Data and Understanding

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In the year 1534 when Cabeza de Vaca escaped from the aborigines of southern Texas by whom he had been enslaved for six years, he made his way on foot from the vicinity of Galveston to the west coast of Mexico. Although his *Relación* was not printed until 1542, the verbal report of Cabeza de Vaca gave impetus to the growing interest in exploration of New Spain. Estevanico, the black, one of de Vaca's companions, served as guide to Fray Marcos de Niza on the first Spanish reconnaissance to reach the village of Zuni in New Mexico.

The earliest Spanish exploring parties hoped to find riches, but expected to acquire, at the least, facts. These "gentlemen of high quality," as Castañeda called them, wanted to see for themselves whether the cities of Cibola had streets of silver. Hearsay was not enough. Rumor was to be replaced by first-hand knowledge.

Without discounting the hope for personal gain, these men presumably were fired with some further intellectual and spiritual motivation, among which must have been the desire for facts about these parts where we are assembled. Inscription Rock, only a few miles west of Albuquerque, bears illuminating tidbits of history. Don Diego de Vargas, says the carved inscription of 1692, came here "A su costa"—at his own expense.

We are attempting to survey and correlate some of the facts which people have gained about the nature of semi-arid lands. We are better off than the early Spanish explorers, for in the intervening period data and information have been accumulated in scope and in detail beyond the imagination of our predecessors. We have

available excellent maps, knowledge of the soils and of the rocks, both at the surface and below the ground, measurements of precipitation, descriptions of the vegetation, data on the flow of streams, experience in the use, if not the husbandry, of the land.

It is true that for the purposes of our complex civilization, the need for additional data has far outstripped the programs of fact-finding. But it appears that an indefinite expansion of the collection of routine measurements would still leave something lacking. I draw the distinction between measurement data and understanding; between the collection of facts and knowledge of processes and interrelationships. Although we have a wealth of data, our understanding of the semi-arid environment is poor.

Understanding the physical and biologic processes operating in an environment is important for living in and with the land. As an example, let us look briefly at the interrelation of the water and sediment in ephemeral streams, and the problem of valley trenching or arroyo cutting.

The Problem of Arroyo Cutting

Many of the alluvial valleys of New Mexico are gutted by trenchlike gullies. The rapid growth of arroyos in southwestern valleys in the United States accompanied the livestock boom of the late nineteenth century. It is clear that the pressure of livestock on the vegetation has materially contributed to the growth of arroyos. But the problem is more complicated. The first American reconnaissance teams of the Army of the West traversed New Mexico in the fall of 1846, some 20 years before American settlers and their livestock had any appreciable effect on local vegetation. In August of 1846, Lt. Simpson marched from Santa Fé to the Navajo country. He crossed the Rio Puerco near Cabezon. So deep was the arroyo at that place that he had to cut down the 30-foot banks to get his brass cannon across. There is enough evidence of this kind (1, 5) to indicate that in certain valleys large gullies existed before American settlement, even in places far removed from heavy grazing by Spanish livestock. It must be supposed that these arroyos were the result of natural rather than human causes.

Geologic and archaeologic studies have demonstrated several

post-glacial but pre-Columbian periods of erosion followed by aggradation. The last period of erosion prior to the present one can be dated by pottery buried in the alluvium as occurring approximately in the period A.D. 1200–1400 (2). The concurrent trenching of alluvial valleys in that period appears to have occurred at least as far north as Wyoming (6) and south into Texas (3).

The problem is further complicated by difficulty in assessing the effect of fluctuations in climatic factors on the recent episode of erosion. In the hundred years of rainfall record in central New Mexico, no progressive shifts of annual totals are discernible. But there has been a progressive change in the number of rains of various sizes. The period 1850 to 1880 was characterized by a deficiency in small rains and a relatively great proportion of rain events of large magnitude. This might be interpreted to mean that coincident with the wave of settlement and accompanying pressure of livestock in the nineteenth century, climatic factors were particularly adverse to maintenance of physiographic equilibrium (4).

The upshot of these considerations is that in the last century there has been a repetition of a physiographic episode which had occurred more than once in post-glacial time. But the recent valley trenching was influenced to more or less extent by activities of man and his grazing animals. The presettlement periods of valley erosion and subsequent alluviation presumably resulted from changes in climatic elements.

The arroyos cut during the last century have radically changed the contribution of sediment which the alluvial valleys provide to the master stream. This change of sediment inflow has probably contributed to the fact that the bed of the Rio Grande at Albuquerque has gradually risen in recent decades and now stands only slightly below the level of the flood plain on which the center of this city stands. The gullies have dissected the valley flats which were the best agricultural parts of the hinterland. The cutting of an arroyo trench lowers the local ground water table and cienaga grasses give way to less productive vegetation. Water formerly could be diverted from the shallow

channel by a simple brush dam, or even by felling a single tree. With the water flowing in the bottom of a deep trench, a much more elaborate dam is necessary, even to make diversion possible. The flood peaks increase because of loss of natural valley storage, and for this reason also, any diversion works must be more elaborate.

Not everyone living in an arid region can depend on major irrigation projects. To the subsistence homesteader who depends mostly on his own axe, plow, cow, and horse to make a living off the land, valley trenching, as it occurred in New Mexico, was a major calamity.

For the earth scientist the arroyo problem poses many questions, among which are these: (1) Assuming that grazing use has contributed materially as a causal factor in arroyo cutting, can a change in land use, specifically, a reduction in grazing pressure, slow down arroyo growth or perhaps reverse the trend and lead to valley aggradation? (2) How much can small structures, water spreaders, and other minor works retard gully development? (3) What is the future trend of physiographic development in these alluvial valleys under present conditions of land use? On the answers to these practical questions depend a host of decisions which would affect the welfare of many people.

Practical measures, including gully control, watershed treatment, and grazing management, have been applied locally in various degrees over a period of two decades. Additional data have been collected to describe the vegetation, the soils, the streamflow, and the sediment yield. Yet it appears that the answer to these questions is not much closer than it was in 1933.

Need for Fundamental Research

What is lacking is a satisfactory understanding of the hydrologic, physiographic, and biologic mechanisms on which depend the stability or instability of the alluvial valley. In the hope of achieving practical answers, no provision for long-term research in fundamental mechanisms has been made. Although some excellent research was started at Mexican Springs in 1933, lack of continuity of funds forced a curtailment of those efforts and

finally their discontinuance. Individual investigations such as the study of Polacca Wash (8) have not been followed up.

First it seems necessary to improve our understanding of the hydrologic relationships between intensity and amount of precipitation, infiltration, and surface runoff, for combinations of soils and vegetation in semi-arid areas. The small experimental watersheds maintained by the Soil Conservation Service and Forest Service in New Mexico and Arizona are a step in this direction, but lack of adequate funds keeps this effort pitifully small relative to the need for such information.

A second field of needed research is in the hydraulics of flow of sediment-laden water. Particularly deficient is our understanding of the nature of bed and bank roughness and the manner in which sediment in transport affects hydraulic resistance. In most ephemeral channels bed roughness is determined primarily by the dunes or ripples formed by moving sediment. We have few observations and no theoretical concepts on which to build an understanding of this phenomenon.

A third broad field is in the mechanics of gully formation, including hydraulic forces, phenomena in the realm of soil mechanics, and physiographic principles.

Our own recent work has been concerned with these problems, and at least indicates some of the possible approaches which appear fruitful. The work began as a study of interrelations of discharge, width, depth, velocity, slope, and sediment in natural channels. On some of these parameters a plethora of data exists in the records of the regular stream-gaging stations. But in the existing network of measuring stations few measurements have been made on water and sediment flows in ephemeral streams draining 1 to 10 square miles. To obtain measurements for analysis, during three summers of work in Wyoming and New Mexico we chased thunderstorms, trying to reach a storm center in time to observe arroyos in flood. When flow was found we waded out into the arroyo and measured the depth, velocity, and width, and sampled the sediment load. Successive sets of measurements were made during the falling stage of the flow. Later, measurements of channel slope and bed material were made.

This investigation led to results which added something to our knowledge of interrelations of sediment and hydraulic factors in ephemeral channels (7). It emphasized an unexpected similarity between perennial channels in humid areas and the ephemeral channels of semi-arid areas. Certain differences, however, were demonstrated, particularly in sediment load characteristics. These differences appear to be reflected in hydraulic factors, particularly in flow velocity.

The current problems of sediment deposition, of arroyo cutting, land management, and water supply emphasize a present deficiency in our understanding of basic physical mechanisms in this environment. Basic data are necessary for, but do not substitute for, basic research.

We have not extracted all the knowledge it is possible to gain even from records and data already collected. Rainfall measurements must be interpreted with an eye to topography, vegetation, and land use. The arroyo problem presents so complex an interrelation between soils, geology, vegetation, hydraulics, and history, that no single discipline can take precedence over others if understanding is to be achieved. These are only two examples of unsolved problems.

If we are to achieve understanding and not merely content ourselves with the collection of facts, we must bring to the task the zeal implied by the words on Inscription Rock, "A su costa."

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