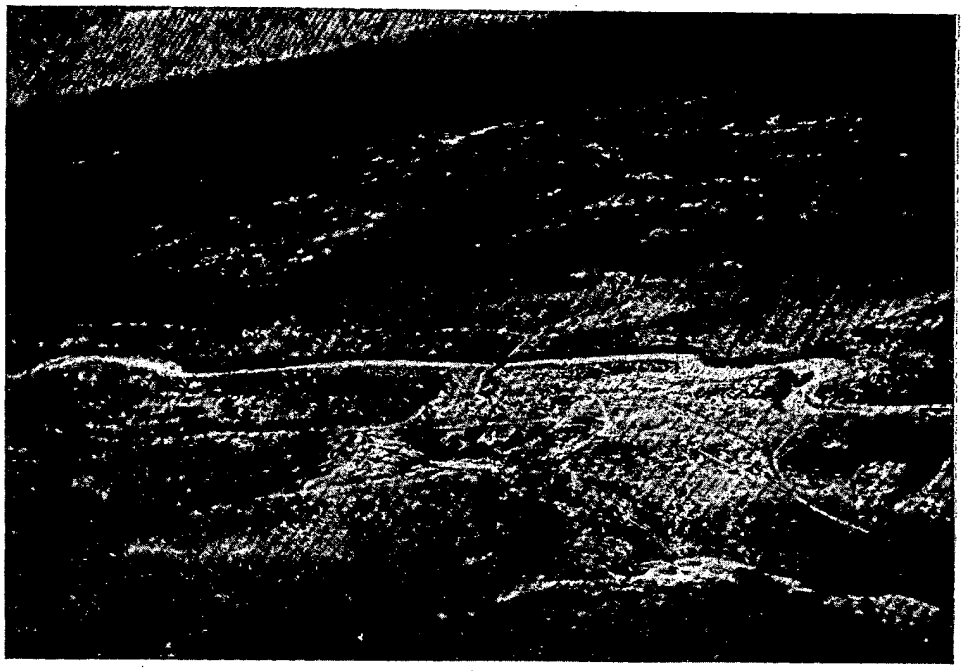
[22] Kirk Bryan, *Science*, 62: 338–344, 1925.



RUINS OF HAWIKUH, SOUTH OF ZUNI
THIS IS THE SITE WHERE CORONADO FIRST MET THE PUEBLO PEOPLE.



TYPICAL FLOOD WATER FIELD ON THE ZUNI RESERVATION
THE PLANTED STREAM CHANNEL IS IN THE IMMEDIATE FOREGROUND.



VIEW OF PUEBLO BONITO AND CHACO CANYON FROM THE AIR
SHOWING THE DEEP STREAM GULLY WHICH HAS APPARENTLY DEVELOPED IN HISTORIC TIMES.

to date the cutting of arroyos in the Southwest. He concluded that active cutting of most of these arroyos (channels) was initiated within the last one hundred years. The present period of arroyo cutting in the semi-arid Southwest coincides, then, with the period of decline in the density of vegetation. Along with other evidence, Bryan's conclusion gives support to our belief that a considerable part of the sheet erosion on ancient agricultural sites, now abandoned, has taken place in comparatively recent time.

Conclusions

(1) The conservation practices examined at four early centers of Pueblo culture had excellent value as water conserving devices. Essentially the same methods have carried over into present day Pueblo agriculture and are in successful use.

(2) Boulder bench terraces on sloping land, probably never gave effective control of soil erosion, but may have had some value on areas where vegetative cover was sufficient to reduce the velocity of run-off water. Check dam bench terraces built so that a level plot of soil was formed, were excellent soil conserving structures so long as they were repaired and maintained. The flood water irrigation fields, on which the major portion of the early corn crops were raised, had an important place in conserving soil and when handled by the Pueblo methods of water diversion, effectually prevented gullying.

(3) The primitive conservation practices of the early Pueblo farmers demanded constant vigilance to maintain them in use and showed that the agricultural economy of this region was delicately adjusted to the needs of the early communities.