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TRINCHERAS AND PHYSICAL ENVIRONMENT ALONG THE RIO GAVILAN, CHIHUAHUA, MEXICO

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Laurance C. Herold

Department of Geography
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March 1965

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PREFACE

For over fifteen years, geographers from the University of Denver have been conducting various field studies on terrain features of the arid southwestern United States and northern Mexico. While much of this was of the nature of field training of students, an increasing interest among the faculty developed in the peculiarities of arid morphological phenomena.

In 1961 members of the Geography Department visited the archeological dig at Casas Grandes, Chihuahua, Mexico, where Professor Arnold Withers, Chairman, Department of Anthropology at the University of Denver, was working. During this visit the presence of the "trincheras" in the adjacent Sierra Madres attracted our attention. It soon became apparent that these very widespread phenomena have had a profound influence on the morphology of the terrain in the mountains as well as on the runoff and hydrology.

Subsequently, several reconnaissance trips were made into the mountains, and one brief field study was conducted. This convinced us that the physical characteristics and influences of the trincheras were worthy of more detailed field study. Cooperative work with anthropologists, soil scientists, and others confirmed this.

Most of the data reported in this volume were collected during the summer field session of 1964 under the direct responsibility of Mr. Laurance Herold. Some related and cooperative work by Mr. William Howard on soil and Dr. Robert Ream on vegetation also is reported here.

Without dwelling upon some very serious problems of logistics, it is apparent that this present report more than justifies the earlier estimates of the value of the study. In addition, it now is clear that much more can be learned about the trincheras themselves and the country which they have so profoundly influenced.

Clark N. Crain

ACKNOWLEDGMENTS

The author wishes to take this opportunity to tender his thanks to the numerous persons who assisted greatly in the completion of this research.

Giving valuable aid in preparation for the field work were Marvin Hoover of the Fraser Experimental Forest, U.S. Forest Service; Orville Parsons of the U.S. Soil Conservation Service, Ft. Collins, Colorado; B.C. Godell, Rocky Mountain Forest and Range Experimental Station, Ft. Collins, Colorado; and Wayne Finn, Denver, Colorado.

The greatest cooperation was given by officials of the Mexican government. I am particularly grateful to Hector Jara, Mexican Consul in Denver, for much information and help; to General Hernandez Palacios, Departamente Cartegrafice Militar, for arranging the release of aerial photographs for use in the study; and to Francisco Gonzalez, Oficina de Telegraphos, Nuevo Casas Grandes, for making accessible the local weather records.

During the summer 1964 field session, the author was greatly assisted by William A. Howard of the Department of Geography, University of Denver, and his wife, Patricia, as well. The following students from the University of Denver made up the field crew: Arthur Griffiths, Victor Mote, Clifford Peterson, Patricia Tomes, and, for part of the summer, Fredric Stephan. In addition, James Carey Crain was most helpful during his brief stay in the field. Several members of the Department of Geography, University of Denver, spent some time in Mexico giving important aid: Professor Thomas M. Griffiths, Robert R. Ream, and Russell R. Hassemer.

In Chihuahua several residents and their families helped make the summer memorable as well as successful. M. L. Wilson of Colonia Juarez supported the group in countless ways. Perfecto Mendoza of Rancho los Charles and Elvin Whetton of Rancho Gavilan generously extended to us the use of their properties for the summer period, and without their interest the work would have been impossible. Earlier excursions to Chihuahua were aided by Jorge Lane of Casas Grandes, Bert Whetton of Colonia Dublan, and Charles Di Peso and Arnold Withers, at that time with the Amerind Foundation excavations at Casas Grandes Ruin. These men generously provided the introduction to the trinchera country near the Rio Piedras Verdes.

Aid in the analysis of materials was gratefully obtained from Paul S. Martin of the Geochronology Laboratory, University of Arizona; Philip B. Kail; and Robert I. Lewellen. Considerable preparation of material for analysis was done by Judy Lampe and Carolyn Hicks. The maps and figures were prepared largely by Richard Hallett, with the assistance of Howard W. Dennis. The aerial photographs and the Frontispiece were taken by Thomas M. Griffiths.

Encouragement to undertake this project and help in the presentation of the report were given by Professor Clark N. Crain and Professor Thomas M. Griffiths of the University of Denver, Department of Geography.

Finally, I should like to emphasize the assistance of my wife, Joyce, in all aspects of the project.

Frontispiece, Trincheras in the Sierra Madre Occidental, Chihuahua, Mexico.

I. INTRODUCTION

> There once were men capable of inhabiting a river without disrupting the harmony of its life. They must have lived in thousands on the Gavilan, for their works are everywhere. Ascend any draw debouching on any canyon and you find yourself climbing little rock terraces or check dams, the crest of one level with the base of the next. Behind each dam is a little plot of soil that was once a field or garden, subirrigated by the showers which fell on the steep adjoining slopes.*

A. Trincheras

This study focuses on trincheras and their natural environment. These unusual stone structures form an outstanding element of the mountain landscape over a large part of northern Mexico. The prehistoric inhabitants of the northern Sierra Madre Mountains of Chihuahua and Sonora, Mexico, from about 1100 to 1450 A. D., materially altered the natural environment by building vast numbers of rock retaining walls, called trincheras, in valleys and on hillsides (Photographs 1 and 2). More or less complete remains of these trincheras today give a terraced appearance to countless slopes and valleys, especially in the higher elevations from about 5, 000 to 8, 000 feet elevation. The rock walls are built perpendicular or oblique to the slope, range from about 0. 5 to 12 feet in height and from about 5 to 550 feet in length and are usually arranged in series with separate trincheras from about 5 to 50 feet apart. These distinctive prehistoric structures apparently occur widely in the northern Sierra Madre in an area of approximately 60, 000 square miles, from near Casas Grandes, Chihuahua, west for 180 miles to about Heroica Caborca on the Rio Magdalena in Sonora. Similar but less developed terraces also occur sporadically in Arizona, New Mexico, and southwestern Colorado.

Trincheras have been noted in literature since the time of initial European contact up to the present; however, most observations have been cursory. The term "trinchera" unfortunately has been used

---

* Aldo Leopold (1949), "Song of the Gavilan, " A Sand County Almanac and Sketches Here and There, New York: Oxford University Press, pp. 150, 151

to describe rock alignments or terraces of varying functions. Cassel's English-Spanish dictionary defines "trinchera" as a trench, entrenchment, deep cut or ditch. Fitting this description are prehistoric rock structures found in northcentral Sonora and described by Bandelier (1892), McGee (1896), Lumholtz (1912), Huntington (1914), Sauer and Brand (1931), Ives (1936), and Johnson (1960). These structures circle or partly circle isolated hills; their function is defensive, apparently, with some evidence of residential and religious uses also.

Other rock structures of a very different sort, but also called trincheras, are found at the eastern edge of Sonora and in western Chihuahua. Here trincheras occur mainly across drainage channels on hillsides and on the gentler slopes in the intermediate and high mountains. Constructed again by prehistoric peoples, their function is not related to defense but rather to provision of garden plots, stabilization of soil, reduction of run-off, and spreading of water. Trincheras of this type have been described by Bandelier (1892), Lumholtz (1903), Blackiston (1905, 1906), Leopold (1937), McCabe (1955) and Withers (1963). The aboriginal peoples associated with these structures are related to the Casas Grandes culture, which is a manifestation of Pueblo culture in northern Chihuahua ca. A. D. 1100-1450. Archeological investigations of the Casas Grandes culture have been carried out by Carey (1931), Brand (1935), Sayles (1936), Lister (1958), and recently by the Amerind Foundation (di Peso, Unpublished).

It is the latter type of trinchera with which this study concerns itself.

B. Objectives

Among the most basic problems about trincheras are the occurrence and nature of the structures themselves and their relation to the physical environment. The objectives of this study involve an attempt to clarify these problems, as follows:

1. The initial objective is an inventory of the distribution and characteristic features of trincheras within a study area of ten square miles in the eastern portion of the Sierra Madre Occidental. The specific field methods for this were plane table mapping and descriptive studies of sample trinchera areas.

2. Of equal importance is the description of the physical setting in which trincheras occur. Field objectives were descriptive

and analytic studies of geology, topography, soils, soil moisture, and vegetation in the study area.

3. Related to the latter is the objective of description of the weather and climate of the area, specifically by observation of weather phenomena during two months of study and comparison of this data with long-range records of nearby weather stations.

The study is viewed as necessarily introductory and broad in nature, for there was insufficient background literature on which to base more specific research problems. The overall objective, in fact, might be considered the establishment of a general background on trincheras and their physical setting.

Further utilization of this material together with problem-oriented research can result in more specific correlations of trincheras and features of the environment. Ultimately, the implications extend to such problems as prehistoric use of environment, the effect of such man-made structures as trincheras on long-range erosive processes, vegetative succession, ground water levels and stream discharge, and also their effect upon modern land utilization.

It should be pointed out that the study does not concern itself with the cultural significance of these aboriginal structures. Very little is known of the makers and users of the trincheras, the settlement patterns and field systems of which they form a part, the historical development into which they fit, and many related topics. However important such culturally-related topics are ultimately, the present research strictly avoids them and is limited to the trincheras in themselves and in relationship to the natural setting. Any analyses of construction and function thus are outgrowths of the general purposes outlined above rather than ends in themselves.

C. Selection of Study Area

The task of selection of a satisfactory site was begun in general as early as the summers of 1962 and 1963, when parties from the University of Denver made reconnaissance trips in the Sierra Madre region. A more intensive search, however, was undertaken successfully in March, 1964, to provide a location suited to specific requirements of this study. The following factors were considered necessary in the study area:

1. A representative density of trincheras of varying sizes and types, in relatively good condition.

2. Diversity of terrain.

3. Accessibility by road for two- and four-wheel drive vehicles.

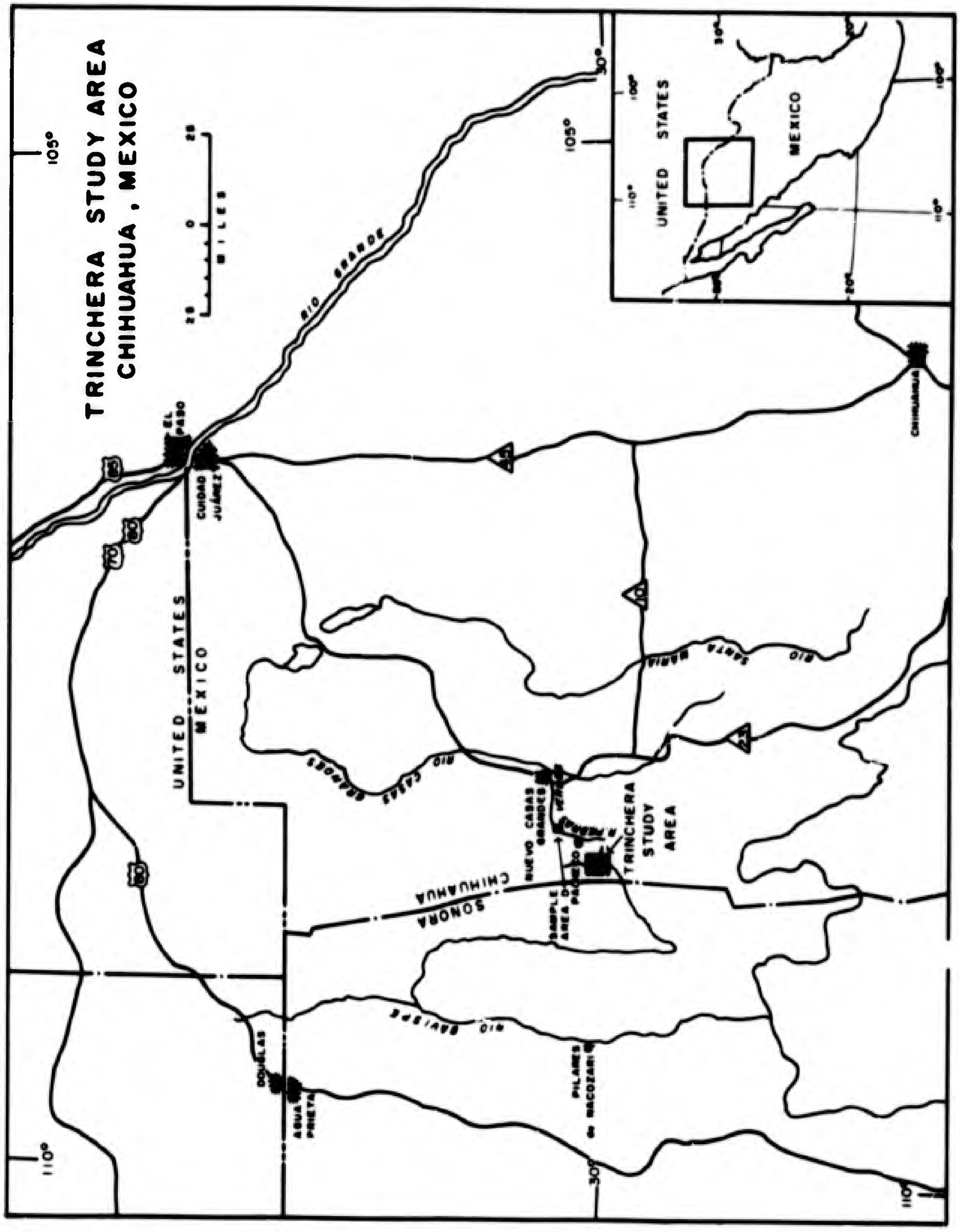
4. Suitable facilities for a permanent camp, i.e., potable water and at least a small house.

The Rancho los Charles ranching site, whose location is outlined in the next section, satisfied all of these requirements. However, as a result of the presence of several ranches and permanent water, there had been some modification of physical environment and trincheras by ranching and lumbering activities. Few, if any, of the original perennial grasses remained; many of the larger Ponderosa pines had been lumbered out in the 1940's; and large numbers of the lower trincheras had been partially destroyed by cattle and horses, as well as by the usual erosive agents. Nevertheless, it was felt that the advantages offered by the area could not be duplicated elsewhere, that an area in more nearly pristine condition would necessarily be located at such a remote location as to be impracticable for the scale of operation planned, and that the modifications in this area would not seriously interfere in a study of this general nature.

D. <u>Location</u>

The study area lies 45 miles southwest of Nuevo Casas Grandes, Chihuahua, Mexico (see Map 1), in the eastern portion of the Sierra Madre Occidental at an elevation of between 5, 300 and 6, 200 feet. The area centers on the confluence of the Rio Gavilan Norte with the Rio Gavilan at approximately 30°2' North Latitude and 180°32' West Longitude.

Accessibility to the study area is via the paved road west from Casas Grandes, then either the dirt road up the Arroyo de la Tinaja to Ejido los Valles and the Gavilan, or the old railroad grade west of Colonia Juarez to Colonia Pacheco and then across the divide to the Gavilan. Many of the roads into and in the area were built in the 1940's for lumber operations and today are maintained largely by the lumber companies and ranchers. The roads can be described accurately as primitive and the location as remote. Depending on road and weather conditions, accessibility from Nuevo Casas Grandes to the study area can be gained in 5 to 7 hard hours by road, a distance of 75 miles.


TRINCHERA STUDY AREA
CHIHUAHUA, MEXICO
25 0 25
MILES
105°
110°
30°
RIO GRANDE
EL PASO
CUIDAD JUÁREZ
UNITED STATES
MEXICO
RIO CASAS GRANDES
RIO SANTA MARIA
NUEVO CASAS GRANDES
TRINCHERA STUDY AREA
SAMPLE AREA
SONORA
CHIHUAHUA
RIO BAVISPE
DOUGLAS
AGUA PRIETA
PILARES de NACOZARI
CHIHUAHUA
UNITED STATES
MEXICO
20°
100°

Map 1

Accessibility by air is also possible since a primitive landing strip is located within the study area. This field, built for lumbering operations, can be used by small aircraft. The flight from the airport at Nuevo Casas Grandes is 43 air miles.

The Base Camp, located in Map 2, was set up on the Rancho los Charles, owned and operated by Senor Perfecto Mendoza. The main ranch house lies on the west bank at the junction of the Rio Gavilan Norte and Huitle Creek. Several hundred yards north along Huitle Creek, several auxiliary ranch buildings provided the site for the camp. *

The general study area shown in Map 2 was delineated at approximately 10 square miles so that representative terrain and trinchera types would be included. The major portion of the area extends to the east and south of Base Camp. Most of the lands of Rancho los Charles and, moreover, of Rancho Gavilan are included.

D. Sample Areas

Within the study area, four sample plots were chosen for large-scale mapping, description, and sampling. Map 2 locates these sample areas. Each plot was chosen for the relationship of its trincheras to some particular topographic or geologic factor, or, in two instances, for some unique type of trinchera.

Area A, the largest sample plot, measures 2,400 by 2,000 feet. It is representative of mesa top and slope land. The bedrock of volcanic flows has been dissected by intermittent stream valleys flowing mainly into the Rio Gavilan Norte. Area A contains exceptionally dense trincheras of varied types and sizes, including outstandingly high walls.

Area B, second in size, is representative of topography formed from ash rather than flow material. Here is a terrain with gentler slopes and coarser, sandier soils. The trincheras include a range of types notable for their generally large size and good condition.

Area C is a slope area of small extent that was chosen for a particular form of trinchera built following the contour of land surface.

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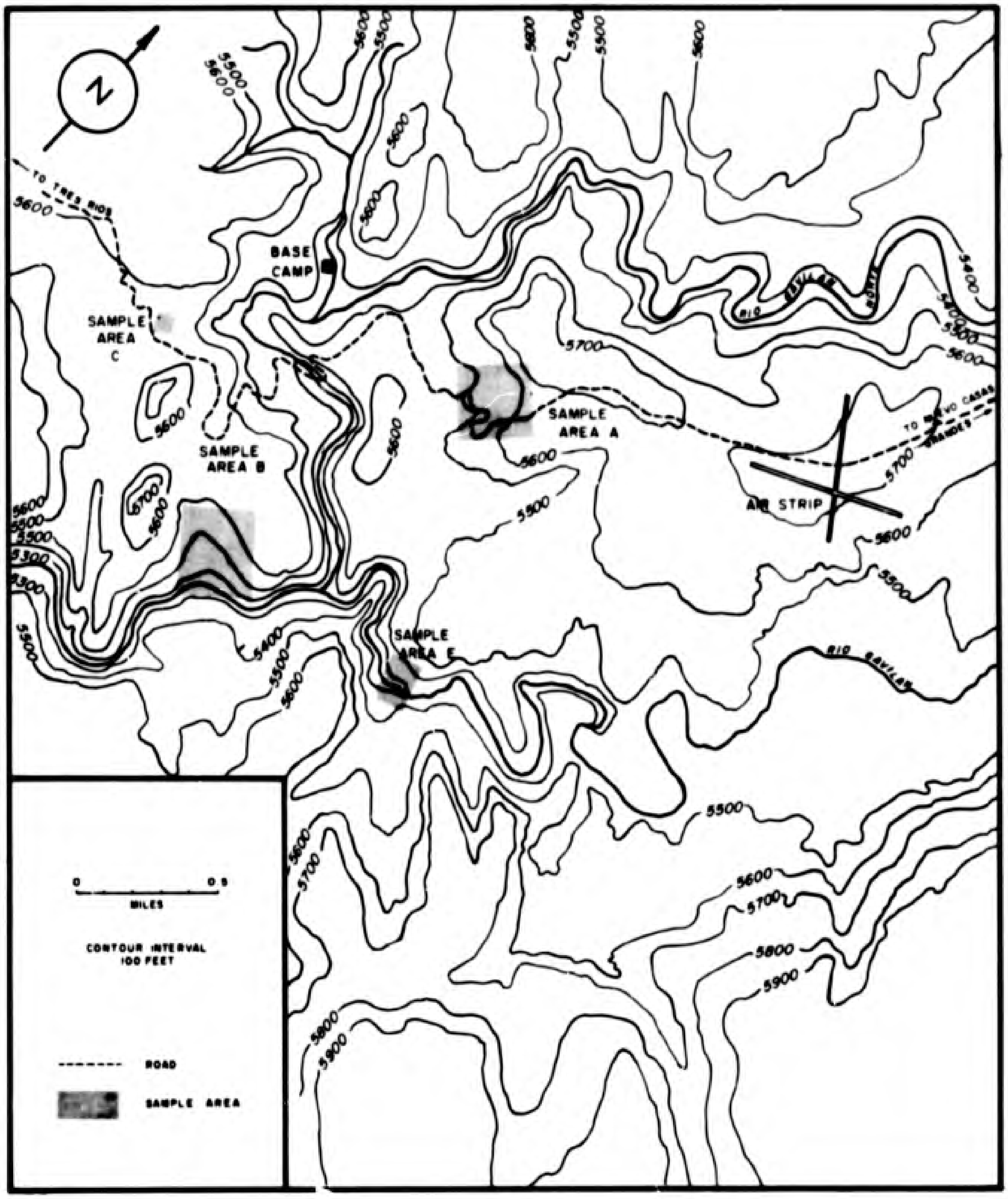
* The situation of Base Camp is described more fully in a later section which locates the weather station near the camp.



Map 2. Topographic Map of Study Area and Location of Sample Areas

Area D lies outside the main study area approximately 20 air miles to the north near Zarogoza and on the Rio Piedras Verdes (see Map 1). The purpose for this site was to permit mappinᵍ and study of a unique type of trinchera that appears to have crossed or partially crossed a permanent stream.

In Area E the arrangement of uniquely long trincheras on flat terrace terrain along the Rio Gavilan was of particular interest.

E. Previous Study in the Area

The only other scientific work done in the Rio Gavilan area was carried out in 1948 by a small group of zoologists led by A. Starker Leopold of the University of California. This collecting expedition was reported in a popular journal (A. Starker Leopold, 1949).*

Another member of the above expedition, Robert A. McCabe, later reported in a short article (1955) on the trincheras and their builders. He notes general characteristics of the trincheras of the Gavilan area and comments on their possible uses.

F. Topography

The topography and relief of the Sierra Madre Occidental have been described by Brand (1937), King (1939), and Hovey (1907). Of the two physiographic provinces represented in northern Chihuahua, the mountain and bolson province located east of Colonia Juarez is of no concern here. The second province, an elevated plateau of dissected volcanic rocks, occupies the extreme western portion of Chihuahua and most of eastern and central Sonora; and it is in this province that the present study is located. (See Photograph 3.)

Here the Sierra Madre Occidental has a regional elevation of near 6,500 feet, with irregular mountain areas rising from 8,500 to slightly over 10,000 feet. Local relief varies from 300 to nearly

* Also, a previous hunting trip to the area by Leopold and other members of his family is the subject of several brief, highly lyrical descriptions, mostly concerning the wildlife and the natural scene, which appear in two books of the journals of the naturalist, Aldo Leopold (1949, 1953).

1,000 feet. The plateau is composed of interbedded lava flows and pyroclastic rocks, dissected both by streams tributary to the Rio Casas Grandes and draining into Lago Guzman and by streams tributary to the Rio Yaqui and flowing into the Gulf of California south of Guymas. The eastern portion of the Sierra Madre is traversed by a series of generally north-south trending faults that have resulted in formation of numerous structural basins.

The study area lies in the headwaters of the Rio Gavilan which flows into the Rio Bavispe and ultimately westward into the Rio Yaqui and the Gulf of California. Thus, the location is immediately west of the divide separating the Rio Gavilan from the northward flowing Rio Piedras Verdes.

G. Climate

The climate of the Sierra Madre Occidental varies greatly with latitude, exposure, and elevation; and there are few recording weather stations in the mountains. Nevertheless, the records of stations at some distance from the study area illustrate some of the general climatic features of the Sierra Madre. Climatic graphs for Nuevo Casas Grandes (4,848 ft. elevation) to the east of the mountains and Pilares de Nacozari (4,622 ft.) in the central portion of the mountains are given in Figure 1.

Precipitation varies from about 15 inches at the lower elevations on the eastern side to somewhat over 25 inches at the higher elevations within the mountains. The precipitation regime has a very strong middle- and late-summer maximum with 60 to 70 percent of the annual total falling during the four months July through October. Much of this summer rainfall probably results from the interaction of convection, orographic uplift, and easterly wave movement. Winter and early spring precipitation may fall in the form of snow.

The summer temperatures of the lower elevations within the basins east of the Sierra Madre are in the upper 70's, with Nuevo Casas Grandes recording a mean temperature of 78.3°* in July and San Buena Ventura (5,038 ft.) having a July mean of 77.5°. At Pilares de Nacozari in the mountains there is a July mean of 77.2°. The winter

* Unless otherwise indicated, all temperatures will be on the Fahrenheit scale.

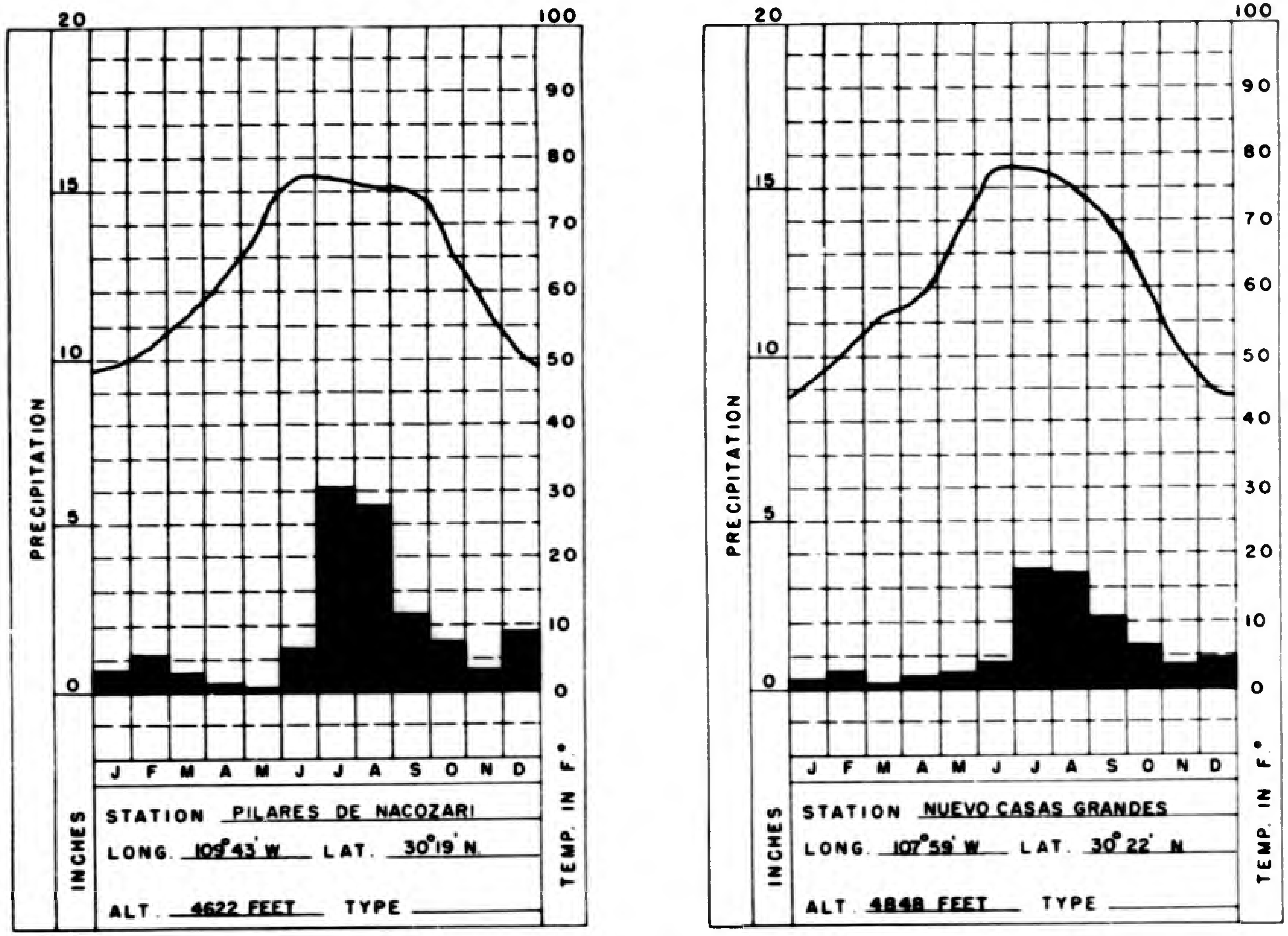


Figure 1. Climate Graphs of Nuevo Casas Grandes and Pilares de Nacozari

temperatures at the lower elevations are in the mid and upper 40's, with Nuevo Casas Grandes recording a January mean of 45.7° and Pilares de Nacozari recording 49.1°. Temperatures at the higher elevations are undoubtedly much lower, with minimum temperatures occasionally reaching 0°.

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II. GEOLOGY

A. Mapping

Maps 2 and 3 present much of the geologic information gained about the study area. Map 2 is a topographic map and Map 3 a geologic map of the area. These are based upon aerial photographs supplied by Army Map Service at a scale of 1:25, 836.

The relief map was constructed from aerial photographs by utilization of a K. E. K. stereo-plotter. Vertical control was established by a series of controlled altimetric traverses in the field. A Paulin microbarograph was set up at the Base Camp, and a Paulin field altimeter was used on the traverses from the nearest known elevation benchmark at Nuevo Casas Grandes (Telegraph Office), 4, 768. 4 feet.* As a result of these traverses, the elevation at Base Camp was determined to be 5, 348 feet.

The geology map (3) was drawn making use of both aerial photographs and reconnaissance on the ground.

B. General Features of Relief

Along the eastern quarter of the study area the topography is made up of the western flanks of the Blue Mountains, which rise to over 8, 000 feet and are one of the more conspicuous mountain masses in this portion of the Sierra Madre Occidental. Several miles north of the study area the Rio Gavilan emerges from this highland area and makes an abrupt right-angle turn to the southwest. Then, as the river enters and continues through the area, it flows along the western margin of the Blues. Numerous steep-gradient streams flowing from the mountains westward are tributary to the Rio Gavilan. The remainder of the study area is largely a well-dissected plateau lying generally at 5, 700 feet. Rio Gavilan and its major tributary, Rio Gavilan Norte, have cut narrow, steep-sided valleys, 200 to 400 feet deep, in the plateau. Resulting is a series of mesas. The most prominent one--more than 2 miles long--is utilized for an airstrip. Many of the mesas are characteristically stair-stepped, as structural terraces are being formed along the contacts between the numerous lava flows and

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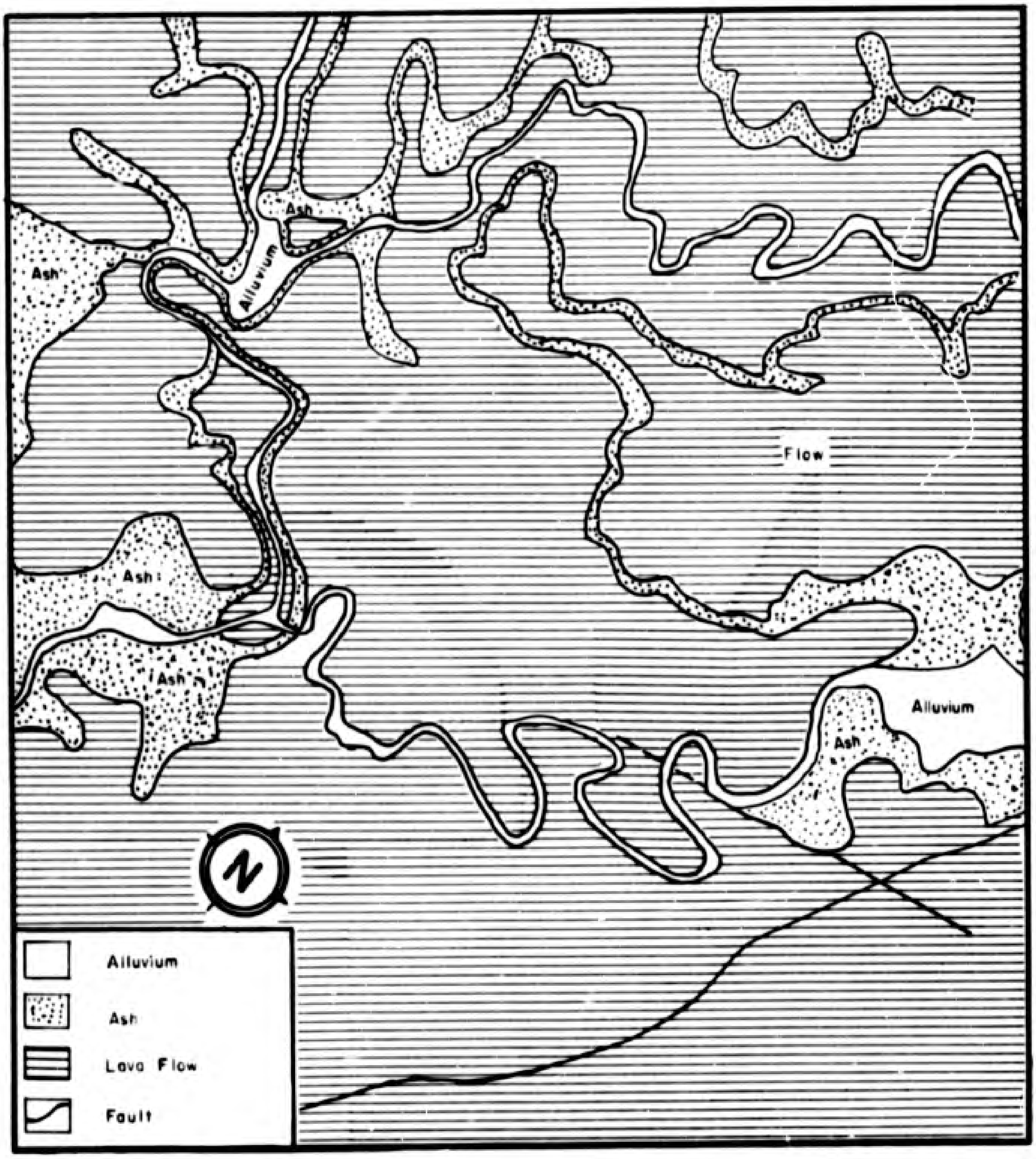
* Published maps show the elevation of Nuevo Casas Grandes to be 4, 850 feet, a corrected elevation for altimeters.



GEOLOGIC MAP of the STUDY AREA
CHIHUAHUA, MEXICO

Map 3

tufaceous bedded formations. The two major streams exhibit well-developed entrenched meanders; while the tributary streams follow short, rather straight courses to their junction with the main streams. The Rio Gavilan, as it traverses the study area, has a gradient of 43 feet per mile.

C. Lithology

The rocks within the study area are entirely igneous, of two types. Aphanitic volcanic extrusives make up a sequence of flows that vary from 15 to 40 feet in thickness. These flows are made up of rhyolites, trachytes, latites, and welded tuffs and trap, with trachytes and latites the most common. In the upper portion of the flows, rhyolite dikes occasionally were intruded, as observed along the sides of the main stream valleys.

The second igneous rock type is that of pyroclastics. Two widespread ash falls were mapped in the study area. First, a 15 to 30 feet thick, well-compacted red ash outcrops on the slope between 5,600 and 5,800 feet. Second, extensive ash fall, varying from 20 to over 200 feet thick, outcrops on the slopes between 5,250 and 5,500 feet. This ash, like the first, is red, well-compacted, and with calcite crystals in the matrix. Also, a thin, discontinuous white ash, with a matrix of silica and bentonite, outcrops between two latite flows at approximately 5,500 feet. Numerous small springs and seeps occur at the basal contact of this ash layer. On the western flanks of the Blue Mountains, at 5,900 feet, a third red ash outcrops.

D. Structure

Over most of the area the flows lie essentially horizontal; however, in the southern portion of the area the ash beds dip 25 to 30 degrees to the east. The most conspicuous structural feature in the area is a fault zone that strikes northeast-southwest along the western margin of the Blue Mountains. Other than the fault scarp, associated geomorphic features are waterfalls and transverse valleys formed along the fault zone.

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III. SOILS*

A. Introduction

Soil is an extremely important environmental factor for a society based upon the simple cultivation of corn, beans, and squash, as were the builders of the trincheras in the Sierra Madre Occidental of Chihuahua. The kinds of soil available to them, like soils that develop at any place in the world, were determined by climate, parent material, vegetation, topography, and time. The soils of the study area can be characterized broadly by the following generalizations:

1. On the steeper slopes, which include the largest proportion of the study area, the soils (Series A and B) are very stony and only several tenths of a foot to a foot deep. In some instances, soil is non-existent on these steep slopes. Large surfaces of exposed bedrock are common, as Photograph 4 shows.

2. On the mesa surfaces and the more gentle structural terraces are found thin, moderately to extensively stony, residual soils (Series C). Rarely are these soils over 1 foot deep. They are influenced strongly by their parent materials. The mesa and slope soils today are utilized only for the grazing of cattle, horses, and goats. (See Photograph 5.)

3. Adjacent to the permanent streams and extending for several 10's to 100's of yards are strips of sandy, terraced alluvial soil (Series D). The 2 ranchos situated in the study area have their houses, barns, outbuildings, and cultivated fields located on these soils. Rancho Gavilan occupies the alluvial soil area at the extreme northwest portion of the study area; and the other rancho, of which Base Camp was a part, occupies the smaller alluvial area in the northwest portion of the study area. The only areas cultivated today utilize these alluvial soils. On them are produced deciduous fruits (whenever late spring frosts do not destroy the buds), small grains (especially oats), corn, melons, and beans.

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* Many of the techniques and soil properties useful in such a field study as this were suggested and clarified by Mr. Orville Parsons of the U.S. Soil Conservation Service, Ft. Collins, Colorado, to whom acknowledgment is gratefully extended.

4. Along many of the steep, narrow valleys and gullies, as well as on the more gentle slopes and some mesas, soils or soil materials have accumulated or been maintained behind the rock trinchera walls. These trinchera plot materials extend to depth from several tenths of a foot to 10 feet or more and over areas from 10 to 5,000 square feet or more in size. Today many of these plots are in the process of being washed away as the trinchera walls become deteriorated and destroyed.

Major soils series as established in the study area, which do not include the trinchera soils, are described in greater detail below. Accompanying this description is a summary chart (Table 1) indicating major characteristics along with a map (Map 4) showing location and distribution. The properties of both the major soils series and trinchera soils appear in Table 2. The last portion of Part III is a summary of trinchera soils.

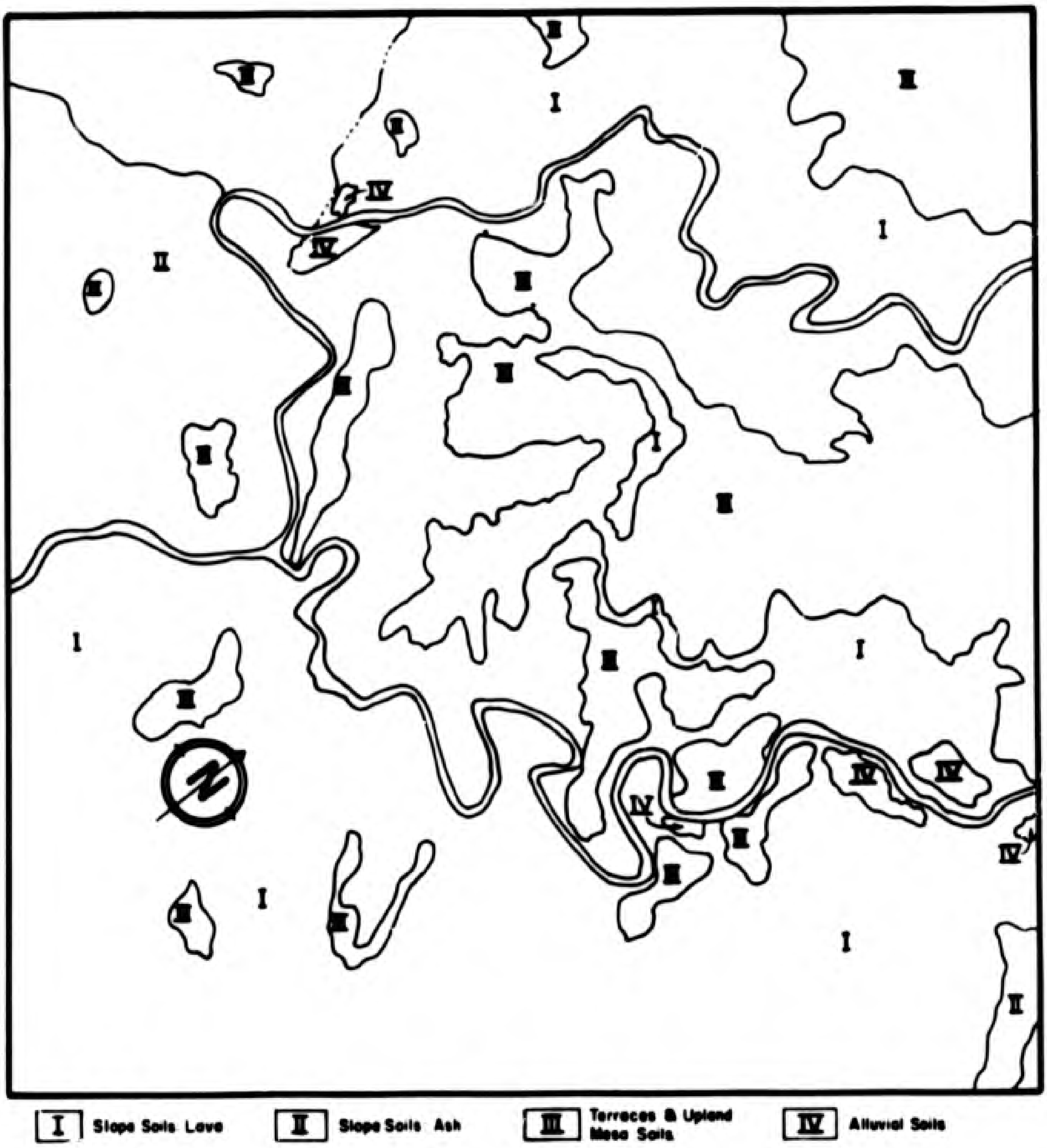
B. Major Soils Series*

Series A. Young and immature, these soils are found on upper and foot slopes. Well-drained and shallow, they have been developed on lava flows which lean more toward the acidic than basic side. Local relief is in the order of 300 feet. Oaks, junipers, and pines, along with low grasses, make up the chief vegetation forms.

The surface is a dark reddish brown loam; 0.1 to 0.3 feet in depth, it is medium blocky in structure. The subsurface layer is a loam, dark gray in color and varying in thickness from 0.3 to 0.5 feet. The entire profile absorbs water readily. The boundary between the surface layer and that of the subsurface is irregular, with discoloration being the chief determinant, one from the other. Both rockiness and stoniness are quite pronounced, falling into Category 4 as developed by the U.S. Department of Agriculture.

Series B. These soils are not too dissimilar in many respects to those of Series A. They differ essentially only insofar as parent material and subsurface color are concerned. Formed from volcanic ash, they show the same kind of youthful and immature characteristics as the soils of Series A. They are found in the same physiographic position as Series A, namely, upper and foot slopes. Like Series A, they are quite shallow and well-drained. Some difference does exist as to structure. Series B soils have a medium subangular structure in contrast to the blocky nature of Series A. Depth as to surface as well as subsurface layers are similar to Series A. General color

* This section was written by William A. Howard.



SOILS MAP of the STUDY AREA
CHIHUAHUA, MEXICO

0 0.5
MILES

Map 4

TABLE I

Physiographic Position, Parent Material, and General Characteristics of Soils Found in the Trinchera Study Area

Physiographic Position	Series	Map Symbols	Parent Material	Relief	Internal Drainage	Surface Soil: Color	Surface Soil: Consistence	Surface Soil: Approximate Thickness	Subsoil: Color	Subsoil: Consistence	Subsoil: Texture	Subsoil: Approximate Thickness
Soils of the Slopes												
Upper and foot slopes	A	I	Lava flow (acidic)	Extreme sloping (300 ft.)	Well drained	Dark reddish brown	Sticky to plastic	(Feet) 0.1-0.3	Very dark gray	Sticky to plastic	Loam	(Feet) 0.3-0.5
Upper and foot slopes	B	II	Volcanic ash	Extreme sloping (300 ft.)	Well drained	Dark reddish brown	Sticky to plastic	0.1-0.3	Dark reddish brown	Sticky to plastic	Loam	0.3-0.5
Soils of the Terraces and Flats												
Terraces and upland flats	C	III	Lava flow (acidic)	Gently sloping	Well drained	Dark reddish brown	Sticky to plastic	0.1-0.2	Dark reddish brown	Sticky to plastic	Loam	0.2-0.5
Soils of the Valley Flats (alluvial)												
Valley flats	D	IV	Alluvial fill	Gently sloping to level	Well drained	Dark reddish brown	Sticky to plastic	2.0-2.5	Dark reddish brown	Sticky to plastic	Sandy loam	

TABLE 2

Properties of Soils in the Study Area

Soil Series	Map Symbol	Color (Moist)	Size Distribution of Sands (Percent) Very Coarse	Coarse	Medium	Fine	Very Fine	Total	Silt (%)	Clay (%)	Textural Grade	Consistency Dry	Wet	pH	Organic Matter (%)	P_2O_5*	K_2O*	$CaCO_3$ Equivalent
Major Soils:																		
A	I	5 YR 5/4	6.0	6.2	4.4	11.8	11.2	39.6	36.4	24.0	Loam	Slightly hard	Slightly sticky	7.4	0.6	209	250	0.3
B	II	2.5 YR 3/4	9.6	12.6	7.5	14.1	6.4	50.2	36.8	13.0	Loam	Slightly hard	Slightly sticky	7.7	2.6	39	360	1.4
C	III	5 YR 2/2	15.6	13.0	4.7	4.1	3.3	40.7	39.8	19.5	Loam	Slightly hard	Sticky	6.9	1.9	174	745	0.7
D	IV	5 YR 3/4	2.0	13.7	14.9	26.8	13.2	70.6	16.4	13.0	Sandy loam	Soft	Non-sticky	7.4	0.8	53	340	0.8
Trinchera Soils:																		
Number	Layer																	
18a	1	2.5 YR 3/6	8.1	8.8	7.7	18.4	11.0	54.0	26.5	19.5	Sandy clay loam	Slightly hard	Slightly sticky	7.7	0.9	95	410	1.7
18a	2	5 YR 3/3	2.0	3.1	2.1	6.4	8.5	22.1	44.4	33.5	Clay loam	Hard	Sticky	7.7	1.4	110	320	1.0
18a	3	10 YR 5/4	6.6	7.2	4.7	10.6	8.6	37.7	39.8	22.5	Loam	Hard	Slightly sticky	7.6	0.6	60	245	1.6
18a	4	7.5 YR 4/4	2.4	5.8	5.8	14.0	9.1	37.1	45.4	17.5	Loam	Hard	Slightly sticky	7.5	0.8	69	290	1.0
18a	5	5 YR 5/3	3.0	4.4	4.0	9.1	7.2	27.7	48.3	24.0	Loam	Hard	Slightly sticky	7.4	0.9	90	250	1.1
28	Rear 2	2.5 YR 3/6	12.9	12.5	6.5	11.5	8.8	52.2	31.8	16.0	Sandy loam	Soft	Slightly sticky	7.6	0.7	43	190	1.2
28	Front 2	2.5 YR 3/6	10.4	20.9	10.7	11.0	6.4	59.4	24.6	16.0	Sandy loam	Soft	Slightly sticky	7.6	0.8	27	220	1.2
28	Rear 3	2.5 YR 3/4	7.9	10.7	6.2	13.8	7.8	46.6	33.9	19.5	Loam	Hard	Slightly sticky	7.4	1.0	58	230	1.1
28	Front 3	2.5 YR 3/4	8.0	9.8	5.3	13.3	10.0	46.4	32.6	21.0	Loam	Hard	Slightly sticky	7.5	0.9	95	275	1.2
246	Surf. to 0.08'	2.5 YR 2/4	7.8	8.5	4.1	6.1	7.3	33.8	38.7	27.5	Clay loam	Slightly hard	Slightly sticky	7.3	1.4	75	330	1.0
414	0.5'	2.5 YR 3/4	3.7	8.4	7.9	15.3	7.1	42.4	36.6	21.0	Loam	Slightly hard	Slightly sticky	5.1	0.6	53	260	1.3
414	1.5'	2.5 YR 3/4	2.1	3.4	5.3	17.2	8.9	36.9	42.1	21.0	Loam	Slightly hard	Slightly sticky	7.8	0.5	84	365	1.0
414	2.5'	2.5 YR 3/4	2.9	8.6	9.7	19.0	10.6	50.8	31.7	17.5	Loam	Slightly hard	Slightly sticky	8.2	0.4	64	230	1.5
319	0.5-1.5'	5 YR 5/2	9.8	9.3	6.8	19.8	7.0	52.7	32.8	14.5	Sandy loam	Slightly hard	Slightly sticky	7.0	2.8	62	565	0.5

All terminology follows USDA usage as outlined in Agricultural Handbook No. 18.

* Pounds per acre

is similar, yet on the Munsell Color Chart soils of Series B fall into 2.5 YR 2/4 category while those of Series A vary slightly by falling into a 5 YR 3/2 designation. The rockiness and stoniness class for Series A holds true for Series B. Also, vegetation association is similar to Series A.

Series C. Soils of this series are located on gently sloping terraces and upland flats. Developed on the same parent material as Series A, these soils are more shallow than either Series A or B.

Like Series A, these soils have a dark reddish brown coloration and fall into a loam classification. The upper layer ranges from 0.04 feet in depth up to an average of around 0.2 feet. The boundary is very irregular, and discoloration from the top to the subsurface layer is about the only criterion for making any sort of differentiation. The subsurface layer is approximately 2 to 4 inches in depth. Structure varies, grading from a moderate to a medium sub-blocky character. Color change is slight from surface to subsurface layers. On the Munsell Chart the surface layer falls into a 5 YR 3/2 designation while the subsurface layer falls into 7.5 YR 3/2 class. The degree of stoniness and rockiness, again, is like that of Series A and Series B, falling into Category 4.

Series D. Soils of this series are found on gently sloping alluvial flats and have formed from fill deposited by the streams in the area. Structure is completely absent, indicating their youthful and immature nature. They fall into a sandy loam textural class and range from approximately 2.0 to 2.5 feet in depth. The surface layer has a dark reddish brown color falling into a 5 YR 3/2 designation on the Munsell Chart while the subsurface layer grades to a 7.5 YR 4/2 class. These are well drained soils and are used quite regularly for modern day agriculture, beans and corn being the most important crops.

C. Trinchera Soils

The properties of trinchera soils analyzed are given in Table 2. The parent materials of these soils are lava flows and volcanic ash. Some of the soils have formed from the weathering of these materials in place; however, the soils found behind the numerous check dam variety of trinchera have been formed from water transported fill. The surfaces of the soils are commonly gently sloping to nearly level. Although well drained, they may be highly saturated with moisture for several months. Texture is quite variable, ranging from sandy loam to clay loam, though loam texture is most common. The consistency when wet is slightly sticky and when dry, hard to slightly hard. Color is strongly influenced by the nature of the parent material but is most commonly reddish brown. Unlike the series soils, trinchera soils are quite free of stones. As in the major soils series, content of organic matter is quite low and potassium and phosphorous are deficient.

The distribution and extent of trinchera plots, and hence of trinchera soils, is given later in Part IX. The more specific data on trinchera soils derived from the trenching of trinchera plots are presented in Part VII.

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IV. WEATHER

A. Sites of Weather Observations

A site adjacent to Base Camp was chosen for the weather shelter (Photograph 6) largely because of its easy access for weather observations, made hourly from 0700 to 2200 hours as well as during rain storms at whatever time they occurred. The weather shelter, rain gauge, anemometer, and other recording and sensing instruments were located on the first terrace of Huitle Arroyo, 4 feet above and 35 feet from the stream. The valley here is 350 feet below the uppermost surface of the volcanic plateau. The flood plain and first terrace are 200 feet wide between the valley slopes. The site had a northeast exposure. The elevation of the weather station was calculated to be 5,348 feet. Several small wooden outbuildings stood 40 to 100 feet from the shelter, and several 15 to 25 feet high oak trees were within 30 feet. The weather shelter and nearby recording equipment stood within an 18 by 72 feet plot originally used as a kitchen garden, whose 4 feet high enclosing wooden fence fortunately offered protection from the ranch animals. The surface of the soil temperature plot was kept as free as possible of vegetation. The dry soil was brown in color (Munsell Color 7.5 YR 4/2).

Satellite weather stations for more limited observations were located at the following sites:

1. Trinchera 18, Area A. Two hundred feet higher than Base Camp, this trinchera is situated within a southwest-facing, 20 feet deep ravine. It is shaded by oak and juniper trees.

2. Trinchera 58a, Area A. This site is 125 feet higher than Trinchera 18. It also faces southwest but is on a slope rather than in a ravine and has little vegetational cover.

3. Trinchera 441, Area B. This site is in the upper portion of a broad U-shaped valley, 100 yards below a major escarpment. It is approximately 50 feet higher in elevation than Base Camp and faces southeast. Trinchera 441 is under light shade from pines.

4. Airstrip. This site is located at the north end of the northwest-southeast arm of the airstrip, 380 feet above Base Camp. The flat surface has no vegetational cover here.

B. Weather Sensing and Recording Equipment

The following instruments were placed in the Weather Bureau type, medium-sized shelter: a minimum thermometer, a maximum thermometer, an official dry bulb thermometer, a Belfort hygrothermograph (USWB spec. 450.8202), a Friez U.S. Army Signal barograph (ML-3), and a Piche evaporimeter.

Adjacent to the shelter was located a Belfort recording raingauge (USWB spec. 450.2201 and 450.2203). A Belfort totalizing anemometer was situated on a 10.0 feet high mast, on which at 0.5, 1.0, 3.0, and 6.0 feet above the ground surface were placed shielded Yellow Springs Instrument air temperature thermisters. Yellow Springs internal probe thermisters were placed on the soil surface and at 0.25, 0.5, 1.0 and 2.0 feet depths to measure soil temperatures. A Yellow Springs wide-range telethermometer was used to measure the temperatures of both the soil and air. A Duvdevani type dew gauge was placed 1 foot above the ground surface. Four small, clear plastic rain gauges were fastened to the fence 4 feet above the ground to record rainfall for rainfall intensity records. A Swan Federer Tanner economical radiometer built at the University of Denver Geography Department was mounted 4 feet from the ground surface for measurement of net radiation.*

At the 4 satellite stations, official Weather Bureau thermometers were placed in the shade 3 feet above the ground. Each station also had a clear plastic rain gauge placed 3 feet high and away from any masking influence of trees.

C. Observations and Analysis

Weather observations began at Base Camp at 0700 hours on 18 June 1964 and continued through 1800 hours on 12 August 1964, a total period of 56 days. As previously mentioned, regular observations were made hourly from 0700 to 2200 hours. The rain gauge, hygrothermograph, and barograph recorded continuously. The precipitation, temperature, and relative humidity charts were changed daily and pressure charts every 4 days. In addition, rainfall intensity measurements were gathered at every occurrence of a severe rainstorm.

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* Dr. B. C. Goodell, Research Forester, Colorado State University, Ft. Collins, Colorado, was very helpful in providing information and many parts necessary for the construction of the radiometer.

Observations at the satellite stations were not made systematically; consequently, only the deviations from Base Camp mean observations are given.

Climatic data for Nuevo Casas Grandes were obtained locally from the weather observor for the period 1 June through 12 August. Climatic data for Rancho Agua Salada were obtained from the rancher, the observor at this small and recently established recording station (elev. 7,185 ft.) located approximately 20 miles north of Rancho los Charles. The period 1 June through 31 July only was available here.

D. Typical Daily Weather

Figure 2 shows hygrothermograph traces for two days: 1100 hours, 21 June, to 1130 on 22 June 1964 and 1100 hours, 3 August, to 1100 on 4 August 1964. These charts were chosen to illustrate the climatic elements of temperature and relative humidity during two typical summer days, one (21-22 June) before the rainy season began and the other (3-4 August) during the rainy season. For the futher orientation of the reader, narrative accounts of the weather on those representative days are given below.

21-22 June. The minimum temperature occurred just before the sun rose at 0645. There was a rapid rise of temperature under clear skies with thin, broken cirrus clouds and calm air. Nearly uniform high temperatures were recorded from 1330 to 1830 hours, under skies with one-tenth or less cloud cover. With the increase of temperature in the morning came a corresponding steady decrease in relative humidity. Then from 1400 to 1900 hours relative humidity readings became uniform. The sun set behind the mountains at 1830 hours. From this time until the sun rose the following morning, temperatures decreased steadily and uniformly, and relative humidity rose correspondingly. Saturated or near saturated air occurred from 1 to 1-1/2 hours just before and after sunrise. No precipitation fell.

3-4 August. Minimum temperatures again occurred just before the sun rose at 0715 hours. Temperature rose rapidly under clear skies until 1200 to 1230 hours when skies typically began to become cloudy. Cloud cover reached 6/10 to 8/10 by 1400 hours. Between 1350 and 1500 hours .34 inch of rain fell, resulting in a rapid decrease in temperatures. Low clouds reduced visibility to a quarter of a mile. Following the thunderstorm the skies cleared somewhat and temperatures increased until the second high for the day was reached just before sunset. After

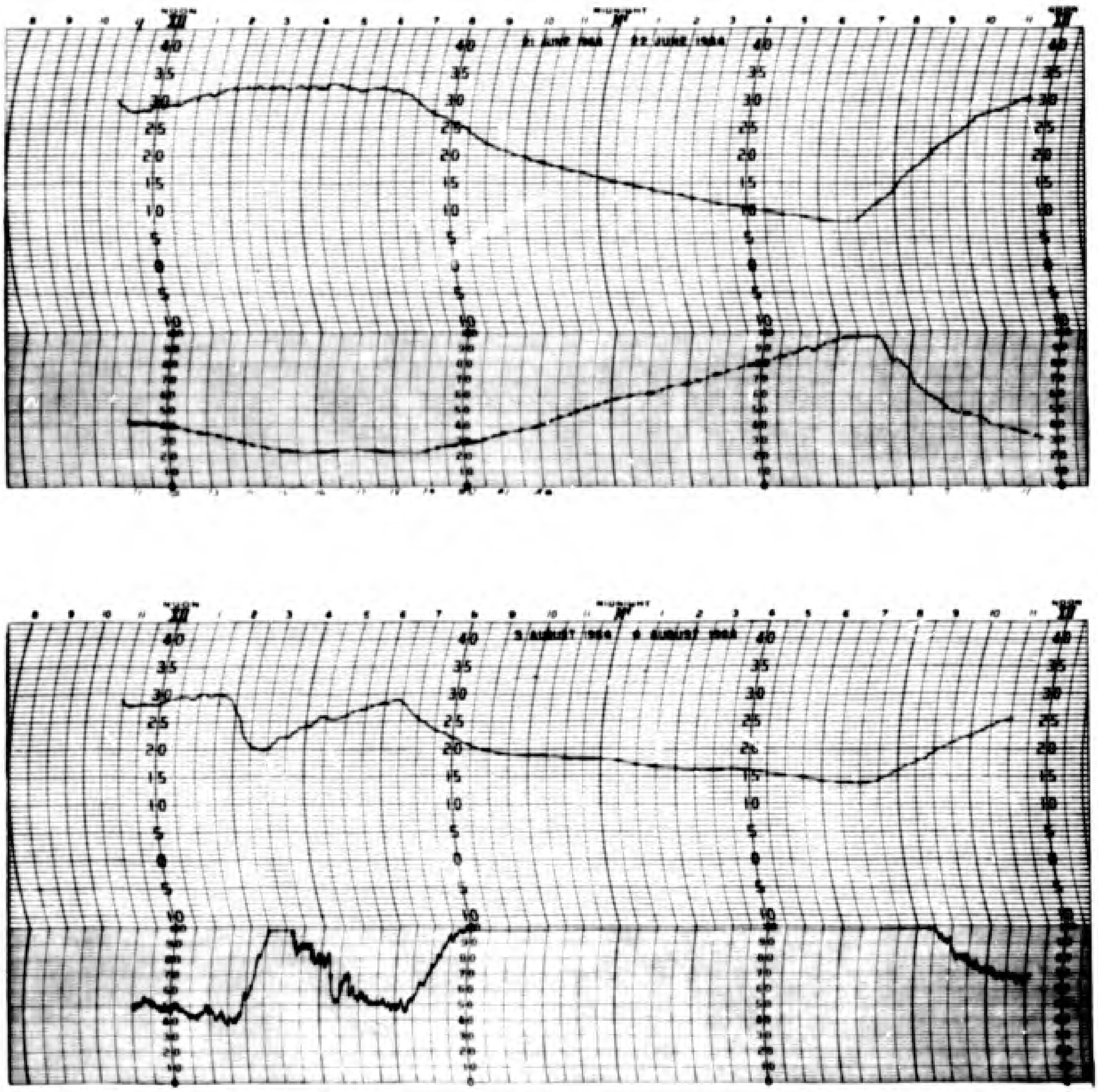

Figure 2. Hygrothermograph Records for 21-22 June and 3-4 August at Base Camp.

sunset there was a uniform decrease in temperatures and an increase in relative humidity until 2000 hours when the skies were completely overcast and the rate of temperature decrease was markedly reduced. Saturated or near saturated conditions of the air remained from then until 0830 in the morning.

E. Temperature

Figure 3 shows graphically the maximum-minimum and diurnal ranges of dry-bulb temperatures for the 56 day observational period.* The absolute maximum of 101° was recorded on 5 July and the absolute minimum of 33° on 23 June. The mean temperature for the period was 72.3° and for the month of July--the only full calendar month observed--73.3°. The mean maximum for the observational period was 88.7°. The daily average deviation from the mean maximum was 3.9°. The mean minimum temperature for the observation period was 56.4°, with the daily average deviation from the mean 3.4°.

From the data in Figure 3, several generalizations can be made:

1. Maximum temperatures show a periodicity of 5 to 6 days of gradual increase of temperatures, followed by several days of high temperatures, then 5 to 6 days of gradually decreasing maximums before another cycle begins again.

2. A similar periodicity of minimums is less apparent but still observable.

3. Many of the warmest days were preceded by low minimum temperatures.

4. From 8 July to the end of the observational period, maximum temperatures were lower and minimum temperatures were higher than during the earliest part of the period.

Time of Occurrence of Minimum Temperatures. As shown by Figure 4, slightly over 66 percent of the minimum temperatures were recorded between 0630 and 0700 hours. Seven percent of the occurrences were recorded in the preceding half hour (0600-0630), and an additional 7 percent were recorded in the following half hour (0700-0730). Thus, time of minimum temperature is highly correlated with the time the sun rose from behind the nearby mountains.

* The numerical data is given in the Appendix A.

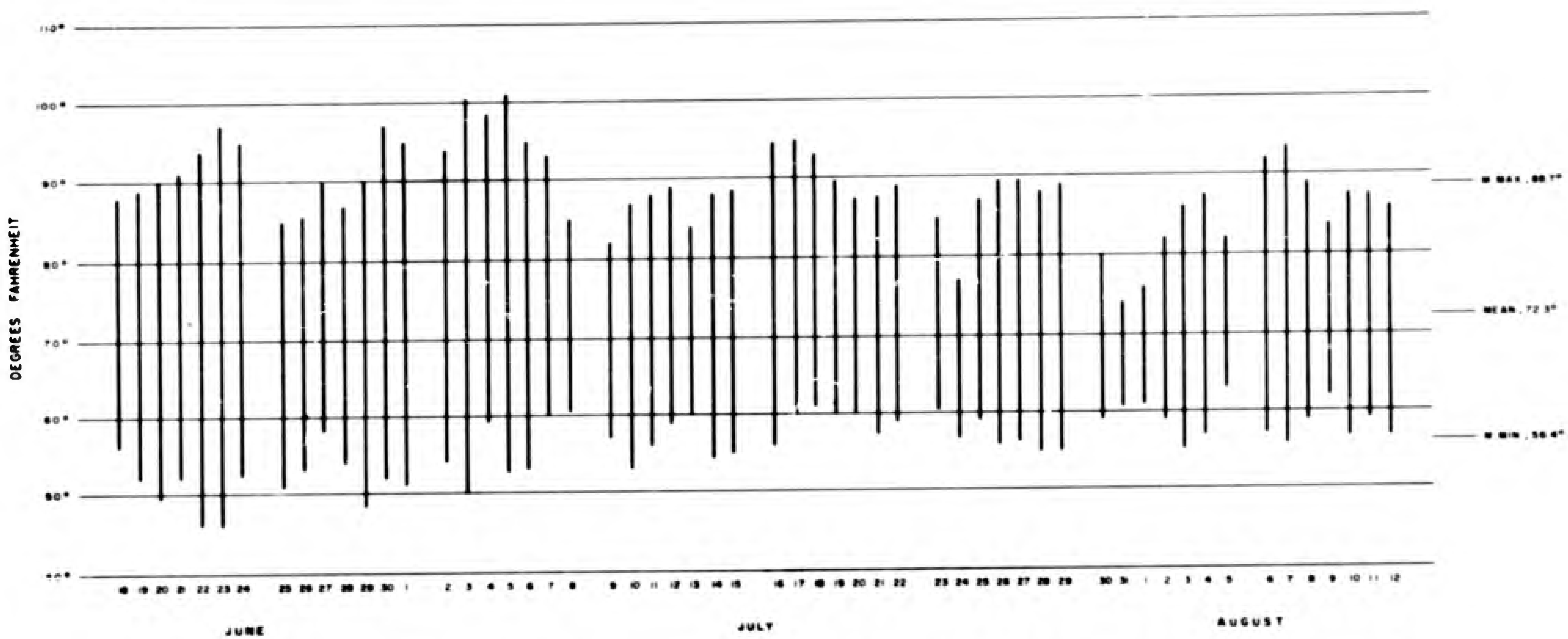

Figure 3. Diurnal Range of Temperatures for Base Camp, 18 June - 12 August.

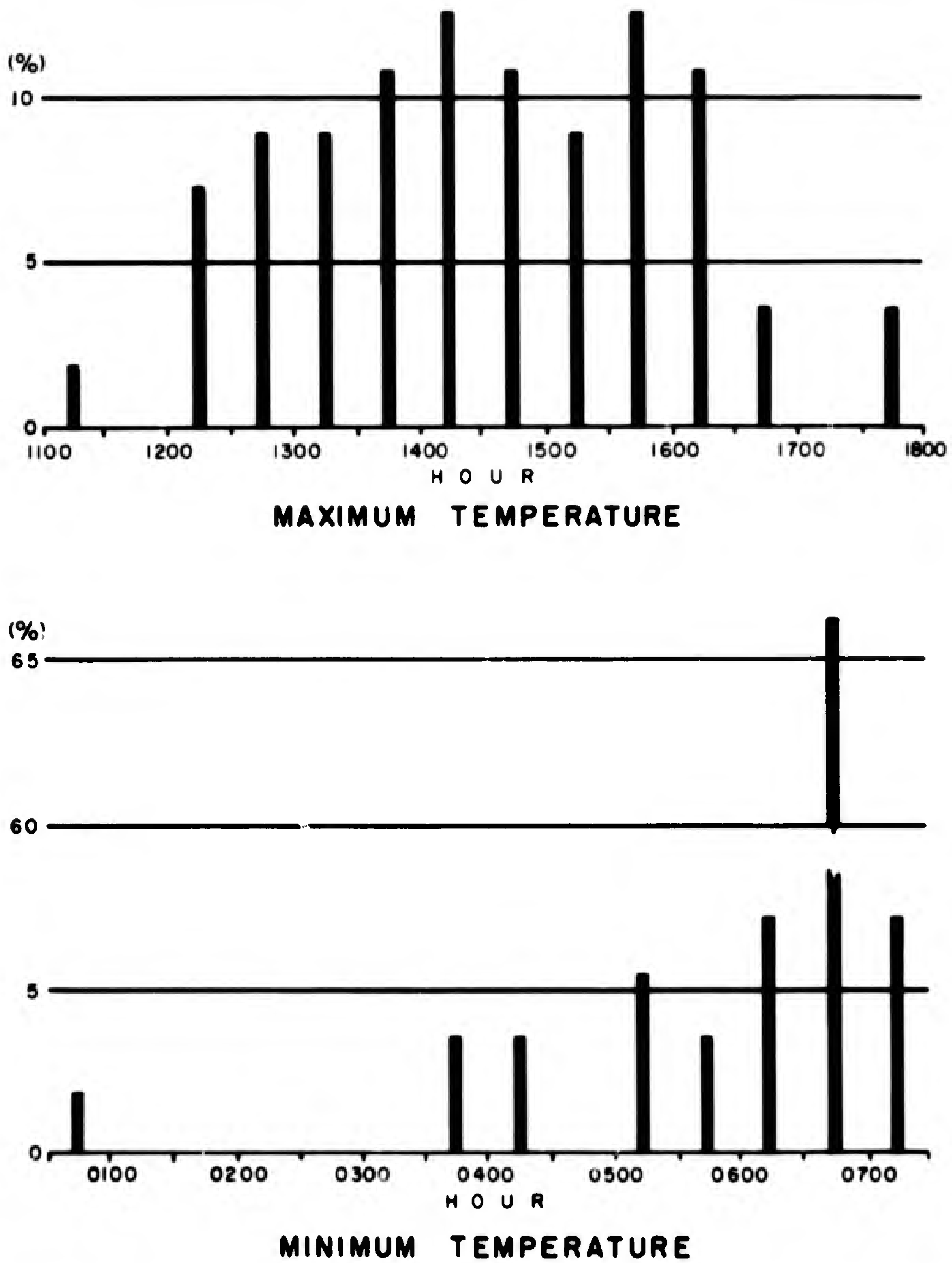

Figure 4. Time of Occurrence of Minimum and Maximum Temperatures, Base Camp.

The remaining occurrences almost entirely resulted from warming conditions early in the morning, initiated by precipitation and cloud cover which upset the normal situation.

Time of Occurrence of Maximum Temperatures. As shown by Figure 4, the occurrence of maximum temperatures had a much broader time distribution. The majority of daily maximums were recorded between 1300 and 1600 hours, and only a few percent differences separate frequencies between 1200 to 1630 hours. A combination of high sun angle and variable mid and late afternoon cloudiness resulted in maximum temperatures occurring over a variety of times.

Frequency of Maximum Temperatures. Figure 5 shows a range of 27 degrees between the highest maximum temperature of 101° and the lowest maximum temperature of 74°. The 101° temperature was recorded at the end of the dry season, and the 74° maximum was recorded during a day of almost complete overcast and gentle rain.

Frequency of Minimum Temperatures. Figure 5 shows a range of 25 degrees between the highest minimum temperature of 63° and the lowest minimum temperature of 38°. The 38° minimum was recorded early in the study period before the rains began, under clear sky conditions, and following a period of high diurnal ranges with daytime maximums nearly all above 90°.

Duration of High Temperatures. The frequency and duration of temperatures above 85° are shown in Tables 3 and 4. Slightly over two-thirds of the days had temperatures over 85° for an hour or longer, and slightly less than one-third of the days had temperatures over 90° for an hour or longer, most of these occurring during the period 30 June to 8 July. Although the absolute maximum for the observation period was 101°, temperatures above 100° had durations less than an hour long.

Index of Discomfort. Many attempts have been made to derive an ojbective index of sensible temperature, or the temperatures actually felt by the human body. Among others, these include Taylor (1946), Stone (1941), Minard (1961), and Thom (1957). The latter is used here to show the daily maximum discomfort experienced during the study period. The formula developed by E. C. Thom is an index of sensible temperatures called a discomfort index, or DI. *

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* $DI = 0.4\ (T_d + T_w) + 15$. The quantity T_d = dry-bulb temperature. Quantity T_w = wet-bulb temperature. Temperatures are degrees Fahrenheit.

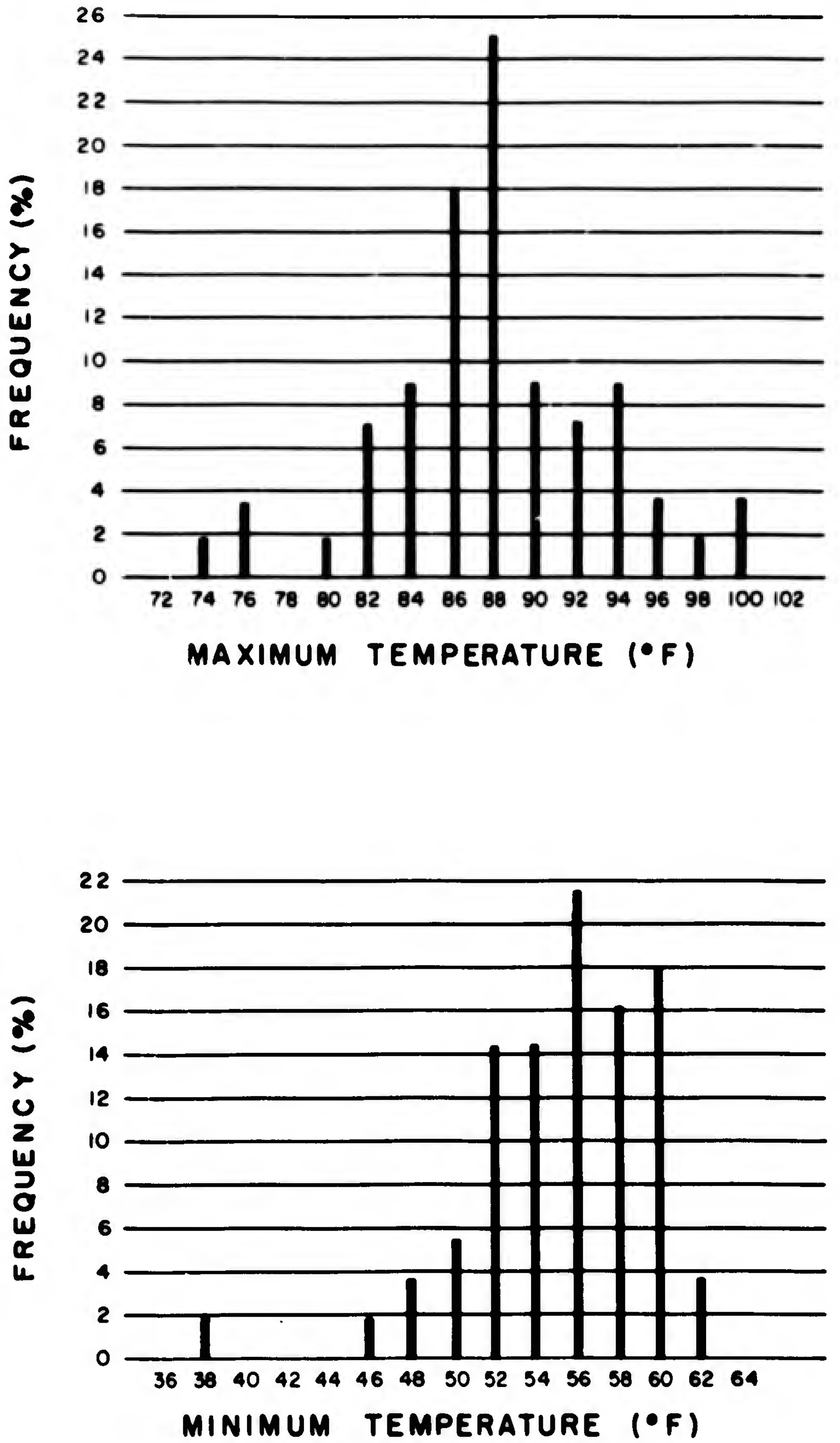

Figure 5. Temperature Frequency (Maximum and Minimum Temperatures), 18 June to 12 August, Base Camp.

TABLE 3

Duration of Temperatures Above 85°, 90°, 95°, and 100°

Base Camp

18 June - 12 August

Duration in Hours	Number of Occurrences 85°	90°	95°	100°
1	7	2	0	0
2	8	6	3	0
3	8	6	3	0
4	3	3	0	0
5	3	1	0	0
6	7	0	0	0
7	2	1	0	0
8	2	1	0	0
9	1	0	0	0
Σ of hours	155	64	15	0

TABLE 4

Days Recording Temperatures Less Than 85°, 85°, 90°, 95°, and 100° for One Hour or Longer

Base Camp

18 June - 12 August

	Frequency (Percent)			
Less than 85°	85°	90°	95°	100°
32.1	67.9	28.6	7.1	0

Table 5 shows the daily maximum DI experienced at Base Camp. According to Thom, "People feel discomfort as the index rises above 70, with over half uncomfortable with the index over 75. Everyone will be uncomfortable by the time the index reaches 79, most people feeling the discomfort acutely by this time. As the index passes above 80, discomfort becomes more serious."*

Temperatures at Satellite Stations Compared to Base Camp. As previously stated, in analysis of satellite station data, only the deviations from Base Camp mean observations are given. The observed temperatures were grouped into two classes for comparison: temperatures observed from 0800 to 0900 hours and those from 1200 to 1600 hours.

Table 6 presents the difference of mean temperatures at each satellite station from Base Camp means. Lower means were recorded from 0800 to 0900 hours at all of the satellite stations except Trinchera 441, which did not differ significantly from Base Camp. From 1200 to 1600 hours the two stations in Area A recorded lower mean temperatures than Base Camp, the airstrip did not differ, and Trinchera 441 was 2° warmer.

Comparison of Temperatures at Base Camp, Nuevo Casas Grandes, and Rancho Agua Salada. Figure 1 shows the monthly mean temperatures for Nuevo Casas Grandes based on a 15-year period. For the month of July, 1964, the only complete month for the 56-day observational period, the Nuevo Casas Grandes mean of 79.9° was 1.6 degrees higher than the 15-year mean. However, this is not a great enough deviation to suggest that July was exceptionally or unusually warm at Nuevo Casas Grandes. Further substantiation is offered by the fact that the June, 1964, mean temperature of 77.4° was 0.3 degrees cooler than the 15-year mean. The mean temperature for July at Base Camp was comparatively cooler: 73.3° or 6.6 degrees below that recorded at Nuevo Casas Grandes. Base Camp also had lower mean maximum and minimum temperatures in July: the mean maximum at Base Camp, 89°, was 5.1 degrees below the July mean maximum of 94.1° at Nuevo Casas Grandes; and a mean minimum of 55.7° at Base Camp was 9.6 degrees cooler than the 65.3° at Nuevo Casas Grandes.

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*Thom, E. C., (April, 1959), Weatherwise, 12, no. 2, 59.

TABLE 5

Max'mum Discomfort Index

Base Camp

18 June - 12 August

Date	Index	Date	Index
18 June	75	16 July	75
19	76	17	78
20	78	18	79
21	78	19	81
22	79	20	77
23	78	21	78
24	77	22	77
25	76	23	76
26	76	24	71
27	77	25	75
28	74	26	79
29	76	27	77
30	78	28	78
1 July	78	29	79
2	79	30	74
3	79	31	71
4	80	1 August	71
5	81	2	73
6	78	3	76
7	76	4	77
8	75	5	75
9	75	6	79
10	76	7	77
11	77	8	76
12	77	9	76
13	73	10	77
14	77	11	78
15	76	12	76

TABLE 6

Deviation of Temperatures at Satellite Stations From Temperatures at Base Camp

Time Period	Mean Temperature Difference			
	Trinchera 18	Trinchera 58a	Trinchera 441	Airstrip
0800-0900 hrs.	-2.5°	-2.0°	none	-2.0°
1200-1600 hrs.	-4.0°	-1.0°	+2.0°	none

Daily weather data which included minimum and maximum temperatures and precipitation were also obtained from Rancho Agua Salada, 7,185 feet in elevation and approximately 20 miles north of Rancho los Charles, for the months of June and July, 1964. Further data for this station as well as any monthly temperature and precipitation means have been unobtainable, thus far. The data available are included only to test the representativeness of the observations made at Base Camp. The July mean at Rancho Agua Salada was 66.4°, or 6.9 degrees cooler than that at Base Camp, slightly more than 1,800 feet lower in elevation. The mean maximum of 77.9° at Rancho Agua Salada was 11.1 degrees cooler and the mean minimum of 54.5° was 2.4 degrees cooler than those means at Base Camp. These lower mean temperatures at Rancho Agua Salada are due to the considerably reduced daytime maximums rather than to any lower nighttime temperatures.

Table 7 summarizes the differences between the mean temperatures of these three stations, and Figures 6 and 7 show the relationship of the daily maximum and minimum temperatures for the stations, as discussed below.

TABLE 7

June-July Mean Temperatures at Base Camp, Nuevo Casas Grandes, and Rancho Agua Salada

	Base Camp	Nuevo Casas Grandes	Rancho Agua Salada
June 15-year Average*	--	77.7°F	--
June, 1964	--	77.4°F	61.5°F
July 15-year Average*	--	78.3°F	--
July, 1964	73.3°F	79.9°F	66.4°F

* Wernstadt, F.E., (1961), World Climatic Data: Latin America and the Caribbean, Pennsylvania State University, Dept. of Geography, p. 54.

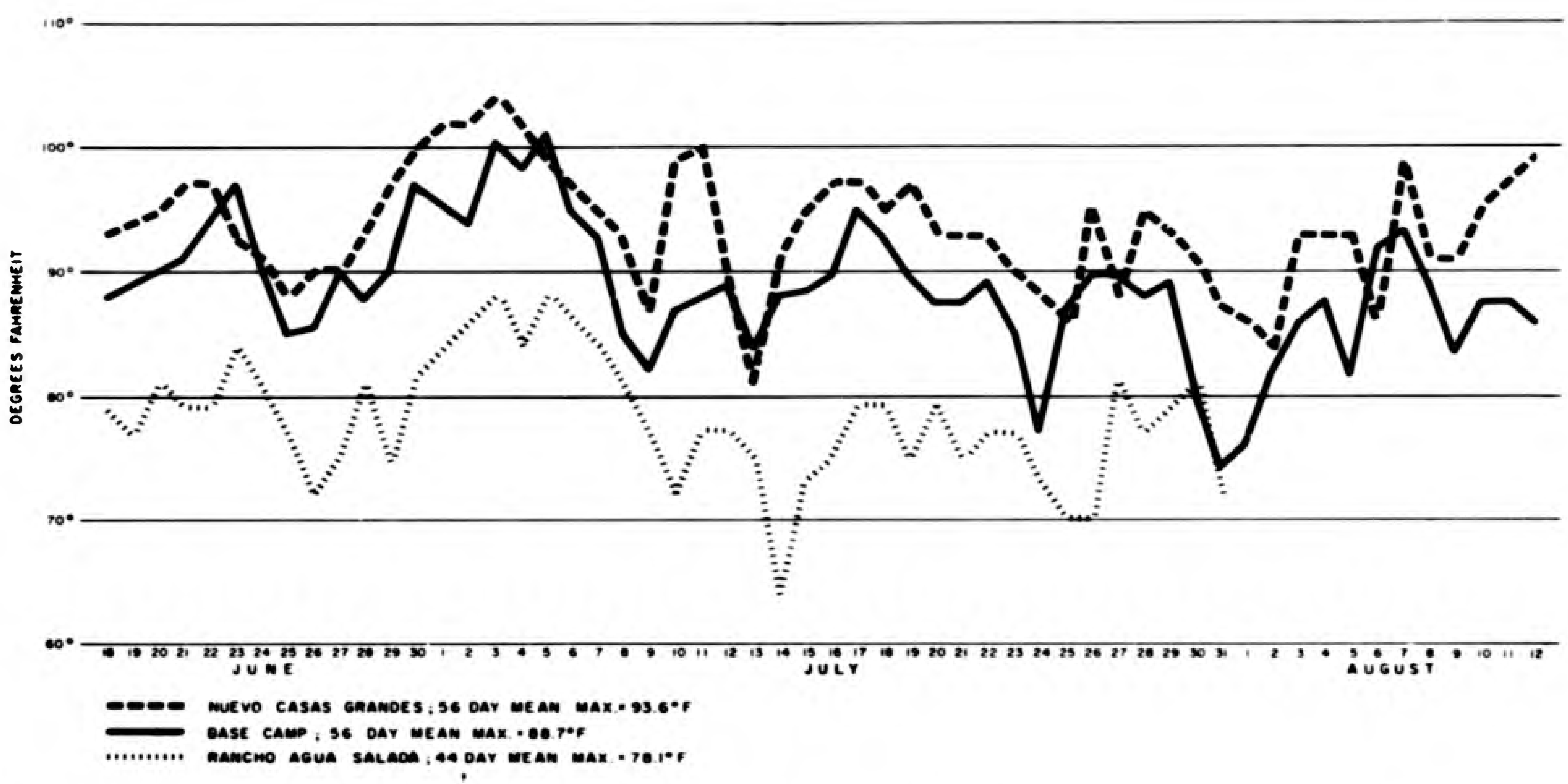

Figure 6. Maximum Temperatures, Nuevo Casas Grandes, Base Camp, and Rancho Agua Salada, 18 June - 12 August.

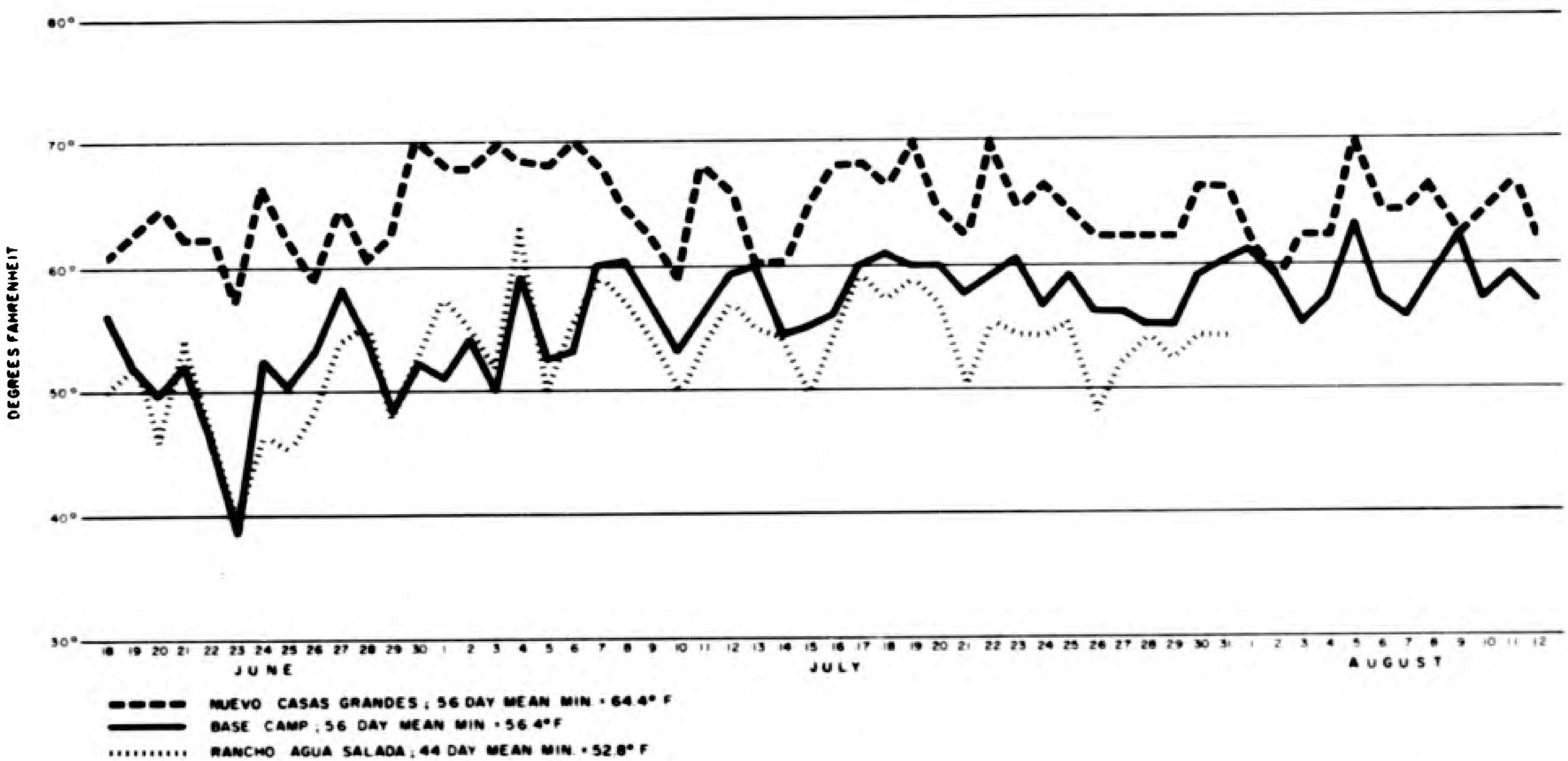

Figure 7. Minimum Temperatures, Nuevo Casas Grandes, Base Camp, and Rancho Agua Salada, 18 June - 12 August.

In general the pattern of maximum temperatures for all three stations follows the same course. The effects of elevation and exposure are shown in the lower temperatures for the two mountain stations. Warming periods, as illustrated by the period 28 June - 5 July, as well as cooling periods, as illustrated by 6-9 July and 20-25 July, are coincident for all three stations. The extreme high temperatures occur in close correlation, although there may be a day lag between the three stations. Several anomalies exist, notably 11 July, 27 July, and 10-12 August. On 11 July rain fell at Base Camp and Agua Salada, but not at Nuevo Casas Grandes. On 27 July there is no obvious explanation for the lack of similarity in temperature between Nuevo Casas Grandes and the two mountain stations. During the period 10-12 August, while there was considerable cloudiness and some rain at Nuevo Casas Grandes, heavy afternoon cloudiness with several torrential thunderstorms occurred at Base Camp. Closer correlation between the maximum temperatures of the three stations existed before the rainy season commenced the first week of July than after it began.

The daily minimums of the three stations correlate very well. The lowest minimum temperature was recorded on the same day, 23 June, at all three stations. There was also a gradual increase in the minimum temperatures following the beginning of the rainy season, although this feature is more noticeable at Base Camp than at the other two stations.

In conclusion, although the two mountain stations differ considerably in elevation, their daily traces of maximum and minimum temperatures appear to be more closely correlated than that of Nuevo Casas Grandes and Base Camp.

F. Vertical Air and Soil Temperatures

Along with hourly weather observations from 0700 to 2200 hours, measurements of free air temperatures and soil temperatures were made from 6 feet above ground level to 2 feet below ground level. Figure 8 shows graphically the mean hourly air and soil temperatures (data in Appendix C), and diurnal ranges of soil temperatures are shown in Figures 9, 10, and 11. Three weeks were selected, as follows:

1. Week 1 (19-24 June, 18 June missing): A period of high diurnal ranges of temperatures and little cloud cover, before the beginning of the rainy season.

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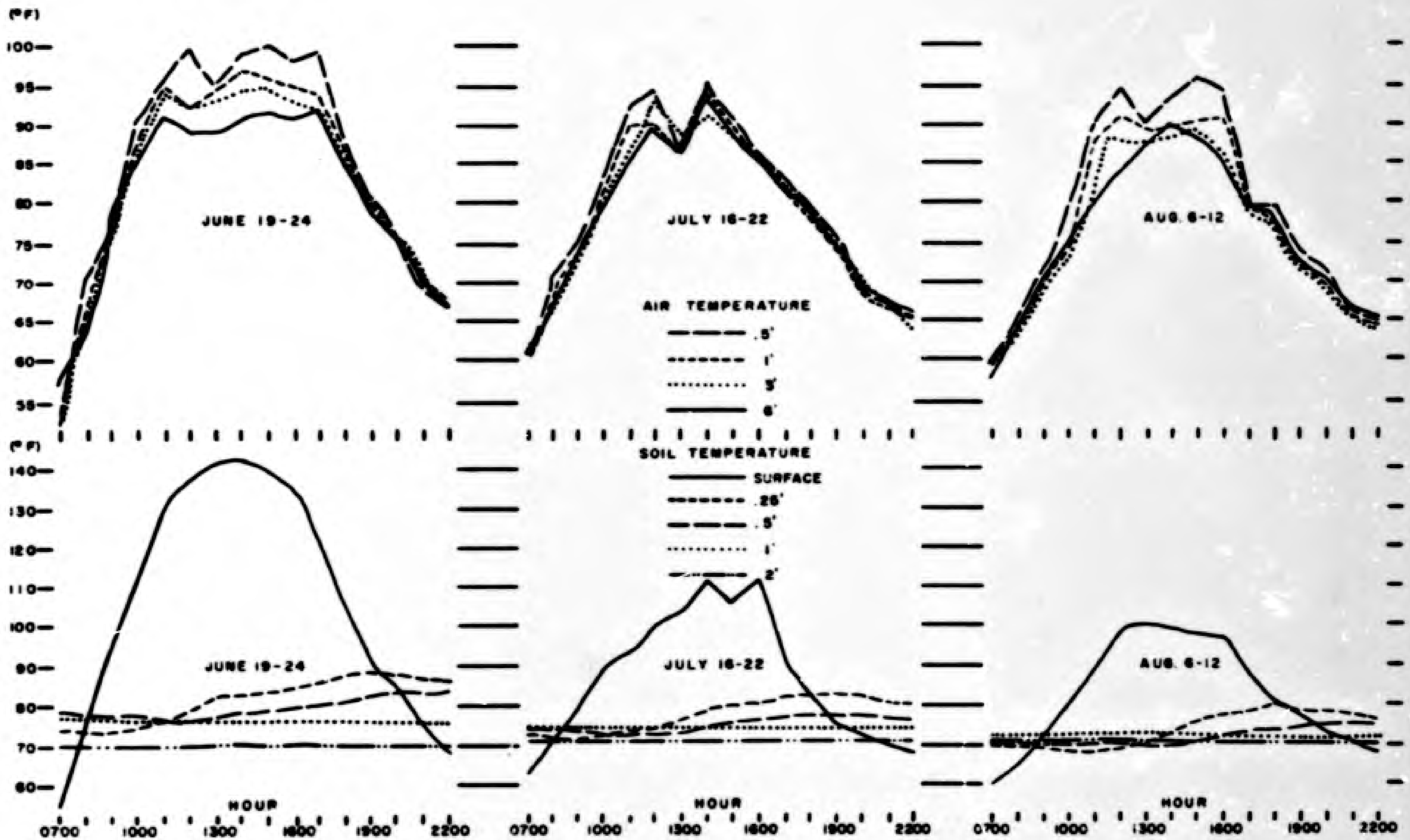


Figure 8. Mean Hourly Air and Soil Temperatures for Three Selected Weeks, Base Camp.

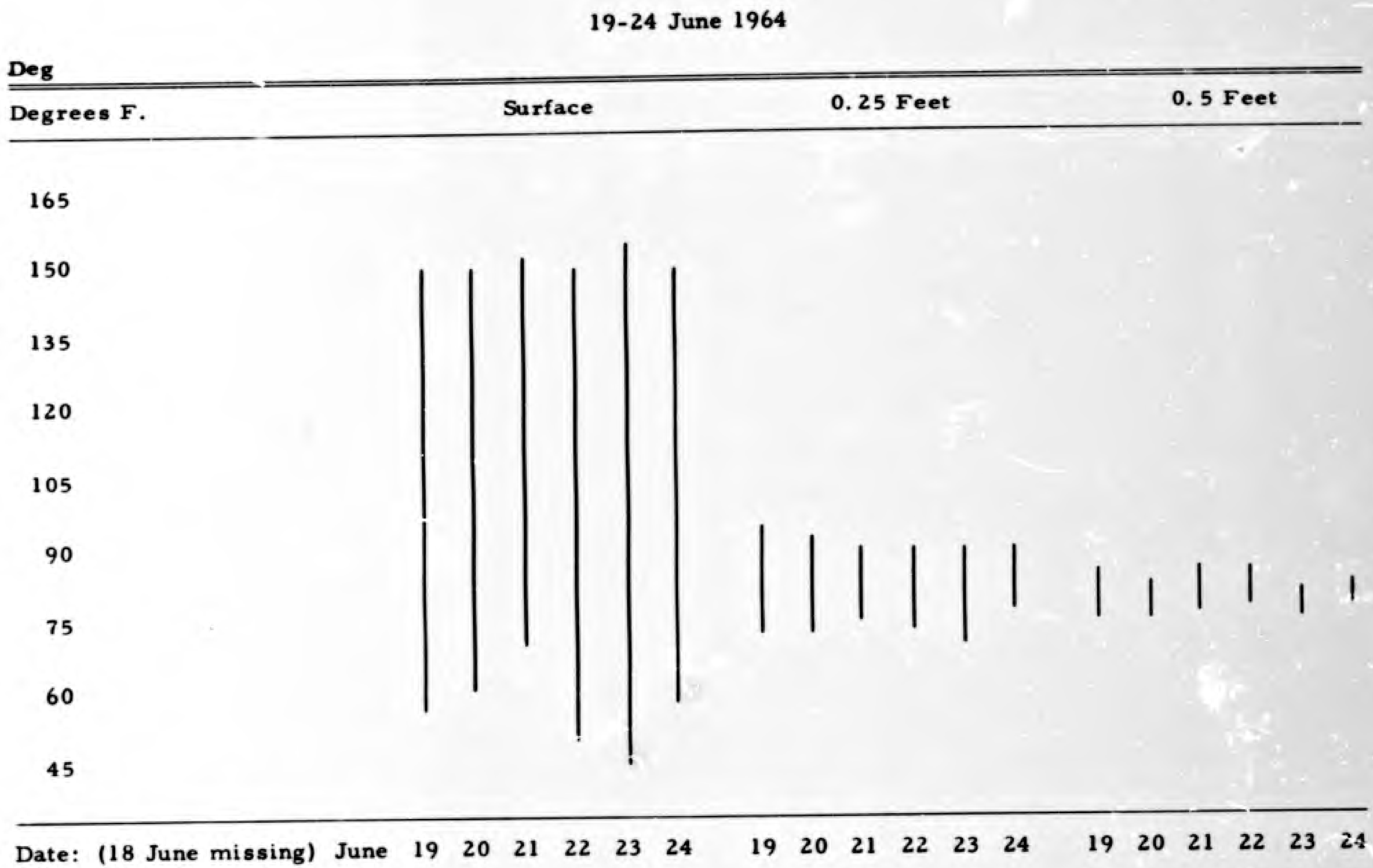


Figure 9. Diurnal Ranges of Soil Temperatures, Soil Surface to 0.5 Feet Depth, 19-24 June.

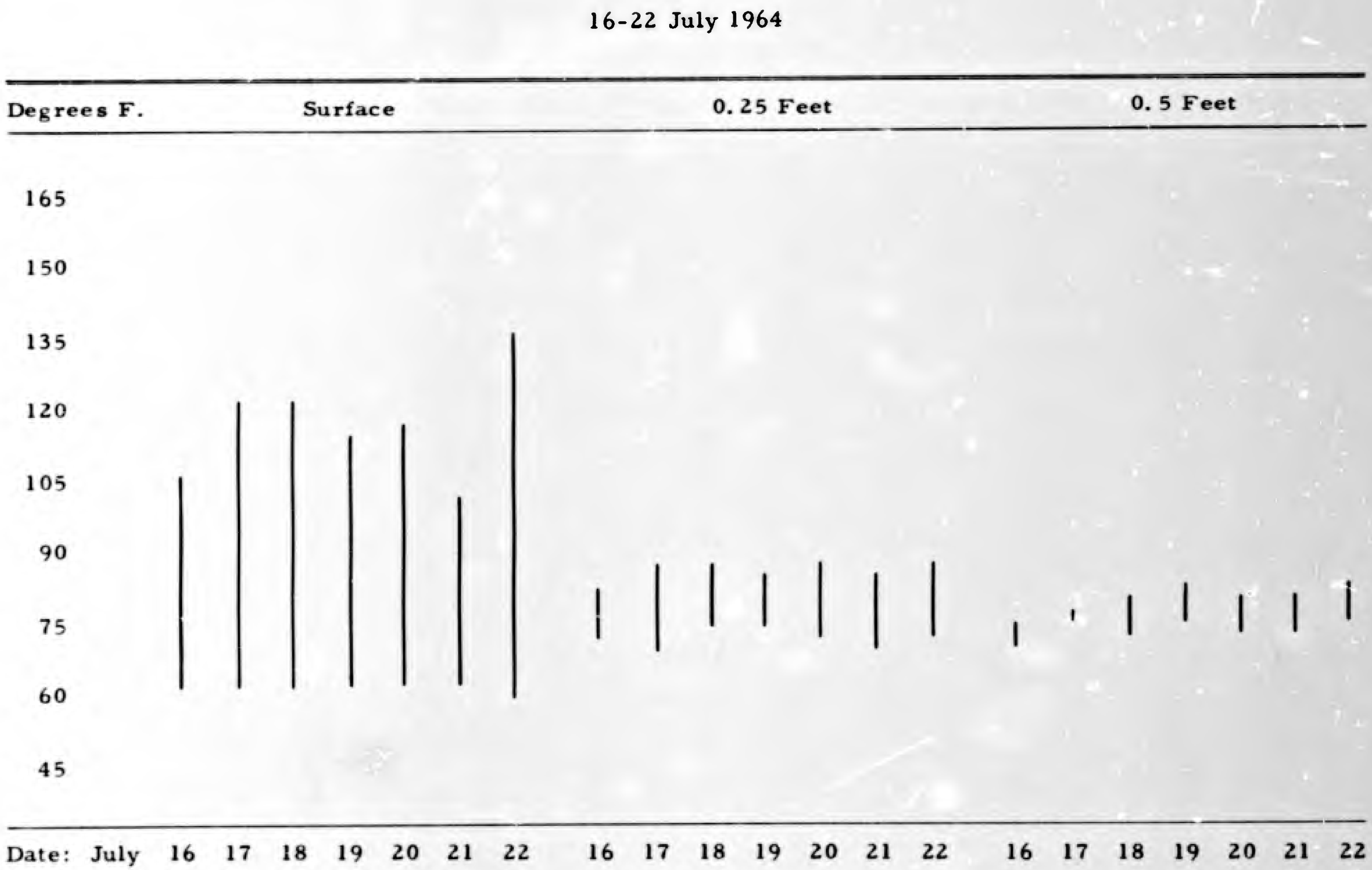


Figure 10. Diurnal Ranges of Soil Temperatures, Soil Surface to 0.5 Feet Depth, 16-22 July.

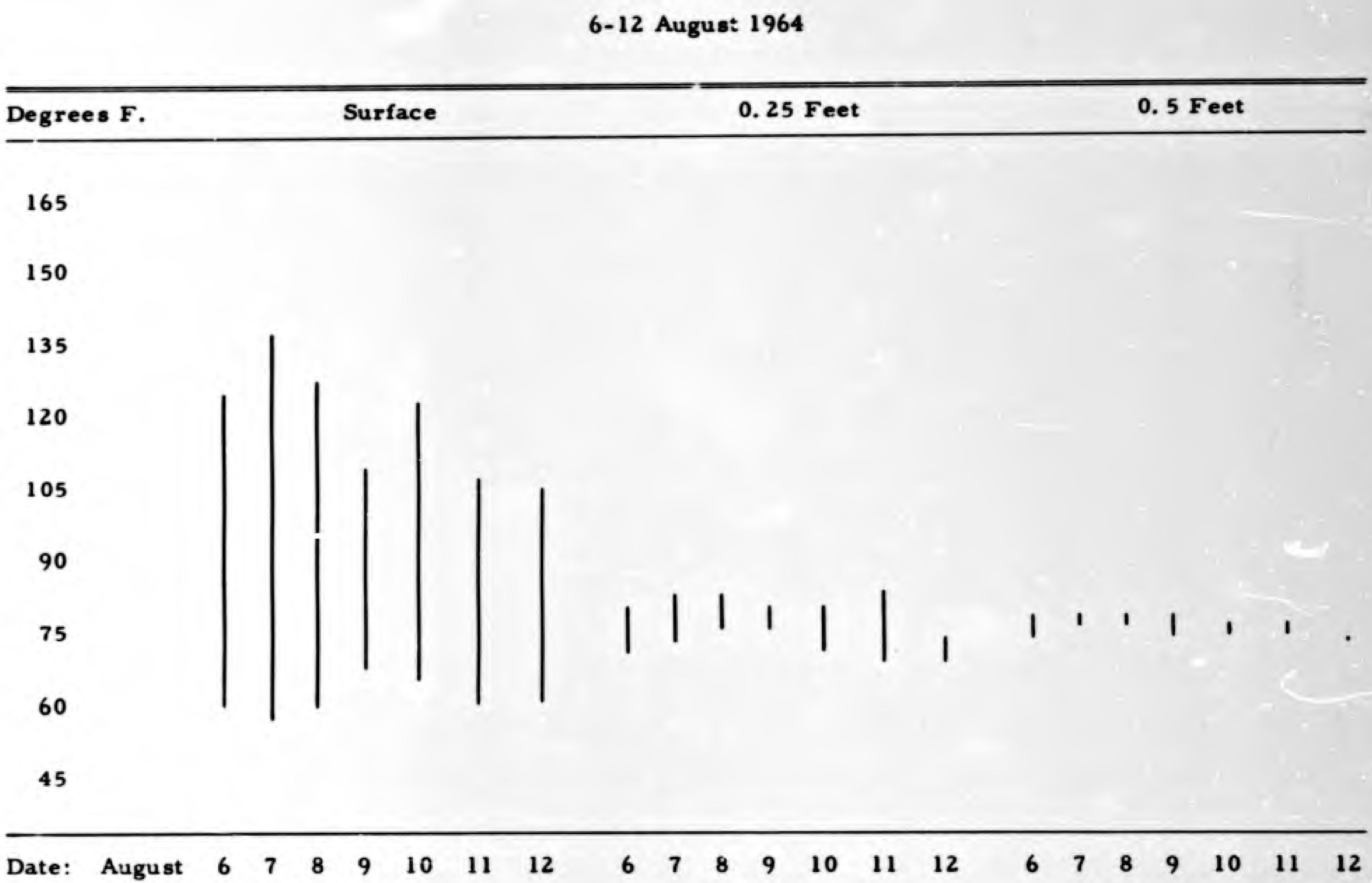


Figure 11. Diurnal Ranges of Soil Temperatures, Soil Surface to 0. 5 Feet Depth, 6-12 August.

2. Week 5 (16-22 July): A period of moderate diurnal temperature ranges, considerable cloud cover, and late afternoon and evening thundershowers.

3. Week 8 (6-12 August): A period of moderate diurnal temperature ranges, variable cloudiness, with several heavy thunderstorms.

Week 1. In Figure 8 appears the mean hourly vertical air temperature 0700 to 2200 hours for the period 19-24 June. The most striking feature of this graph is the close correlation of all temperatures for all heights 0.5-6.0 feet for the period 0700 to 1100 hours and from 1800 to 2200 hours. A marked temperature gradient occurs between 0.5-6.0 feet from 1200 to 1700 hours. The lowering of temperatures 1200 to 1300 hours undoubtedly results from increased cloudiness in the early part of the afternoon. A second maximum of air temperatures occurs at all levels between 1500 and 1700 hours under conditions of clearing skies. Also observable is a long plateau of high temperatures from 1100 to 1700 hours.

Figure 8 also shows graphically the mean hourly soil temperatures for the week 19-24 June, Appendix C gives surface and subsurface soil temperatures, and Figure 9 shows the diurnal range of soil temperatures. Of particular note is the very high diurnal range of soil surface temperatures, slightly over 80 degrees, with the daily maximums occurring between 1300 and 1400 hours. There is a very great dampening of diurnal temperature fluctuations with depth, with only a 1 degree diurnal range at 1 foot depth. A lag occurs in soil warming with depth so that daily maximums at 0.25 feet occur between 1800 to 2000 hours, 4 to 6 hours after the occurrence of the surface maximums. At the 0.5 feet level the occurrence of the maximum temperature possibly is after 2200 hours when observations were not made. The mean temperatures for 0700 to 2200 hours are as follows: 81.5° at 0.25 feet; 79.0° at 0.5 feet, a reduction of 2.5 degrees; 76.5° at 1.0 feet, a reduction of 2.5 degrees; and 72.1° at 2.0 feet, a reduction of 4.4 degrees.

Week 5. One month later (16-22 July) after the rainy season began, after 3.85 inches of precipitation had fallen, and during a period when 0.88 inches of rain fell from 6 storms, air and soil temperatures had changed considerably.

Differences in air temperature from the situation of Week 1 are apparent immediately. There is a greater temperature gradient between all levels from 0800 to 1100 hours than during Week 1. Now there is no plateau of high temperatures from 1100 to 1700 hours, and a considerable reduction of temperatures exists at all levels in the early afternoon. A double maximum of air temperatures is more marked than before, again due to clearing skies in the middle of the afternoon. There is a much lower range of diurnal temperatures at all levels with a lower temperature gradient between all levels during the middle of the day from 1100 to 1700 hours. The onset of decreasing afternoon temperatures is at 1400 hours rather than at 1700 hours as during Week 1.

As compared with Week 1, there is a much lower diurnal range for the surface temperatures and a slightly reduced diurnal range for the 0.25 and 0.5 feet depths. Diurnal ranges for the 1.0 and 2.0 feet levels remain negligible. Maximum soil surface temperature occurs later in the day, between 1400 and 1600 hours. Maximum temperature at 0.25 feet depth is several hours earlier than during Week 1, at 1700 hours rather than the 1900 hours of Week 1; and it extends over 4 hours to 2000. The mean temperatures for the period 0700 to 2200 hours are as follows: 77.4° at 0.25 feet; 75.8° at 0.5 feet, a reduction of 1.6 degrees; 74.7° at 1.0 feet, a reduction of 1.1 degrees; and 72.0° at 2.0 feet, a reduction of 2.7 degrees. In comparison with the earlier observational period, mean soil temperatures have been reduced for the 0.25, 0.5, and 1.0 feet levels, with the greatest reduction in the 0.25 feet level; and there was only a small decrease in the mean temperature of the 2.0 feet level. There has also been a reduction in the temperature gradient between all levels.

Daily fluctuations of soil temperatures are shown by Figure 10.

Week 8. This period (6-12 August) occurred at the end of the 56-day observational period, during a time of variable cloudiness with late afternoon and night heavy thunderstorms, when a total of 3.42 inches of rainfall fell. In many respects, the air temperature curves (Figure 8) are intermediate in character between those curves plotted for the first two periods. The diurnal range of temperatures at all levels was greater than during Week 5 but less than during Week 1. The effect of early afternoon cloudiness is apparent, and the lack of mid- and late-afternoon thunderstorms is shown by the second peak of maximum temperatures at 1500 to 1700 hours. The nearly uniform temperatures between 1700 and 1800 hours, first observable in the 16-22 July period, are again present.

The most significant features of the graph for mean soil temperatures during Week 8, especially in comparison with Week 5, are: (1) the higher diurnal range of temperatures on the surface and at the 0.25 feet level; (2) reduced temperature gradients between the 0.5, 1.0, and 2.0 feet levels; (3) earlier occurrence of the maximum temperature on the surface; and (4) later occurrence of the maximum temperature at the 0.5 feet level (1800 hours rather than at the previous 1700 hours). As a result of the deep wetting of the soil following the summer storminess, the mean temperatures at all levels were lower than during Week 5. The mean temperatures for this period, 6-12 August, and the temperature gradients are as follows: at the 0.25 feet level the mean temperature was 74.3°; at 0.5 feet, 72.8°, a reduction of 1.5 degrees; at 1.0 feet, 72.7°, a reduction of 0.1 degrees; and at 2.0 feet, 70.9°, a reduction of 1.8 degrees.

Figure 11 shows graphically the diurnal range of temperatures for each level during Week 8.

G. Sky Cover

Table 8 summarizes sky cover observations during three selected periods: Week 1 (18-24 June), Week 5 (16-22 July), and Week 8 (6-12 August). Table 9 gives the mean cloudiness by hour for the three weeks.

TABLE 8

Sky Cover During Three Selected Weeks

Base Camp

Sky Cover (tenths)	Frequency (%) of Observations Week 1 18-24 June	Week 5 16-22 July	Week 8 6-12 August
Clear (≤ 0.1)	50	11	2
Scattered (.1 - .5)	35	42	50
Broken (.6 - .9)	7	37	39
Overcast (1.0)	8	10	9

Week 1. The June period had overwhelmingly the least amount of cloud cover: 50 percent of the observations recorded clear skies and mean cloudiness was 0.21. From 0700 to 1100 hours mean cloud cover was 0.1 or less. Skies became cloudier from 1200 to 1500 hours with the greatest cloudiness of 0.4 occurring at 1500 hours. Then, until the last cloud observations were made at 2000 hours, there was a gradual decrease to 0.2.

TABLE 9

Mean Hourly Cloud Cover During Three Selected Weeks

Base Camp

Time	Cloud Cover in Tenths Week 1 18-24 June	Week 5 16-22 July	Week 8 6-12 August
0700	.10	.50	.45
0800	.05	.50	.60
0900	.10	.25	.50
1000	.05	.25	.40
1100	.10	.20	.30
1200	.25	.31	.30
1300	.25	.50	.40
1400	.30	.55	.45
1500	.40	.60	.50
1600	.35	.70	.50
1700	.35	.50	.55
1800	.30	.40	.65
1900	.20	.60	.40
2000	.20	.65	.50
	$\bar{x}$ = .21	$\bar{x}$ = .46	$\bar{x}$ = .46

Week 5. In the July period the mean cloudiness had risen to 0.46. Most observations reported scattered clouds (42 percent) or broken skies (37 percent), and only 11 percent of the observations were of clear skies. In early morning at 0700 and 0800 hours the mean cloudiness was 0.5, these clouds often taking the form of low stratus clouds. Then from 0900 to 1100 hours the skies cleared. Between 1200 to 1600 hours the skies became progressively overcast until a maximum cloud cover of 0.7 was reached at 1600 hours. At 1700 to 1800 hours occurred a period of clearing, which was followed by increased cloudiness at 2000 hours, the time of last observation.

Week 8. For the August period, mean cloudiness was 0.46. A greater majority of the observations than ever reported scattered clouds (50 percent) and broken skies (39 percent). Only 2 percent of the observations were of clear skies. There was considerable morning cloudiness. Skies cleared around noon, with 0.3 cloud cover at 1100 and 1200 hours. From 1300 to 1800 hours the skies became more overcast with the greatest amount of cloudiness, 0.65, occurring at 1800 hours. From then until 2000 hours the skies cleared somewhat.

Although the mean cloudiness was 0.46 for both the July and August periods, the July week had somewhat clearer morning skies (0900 to 1100) and cloudier afternoon skies (1200 to 1600) than did the August week.

H. Radiation

As previously mentioned, a net radiometer was built following the plans outlined in Soil Bulletin No. 4, Department of Soils, College of Agriculture, University of Wisconsin, by Swan, Federer, and Tanner. This instrument was used to record net radiation at Base Camp during times of no possible precipitation. Readings were normally made during the day from 0800 to 2100 hours. Appendix B gives net radiation, dry bulb air temperatures, and surface and 0.25 feet soil temperatures for all times when net radiation was measured during the 56-day study period.

Figure 12 shows net radiation, dry bulb air temperatures, and cloud cover for 5, 13, and 23 July 1964. High temperatures particularly characterized 5 July. On this day there were 8 hours of 90° and over recordings, reaching a maximum of 101.3°, the absolute maximum for the study period. Skies were fairly clear but hazy and air was calm. In contrast, 13 July was a day of considerable cloudiness, thunder, but no moisture, moderate warmth with 4 hours over 80° and a maximum of 84°, and calm air. July 23 was a day moderately cloudy and warm, with 7 hours over 80°, a maximum of 85°, and calm air.

I. Pressure

At the time the weather instruments were set up (17 June 1964 at 1600 hours) the barograph was set at 29.92 inches Hg. On 1 July at 1200 hours the barograph was adjusted to correlate better with the adjusted sea level pressure readings at El Paso, Texas; Douglas, Arizona; and Ciudad Chihuahua, Chihuahua. Using these three stations as references the barograph was reset 0.25 inches Hg. lower.

From 18 to 27 June there was a well-developed diurnal cycle of pressure change. Highest pressures were recorded between 0900 to 1200 hours, and minimum pressures between 1800 to 2000 hours. Pressures rose slightly after 2000 hours and remained essentially constant until 0600 hours the following morning, when the rise to the diurnal or daily peak at 1200 hours began. This diurnal range had a magnitude

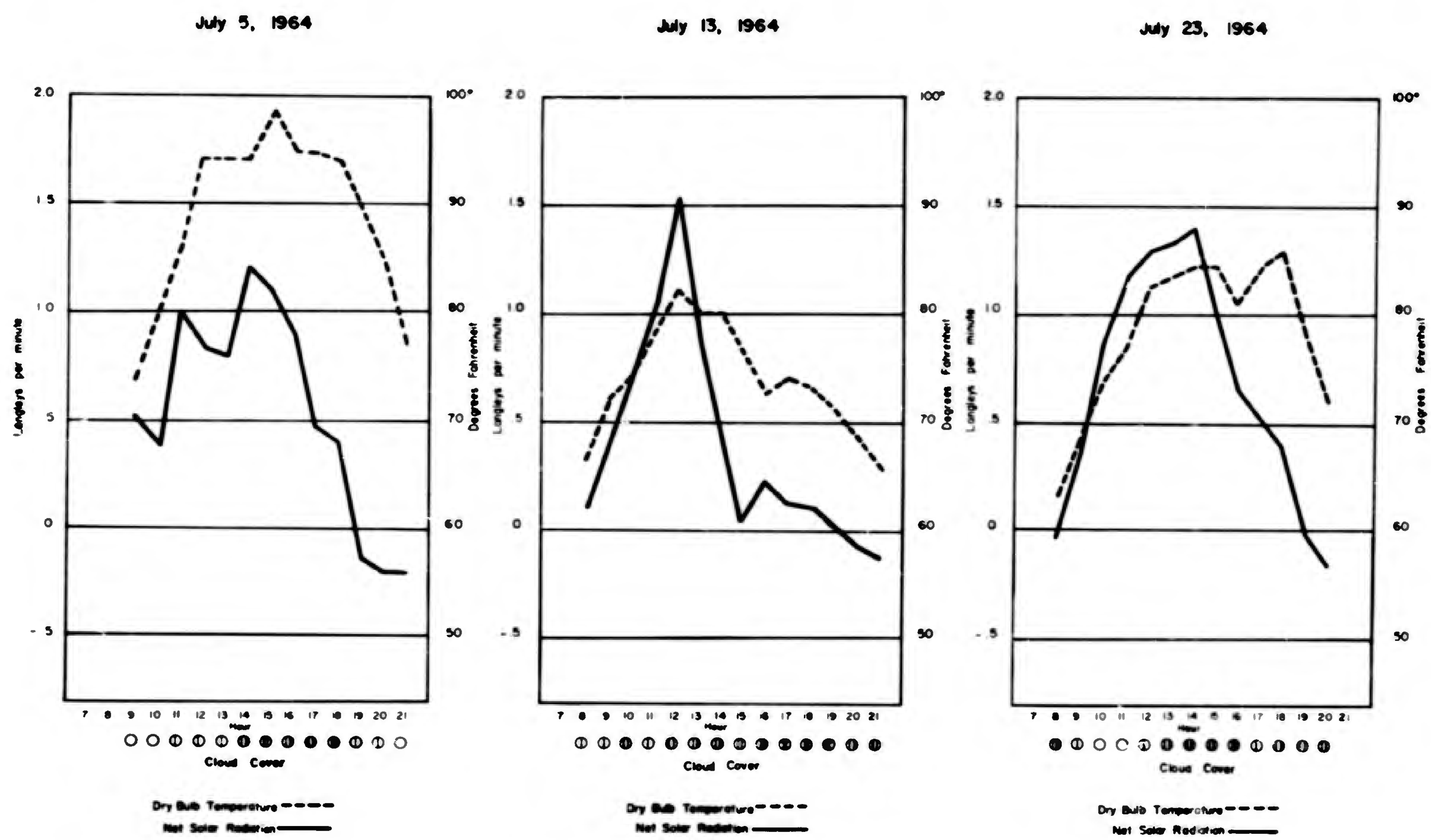


Figure 12. Net Radiation, Dry Bulb Air Temperatures, and Cloud Cover, Base Camp, 5, 13, and 23 July.

of . 08 to . 10 inches Hg. Figure 13 shows a barogram from 1130 hours, 21 June, to 1100 hours, 25 June, which well illustrates this pattern. This chart does not reflect the 0. 25 inches Hg. adjustment.

From 26 June to 7 July the diurnal cycle became irregular. Some days recorded little, if any, diurnal pressure change; while other days experienced a marked fall in pressure in the late afternoons and early evenings. From 7 July to 12 August only occasionally were there any diurnal pressure changes, these of the magnitude of 0. 02 inches Hg. or less. Figure 13 shows a barogram from 1100 hours 27 July to 1100 hours 31 July, which is representative of this situation. This chart does reflect the 0. 25 inches Hg. readjustment made of 1 July.

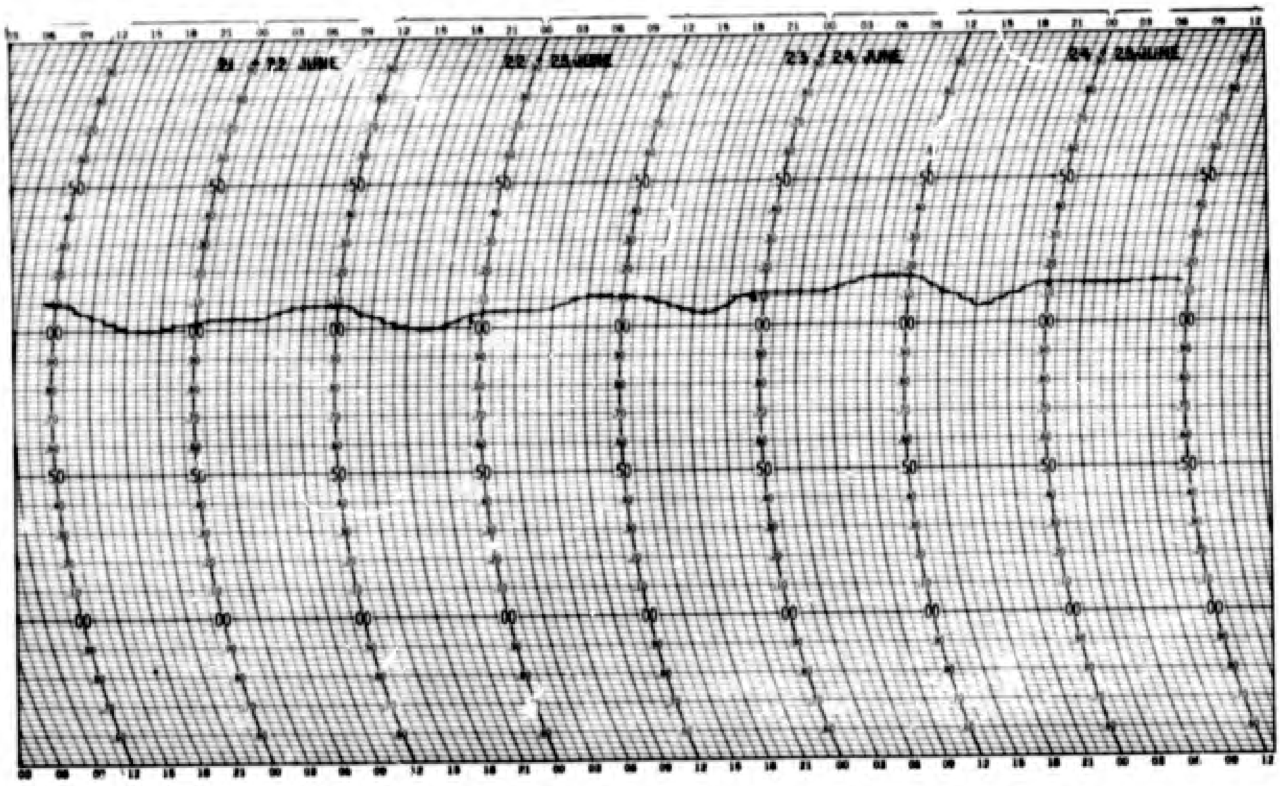
J. Precipitation

The general pattern of precipitation in the Sierra Madre Occidental has been described in Part I. Figure 14 and Table 10 show the amount of rainfall daily during the 56-day study period and Table 11 summer rainfall at the Rancho los Charles Base Camp, as well as at Nuevo Casas Grandes and Rancho Agua Salada. In Appendix D are given the major features of each storm with at least 0. 01 inches of rainfall, and it should be noted that occasionally several storms occurred during a single 24-hour period. Tables 12 and 13 show the frequency of precipitation amount and duration per storm, and Table 14 compares the time of beginning of storms at Nuevo Casas Grandes and Base Camp.

Amount of Rainfall. During the 56-day period, 45 days recorded a trace or more of rainfall, with 34 of these days recording a measureable amount. The total amount was 11. 24 inches. The quantities were disposed very unevenly over the period as follows: 0. 39 inches in June, 6. 90 inches in July, and 3. 95 inches in the first 12 days of August.

Table 12 shows the relative frequency amount per storm. Nearly 40 percent of the storms recorded only a trace of moisture, while 9 percent recorded 0. 51 inches or more of moisture.

Rainfall Intensity. The technique for measuring rainfall intensity used four plastic farm-type rain gauges mounted adjacent to and at the same height as the recording rain gauge. The time of each storm beginning was noted on a stop watch. After 10 minutes the amount that had fallen was recorded and the first gauge was emptied. At the end of the second 10-minute period the second gauge was read,



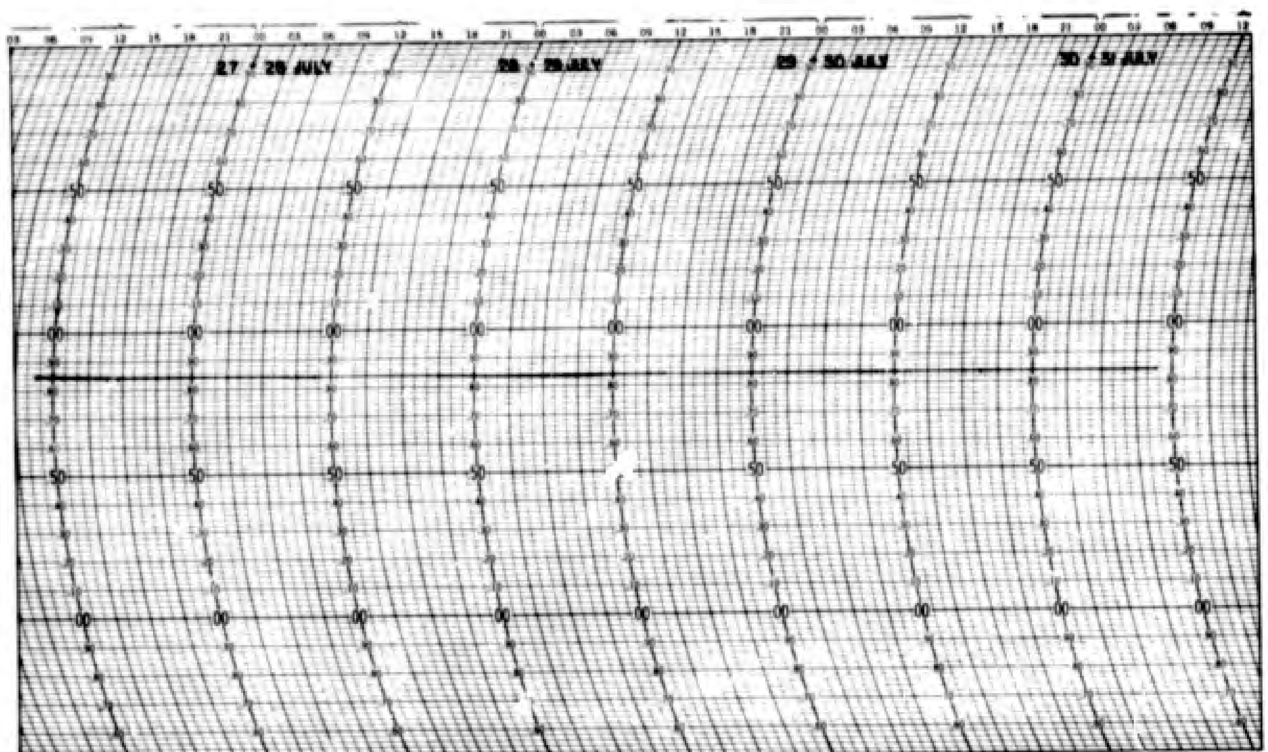


Figure 13. Barograms, 1130 Hours 21 June - 1100 Hours 25 June and 1100 Hours 27 July - 1100 Hours 31 July, Base Camp.

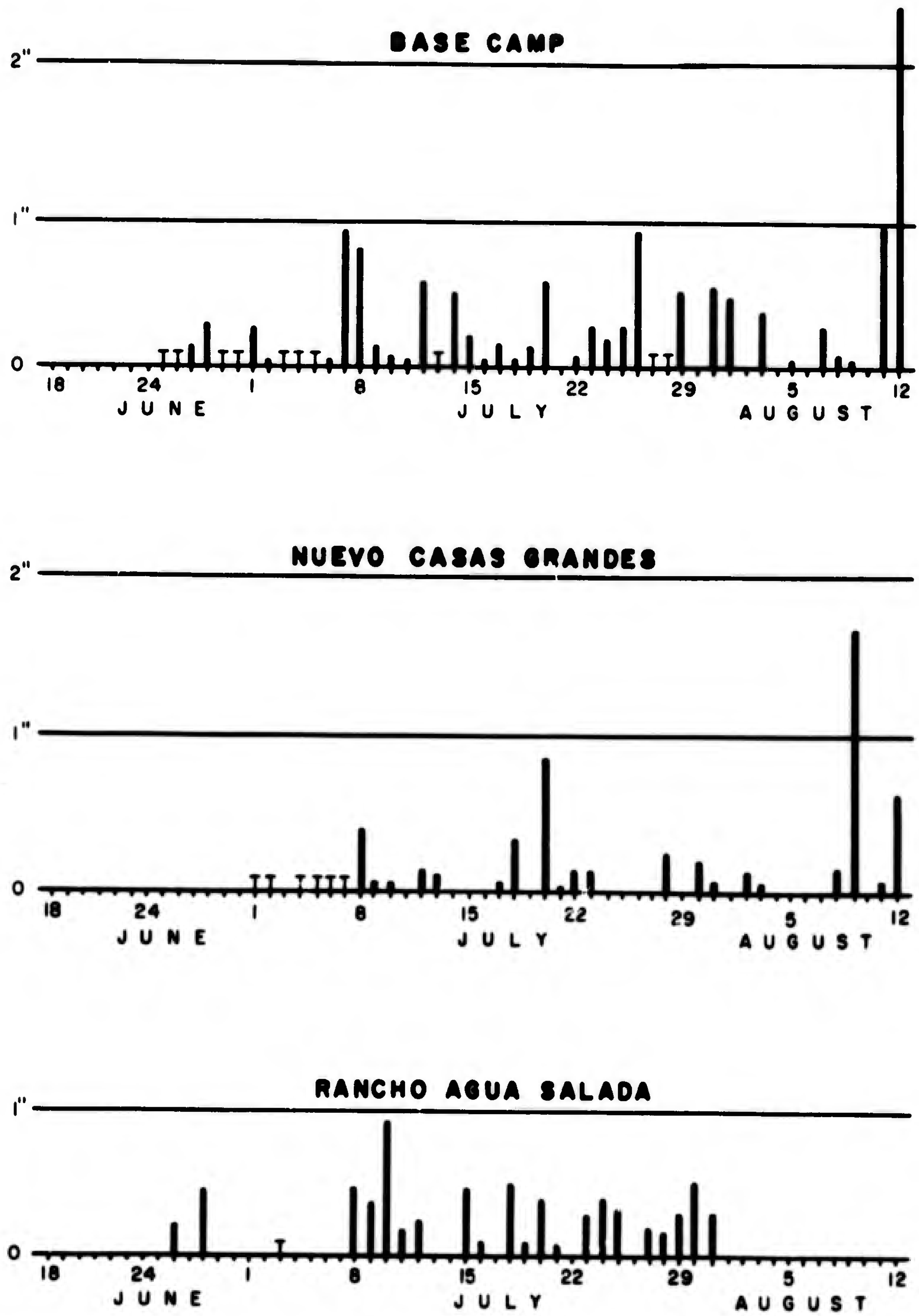


Figure 14. Daily Rainfall, Base Camp, Nuevo Casas Grandes, and Rancho Agua Salada, 18 June - 12 August.

TABLE 10

Daily Rainfall for Base Camp, Nuevo Casas Grandes and Rancho Agua Salada

18 June - 12 August

Date	Base Camp (Inches)	Nuevo Casas Grandes (Inches)	Rancho Agua Salada (Inches)
18 June			
19			
20			
21			
22			
23			
24			
25	T		
26	T	.04	.20
27	.12		
28	.27		.40
29	T		
30	T		
1 July	.26	T	
2	.02	T	
3	T		T
4	T	T	
5	T	T	
6	.06	T	
7	.93	T	
8	.83	.40	.40
9	.11	.04	.32
10	.05	.04	.92
11	.02		.12
12	.52	.16	.20
13	T	1.28	
14	.46		
15	.18		.40
16	.04		.08
17	.14	.08	
18	.02	.32	.44
19	.11		.08
20	.52	.92	.32
21		.08	.06

TABLE 10 (Cont.)

Date	Base Camp (Inches)	Nuevo Casas Grandes (Inches)	Rancho Agua Salada (Inches)
22	.07	.12	
23	.24	.12	.24
24	.17		.32
25	.25		.28
26	.94		
27	T		.16
28	T	.24	.10
29	.42		.24
30	.05	.20	.44
31	.49	.08	.26
1 August	.04		No Data
2	T		No Data
3	.34		No Data
4			No Data
5	.03		No Data
6			No Data
7	.22		No Data
8	.08	.12	No Data
9	.02	1.64	No Data
10			No Data
11	.98	.04	No Data
12	2.24	.60	No Data

TABLE 11

Summer Rainfall at Base Camp, Nuevo Casas Grandes, and Rancho Agua Salada

	Precipitation in Inches		
	Base Camp	Nuevo Casas Grandes	Rancho Agua Salada
June:			
Total 1964	0.39*	0.08	0.60
15-Year Average**	--	0.53	--
July:			
Total 1964	6.90	4.04	5.38
15-Year Average**	--	3.58	--
August:			
1-12 August, 1964	3.95	3.52	--
15-Year Average**	--	3.40	--
18 June-12 August, 1964	11.24	7.64	--

* Although observations began on 18 June, inquiries at nearby ranches confirmed that no precipitation had fallen in June before the 25th.

**Wernstadt, F. E. (1961), World Climatic Data: Latin America and the Caribbean, Department of Geography, Pennsylvania State University, p. 54.

TABLE 12

Amount of Rainfall per Storm

Base Camp

18 June - 12 August

Amount in Inches	Frequency (%) of Observations n = 64
< 0.01	39.0
0.01 - 0.10	21.8
0.11 - 0.20	11.0
0.21 - 0.30	12.6
0.31 - 0.40	1.5
0.41 - 0.50	4.7
0.51 - 0.60	1.5
0.61 - 0.70	1.5
0.71 - 0.80	0
0.81 - 0.90	0
0.91 - 1.00	4.7
> 1.00	1.5

TABLE 13

Duration of Rainstorms With 0.01 Inches or More Precipitation

Base Camp

18 June - 12 August

Duration	Frequency (%) of Observations n = 39
< 30 min.	17.9
30-59 min.	15.4
1 Hr. - 1 hr. 29 min.	10.2
1 Hr. 30 min. - 1 hr. 59 min.	10.2
2 hr. - 2 hr. 29 min.	7.7
2 hr. 30 min. - 2 hr. 59 min.	2.5
3 hr. - 3 hr. 29 min.	10.2
3 hr. 30 min. - 3 hr. 59 min.	5.1
4 hr. - 4 hr. 29 min.	5.1
4 hr. 30 min. - 4 hr. 59 min.	5.1
5 hr. - 5 hr. 29 min.	10.2

TABLE 14

Time of Storms at Base Camp and Nuevo Casas Grandes

Occurrence by Hour of Beginning
% Frequency

18 June - 12 August

Hour	Base Camp* n = 39	Nuevo Casas Grandes** n = 24
0100-0159	7.7	0
0200-0259	2.6	0
0300-0359	0	0
0400-0459	0	0
0500-0559	0	0
0600-0659	0	0
0700-0759	0	0
0800-0859	0	0
0900-0959	0	0
1000-1059	0	0
1100-1159	0	0
1200-1259	2.6	0
1300-1359	7.7	0
1400-1459	12.8	0
1500-1559	5.1	12.5
1600-1659	10.2	12.5
1700-1759	2.6	4.2
1800-1859	5.1	12.5
1900-1959	7.7	0
2000-2059	12.8	8.3
2100-2159	2.6	20.9
2200-2259	10.2	25.0
2300-2359	5.1	4.2
2400-2459	2.6	0

* Minimum amount 0.01 inches

** Minimum amount 0.04 inches

that amount less the amount of the first 10 minutes was recorded, and the second gauge was emptied. This procedure continued until the end of the storm. Some problems were associated with this technique: (1) with small amounts of rainfall a large proportion of the drops adhered to the sides of the gauge, causing difficult recording; and (2) under extremely heavy intensity there was some loss due to splashing.

The most intense rainfall period during any given storm was usually during the first 10 to 20 minutes. Rarely did the amount of the second 10-minute period exceed that of the first. Characteristically, only 30 to 50 percent of the first 10-minute total fell in the second 10 minutes.

The greatest amount falling in 10 minutes was 1.05 inches during the storm of 12 August. The most frequent amount recorded was less than 0.01 inches per 10 minutes.

Time of Beginning and Duration of Storms. No rainfall was recorded between the hours of 0300 and 1159. The greatest frequency of storm beginnings occurred from 1400 to 1459 hours. From 1500 to 2459 hours there was little significant difference in the frequencies, considering the number of storms involved. However, slightly more storms occurred in the evening and night (after 1859 hours) than in the afternoon. The two most severe storms began very near midnight, both before and after 0100 hours.

A relatively large proportion (20 percent) of the storms were of considerable duration--4 hours or more. However, the amount of precipitation falling after the first hour was usually rather negligible. Brief storms of 30 minutes or less duration occurred in 18 percent of the cases.

Hail. Very soft hail occurred for a few minutes on one occasion.

Dew. Dew was observed on 39 mornings. Seven of these mornings recorded both rain and dew; therefore, measurable amounts occurred on 32 days only. Of the 56 days of observation, 13 mornings recorded no dew and 4 mornings are missing dew observations. Table 15 shows the occurrence of dew by amount as recorded by the Dudevani Dew Gauge.

TABLE 15

Quantitative Occurrence of Dew

Base Camp

18 June - 12 August

Dew Number*	Frequency	ml. of moisture**
1	6	.12
2	8	.36
3	5	.38
4	8	.88
5	2	.30
6	3	.60
7	0	0
8	0	0
	Σ 32	Σ 2.65

* Dudevani number

**Derived from figures included with the Dudevani dew gauge

<u>Variation in Amount of Rainfall Between Base Camp, Trinchera 58a, and Airstrip</u>. Rainfall from 23 separate storms was recorded by a rain gauge situated at the satellite weather station in the open adjacent to Trinchera 58a, 0.8 miles east of Base Camp. A total of 5.52 inches of moisture fell here, varying from 0.01 to 0.98 inches of rainfall during separate storms. From these same storms 6.26 inches of moisture fell at Base Camp. For 11 of the storms, Base Camp recorded a larger amount than Trinchera 58a; for 10 storms, Base Camp recorded less; and in two instances the amounts were the same. The mean difference in amount recorded was 0.08 inches. Expressed differently, the rainfall at Trinchera 58a averaged 93 percent of the amount recorded from the same storms at Base Camp.

Moisture was recorded for 24 separate storms by a rain gauge situated in the open at the northwest end of the airstrip, 1.9 miles northeast of Base Camp. From these storms a total of 10.39 inches of moisture fell at the airstrip, varying from 0.01 to 2.0 inches. Rainfall occurred at Base Camp during only 21 of these storms, recording 7.84 inches total precipitation. During 8 storms a greater amount was recorded at Base Camp than at the airstrip, while during 12 storms the greater amount was recorded at the airstrip, and for 1 storm both stations recorded the same amount. The mean difference in amounts recorded was 0.33 inches. The rainfall at the airstrip averaged 135 percent of the amount recorded from these storms at Base Camp.

In summary, while these two satellite stations were close enough to Base Camp so that in most instances rain occurred at all three places, the amount that fell varied considerably, particularly in comparing the airstrip to Base Camp. The great variability in amount and occurrence seems to be a very important attribute of the summer storms of the Sierra Madre Occidental, as, of course, it is of many mountainous areas.

Comparison of Rainfall at Base Camp, Nuevo Casas Grandes, and Rancho Agua Salada. Table 11 gives in summary form and Table 10 and Figure 14 in daily form the differences in precipitation between the three stations. Table 14 shows the time of occurrence of 24 storms (.04 inches, or 1 mm., or more precipitation) at Nuevo Casas Grandes and 39 storms (0.01 inches or more) at Base Camp. The following generalizations about precipitation at the three stations can be made:

1. Although June in Nuevo Casas Grandes was considerably drier than average, July recorded 12 percent more than average precipitation and during the first 12 days of August 0.12 inches more rainfall was recorded than the average for the whole month. It thus seems possible that during the 56-day study period precipitation at Nuevo Casas Grandes was somewhat greater than normal.

2. From the limited material available, it is extremely hazardous to generalize on the probable greater precipitation in the mountains. A suggestion may be made, however, that 25 to 50 percent more rainfall occurs during the summer months, June through August, at Rancho los Charles and Rancho Agua Salada than at Nuevo Casas Grandes.

3. The comparison shown in Table 14 suggests that the time of occurrence of storms is later during the day at Nuevo Casas Grandes than at Base Camp.

4. Although rainfall may occur at all three stations on the same day, this situation is undoubtedly a result of chance as most of the storms are very local, as the previous sub-section indicated.

K. Relative Humidity

The lowest relative humidity readings during the 56-day study period were recorded 1400 to 1630 hours on 23 June when the relative humidity stood at 14 percent. The temperature at this time was 93° to 97°. The greatest duration of high relative humidity occurred from 1500 hours, 27 June, to 0900 hours, 28 June, a total of 18 hours. Temperatures during this period never exceeded 65°.

Hourly Relative Humidity. Table 16 shows the mean relative humidity by hour for three weekly periods: Week 1 (18-24 June), Week 5 (16-22 July), and Week 8 (6-12 August).

In the period 18-24 June just before the beginning of the rainy season, nighttime relative humidity readings were 40 to 90 percent, with saturation normally occurring just before sunrise. Following sunrise at 0700 hours there was a steady decrease in relative humidity. The lowest mean of 29 percent was recorded between 1500 and 1600 hours. Then came a gradual increase in relative humidity to 0700 hours the following morning when the mean relative humidity was 95.3 percent.

During Week 5 mean relative humidity readings of 98+ percent were recorded during nights from 2200 hours to 0800 hours the next morning. Following sunrise relative humidity steadily decreased to 1400 hours when the mean relative humidity was 41.9 percent, higher by 13 percent than the mean low of Week 1. After 1400 hours, the relative humidity began to increase until saturation occurred around 2100 hours.

During Week 8 mean relative humidity readings of 98+ percent were again recorded at night between 2200 and 0800 hours. The minimum of 51 percent relative humidity which occurred at 1600 hours was 22 points higher than the minimum of the June period.

Comparison of Relative Humidity at Base Camp and Nuevo Casas Grandes. Table 17 shows the weekly mean relative humidity for 0600, 1200, and 1800 hours at Base Camp and Nuevo Casas Grandes. Relative humidity readings were nearly always greater at Base Camp. The four exceptions all occurred during Weeks 1, 2, and 3, mostly at 1800 hours.

The greatest difference between the two stations was observed at 0600 when relative humidity readings of over 90 percent occurred

TABLE 16

Hourly Mean Relative Humidity During Three Selected Weeks

Base Camp

	Mean Relative Humidity in %		
Time	Week 1 18-24 June	Week 5 16-22 July	Week 8 6-12 August
0100	63.6	98+	98+
0200	71.1	98+	98+
0300	78.3	98+	98+
0400	83.9	98+	98+
0500	89.7	98+	98+
0600	94.3	98+	98+
0700	95.3	98+	98+
0800	73.0	98+	98+
0900	56.9	83.9	89.0
1000	46.9	72.4	79.9
1100	38.4	60.9	67.4
1200	33.1	50.7	57.4
1300	31.7	48.0	56.4
1400	29.7	50.6	52.0
1500	29.1	53.4	42.3
1600	29.4	57.1	51.3
1700	29.6	60.4	62.3
1800	32.6	58.4	67.6
1900	36.0	63.6	81.3
2000	41.0	80.9	85.7
2100	46.6	93.7	94.7
2200	51.4	98+	98+
2300	56.9	98+	98+
2400	62.3	98+	98+

TABLE 17

Weekly Mean Relative Humidity at Selected Hours

Base Camp and Nuevo Casas Grandes

Date & Location	Mean Relative Humidity in %		
	Hour: 0600	1200	1800
18-24 June			
BC*	94.3	33.1	32.6
NCG**	55.8	31.8	38.8
25 June - 1 July			
BC	98.0	36.1	36.1
NCG	73.7	38.8	36.1
2-8 July			
BC	97.6	35.0	38.4
NCG	62.1	32.8	42.4
9-15 July			
BC	97.7	51.3	67.1
NCG	80.6	50.0	45.4
16-22 July			
BC	98.0	50.6	57.9
NCG	77.8	51.7	45.4
23-29 July			
BC	98.0	49.0	60.0
NCG	80.1	48.4	53.2
30 July - 5 August			
BC	98.0	60.1	81.6
NCG	83.6	56.6	55.5
6-12 August			
BC	98.0	57.4	67.6
NCG	83.0	50.0	45.8

* Base Camp

** Nuevo Casas Grandes

uniformly throughout the summer at Base Camp. In contrast, mean relative humidity readings at Nuevo Casas Grandes at 0600 never exceeded 83.6 percent, which nevertheless was the highest mean value there. In the week before the rainy season began, 18-24 June, the 0600 mean at Nuevo Casas Grandes had been as low as 55.8 percent. These higher early morning relative humidity readings at Base Camp probably resulted from the lower minimum temperatures there than at Nuevo Casas Grandes.

The closest correlation between the two stations occurred at 1200 hours, when the differences were usually only 1 to 3 percentage points. Relative humidity readings at 1800 hours, while more similar for the two stations than the 0600 hour readings, did not show the close correlation of the 1200 hour readings. This situation may be a result of the great variability in the appearance of the rainy season showers and thunderstorms.

L. Evaporation

Evaporation measurements were made by means of a Piche Evaporimeter placed inside the weather shelter at Base Camp. Table 18 shows the daily mean evaporation for each weekly period during the 56-day study period.

TABLE 18

Daily Mean Evaporation

Base Camp

18 June - 12 August

Date	Daily Mean Evaporation in ml.
18-24 June	7.7
25 June - 1 July	3.9
2-8 July	4.6
9-15 July	2.6
16-22 July	3.1
23-29 July	2.5
30 July - 5 August	2.4
6-12 August	2.4

A great decrease in the amount of evaporation occurred after the first week as a result of increased relative humidity, the occurrence of the first storms of the rainy season, reduced daytime temperatures, and reduced air movement--all of which took place in the second week.

In the week of 2-8 July very high temperatures for the first 6 days resulted in an increase in evaporation over the preceding week.

M. Wind

A totalizing anemometer with a starting speed of 2 mph was placed 10 feet above the ground adjacent to the weather shelter. Table 19 shows the daily run of the wind, and Table 20 shows the relative frequency of wind speed and wind direction for the 8 weekly periods during the study.

Wind Speed. Eighty-seven percent of the hourly observations recorded calm air conditions. The highest wind speed, 12 mph, was observed 18 June at 1600 hours. Wind speeds from 0700 to 2200 hours were generally light.

The highest values were recorded in June before the rainy season began. After the beginning of the heavier rains on 7 July, measurements of over 26 miles per day became unusual. Such a daily run as the 32.5 miles of 29 July was exceptional once the rainy season commenced. This amount was due to unusually strong winds that preceded and accompanied an evening thunderstorm.

Wind Direction. As shown by Table 20, in every week except one, less than 17 percent of the observations gave wind direction. Calm air was overwhelmingly the most normal situation. At those observations when wind was blowing, no single direction (or several directions) is predominant. However, both before and after the rainy season the most common directions were those with either an easterly or westerly component.

TABLE 19

Daily Run of the Wind

Base Camp

18 June - 12 August

Date	Miles per Day	Date	Miles per Day
18 June	62.5	16 July	12.0
19	42.6	17	21.7
20	44.2	18	23.0
21	81.8	19	21.2
22	35.5	20	24.7
23	52.4	21	26.4
24	46.1	22	26.0
25	29.2	23	27.9
26	32.5	24	14.4
27	16.1	25	19.6
28	24.3	26	19.7
29	19.4	27	19.4
30	24.5	28	14.7
1 July	31.4	29	32.5
2	19.0	30	7.8
3	25.6	31	5.0
4	25.0	1 August	11.8
5	29.9	2	14.5
6	29.3	3	14.9
7	22.0	4	22.6
8	12.9	5	15.1
9	12.1	6	17.9
10	11.3	7	27.3
11	15.3	8	26.2
12	23.8	9	15.4
13	20.1	10	22.3
14	17.3	11	19.3
15	19.6	12	13.7

TABLE 20

Weekly Wind Speed and Direction

Base Camp

18 June - 12 August

Date	Wind Speed (Frequency %)			Wind Direction (Frequency %)							
	Calm	1-2 mph	Over 2 mph	N	NE	E	SE	S	SW	W	NW
18-24 June	50	33	17	6	7	7	1	5	5	10	9
25 June - 1 July	92	7	1	1	1		1	1	1	2	1
2-8 July	95	4	1			2			1		2
9-15 July	83	12	5	1		4	5	1	2	4	
16-22 July	83	15	2		2	7	2	2	1	1	2
23-29 July	98	1	1								2
30 July - 5 August	95	5		1	1		1		1		1
6-12 August	93	7		2		3	1				1

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V. VEGETATION*

> To the superficial eye the Gavilan is a hard and stony land, full of cruel slopes and cliffs, its trees too gnarled for post or sawlog, its ranges too steep for pasturage. But the old terrace-builders were not deceived; they knew it by experience to be a land of milk and honey. These twisted oaks and junipers bear each year a crop of mast to be had by wildlings for the pawing. The deer, turkeys, and javelinas spend their days, like steers in a cornfield, converting this mast into succulent meat. These golden grasses conceal, under their waving plumes, a subterranean garden of bulbs and tubers, including wild potatoes. Open the crop of a fat little Mearn's quail and you find an herbarium of subsurface foods scratched from the rocky ground you thought barren. These foods are the motive power which plants pump through that great organ called the fauna. **

A. Introduction

The general aspect of the vegetation that Leopold saw in this area is that of a savanna or open woodland. The mast he referred to is a result of many species of oak which are prevalent in the landscape. Photograph 3 provides an aerial view of the vegetation typical of this area, with pines dominating the left center edge of the picture and oaks dominating the remainder. Another important tree in this region is the Alligator Juniper (*Juniperus pachyphloea*). Two species of pine are important in this area, the Chihuahua Pine (*Pinus chihuahuana*) and the Long-needled Pine (Pinus apacheca), and these are generally found on the more favorable sites. On xeric sites, such as south-facing slopes or places with little or no soil, oaks are the dominants, usually as gnarled trees less than 25 feet in height. When these oaks were examined, to determine the species present, we were confronted with a bewildering array of combinations of characteristics that made identification in the field impossible. They exhibited very striking examples of intergradation of several species, in addition to the fact that there is also a lot of intraspecific variation in some species groups.

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* This section was written by Robert R. Ream.

** Aldo Leopold (1949), "Song of the Gavilan," *A Sand County Almanac and Sketches Here and There*, New York: Oxford University Press, pp. 150, 151.

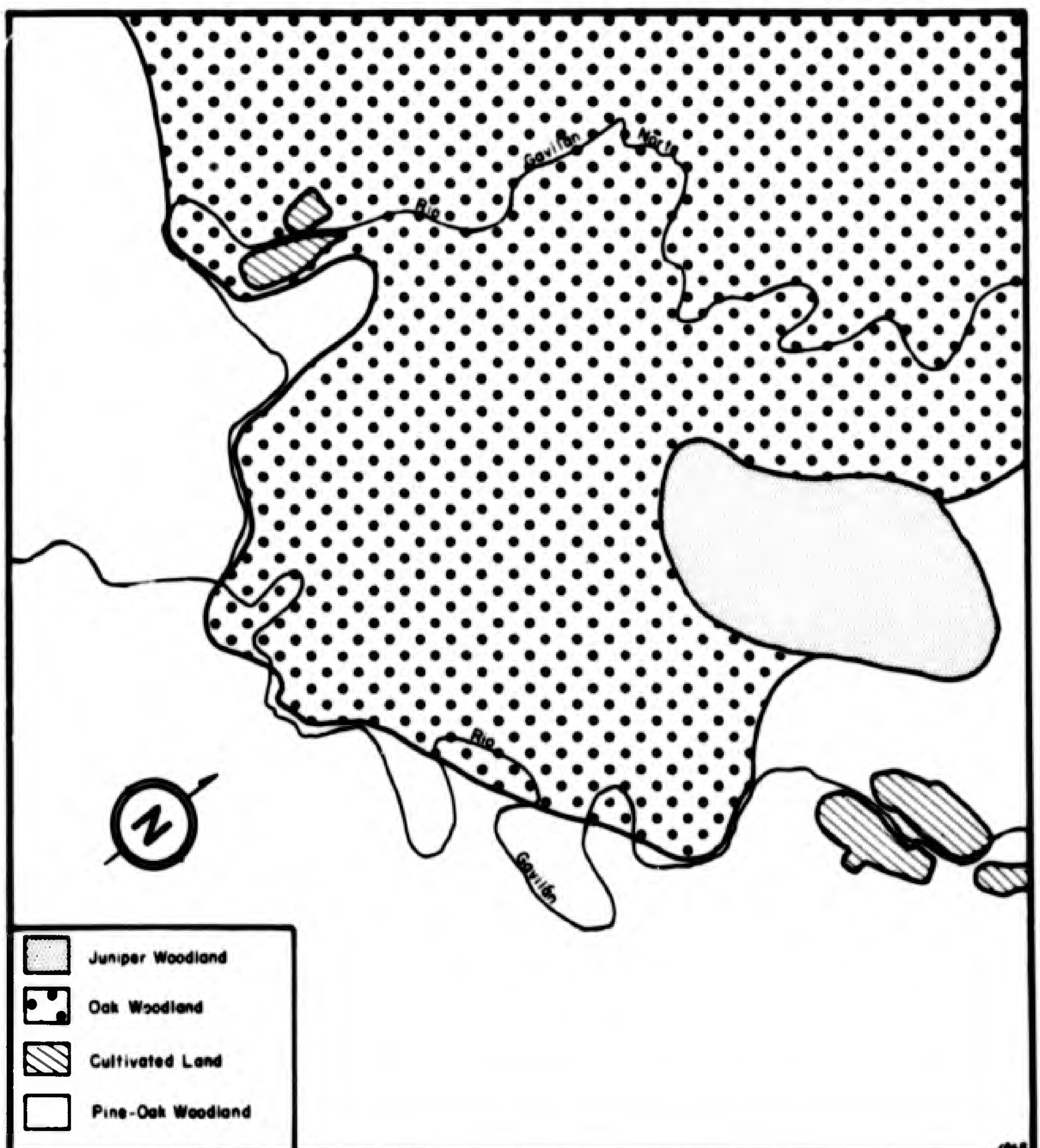
One exception to this confusing assemblage of oaks is the Silverleaf Oak (Quercus hypoleuca), an evergreen oak with leaves similar to an olive, and quite distinct from other oaks present.

A rough map was made of the vegetation in the study area (Map 5), but it must be realized that the vegetation here is a very complex mosaic and the map generalizes this to show areas where one type is more prevalent than another. Oaks are abundant throughout the study area, but pines are much more restricted in their distribution, partly because of their requirement for a more mesic site than oaks. Probably of far greater importance however, is the fact that much of this area has been logged, removing the pines and leaving oaks and junipers to dominate the landscape. The area shown on the map as Juniper Woodland is an area which is a flat plateau that exhibits only charred stumps of the pine forest that must have covered the plateau less than 50 years ago. Human influence on the vegetation has been especially great in the last 25 years. Not only has much of the pine forest been decimated, but the number of cattle using this area as grazing land has increased greatly in recent years. This can be observed in the ground layer vegetation which is now dominated by weedy annuals, but less than 30 years ago was dominated by grama grass (Bouteloua spp.) and other perennial herbs (A. Leopold, 1949).

Presently, there is no ground cover at all until the rains begin in July, bringing up annual weeds, wild onions, and other unpalatable species. The vegetation in this area reflects the strongly seasonal climate, already discussed in this paper. Most oaks are deciduous and many of them do not put out new leaves until the end of the dry season in July. When the study team first arrived in this area, the landscape had the aspect of a winter landscape, since many trees were without leaves and the ground was completely barren.

B. Vegetation of Study Areas A and B

The vegetation in these two areas was sampled in order to obtain information about composition, structure, and any effect that trincheras may have on the vegetation. The sampling that was done was limited to woody stems 1 inch dbh or greater (dbh is diameter at breast height or 4.5 feet). These stems will be referred to as trees in the remainder of this paper, even though some are saplings in forestry terminology. This will also eliminate the problem of what to call dwarfed shrub or brush stems of oak species that never really become trees. In order to assess the possible significance of the trinchera



VEGETATION MAP of the STUDY AREA
CHIHUAHUA, MEXICO

0 0.5
MILES

Map 5

effect on the vegetation, a distance sampling method was used at 100 points in each of the two study areas. From a point halfway across the top of each trinchera, the distance to the closest individual was measured; this is called the closest individual distance. Next, the closest individual distance was determined from a point halfway between two successive trincheras along the drainage. This, then, provided us with 50 pairs of measurements to compare significance of the trinchera effect. In addition, the distance was determined from each of the closest individuals to its nearest neighbor tree. This not only increased the sample size for composition and structure estimates but also provided a means by which we could get an estimate of the degree of aggregation in each stand.

For each of the 200 individuals sampled, basal area and height were measured and the species, as far as possible, was recorded. Basal area was measured at breast height (4. 5 ft.). Specimens were collected for each species encountered during the sampling, as well as some herbaceous species that were found in flower at the time. These specimens include the great variety of oaks that were found and which have not been identified to date.

Composition of the Vegetation. In terms of species presence, the two study areas are very similar; but in terms of density, dominance, and height there is a marked difference between the two areas. Tables 21 and 22 summarize the data by species for Areas A and B. In these tables density refers to the number of individuals sampled for each species, dominance is the total basal area for each species, and height is the sum of all individual heights for each species. The relative values for each of these represent the percent that each species contributes to the total. The importance value for each species is the sum of the relative density, relative dominance, and the relative height.

Oaks are important components in both study areas, with a total importance value of 196 in Area A and 92 in Area B, out of a total possible of 300. In terms of density, or number of stems, oaks are more numerous than pines and junipers in both areas. Junipers in Area A had a total importance value of 64, while Chihuahua Pine, the only pine present, had an importance value of 37. In Area B pines had a total importance value of 141, and Alligator Juniper had an importance value of 67. In terms of density, however, only 30 percent of the individuals in Area B are pines, while 39 percent are oaks and 31 percent are junipers. The high importance value of the pines in this area is a result of the much greater height and basal area of individual pine trunks.

TABLE 21

Species Composition in Area A

	Density		Dominance		Height		Importance Value
	1 Actual	2 Relative	3 Actual	4 Relative	5 Actual	6 Relative	Columns 2 + 4 + 6
Quercus spp. Other Oaks	131	65.5	5,710	63.4	1,841	58.1	187.0
Quercus hypoleuca Silverleaf Oak	8	4.0	131	1.4	113	3.6	9.0
Juniperus pachyphloea Alligator Juniper	39	19.5	1,555	17.2	623	19.7	56.4
Pinus chihuahuana Chihuahua Pine	14	7.0	1,439	16.0	449	14.2	37.2
Juniperus Flaccida (?) Drooping Juniper	6	3.0	120	1.3	103	3.2	7.5
Robinia rusbyi (?) Locust	2	1.0	58	0.6	41	1.3	2.9
Total	200	100.0	9,013	99.9	3,170	100.1	300.0

TABLE 22

Species Composition in Area B

	Density		Dominance		Height		Importance Value
	1 Actual	2 Relative	3 Actual	4 Relative	5 Actual	6 Relative	Columns 2 + 4 + 6
Quercus spp. Other Oaks	55	28.0	2,801	21.5	1,090	22.0	71.5
Quercus hypoleuca Silverleaf Oak	22	11.0	316	2.4	363	7.4	20.8
Juniperus pachyphloea Alligator Juniper	62	31.0	2,018	15.5	984	20.0	66.5
Pinus chihuahuana Chihuahua Pine	45	22.5	6,106	46.9	1,859	37.6	107.0
Pinus apacheca Long-needle Pine	15	7.5	1,772	13.6	647	13.1	34.2
Total	200	100.0	13,013	99.9	4,943	100.1	300.0

Structure of the Vegetation. Structure of the vegetation in the two study areas is markedly different, and this is most noticeable in the aspect or physiognomy. Figure 15 illustrates the difference in distribution of tree heights between the two study areas. It is important here to note differences in the taller height classes, or the right hand side of the figure, because this is where the big difference in physiognomy occurs. In Area B, pines which average 40 to 50 feet in height are the aspect dominants, and this area has the appearance of a pine savanna or woodland. Although there is an occasional pine in Area A, the general aspect is that of oak brush or oak woodland, with individuals averaging 15 to 25 feet in height.

In terms of actual stand density the two areas are very similar, Area A having 82.3 trees per acre and Area B, 86.8 trees per acre. Table 23 shows the distance measurements that were obtained, each figure indicating an average of 50 measurements. The density estimates given above were determined from the average distance to closest individual measurements. If trincheras were producing no effect on tree distribution, then the average distance to the closest individual from points on trincheras would be nearly the same as the average for points placed between trincheras. However, Table 23 shows that there is a difference of 2.0 feet in Area A and 5.2 feet in Area B, in both cases the distance from the point on the trinchera being shorter. When tested for significance with the *t* test, the difference in Area A was not significant but in Area B it was highly significant at the 1 percent level.

TABLE 23

Distance Measurements in Areas A and B

	Point on Trinchera (Feet)	Point between Trinchera (Feet)	Average (Feet)
AREA A			
Distance to Closest Individual	10.5	12.5	11.5
Distance to Nearest Neighbor	7.7	8.5	8.1
AREA B			
Distance to Closest Individual	8.6	13.8	11.2
Distance to Nearest Neighbor	9.3	10.8	10.1

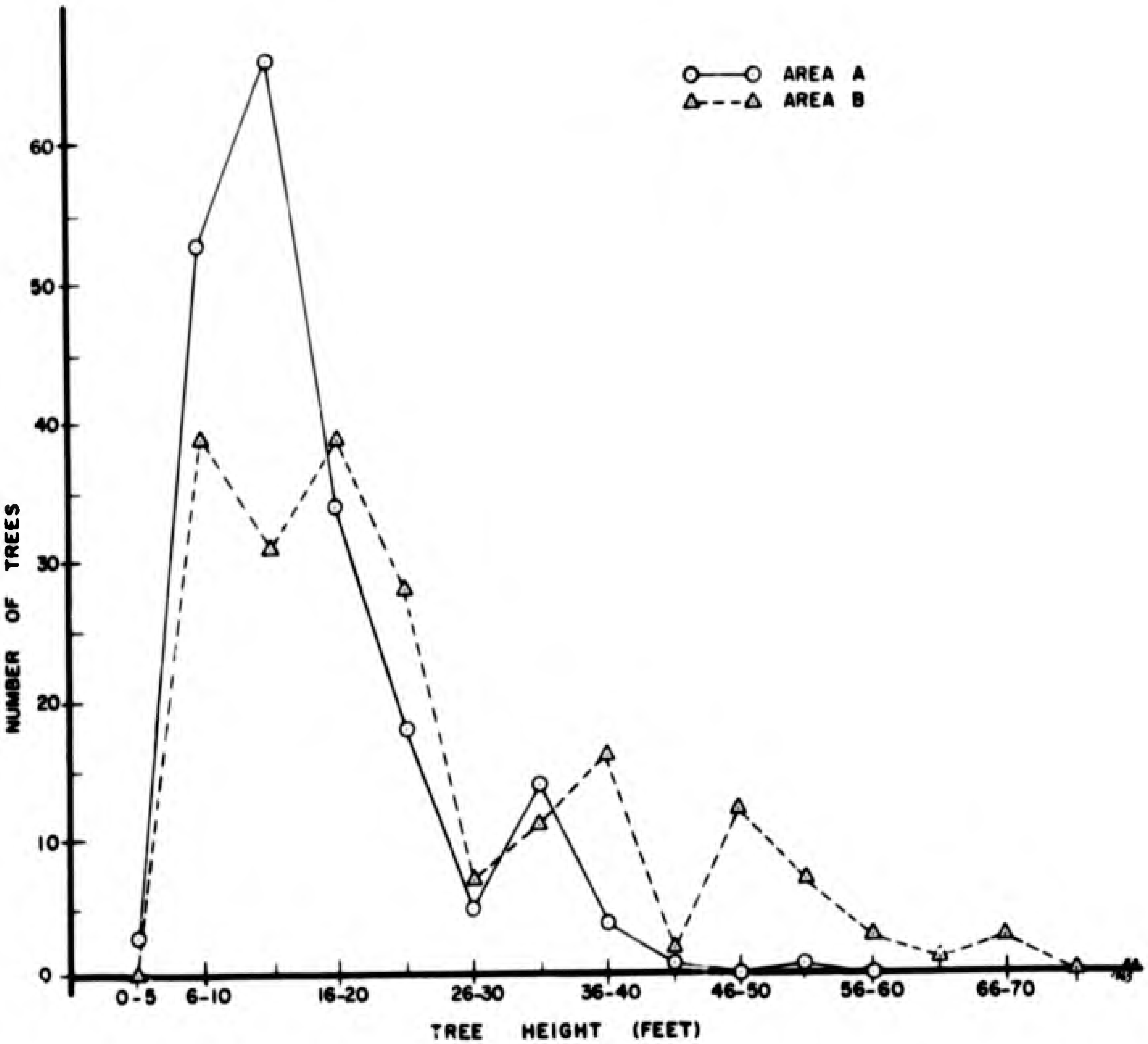


Figure 15. Frequency Distribution of Tree Heights

In a randomly distributed population the nearest neighbor distance should be about 20 percent greater than the closest individual distance (Cottam and Curtis, 1956). If 20 percent is subtracted from the nearest neighbor distance, then the ratio of the closest individual distance to the corrected nearest neighbor distance should be about 1.0 with a random population. In a regular population, where all individuals are equally spaced, this ratio is 0.5, and in an aggregated population the ratio would be somewhere above 1.0, depending upon the degree of aggregation. When this index of dispersion or ratio of the two distance measurements was applied to the average distance measurements for Areas A and B, it was found that Area A had a ratio of 1.70 and Area B had a ratio of 1.33. This indicates that the individuals in Area A are quite highly aggregated while those in Area B are slightly aggregated.

C. Discussion

Because of the complexity of the topography, soils, and climate in the study area, the resultant vegetation is also complex and difficult to interpret. Trees were associated more closely with trincheras than with the area between trincheras, but only Area B showed a highly significant association. It is assumed that this association is a result of influences on the environment produced by the trincheras. Some likely factors might be (1) an increase in soil moisture, (2) an increase in soil depth, (3) an increase in fertility, or (4) any combination of these. Lack of a significant association in Area A may be due to the fact that this area was dominated almost entirely by oaks; and the dispersion of oaks tends to be quite aggregated, so that there are large areas that are quite open and also areas with dense clumps or clones of oak. This aggregated dispersion pattern of oaks is a result of their vegetative reproduction, or growth by means of shoots from an original parent plant. Because of this aggregated dispersion of individuals, the distance measurements taken would tend to be much more variable and statistical significance would therefore decrease. This pattern of dispersion is further substantiated by the two indexes of dispersion values discussed in the last paragraph, 1.70 for Area A and 1.33 for Area B.

Recent human exploitation has perhaps produced the greatest barrier to logical explanation of vegetation pattern and distribution. Lack of a significant association of vegetation with trincheras in Area A is due, in part at least, to recent human disturbances. There are many stumps of large old pine trees scattered throughout Area A, indicating that many of the original pines in this area have been logged off.

Most of these stumps are charred, and many trees in Area A exhibit fire scars. Whether these fires were initiated by humans or by lightning, they have had an effect on the vegetation and have probably caused an increase in the degree of aggregation of individuals. When an individual oak stem is burned off, there is still a woody basal plate immediately below the surface of the ground which has not been damaged; and the following year a number of new shoots will emerge from this basal plate, producing a clump of oak stems. Several lightning fires were observed by the trinchera study team during the summer of 1964, but most of these were limited to large old pine trees which had been struck. Fire is a common occurrence in this area; therefore, the pines in this region have adaptations such as thick bark which make them resistant to fire.

Heavy grazing has so changed the ground layer vegetation that no attempt was made to sample it for comparison of the two areas or to detect the effect of trincheras on this vegetation. When Aldo Leopold first visited the Gavilan with his sons in 1937 (A. Leopold, 1949 and 1953), exploitation of the land had barely begun; but when his son again visited the area in 1948, vast changes in the ground layer vegetation had already taken place:

> The original bunch-grass sod (largely Bouteloua hirsuta) of the river bottomlands and of the more accessible mesas already had been slicked off by concentrated grazing, and in its place grew spindly annual weeds, some native but many of Mediterranean origin. (A. S. Leopold, 1949).

Since 1948 the changes in the vegetation have probably been even greater; and erosion has been greatly accelerated, causing destruction of many trincheras. As erosion is accelerated, productivity of the land is decreased.

When one observes this unique area, he cannot help but wonder at the labor involved in building these trincheras and the tremendous population that this area must have supported to do this work. Certainly the productivity of the land was far greater at that time than at present, when cattle are roaming over the area searching for the little forage that remains. The prehistoric tribes in this area built terraces which slowed down the normal erosion and increased the productivity of the land by increasing soil depth and infiltration of moisture. In other words, these Indians were an important component of their ecosystem and contributed to building up this ecosystem. The Gavilan area is very unique in the fact that two extremes in land use can be observed in one place. Primitive man painstakingly built up and contributed to his ecosystem, while modern man is tearing down or degrading the ecosystem on which he and his offspring must depend for their living.

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VI. TRINCHERAS

A. Construction of Sample Area Maps

The locations of the 479 trincheras surveyed appear on Maps 8 through 11. These location and relief maps for Sample Areas A, B, C, D, and E were drawn from plane table sheets made in the field at a scale of 1:600. Vertical control was established by running several altimetric traverses from Base Camp to the principal bench mark in each sample area. The final bench mark elevation in each area was determined by averaging the results of these altimetric traverses.

B. Trincheras Surveyed

Exhaustive searches on foot were made so that no recognizable trincheras, in whatever incomplete condition, were omitted in the mapped areas. In some cases, however, limited time forced termination of surveying at the end of a plane table sheet rather than at actual termination of trincheras, as at the head of a particular drainage. For better orientation of the reader, the following sub-sections briefly note the location of the surveyed trincheras and adjacent unsurveyed ones.

Sample Area A. The 315 trincheras located here (numbered 1-296 with sub-letters) comprise two-thirds of all surveyed trincheras. Not only is Area A the largest of the areas (95 acres), but also it contains the greatest density of trincheras.

At the southwest several intermittent streams continue out of the area; trincheras occur along their course although not as densely as in the surveyed area above. At the northwest above Trinchera 292, a series of about 14 check dams, 3 to 4 feet high, 10-20 feet long, and often well-coursed, continues up the face of the hill. More trincheras probably extended up the badly eroded arroyos and hillside behind 296 also. The remaining drainages at the north were explored and no further trincheras found. There are no trincheras immediately to the northeast of the area and on the southeast plateau surface. However, the slopes below the bounding escarpment probably contain some examples.

Sample Area B. A total of 93 trincheras (numbered 400-486 with sub-letters) was surveyed in this area (approximately 59 acres in size), the entire drainage of a small intermittent stream emptying directly into the Rio Gavilan. Adjoining the area on the west a similar but much shorter drainage area contains other trincheras, particularly terraces resembling 401-408. Also on the riverside but to the east on a higher flat area occur many linear borders. All trincheras present in the drainage area were surveyed, with one exception: above trinchera 433 at the west in two small steep washes are several almost obliterated check dams, about 15-20 feet apart and possibly 2-3 feet high.

Sample Area C. The 14 trincheras surveyed on this small slope area (approximately 9 acres) are numbered 500-513. No further check dams occur upslope, but there are some nearby in a small valley to the west.

Sample Area D. Forty-six trincheras (300-343 with sub-letters) were surveyed in this small area (approximately 21 acres), far removed from the other locations but chosen for its distinctive riverside type of trincheras, along with others.

Limited time prevented extensive exploration of this vicinity. However, it is known that many walls continue up the arroyo of 307-312 at the south of the area; and, also, 12 more occur along the main arroyo beyond the last check dam surveyed, 343. Remains of other riverside trincheras might be found with careful searching along the Rio Piedras Verdes, but only the 9 surveyed are clear examples in this vicinity. An additional riverside trinchera possibly was located between 304 and 305.

Sample Area E. Only 11 trincheras (550-561) were surveyed at this river terrace location of 16 acres extent, since the two extensive linear border trincheras formed the major interest here. Further trincheras extend up the slope from 556. To the east of 550 and 561 lies a concentration of settlement sites.

C. Data Gathered

In addition to the mapping of trinchera distribution, the principal investigator and one assistant undertook to amass descriptive data on each individual trinchera that was surveyed. Noted was not only the structure itself, but also the particular environment surrounding each trinchera.

Specifically, the following items were recorded:

1. Trinchera type
2. Condition
3. Size: length, height, width
4. Distance to next higher trinchera
5. Trinchera plot size
6. Number of stone courses high
7. Type and size of rocks: maximum, minimum, average
8. Features of construction
9. Topographic situation
10. Slope of land: trinchera plot, perpendicular to trinchera, parallel to trinchera
11. Vegetation: in trinchera plot, adjacent to trinchera
12. Character and depth of soil: in trinchera plot, adjacent to trinchera
13. Bedrock: relation to trinchera, type and character
14. Sketches of trinchera aspect and of trinchera
15. Other comments

Items 1-5 and 8 are presented for each trinchera (wherever possible) in Appendix E.

With a total of 479 trincheras surveyed, obviously time was too short to allow detailing of all the above features for every trinchera. In practice, an entire inventory was made on a prepared sheet form for only those trincheras in good to excellent condition, allowing more or less complete description. Some particularly interesting trincheras were, in addition, excavated for analysis of construction and stratigraphy. In many cases, a consecutive series of trincheras was so similar in form and setting as to allow its description as a group on a single sheet, with separate detailing of only the most important differences from one trinchera to another. The bulk of trincheras were in such poor or partial condition that more brief notes sufficed for their adequate description. For these trincheras, size and construction were always noted, and other details were recorded as they appeared significant. Cross references to completely described trincheras also speeded the process.

Analysis both in detail and general is possible utilizing the above data. In Area A, for example, 20 trincheras were described individually with completeness, of which 3 were excavated; 71 were treated completely but in series; and the remaining trincheras, partly destroyed for the most part, were noted more briefly.

D. Present Condition

The trincheras probably have stood unattended and exposed to destructive elements of the environment for at least 500 to 600 years. During about the last 50 years modern settlement has added the depredations of cattle and lumbering activities, which change the vegetation and speed erosive processes and sometimes directly break down the trincheras. Little wonder, then, that few trincheras remain in pristine condition. Although trincheras still dot the countryside in many parts of the Sierra Madre Occidental, they can today give only indications of the original trinchera system. Yet, incomplete as they usually are individually, the remains taken together present both broad and detailed and, it is thought, largely accurate views of trincheras.

Statuses. The present condition of trincheras is astonishingly varied--from nearly original to actually obliterated, with every stage of completeness or destruction in between. The trincheras studied can be classified into the following statuses, with regard to condition:

1. Complete trinchera. This type of wall is whole or essentially so; only a few rocks are gone; the plot may show only slight erosion. An example is seen in Photograph 2.

2. Partially complete trinchera. The full wall or most of it is standing in some parts although it is entirely or partly gone in other places; there is destruction to varying degrees, but in general half to three-quarters of the trinchera is in a near original state; the plot is usually partly eroded away.

3. Fragmentary trinchera. The wall is almost entirely destroyed; enough stonework remains to indicate a definite wall but usually less than half is standing; the plot is extremely eroded so that soil is absent or very scanty and pebbles and rocks may litter the surface.

4. Obliterated trinchera. The wall is so completely destroyed that either no trace of it remains or insufficient evidence remains to prove its presence; an unorganized concentration of rocks, hinting inconclusively at a wall, may be present; no definite plot exists in a generally highly eroded area.

The present condition of all trincheras according to the first three statuses was noted during the course of the trinchera survey. The state of obliteration being negative, essentially the present non-existence of trincheras which once did exist, obliterated trincheras could not, of course, be surveyed or described. Only speculations about them are possible, based upon the conjunction of questionable remains and suitable topographic situations. Hence, this state of obliteration will not be pursued further.

Determinants. The present condition of each trinchera results from a complex of interrelated factors arising out of the structure itself, the fill behind it, the total environment surrounding it, and the care it receives. Presumably the latter category can be dismissed as inoperative since hundreds of years ago, for there are no records or evidences of use or upkeep of the trincheras in the study area after the period of their construction, circa 1100-1450 A. D.

The design and engineering features of trincheras undoubtedly are important in determining the resistance offered by the structures against forces of deterioration. Size, materials, design, construction techniques, relation to bedrock, etc., affect the stability of the walls. Some variations are more successful for longevity than others. As an extreme example, it cannot be doubted that the excellent condition of the trinchera 16 to 18a series results primarily from engineering and design features of these massive walls and plots, for trincheras in nearly identical situations (especially 79 and 80 to the west) but of much lesser size and inferior construction are in far worse condition. At the other extreme, low single-stone alignments appear relatively stable, their eventual obliteration being caused by sedimentation around and over them rather than by destruction of the wall as such. For the majority of trincheras of more medium size, however, such correlative statements cannot yet be made, for the various design and engineering features are not known enough for assessment of their roles in the preservation of trincheras.

The character, especially the texture, of trinchera fill appears to be an important consideration also. On the basis of a small sample of trinchera fill, the fill in Sample Areas B and D appears to be, in general, coarser textured and with higher porosity than fill in other areas. The general condition of trincheras in these two areas is better than elsewhere.

The most active agencies within the environment which combine toward the deterioration of trincheras can be summarized as follows:

1. Mass wasting, resulting in displacement of rocks within and from the walls, removal of fill by slumping, and movement of colluvium from nearby slopes to trincheras.

2. Hydraulic action of water, resulting in erosion of plots, displacement of rocks from walls, removal of clayey mortar from walls, and deposition of alluvium.

3. Biologic agents, including plants, which dislodge rocks in walls with root growth, and animals (including man), which displace rocks and disturb the terrain and vegetation.

Extremely significant in interaction with the above are the broad features of the environment: topographical, vegetational, climatic. The torrential nature of the precipitation combined with extreme local relief is responsible for the effectiveness of stream erosion, the primary cause of trinchera destruction. But it is thought that the factor contributing most of all is vegetational cover. The disturbance of vegetation, such as has occurred in modern times particularly, speeds not only the erosive processes in general but also the deterioration of trincheras. In those areas where man and cattle have disturbed the ground cover least, trincheras are in the best condition.

In consideration of the destructive elements involved, the effectiveness of trincheras in maintaining mantle and slowing the rate of erosion is remarkable. Many crucial problems remain to be solved before the degree of effectiveness is known. More data relative to these matters will be presented in later sections on construction of trincheras and their relation to local terrain.

Condition of Surveyed Trincheras. Complete trincheras account for about 18 percent of all trincheras surveyed (85 of the total 477). This representation may seem surprisingly high, yet it should be remembered that "complete" trincheras as here defined need not be perfect and, indeed, in every case have suffered some small degree of damage. The majority of trincheras have been more damaged: about 65 percent (311) are partially complete. The average trinchera, then, is in a fair to good state of preservation. Fragmentary trincheras make up the remainder, 17 percent (81); thus, very poor remains essentially balance very good remains, both forming minorities.

The condition of trincheras tends to vary significantly from area to area. Although outstanding for the number, density, and variety of its trincheras, Sample Area A contains relatively more poorly-preserved trincheras than the other areas. Fragmentary walls total 66, or 21 percent of the total, which is higher than elsewhere. The bulk of trincheras is partially complete--204, or 65 percent. A great many of these are in relatively poor condition, with gullying, collapse of walls, and deposition from sheet flood all taking a toll, often in conjunction. However, even though their proportionate share is not high at 14 percent of the total, the 45 complete trincheras in Area A offer more than adequate evidence of original condition.

Sample Area B, on the other hand, contains relatively well-preserved trincheras. Fragmentary trincheras are few (12, or 13 percent of all). While partially complete trincheras (69, or 74 percent) are even more in the majority than in Area A, they tend to be in better condition. Partial damage usually has been caused by gullying only, without collapse of walls or deposition; hence, large sections of the walls and plots are intact though other, generally smaller, sections may have been destroyed by rather abrupt cuts. Such cutting of trincheras has been so general that the number of complete trincheras is reduced to 12 (13 percent). However, this latter fact does not materially alter the generally better condition of trincheras here than in Area A.

In Sample Area C all 14 trincheras are partially complete. Their condition is fairly poor as a result of re-establishment of drainage courses in their old positions, collapse of walls, and slumping of the mantle.

In the more removed location of Area D, trincheras tend toward relatively excellent condition. About 70 percent of the 46 trincheras are complete. There is no gullying on the slopes surveyed and, hence, a negligible amount of cutting of the walls and plots. In a few cases forward collapse of walls has occurred, and some plots have been destroyed by colluvium and rockfall from nearby slopes. The long linear border 331 is partially complete because washing out of the fill has left the wall exposed over part of the length. Of the partially complete trincheras (12 total), half are the riverside type which have been damaged to an unknown extent by the waters and sediments of the Rio Piedras Verdes. The 3 fragments of riverside trincheras are the only fragmentary remains found in Area D.

The 11 trincheras of Sample Area E also remain in relatively excellent condition. Seven trincheras are complete, including the long linear borders 550 and 561. The 4 partially complete trincheras are all check dams, the lowest in the drainage course and damaged by cut walls.

E. Dimensions of Trinchera Walls

Trincheras vary so greatly in size that one "typical" trinchera does not exist. The most striking range occurs in height: from examples only 1 stone or 0.2-0.5 feet high to 2 gigantic trincheras fully 12 feet tall, about 15 stone courses. Extremes of length, though less spectacular structurally, are even more marked: 4 trincheras span gullys only 4-5 feet wide, while by far the longest linear border trinchera extends a winding length of 550 feet, with the addition of 3 subsidiary cross-walls totaling 102 feet. In width, some walls are as narrow as a single stone, 0.5 feet thick; whereas a maximum of 10 feet in thickness is reached by one of the riverside trincheras. Such extremes in size testify to the considerable variety of topographic situations, probable purposes, and constructional techniques and skills involved in the building of the trincheras.

The progression in size from smallest to largest in each dimension is far from regular, and certain sizes appear with much greater frequency than others. Figure 16 shows both the broad scattering and the marked clustering of trinchera sizes in Area A. Table 24 summarizes this data, as well as the more limited yet similar data from Areas B, C, D, and E. In the following sub-sections, height and length will be treated for all areas and then for each individual area. Width will be discussed more briefly since the data are quite incomplete. Riverside-type trincheras are excluded from these analyses since they form a special case.

F. Height

The maximum height of each trinchera wall is used in this analysis. Unfortunately, however, any breaks in the walls usually include the probable highest points, where the original as well as present drainage courses often run. For such incomplete walls, original heights have been projected as accurately as existing rocks would indicate. While actual remaining maximum heights were measured to tenths of a foot, projected heights in many cases

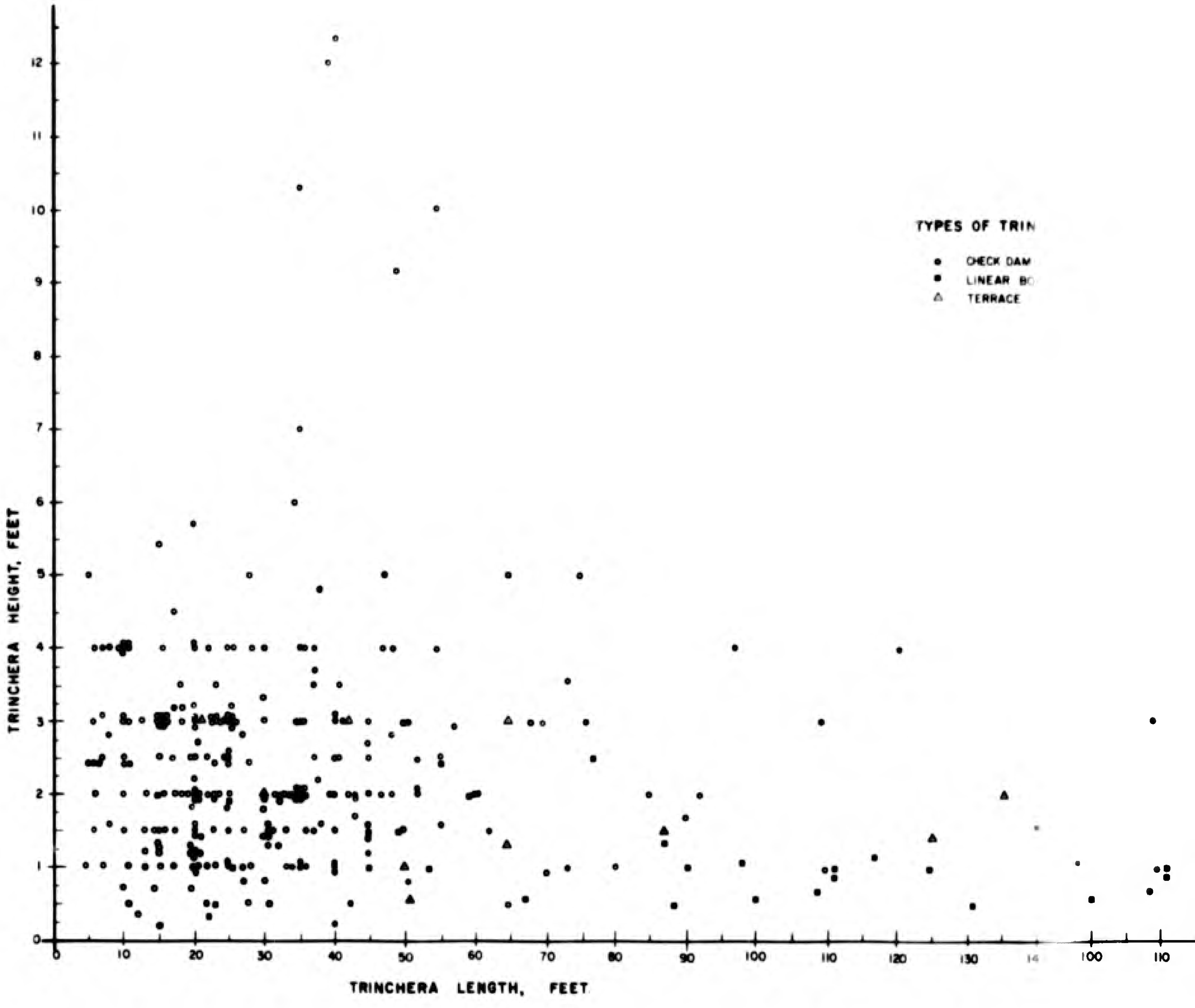

Figure 16. Length and Height of Trin... ...ength and

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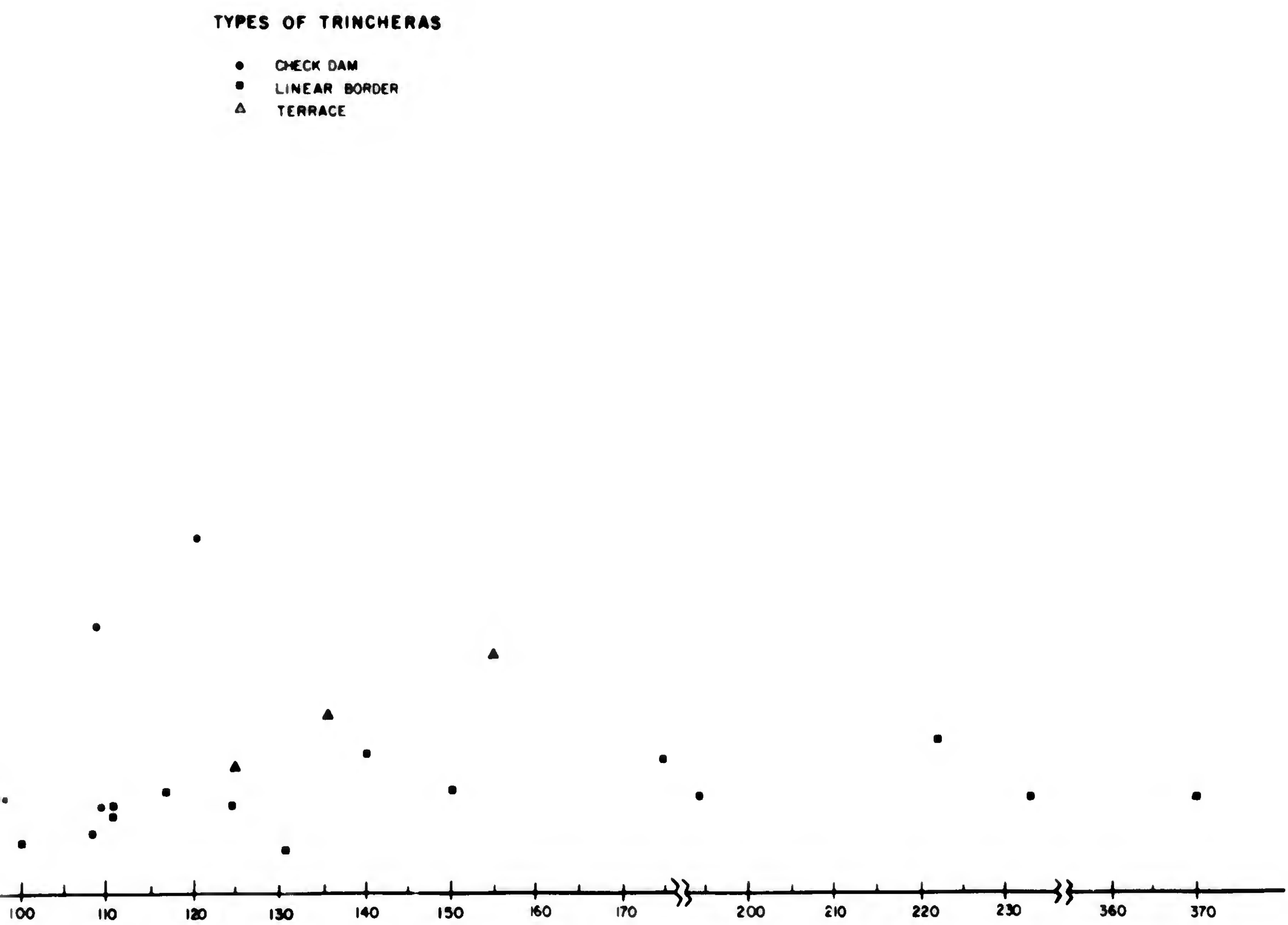

ength and Height of Trincheras, Area A

B

TABLE 24

Dimensions of Trincheras

Dimension (in feet)	Sample Area: A No.	A %	B No.	B %	C No.	C %	D No.	D %	E No.	E %	Total No.	Total %
Height												
10 or more	4	1.3	--	--	--	--	--	--	--	--	4	0.9
8- 9.9	1	0.3	4	4.4	--	--	1	2.7	--	--	6	1.3
6- 7.9	2	0.6	4	4.4	--	--	7	18.9	--	--	13	2.8
4- 5.9	34	10.9	16	17.8	1	7.0	16	43.2	1	9.1	68	14.7
2- 3.9	145	46.6	57	63.3	13	93.0	12	32.4	4	36.3	231	49.9
0- 1.9	125	40.2	9	10.0	--	--	1	2.7	6	54.5	141	30.4
Total	311	100.0	90	100.0	14	100.0	37	100.0	11	100.0	463	100.0
Length												
100 or more	18	5.7	6	6.5	1	7.1	--	--	4	36.3	28	6.0
90-99.9	5	1.6	1	1.1	--	--	1	2.7	--	--	7	1.5
80-89.9	5	1.6	2	2.1	3	21.4	--	--	--	--	10	2.1
70-79.9	6	1.9	6	6.5	1	7.1	--	--	--	--	13	2.8
60-69.9	10	3.2	4	4.3	2	14.2	1	2.7	1	9.1	19	4.0
50-59.9	17	5.4	12	13.0	--	--	4	10.8	1	9.1	34	7.2
40-49.9	36	11.5	10	10.8	1	7.1	8	21.6	1	9.1	56	11.9
30-39.9	56	17.8	17	18.5	3	21.4	11	29.7	1	9.1	88	18.7
20-29.9	79	25.1	17	18.5	2	14.2	10	27.0	--	--	109	23.1
10-19.9	61	19.5	16	17.3	1	7.1	2	5.4	3	27.3	84	17.9
0- 9.9	21	6.7	1	1.1	--	--	--	--	--	--	22	4.7
Total	314	100.0	92	100.0	14	100.0	37	100.0	11	100.0	470	100.0
Width												
4 or more	--	--	1	2.8	--	--	1	6.7	--	--	2	0.1
3- 3.9	9	8.0	5	14.3	--	--	4	26.7	1	33.3	19	11.1
2- 2.9	28	24.7	14	40.0	6	100.0	9	60.0	2	66.7	59	34.4
1- 1.9	57	50.4	13	37.1	--	--	1	6.7	--	--	71	41.3
0- .9	19	16.8	2	5.8	--	--	--	--	--	--	21	12.2
Total	113	100.0	35	100.0	6	100.0	15	100.0	3	100.0	172	100.0

necessitated approximate measures to the nearest half foot--hence, the higher frequencies at heights 1. 0, 1. 5, 2. 0 feet, etc., obvious in Figure 16. In keeping with such enforced generalization of data, the analysis of height has been kept fairly simple statistically.

The height of each individual trinchera is seldom uniform along its entire length, for (1) the stones forming the top course of the wall vary in size and (2) most importantly, the ground level on which the wall is set varies in relief. Most nearly uniform in height are the long, low terraces and linear borders because they are situated parallel, or nearly so, to the contours of the land. Only in adjustment to the microrelief, seldom over a foot, which it traverses, does the height of a terrace vary, as the top of the wall remains essentially level. For example, only 0. 6 of a foot maximum variation in height occurs in the 140 feet length of Trinchera 248 (Photograph 7), which is located near the escarpment on the broad upper surface at the northeast end of Area A. The following heights are recorded for 248: 1. 4 feet at the north end, 1. 6 feet at the center, 1. 9 feet maximum height to the south of center, and 1. 3 feet at the south end.

The greatest variations in height along individual walls occur in check dams, for they run generally perpendicular to contours in drainage courses. Here, also, more surface irregularities are apt to have been caused by increased erosion. The more V-shaped the valley, the more irregular the height of the wall as its base conforms to the relief. A number of examples illustrate the degrees of variation in height encountered:

1. Trinchera 18a, near the southwest edge of Area A, is situated in a deep, narrow valley whose walls rise about 35 feet to a top width of about 75 feet. The 39 feet length of 18a spans the valley at a maximum height of 12 feet, measured at the center of the valley. But as the floor rises in its V-shape, the check dam constricts to 3 feet height on each end.

2. A short distance up this same valley, Trinchera 3 (35 ft. long) was originally about 7 feet high at its center and tapers to 5 feet at the ends. Trinchera 4 (47 ft. long) was 5 feet high at the center and tapers to 2 feet at the ends.

3. A further 450 feet up this valley, where it has widened and flattened greatly, Trinchera 31 extends for a distance of 121 feet, both straight and curving across four separate small arroyos entering from

above. The valley floor is uneven and interrupted at its center by an outcrop of bedrock. This trinchera varies in height from 1.9 to a projected 4.0 feet.

4. CheckDam 441 in Area B is situated across the upper portion of a broad U-shaped valley, 100 yards below the high, steep escarpment which terminates the valley. The 74 feet length is bisected by a bedrock outcrop to the height of the dam. The maximum height of 6.6 feet is reached in the western section of the wall and the eastern section varies from 2.3 feet to a projected 4.6 feet.

Along the extent of individual check dams, then, maximum variation of height can be from about 1-9 feet, or about 25-75 percent of the greatest height. Frequencies of variation are not known since detailed information on all heights was not gathered.

Maximum height was obtained for 463 trincheras. Within the total range from 0.3 to 12.3 feet, heights are extremely positively skewed: 80 percent are less than 4 feet. More specifically, 30 percent (141 walls) measured 0-1.9 feet and, most outstandingly, 50 percent (231) are 2.0-3.9 feet in height. Thus, the majority of trincheras might be generally described as low to medium in height--certainly not spectacular in this dimension. Relative frequencies of heights from 4 feet on decline drastically.

In generalization are the following descriptive categories of height and their relative frequencies:

1. Low trincheras (0-1.9 ft. high)--30 percent
2. Medium trincheras (2.0-3.9 ft. high)--50 percent
3. High trincheras (4.0-5.9 ft. high)--15 percent
4. Very high trincheras (6 ft. or more high)--5 percent

Sample Area A. Each sample area presents a pattern distinctive from the overall view of trinchera heights. Since Area A supplies most of the trincheras (311 with height measurement), it most closely follows the overall pattern, but with some significant departures.

Heights are greatly concentrated in the lowest two classes: 86.8 percent of the trincheras fall below 4 feet in height.

The lowest class, 0-1.9 feet, accounts for 40.2 percent. Most of these are 1.0-1.9 feet high; however, 24 are less than a foot high. Such very low trincheras are virtually limited to this area--only one other occurs in Area B. Consisting of a single course of stones, sometimes backed by smaller rubble, as little as 0.2 feet in height may be achieved by the trinchera as presently standing. Most rise 0.5-0.8 feet. It is apparent that deposition on both sides of the stones often may have obscured their original height, which probably would have been near the height of the stones used, usually from a half foot to nearly a foot but sometimes as small as 0.3 feet. Whatever their exact size, trincheras below a foot in height are quite remarkable, and their concentration in Area A is equally so.

The modal height class is 2.0-3.9 feet high, with 46.6 percent. High trincheras from 4.0-5.9 feet show a greatly declined frequency. Very high trincheras, all 6 feet or over, take a still more drastic decline in frequency, to a total of 7, or about 2 percent of the total.

The distinction of Area A, however, lies particularly in its 4 check dams of 10 feet and over. These, combined with a couple of other high walls, form an incomparably spectacular grouping at the west side of the area in the most deeply engorged section of the main drainage surveyed. Beginning at the topmost in the series, Trinchera 5 rises 10 feet on and around massive boulders at the brink of a major escarpment. Directly below and only 4 feet from the base of Trinchera 5 is Trinchera 4, which is 5 feet high. So closely related are these 2 check dams that they give the impression of forming a single, stepped trinchera in which a total vertical distance of 20-25 feet is covered in 2 stages. Then intervene 3 trincheras of 5, 4, and 4 feet heights in a more open, shallow portion of the valley. Next, and again at a break in slope, Trinchera 16 reaches 9.2 feet to begin the most outstanding series of high walls. Trinchera 17 follows at 10.3 feet height, then 18 (Photograph 8) reaches the record of 12.3 feet, and finally 18a is 12 feet high. Below this point are several unsurveyed check dams of medium height. In their fairly extensive searches for trincheras in the Chihuahuan Sierra Madres, the University of Denver parties have found no other trincheras to match these in height.

In summary for Area A:

1. Typical trincheras are low to medium in height, i.e., below 4 feet. The majority measure 1.0-2.9 feet high.

2. Very low walls (less than 1 ft.) occur in a small number of cases but significantly more often than in the other sample areas.

3. High walls (4.0-5.9 ft.) occur but are not frequent.

4. Very high walls (over 6 ft.) occur rarely, yet the highest (10 ft. and over) series of check dams encountered is located here.

Sample Area B. Ninety of the trincheras in Area B yielded height measurements. The pattern of relative frequencies of heights diverges markedly from that of Area A, as well as from that of all areas together. In broad outline the patterns do resemble each other: the 2.0-3.9 feet class is the most common one, and frequencies of heights both below and above this medium height decline. But specific height frequencies within this general pattern are quite different in Areas A and B.

The height of trincheras in Area B can be summarized as follows:

1. A majority of trincheras are of medium height (2.0-3.9 ft. and especially 2.0-2.9 ft.).

2. Low trincheras are uncommon.

3. High (4.0-5.9 ft.) and very high (6.0-9.9 ft.) walls occur more commonly than in the other areas, although maximum heights (10 ft. or more) are not reached here.

4. The average height of trincheras exceeds both that of Area A walls and of total walls surveyed.

Sample Area C. The 14 trincheras of this area are almost uniformly of medium height, approximately 3 feet tall, with 500-504 the lowest at 2.5-3.0 feet. The one exception, Trinchera 505, measures 4 feet. Thus, the average height here coincides generally with that for all trincheras, but the usual variations to both higher and lower heights are absent.

Sample Area D. The 37 trincheras analyzed for height exclude the riverside structures, which form a non-comparable type. The pattern of variation here departs significantly from those of the other areas, chiefly in the greater height of the trincheras.

To summarize for Area D, the following characteristics appear:

1. Average height is greater than elsewhere in surveyed areas. Most walls are medium to high (2.0-5.9 ft.) and especially tend toward the high class (4.0-4.9 ft.).

2. Low trincheras rarely occur.

3. Very high trincheras are extraordinarily frequent in the 6.0-7.9 feet class but also occur to 9 feet.

4. Affinities between trinchera height in Areas B and D exist, but Area D is even more skewed toward tallness of trincheras than is Area B.

Sample Area E. All 11 trincheras yielded height measurements. The distinction of this area lies in the relative prevalence of low walls, 0-1.9 feet: 6 trincheras, or 55 percent of all, make this the modal class. All measure 1 foot except one, which is 1.5 feet high.

Almost as frequent, the 2.0-3.9 feet medium walls number 4. The highest wall is a high check dam of 4 feet.

Thus, Area E is characterized by mainly low trincheras, some medium and rarely high ones.

G. Length

The maximum lengths of trinchera walls, to the nearest foot, were measured by tape in the field or were calculated from the survey maps. In the case of partially complete or fragmentary walls, the original extent was estimated in the field from evidence of aligned rocks, valley walls, etc.

Though height and width are complicated by present condition of walls, variations in size of rocks, local relief, and type of construction, this dimension is generally straightforward and accurately measurable. Hence, very few trincheras failed to yield length data. Table 24 shows the frequency of lengths by 10 feet increments to 100 feet or more for each sample area and the total. Figure 16 presents the relationship of height and length in Area A. The length of subsidiary or cross-walls is not included in the tables and analyses.

The highest frequency (23.1 percent) of trincheras measures 20-29.9 feet long. Closely following are the nearest classes--10-19.9 feet and 30-39.9 feet in length. Thus, lengths are highly skewed positively in the 0-100+ feet range. Few trincheras measure less than 10 feet. From 40 feet on, the longer the trinchera, the less frequently it occurs. The larger frequency of 100 feet or longer walls is broadly scattered over a range of 100-550 feet.

In further generalization, lengths of trincheras surveyed can be described thus:

1. Short walls less than 10 feet long are rare (approximately 5 percent).

2. Medium lengths (10-39.9 feet) are frequent (50 percent). Lengths of 20-29.9 feet are most common.

3. Long trincheras of 40-69.9 feet are fairly common (23 percent).

4. Long trincheras of 70-99.9 feet are rare (6 percent).

5. Very long trincheras (100 or more feet) are rare (6 percent).

Sample Area A. The 314 trincheras measured in this area follow the length pattern of the total very closely. The largest class (25.1 percent) measures 20-29.9 feet. Substantial numbers also are near this at 10-19.9 feet and 30-39.9 feet. Few occur below 10 feet long. There is a fairly steady rate of decrease in relative frequency with greater length above 40 feet until the class including all walls of 100 feet or more, which includes relatively more examples by reason of its broad limits. An especially numerous series of very long linear alignments is situated on the mesa top in this area, some of which are shown in Photograph 9.

Sample Area B. The same 3 medium length classes (10-39.9 ft.) are most frequent among the 92 walls measured in Area B but are nearly equal and do not peak in the 20-29.9 feet class as in Area A and the totals. Short walls of less than 10 feet occur even less than in Area A. The decrease in frequency with increased length is not so uniform as in Area A; and long walls are more common, especially those 50-59.9 feet and 70-79.9 feet long.

Thus, trinchera lengths in Area B can be characterized as relatively longer than in most areas, though the average trinchera remains medium in length.

Sample Area C. The size of the sample is small (14); however, it shows a typical length much longer than is found in either Area A or B. Short walls less than 10 feet long are absent and those 10-19.9 feet long are uncommon. A higher frequency occurs from 20 to 39.9 feet, but walls of 60-69.9 feet and 80-89.9 feet lengths are equally as numerous.

Sample Area D. In the Piedras Verdes area, the distribution of 37 lengths is much more concentrated into a few classes than in the previous areas--nearly 80 percent of the trincheras measure between 20 feet and 49.9 feet long. Walls below 20 feet are uncommon and below 10 feet, nonexistent. Thus, the average is distinctly longer than in Area A. However, the very long walls seldom occur here; only 2 examples measure over 59.9 feet long.

Sample Area E. The 11 trincheras of this small area show an extreme range in length, which is, indeed, a primary reason for the survey here. On the one hand are several 10-19.9 feet check dams; then 4 lengths are scattered from 30 feet to 69.9 feet; and finally occur 4 terraces and linear borders of over 100 feet lengths, culminating in the maximum surveyed length of 550 feet.

H. Width

Assessment of this dimension, referring to the greatest width across the top of trinchera walls, proved most difficult because of frequent collapse of the topmost courses, variation in size of the top rocks, the presence of fill and washed rocks covering all or part of the top, and the indefinite blending of back wall into plot. Walls of stone face-rubble backing construction offered the greatest problems, for the pebbles and small stones forming the back often make up a very indefinite zone. Measurements of width were taken only if a top view or exposed cross section clearly delineated the back of the wall (the face almost always was obvious). Unfortunately, as few as about a third of the trincheras showed width distinctly. Thus, the analysis of width is limited although it is instructive enough in general considerations of width to merit presentation. Further data appear in the sections on the construction of trincheras, especially in the diagrams of various types of walls.

In the later discussion of construction, it is pointed out that some walls vary in width vertically, taking a wedge-shape in cross-sectional view with the widest end at the bottom of the wall. Horizontally, i. e., along the length of a wall, overall width usually varies little. However, individual rocks often vary in size sufficiently to interrupt the width as well as the height from place to place, particularly in walls which utilize bedrock or massive in-place boulders in their construction.

A total of 172 trincheras yielded width measurements. Table 24 presents the classed frequencies by sample area and totals. Again, the riverside trincheras are omitted in that they form a special case.

At one extreme are 5 single-stone alignments 0.5 feet wide and at the other extreme is a terrace wall of rubble loosely piled to a width of 5 feet. If descriptive terms are applied, the pattern of trinchera widths can be summarized thus:

1. Trincheras are most often of medium width (1.0-1.9 ft.). Also, many are of medium width (2.0-2.9 ft.).

2. Narrow walls of less than a foot width occur in small numbers.

3. Wide walls (3.0-3.9 ft.) also appear in small frequencies, but very wide walls (4 ft. or more) are rare.

<u>Sample Area A</u>. Of the 113 trincheras yielding width measurements, 50 percent are of medium width (1.0-1.9 ft.). The narrow class below 1 foot is outstandingly frequent compared with the other areas; in fact, all except 2 of the narrow walls surveyed are located here. On the other side of the modal class, the medium-wide walls (2.0-2.9 ft.) are second most frequent with a quarter of the trincheras. Finally, wide walls (3.0-3.9 ft.) are uncommon at 8 percent of the total, the largest measuring 3.5 feet.

<u>Sample Area B</u>. The 35 trincheras in this group are negatively skewed in comparison with other areas. Narrow walls are rare although 2 examples do occur. Area B seems characterized equally by medium and medium-wide trincheras of 1.0-2.9 feet width, with wider walls somewhat common also. This pattern of increased average width closely parallels the greater average height and length of trincheras in Area B.

Sample Area C. The 6 trincheras yielding width data measure approximately 2.0 feet and, therefore, fall into the medium-wide class.

Sample Area D. Like those in Area B, this group of 15 trincheras is wider on the average than most trincheras. In fact, even without considering the massive riverside trincheras here, the walls of Area D are outstanding for their width, as well as their average height.

There are no narrow trincheras and only one of medium width (1.0-1.9 ft.). The medium-wide class (2.0-2.9 ft.) is modal with 60 percent. In addition, wide trincheras (3.0-3.9 ft.) have a relatively high frequency, and there is one very wide wall of 4 feet.

Sample Area E. Medium-wide and wide classes are represented in the 3 trinchera widths measured. Specifically, the widths are 2 feet and 3 feet for linear borders and 2.5 feet for a check dam.

I. Types of Trincheras

The foregoing discussion of dimensions made obvious the great variation in sizes of trincheras. Implicit in this variation are differences, both quantitative and qualitative, in the effect which trincheras have upon elements of the physical environment. Various dimensions relate to various types of trincheras. The broad presentation of variation, thus, leads to the definition of specific types.

Four principal types of trincheras have been defined in the study area. Their identities are based upon several interrelated and mutually dependent features of both the structures and the environment, as follows:

1. The form and dimensions of the trinchera wall and plot.

2. The physiographic situation.

3. The relation of the trinchera to mantle.

Defined below are check dams, linear borders, terraces, and riverside trincheras. The check dam type also occurs commonly in aboriginal field systems in other parts of the American Southwest. Linear borders have been identified at Point of Pines, Arizona, and other places; and structures similar to terraces may be found elsewhere in the Southwest.* Riverside trincheras, however, are unique to the Sierra Madre Occidental, as far as is presently known.

The distribution of the 4 types in the study area is summarized in Table 25. The important relationships to dimensions are outlined in Table 26, as well as shown graphically for Area A in Figure 16.

Check Dams. By far the most typical trinchera found in the study area, check dams make up 84 percent of all trincheras. Examples appear in Photographs 1, 2, 8, and others.

Their most distinctive feature is physiographic situation. Check dams are always situated in drainage courses perpendicular, or nearly so, to the drainage course and parallel to the contours of the valley. The valleys in which they occur can vary greatly in depth and width, from extreme V-shaped to shallow U-shaped valleys. Nearly all conditions of channel gradient are possible, except the very steepest (over 30°).

Check dams take a step-like form along a drainage course, the vertical or angled walls comparable to risers and the nearly horizontal (1°-3°) plots comparable to treads of stair-steps. They are almost always arranged in series with check dams a variable distance apart, from 5 to 180 feet but most commonly 20-30 feet. In profile (see Map 6b), a series of check dams definitely interrupts the natural slope of a drainage course, superimposing a partial stepped profile.

Check dams are invariably built so that the ends of the wall rest against bedrock, usually so that the wall ends are buttressed against the valley sides. Hence, the length of a check dam largely conforms to the width of the particular stream course in which it is situated; and lengths vary greatly, from 4 feet to 109 feet. Check dams are more

* For comparative studies, the reader is referred to Rohn (1963), Herold (1961), Woodbury (1961), Stewart and Donnelly (1943), Hack (1942), Stewart (1940), Brand (1936), Forde (1931), and Bryan (1929). Terminology is far from uniform, unfortunately, in these and in the present study; but this complex topic cannot be taken up in any detail here.

TABLE 25

Occurrence of Types of Trincheras

	Check Dams		Linear Borders		Terraces		Riverside Trincheras		Total Trincheras	
	No.	%	No.	%	No.	%	No.	%	No.	%
Area A	272	86.3	32	10.2	11	3.5	--	--	315	100.0
Area B	81	87.1	1	1.1	11	11.8	--	--	93	100.0
Area C	8	57.1	--	--	6	42.9	--	--	14	100.0
Area D	36	78.3	1	2.2	--	--	9	19.5	46	100.0
Area E	5	45.4	2	18.2	4	36.4	--	--	11	100.0
Study Area	402	83.9	36	7.5	32	6.7	9	1.8	479	100.0

TABLE 26

Dimensions of Types of Trincheras

	Check Dams		Linear Borders		Terraces		Riverside Trincheras	
	No.	%	No.	%	No.	%	No.	%
Height (feet)								
10.0 or more	4	1.0	--	--	--	--	--	--
8.0 - 9.9	6	1.5	--	--	--	--	--	--
6.0 - 7.9	13	3.3	--	--	--	--	2	22.3
4.0 - 5.9	67	17.0	--	--	1	3.1	3	33.3
2.0 - 3.9	202	51.1	7	19.4	22	68.8	4	44.4
0.0 - 1.9	103	26.1	29	80.6	9	28.1	--	--
Totals	395	100.0	36	100.0	32	100.0	9	100.0
Length (feet)								
100 or more	12	2.9	16	44.4	10	31.3	--	--
90.0 - 99.9	4	1.0	3	8.3	--	--	--	--
80.0 - 89.9	3	0.7	2	5.6	5	15.6	--	--
70.0 - 79.9	10	2.4	1	2.8	2	6.3	--	--
60.0 - 69.9	13	3.2	1	2.8	5	15.6	--	--
50.0 - 59.9	27	6.6	3	8.3	4	12.5	--	--
40.0 - 49.9	51	12.4	3	8.3	2	6.3	1	11.0
30.0 - 39.9	84	20.4	1	2.8	3	9.4	2	22.3
20.0 - 29.9	103	25.0	5	13.9	1	3.1	2	22.3
10.0 - 19.9	83	20.1	1	2.8	--	--	4	44.4
0.0 - 9.9	22	5.3	--	--	--	--	--	--
Totals	412	100.0	36	100.0	32	100.0	9	100.0

commonly shorter than other types, the greatest frequencies occurring in the lengths from 10 to 39.9 feet. Walls less than 10 feet long are exclusively check dams. Few check dams are as long as 60 feet or over. The range of heights is also great, more than for any other type of trinchera, from 0.3 feet to 12.3 feet. Most check dams (51 percent) measure 2.0-3.9 feet high, and very few are 6 feet or more high. The sizes of check dams, then, are not completely distinctive but rather overlap with those of other trinchera types.

Check dams usually extend straight across a valley but may be curved or angled. Although there are instances of connected check dam walls, no subsidiary walls are appended to check dams.

Check dam plots are invariably formed from water deposited alluvium. It is primarily in this sense that the walls have served as check dams, i.e., to catch (check) and hold (dam) alluvium rather than water (although some water is held in the form of soil moisture).

Check dams as here defined compare closely with structures found in other parts of the Southwest, with the notable exceptions that check dams are much more numerous and reach much larger sizes in the Sierra Madre. Stewart and Donnelly, Rohn, Forde, and others name similar structures "check dams" also; however, Hack uses the terms "trinchera plots" and "trinchera fields" and Woodbury uses "terraces."

Linear Borders. Although not common in the study area (7.5 percent of all trincheras), linear borders are quite distinctive in form, situation, and relation to mantle. This type consists of a long, low stone alignment built along a gently sloping or flat surface, together with an extensive plot of primarily residual mantle. (See Photographs 6, 7, and 9.) Since this type approaches the linear borders identified at Point of Pines, Arizona, by Woodbury, his designation is adopted here.*

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* Richard B. Woodbury, (1961), Prehistoric Agriculture at Point of Pines, Arizona. Memoirs of the Society for American Archaeology, No. 17, pp. 12-13.

However, the linear borders reported by Woodbury differ from those described in this study in their situation on steeper hillsides in some cases, their more close-spaced and parallel arrangement, their apparently less stepped profile, and their lack of structure into walls.

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The walls of linear borders usually consist of a single stone alignment or a stone face with rubble backing. Their height is invariably very low, mostly 1 to 3 stones high and measuring less than 2.0 feet (down to 0.3 ft.), with a few up to 3.0 feet in height. Situated on open slopes or mesa tops, linear borders have few limits placed on their extent and, thus, reach the greatest lengths of any trinchera type. Nearly half are 100 feet or longer, most of these from 100 to 200 feet but with examples to 550 feet. Other linear borders have lengths from 20 feet up. Seldom do they form completely straight walls, although long sections extend nearly straight before another section angles away slightly.

These trincheras parallel the contours of gently sloping (1° -3°) or flat surfaces. In many instances, a linear border is situated just behind an escarpment on such a surface (see 248 in Photograph 7). Linear borders do not cross major drainage areas although they may cross minor irregulatities in the relief and miniature stream channels.

Though usually arranged in series, the borders can be anywhere from 20 to 216 feet apart and are seldom exactly parallel. Linear borders also can occur individually, in which case they tend to be extremely long. The mesa top examples in Area A (234-248, etc.) illustrate series of linear borders, while 331 in Area D is an isolated example.

Often there are short walls or alignments perpendicular or angled back from the longitudinal walls at their ends or elsewhere. They are generally about 10 feet long but may reach 60 feet. Such cross-walls never connect the linear borders and, therefore, do not resemble the grid borders described by Woodbury.*

Linear borders are stepped, or terraced, only in a minor way. The profile of the slope of land is broken only slightly by a wall as it holds the forward portion of the plot to near the low height of the wall. However, the borders are definite walls with fill behind rather than only piled rocks.

The large plots (up to approximately 20,000 sq. ft. in size) contain primarily residual mantle. Small areas of alluvial fill may be found directly behind the walls.

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* Ibid., p. 13.

<u>Terraces</u>. Almost as frequent as linear borders, terraces are in many other respects similar to them (Photograph 10). Terraces, too, are situated on slopes rather than in drainage courses and take a relatively long, low form. However, terraces vary in particulars so that they form a distinguishable type. *

Most importantly, terraces have an emphatically step-like appearance--hence, their name. The walls are higher, more vertical, and generally better coursed than linear borders, more nearly approaching check dam walls in these respects. Most terrace walls stand 2.0-3.9 feet high. The plots behind slope more gently (2°-7°) than the general slope profile, on which they are superimposed as step-like features.

Terraces are considerably longer in general than check dams yet are usually not so long as linear borders. The largest frequencies of terraces measure 50 feet or longer, with a third over 100 feet to 242 feet. None are less than 20 feet long. The walls tend to form straight lines more often than do other types. Cross-walls or alignments sometimes extend back from the wall into the plot, often functioning to contain the fill at the sides of the plot. Usually arranged in series, terraces most often are 20 to 40 feet apart but may be as widely spaced as 100 feet.

Like linear borders, terraces parallel contours of slopes; but steeper slopes, actually hillsides of 3°-10°, are utilized, to the exclusion of the more flat mesa tops. Although terraces as such do not cross drainage courses, some terraced slopes adjoin valleys so that the terraces seem to be continuous with check dams in the drainage course. An example of this situation is Trinchera 58a, which takes classic terrace form throughout most of its extent near the base of a steep hillside yet terminates at its western end in low check dam form across a small, steep valley, just before the drainage spreads into a flatter bench surface.

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* Woodbury did not, apparently, find similar structures at Point of Pines. Instead, he uses the term "terrace" for what are here called "check dams." Without elaborating the point, the author finds "terrace" applicable in both its original physiographic and agricultural senses only to slope situations, not valleys.

Terrace plots are formed of both residual and alluvial mantle, the relationship between the two depending on the particular physiographic situation.

Riverside Trincheras. This rare type of trinchera occurs along the banks of permanent streams of large size. A massive boulder wall or buttress structure begins on the flood plain and extends into the stream, approximately perpendicular to stream flow (Photographs 11 and 12). Long-term stream erosion and deposition having left the structures in fragmentary or partial condition, it is problematic whether streams were crossed or how far the trincheras originally extended.

The structures are formed of rounded and subangular boulders, mostly 2 to 4 feet on a side. In one example a boulder 8 feet in size is used. The better preserved specimens show up to four rocks placed on top of each other and one or two rocks across the walls. There is much smaller (0.6-0.8 ft.) rock rubble and clayey material along with the massive boulders but no evidence of a definite rubble core with rock facing. The rocks are not piled haphazardly but show some care in placement to form walls of considerable stability. The present height of the walls varies from 2.3 to 7.0 feet and the width from 2.5 to 10.0 feet. Length has been much destroyed or obscured* and presently varies from 10 to 40 feet, the best preserved walls approaching the upper limit.

The riverside trincheras surveyed appear in a series of 7 on an outside curve of the river, individual structures being spaced 60-205 feet apart. Two further fragments are situated on the opposite bank of the river 180 feet away, approximately opposite 2 trincheras in the main series. That these paired walls opposing each other are remnants of walls which originally crossed the river is a speculation totally impossible of proof or disproof.

Alluvial fill has accumulated on both sides of the riverside trincheras. The walls generally stand well above this alluvium at the stream end, at least.

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* At the time of surveying, the moderately high waters of the Piedras Verdes covered some of the ends, and sand fill covered the bank ends of some.

Distribution of Types. The extremely non-uniform distribution of the four types of trincheras within each sample area and the study area as a whole is shown in Table 25.

Check dams, overwhelmingly the most frequent type, are especially prominent in Sample Areas A and B, where they comprise about 87 percent of the trincheras. They appear very frequently in Area D, also, although less so. However, in Areas C and E check dams comprise only approximately half of the trincheras.

Although linear borders and terraces form minorities of almost equal total numbers in the study area (about 7 percent), their distributions differ greatly. Linear borders are most prominent in Area A, nearly 90 percent of this type being found there. Area E is relatively well endowed with its two linear borders, but B and D have only one each and C has none.

Terraces, on the other hand, have a low relative frequency in Area A. They are significantly more important than linear borders in Area B; and in C and E terraces far outnumber linear borders and nearly approach the frequency of check dams.

Riverside trincheras, the greatest rarity among the types, were studied only in Sample Area D. They make up a significant proportion (about 20 percent) of the trincheras here. Also, several remnants of riverside trincheras were observed along the Rio Gavilan about a mile downstream from Rancho Gavilan and nearest to E of the sample areas. These fragments were not surveyed; however, their presence here along another river is most interesting.

J. Design and Construction of Walls

Although the design and construction of trinchera walls were not topics pursued exhaustively in the field, much was learned about them through the soil trenches, natural exposures of walls, and exterior appearance of walls. Four main wall designs were identified: a stone alignment, stone facing with rubble backing, double wall with rubble core, and piled rubble. Each is described below and illustrated in cross section in Figure 17.

Positive identification of the design of each trinchera would, of course, have been impossible without extensive excavation, hence damage to the walls. The probable classifications that field observations

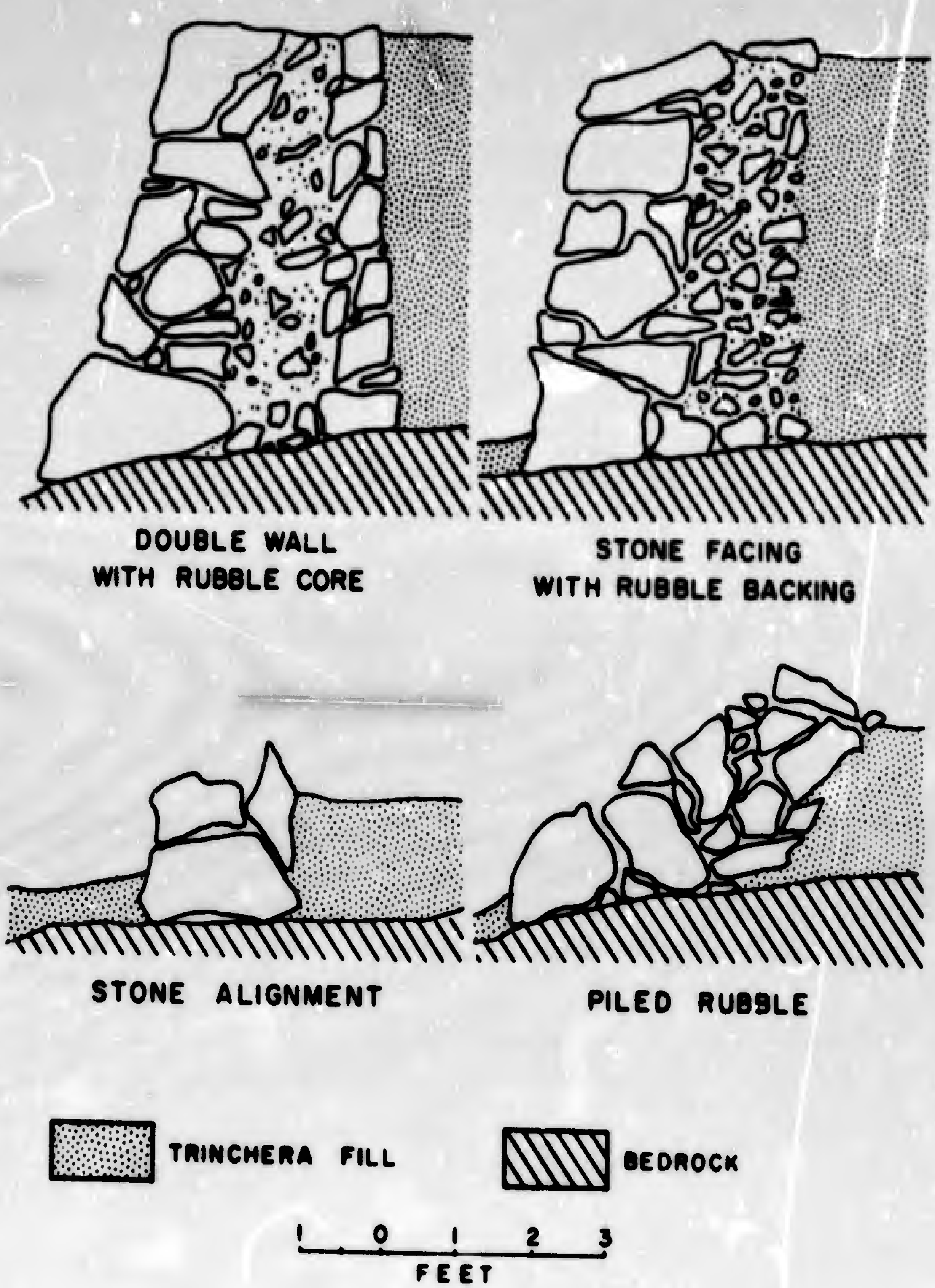

Figure 17. Designs of Trinchera Walls Representative Cross Sections

did allow are included in Appendix E. Many of the unclassified walls probably are either facing-with-rubble or double-wall designs; however, surface indications did not make the distinction clear.

Stone Alignments. The most simple trinchera design consists of stones placed in a single or double row. The resulting narrow stone alignment generally appears one or two stones high. (See Photograph 20.) It is relatively straight in its length, which can vary from some of the shortest to the longest trincheras.

The stones utilized in alignments tend to be smaller than in the faced designs. The range of stone size is 0.25 to 3.0 feet across, but most measure 0.5-1.0 feet. Variation of sizes in an individual alignment can be only a few tenths of a foot or up to 2 feet. When both large and small are used, the smaller ones are laid in double or more thickness to equal the width of the larger stones. Single stone alignments occur more commonly than double ones, however.

These walls utilize a minimum of small rock material in the interstices between the main stones. There is a general lack of rubble associated with them, the alignments usually appearing as clear-cut lines of stones. In the cases where some small rubble appears behind the alignment, these pebbles do not seem to be organized into the structure of the wall but rather are a result of selective deposition behind the low barrier.

Subangular and rounded stones are utilized. There is no rigid pattern for placement of the stones--sometimes rectanguloid or slab-like stones are laid flat; in other cases slabs are set on end, and rounded and irregular stones are placed as best they fit. If slabs are used, they tend to be numerous rather than isolated in a wall and they usually form a rather uneven top surface, extending higher than the fill behind. Even coursing of stone is uncommon.

Alignments are used for check dams most often but also for linear borders and terraces and cross-walls on them. In addition to the type of alignment here treated, the riverside trincheras are essentially stone alignments, albeit of a very special, gigantic nature.

Stone Facing with Rubble Backing. A popular design for trinchera walls, the facing-with-rubble design further develops the stone alignment and adds a back support to it. The wall facing consists of coursed stonework, usually one and two stones thick. Immediately behind is a rubble backing formed of mixed clayey material, smaller rocks, and pebbles.

The stone facings utilize a variety of stones generally. Subangular, angular, and rounded stones are all used and shapes vary widely. The larger rocks (to 5.0 ft.) are leveled and positioned with smaller ones (from 0.25 ft.). Average stone size is on the order of 0.7-1.5 feet. Large boulders often appear at the base. Good coursing is uncommon. The faces are mostly vertical or slanted back only 5°-10° from vertical; however, there are examples with greater angle of face, to 45° or 50°, especially in the lower walls.

The rubble backing of the wall parallels the face in a zone of fairly uniform width, about 1 to 2 feet. Much of the rock rubble--a miscellaneous mixture of rounded to angular material--measures 0.25-0.5 feet on a side. The top surface of the rubble zone often is partly overlaid with fill from the plot, but the rubble intrudes to an extent that grass or weed cover is likely to be sparser immediately behind the wall face than further back.

A variation on facing-with-rubble design occurs in Area D, where the rock used is characteristically platey, slab or wedge-shaped. These walls have a single-stone-thick facing of rocks (0.1-0.2 × 1.0-3.0 × 1.0-1.5 ft.) set flat. The backing, not so mixed as usual above, consists mostly of smaller platey rocks (0.6-0.8 ft.) placed usually two wide. This design, then, has a wide stone facing backed by two small stones.

The strengthening of these walls by the rubble backing allows them to be extended to greater heights than the simple alignments. Some check dam examples reach 7-9 feet in height. However, the design also adapts to low height and many linear borders and terraces use facing with rubble.

Double Wall with Rubble Core. This design essentially duplicates the one last described--with the addition of a back stone wall to contain the rubble fill. In cross section the wall consists of, first, a facing of coursed medium to large stones, followed by a core of unassorted clayey material and small rock rubble, and finally a back wall of coursed stones, smaller than those on the face. This design of wall appears to be substantially superior to the other kinds in its engineering qualities, and many of the larger check dams show evidence of being double-walled, including three of the trenched checked dams (18a, 29, and 414). This design was recognized in terraces and linear borders, as well.

The previous description of stonework on face walls applies closely here also. The rocks reach larger sizes, however, in the taller walls, with 2 and 3 feet rocks appearing mostly near the bases quite commonly. Few facing rocks in the larger double walls are under a half foot across, and most measure 1.0-1.5 feet. A feature noticed in a number of these walls was the use of slabs placed flat as the top course of the walls. Again, rocks used vary greatly in shape, and coursing is poor except in a few walls.

The rubble core generally takes up less than a third of the total wall width. The back wall is similar to the front one, of mixed stones laid one or two thick; but its rocks are invariably smaller and the wall formed is generally much narrower.

Although some of the double-walled trincheras have vertical faces, the majority slant in toward the top, anywhere from a few degrees to 45°-50° from vertical, with about 15°-30° being common. Since the back walls are also often slightly oblique, less than the faces, in cross section many of these walls take a distinctive wedge shape. In typical examples, walls narrow 0.5-2.0 feet from base to top.

In two of the highest double walls (No. 17 at 10.3 ft. and No. 18a at 12 ft.), the faces vary in obliqueness from base to top, near midway in the height the angle of face altering markedly, in one case to greater obliqueness and in the other to lesser. This transition in 18a coincides with other constructional and stratigraphic differences so that it probably indicates separate periods of construction.*

Piled Rubble. This final wall design might more properly be thought of as a lack of design. Unassorted rocks are simply piled along a sloping surface into a rough "wall". With unorganized and uncoursed stones, the face and top are highly irregular. These walls invariably present an extremely oblique face, as the piles extend across a relatively great width in order to gain small height. Angles of face from 45°-75° from the vertical are normal as the walls rise 1-3 feet in a width of 2-5 feet.

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* See analysis of 18a soil trench in "Trinchera Soils" section.

Larger boulders often occupy positions near the base and possibly extend through the height of the wall. Every type and size of stone is used, presumably whatever is available nearby.

Piled rubble walls could not be expected to be very strong or durable. Their infrequent occurrence is limited almost entirely to the lower trincheras--terraces and linear borders--which function primarily to stabilize mantle rather than to accumulate it.

Additional Features of Construction. Some further generalizations about construction of trincheras should be briefly made, as follows:

1. The size of rocks used varies greatly but in individual walls will trend toward a general size; i. e., small, medium, large, or massive. The general size correlates with height of the wall, with some exceptions, notably on the Rio Piedras Verdes, where the largest boulders of all appear in the relatively medium-high riverside trincheras and very large slabs make up most of the check dams.

2. Size and shape of rocks seems to have been altered little, if any, by the builders of the walls; no shaping was observed. These volcanic rocks are extremely hard. More importantly, already well-weathered, the rocks were easily available in usable form. The form of rocks, then, depends mostly on local bedrock and how it has weathered out, as in the example of Area D check dams above.

3. The principle of availability accounts in large part for rocks appearing in individual walls. Massive in-place boulders, washed down drainage courses or exposed from bedrock,often form the bases of walls; or natural ledges or outcrops are utilized for parts of walls. Then, the large angular rocks utilized are of exactly the same composition as adjacent bedrock, from which they could have been levered. Finally, the smaller, more rounded boulders used often are rock types found upslope, from where they washed down or were carried down by gravity or by hand.

4. However, availability of rocks was hardly the sole guide to their usage; for particular sizes, shapes, etc.,were chosen for various placements, types of walls, and designs, as the above points have shown. The builders' knowledge of rocks is, for instance, shown in their almost complete avoidance of boulders of ash, which, although readily available near the ash beds, is too light-weight and easily weathered to make a good building material.

5. While great skill in stonework is abundantly displayed, so also is rather haphazard construction. The majority of trincheras probably fall somewhere in between those extremes.

6. The constructional technique almost always utilized bedrock as a means of tying the walls to the land surface. Local bedrock outcrops, to which ends are tied, figure importantly in the location, extent, and shape of walls, especially check dams (Photograph 14). Most sit directly on bedrock as Photograph 15 shows. The exceptions seem to be the lower walls which stabilize pre-existing mantle, whether alluvial or residual.

7. The longitudinal shape taken by trincheras follows no rigid pattern. While most check dams extend directly across drainage courses between the available bedrock outcrops, some take crooked paths which may or may not be related to local relief. Numerous check dams form fairly symmetrical curves, which can be either concave or convex to the plot behind, as adjacent Trincheras 18 and 18a illustrate. Other walls curve asymmetrically or combine curving with straight sections. Linear borders generally conform to slope contours but may wander away from them also.

In a uniquely shaped pair of check dams in Area D, the straight wall of 324 is topped (extended higher) at one end by 325, which then departs in a curve further upslope, so that the whole takes a single step on one end and two steps on the other.

8. Cross-walls extending back from linear borders and terraces add further, greatly varied elaborations to shape. End cross-walls appear to function similarly to the main walls; however, the ones interrupting plots--almost always single stone alignments set flush with the plot surface--appear non-functional with regard to mantle and may be divisions of the plots.

K. Concluding Statement

The trincheras studied have shown outstanding variety in size, type, design, materials, and quality of workmanship. It appears that adaptability to terrain, available materials, intended functions, and individual skills and preferences all played a part.

Yet, considerable organization is obvious. Trincheras individually and as a group are standardized to some degree, as has appeared in the generalizations which can be made about them. Furthermore, organization of effort must have been necessary in the building of such extensive systems of trincheras as these.

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VII. TRINCHERA SOILS

A. Introduction

Several trinchera plots were trenched for information about the nature of the fill behind trinchera walls and the construction of the walls themselves. Particularly desired were stratigraphic records preserved in the fill, if such stratigraphy existed. Trincheras 18a, 28, 29, and 246 in Area A and Trinchera Plot 414 in Area B, all located on Maps 7 and 8, were trenched. In each excavation but one (18a) the trench was taken down to bedrock. Additionally, the soil of Trinchera 319 in Area D was examined though not by trenching.

The results of each of these excavations are treated below. Table 2 presents the properties of soil samples taken from many of the levels in the trenches. General conclusions based on the stratigraphic analysis will then be given.

The last portion of this section contains a report on soil moisture tests.

B. Trinchera 18a

This trinchera is located within one of the relatively deep tributary valleys that drain into the Rio Gavilan Norte in Sample Area A. At this location the valley is approximately 30 feet deep, with walls of bedrock, and with a gradient of 18°. The trinchera wall is at a maximum 2 feet thick at the top, 39 feet long, and 12 feet high--one of the highest and most massive trincheras found. It is constructed of rather large boulders, the general angularity of some suggesting that they had possibly been levered out of well-jointed bedrock portions of the valley wall. With a slight convexity, the trinchera wall faces up the valley. Fill behind the wall forms a plot of 1,056 square feet.

A trench 3 feet wide, 14 feet long, and 5.2 feet deep was dug extending from behind the trinchera wall. Four distinct layers or strata with clear boundaries were distinguished within the first 5 feet of the trinchera fill, and later the trench was deepened to include another layer, all of which are shown in Figure 18. In Photograph 16 of the trench, string lines mark the boundaries between the layers. Photograph 18 is a profile of the fill 9 feet behind the trinchera wall and shows more clearly the textural and structural character of the fill. The layers in the fill of Trinchera 18a are described as follows:

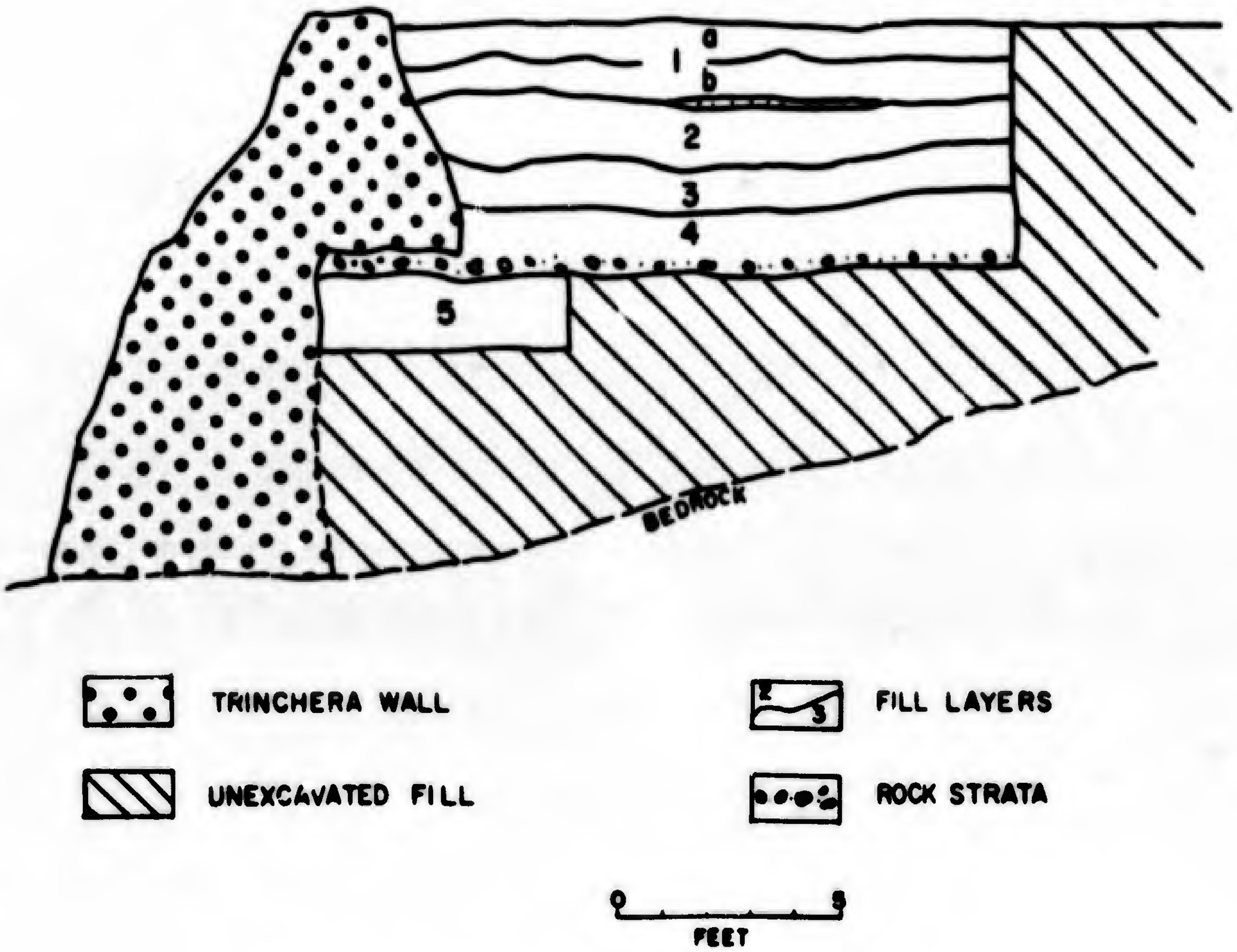

Figure 18. Cross Section of Trinchera 18a.

Layer 1. The uppermost layer varied from 1.3 to 1.6 feet thick and was reddish brown in color. The highest 0.8 feet (Layer 1a), exhibited a weak subangular blocky structure. The lowermost 0.6 feet (Layer 1b), differed from 1a in that it was essentially structureless and contained a discontinuous strata of very coarse sand and gravel with pockets 0.5 - 0.6 feet deep.

Layer 2. This layer varied from 1.0 to 1.8 feet thick. Again the layer boundary was clear and fairly abrupt. This reddish brown layer exhibited a moderate prismatic structure, the finest texture (clay loam) of any layer within the trinchera plot, and occasional small flecks of carbon.

Layer 3. This layer varied from 0.7 to 1.2 feet thick and was markedly different from the other layers in color, brown 10 YR 5/3, when dry. No inclusions of coarse sand or gravel were present. The structure was a weak subangular block.

Layer 4. Varying from 0.8 to 1.0 feet thick, this layer was brown in color and exhibited negligible structure (perhaps weak granular). In the lowest 0.5 - 0.7 feet of this layer the soil grades into a considerable quantity of moderate-sized, 0.3 - 0.5 feet angular stone and gravel.

Layer 5. As the height of the trinchera wall of 18a was 12 feet, a trench down to bedrock was considered unfeasible, and a 5 feet deep trench was thought adequate for an impression of the nature of the trinchera fill. However, the presence of the continuous layer of rocky fill at about 5 feet depth (terminating layer 4) raised several questions which prompted the decision to go down an additional two feet in a pit directly behind the trinchera wall. Below the layer of rock was exposed Layer 5, a rock-free layer similar in most all respects to Layer 2.

Another significant discovery in the additional 2 feet excavated was the termination of the back wall of the trinchera at the point of the rock and gravel layer, which continued under the back wall, as did Layer 5. It is not known whether a lower back wall existed somewhere below this point. Additionally important, a 0.5 feet offset in the front trinchera wall at 7 feet height with differing vertical angles of wall below and above the offset, coincides with the termination of the back wall and the stony layer. (See Figure 18.)

Conclusions for 18a. From this evidence there appear to have been more than one period of construction for the Trinchera 18a. Conceivably, an early wall to a height of 7 feet existed, the fill behind it topped by Layer 5. This potentially arable plot was then destroyed by deposition of rock and gravel upon Layer 5. The upper 5 feet high portion of the wall was then built to trap additional soil material. Whether this construction was done in stages corresponding with the boundaries between the fill layers is not known; however, the clear layers within the fill and the distinguishable soil structure suggest that the addition to Trinchera 18a was built after a considerable period of time.

C. Trinchera 29

Located in the same drainage course as 18a, Trinchera 29 lies 750 feet upslope and 100 feet higher in elevation. The valley here is considerably more open, with the valley sides more gentle than at 18a. The situation of Trinchera 29 is a miniature embayment only a few feet below one of the many small escarpments formed by the intersection of a contact between two lava flows and the slope.

The trinchera wall of 29 is 3.5 feet at its maximum height and 73 feet long. Constructed of irregularly shaped boulders, the largest about 2 feet on a side, the wall shows little coursing of the stonework. The placement of the stones was done in such a fashion as to take advantage of the irregular nature of the bedrock surface. Mantle had filled behind the trinchera wall to an average depth of slightly over three feet. The trinchera plot thus formed had a nearly level surface and covered 4,500 square feet. A portion of the trinchera wall had been destroyed, and the plot was in the process of gullying.

A trench was dug extending back 21 feet from the trinchera wall and down to bedrock. In the process of trenching, a buried Trinchera 29a was uncovered 18 feet behind 29 and parallel with it. A cross-trench 8 feet long and 4 feet wide was dug encompassing part of 29a. Photograph 17 and Figure 19 show the relationships between the trinchera walls, the trenches, and bedrock.

Two distinct strata were distinguished in the 3 - 5 feet fill behind the trinchera wall of 29, illustrated in Photograph 19:

Layer 1. This stratum was composed of the uppermost 0.7 - 1.0 feet portion of the fill and exhibited a rather indistinct contact with

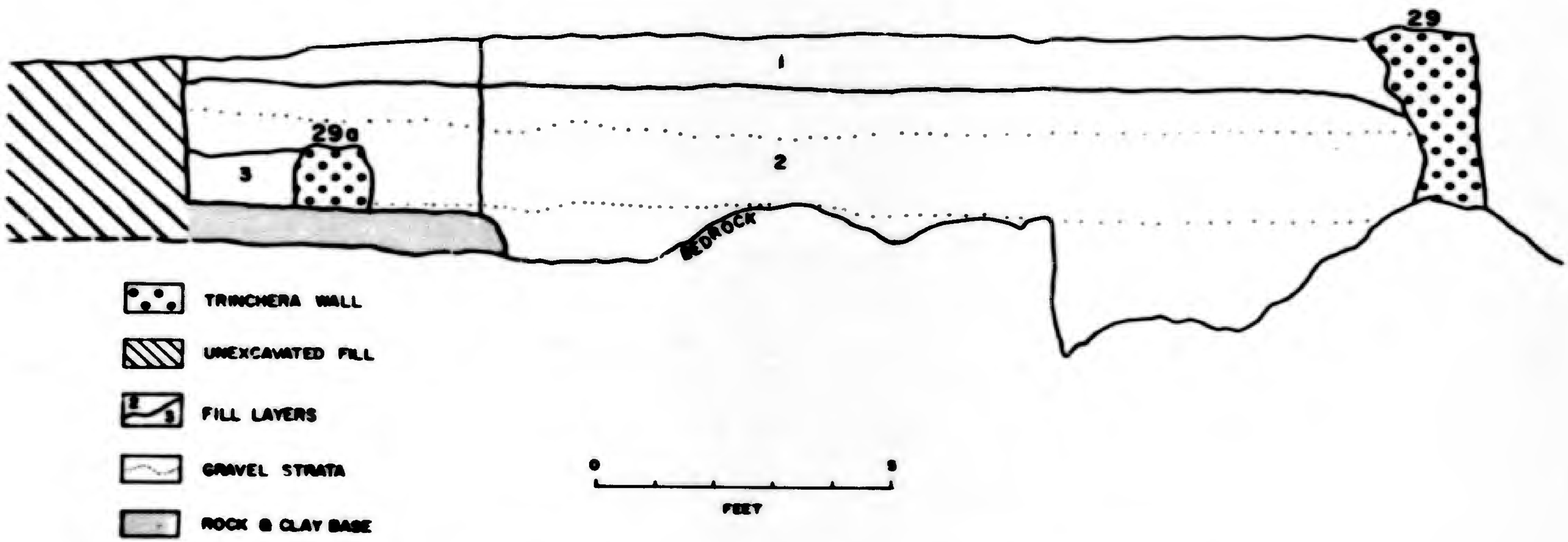

Figure 19. Cross Section of Trincheras 29 and 29a.

the layer below. Layer 1 appeared to be the product of the weathering of the fill below it. This soil layer had two fairly distinct horizons. The upper or A horizon varied from 0.2 to 0.5 feet thick, was reddish brown in color, and had a weak to moderate subangular blocky structure. The lower or B horizon varied from the A horizon mainly in its slightly darker color and by its harder consistency when dry. There was a negligible difference in texture (see Table 2).

Layer 2. This layer varied between 2.2 to 4.6 feet deep depending upon the irregular surface of the bedrock upon which it lay. This fill material was very friable when dry, exhibited no tendency for individual soil or fill particles to cluster, and had a considerable variance in texture from place to place. As shown by Photographs 17 and 19, this fill showed abundant evidence of its having been deposited by water action. Within the layer were numerous strata and lenses of angular and subangular pebbles 0.03 - 0.10 inches on a side. Two especially well-pronounced pebble and gravel strata were traced at 1.4 - 1.6 feet and 2.4 - 2.8 feet below the surface. A very large proportion of the fill was composed of rocks (particles 2mm. or larger in size), about equally divided between fragments of the lava flow upon which the fill rested and of the volcanic ash which outcropped 300 feet upslope from 29.

D. Trinchera 29a

As previously mentioned, during the trenching of the fill of 29 a buried trinchera -- 29a -- was uncovered. Very low, only 1.2 feet high, this trinchera was built upon a 0.6 - 0.8 feet thick base of small rocks (up to 0.6 feet on a side) in a matrix of clayey fill. Trinchera 29a was traced for 8.4 feet parallel to Trinchera 29. Three layers were detected in the fill behind the wall, as outlined in Photograph 20, as follows:

Layer 1. Other than its being more shallow due to erosion of the trinchera plot at this location, Layer 1 material behind Trinchera 29a was not significantly different from Layer 1 behind Trinchera 29. In fact, lying well above Trinchera 29a, Layer 1 material was uninterrupted and continuous from its start behind 29 to the end of the trench behind 29a.

Layer 2. The upper and lower contacts of this layer are traced by string and stone in Photograph 20. Layer 2, though much more shallow (approximately 1.0 ft. thick), exhibited the same qualities as

Layer 2 behind Trinchera 29. Of particular note is the continuation of the 1.4 - 1.6 feet gravel strata. Also uninterrupted by trinchera wall 29a, Layer 2 material appears to be continuous from behind 29 to the termination of the trench.

Layer 3. Below Layer 2 and resting upon the rock and clay platform upon which Trinchera 29a was constructed was a 1 foot thick layer of material exhibiting a moderate prismatic structure and a loam texture. The contact between Layers 2 and 3 corresponded with the height of the top of trinchera wall 29a, and Layer 3 exists only behind 29a. In front of 29a at the same level is the Layer 2 material of 29 (see Figure 19).

Conclusions for 29 and 29a. The relationship between Trincheras 29 and 29a and the levels of mantle behind them suggest a sequence of construction and deposition. It is probable that Trinchera 29a was constructed first either to collect or to stabilize soil behind it. The second stage was the construction of 29, which trapped stream-carried deposits behind it. These materials accumulated to such a depth (Level 2) that 29a and its plot (Level 3) were covered. The uppermost foot of this fill subsequently has been weathered to produce a soil (Level 1) similar in many respects to that which was behind 29a (Level 3).

E. Trinchera 28

Located in the same drainage course as 18 and 29, Trinchera 28 is 85 feet down the valley and 15 feet lower in elevation than 29. During reconnaissance prior to surveying, several aligned stones were found exposed by a small gully that was in the process of eroding the fill behind Trinchera 12. A 3 feet wide and 8 feet long trench was dug parallel to the exposed stones, uncovering more of what was then recognized as a trinchera and numbered 28. The height of this trinchera was very irregular, varying from 0.5 to 2.1 feet. Unlike the wall of 29a, Trinchera 28 was built directly upon the bedrock surface.

Behind Trinchera 28 lay three recognizable layers of fill:

Layer 1. Varying between 0.2 and 0.8 feet thick, Layer 1 was in most respects similar to Layer 1 (topsoil) in the fill of 29. This layer was being very actively eroded.

Layer 2. Below Layer 1 was a layer of alluvial fill 0.6 - 1.3 feet thick, ending at a level even with the top of the trinchera wall.

This material was very similar in character to the Layer 2 of Trinchera 29 in that it had no structure, contained numerous small fragments of rock, and showed a bedded character indicating water deposition.

Layer 3. Next was a layer of mantle 0.3 - 0.7 feet thick lying directly behind the trinchera wall from its top level to bedrock. Exhibiting marked structural and textural differences from the fill above it, Layer 3 was similar to Layer 3 material found behind Trinchera 29a. This layer had the definite appearance of a soil which had been covered by the deposition of Layer 2 material, i.e., Layer 3 was a buried soil.

Fill in Front of 28. Unlike the situation at 29a where a decided difference existed in the material on either side of the buried trinchera, at 28 the layers were essentially the same on both sides of the wall. In front of Wall 28 were found the following:

1. Layer 1 material (topsoil) continued to a somewhat greater depth (maximum 1.2 ft.) due to lack of gullying.

2. Layer 2 material (alluvial fill) continued in front of 28 down to a depth corresponding with the top of the trinchera wall. There appeared to be no difference in this fill from one side of the trinchera to the other.

3. Below this alluvial fill and below the top of the wall was a layer of mantle similar in color, texture, and structure to the assumed buried soil behind 28. This layer varied from 0.5 to 0.9 feet thick and rested upon bedrock.

Since the trench was not extended downslope, it is not known whether these fill layers continued as far as Trinchera 12, 32 feet in front of 28.

Conclusions for 28. Several possible explanations must be admitted for the levels present and the lack of interrupting influence by Trinchera 28 upon the surrounding fill. A first possibility is that Layer 3 material had been formed by the weathering of some earlier accumulated fill behind Trinchera 12 when it was at a lower height and that 28 was intruded into or behind this soil. Then the modification of Trinchera 12 caused a deposition of alluvial fill (Layer 2) to cover this Layer 3 material. Finally, Layer 1 would have formed from the topmost part of Layer 2.

There is the second possibility that the Layer 3 material found on either side of Trinchera 28 was residual soil and that 28 was constructed to reduce the erosion of the original mantle rather than to accumulate fill. Similar functions may have been served by 28a, a second and untrenched trinchera upslope from 28, as well as other possible trincheras now buried by the fill (Layers 2 and 1) accumulated behind 12. Trincheras 28 and 28a were so low that they would have been rather ineffectual in causing the accumulation of waterborne fill, but they could have been quite effective in maintaining or stabilizing the earlier residual soil. In this case, the accumulation and formation of Layers 2 and 1 would probably have been related to modification of Trinchera 12, as in the first explanation above.

F. Trinchera 246

This trinchera was located in Sample Area A on a broad structural terrace rather than in a drainage course as were the previous trenched trincheras. The trinchera wall was 117 feet long, averaged 1.2 feet high, and was constructed of two courses of rounded rocks, averaging 0.6 feet on a side, which rested on the bedrock surface. The land sloped little -- 1 to 2 percent perpendicular to the trinchera wall-- and the rocks of the wall were aligned so as to follow the contour of the land. The large plot behind the wall measured 5,900 square feet. Trinchera 246 was one of several in the area of similar dimensions and construction.

The dark reddish brown soil behind Trinchera 246 varied from 0.6 to 0.8 feet deep. There was no evidence of any soil horizons. This clay loam soil exhibited moderate subangular blocky structure and in the lowest 0.1 - 0.2 feet contained fragments of parent material (lava flow). The soil was essentially stoneless.

Although no samples were taken for comparison, soil adjacent to Trinchera 246 and uninfluenced by it or other trincheras did not differ macroscopically in color, texture, consistency, or structure from the soil behind and in some way controlled by 246. The only difference noted was the degree of stoniness: while the soil behind Trinchera 246 was essentially free of stones, soils adjacent had a slight covering of stones.

Thus, Trinchera 246 does not appear to have in any way actively affected soil formation, as did Trincheras 18a and 29. The trinchera was probably constructed only to maintain and stabilize the soil. Initially, or perhaps gradually as the soil was tilled, the stones from the field were removed and used to extend the trinchera wall.

G. Trinchera 414

The trinchera wall of 414 in Area B was 42 feet long, 3 feet high, and 3.1 feet thick, composed of two courses of stone with rubble fill between them. Topographically 414 was situated at the lower end of a stream course, 600 feet away from its junction with Rio Gavilan. The greatest part of the drainage area of this small basin lay upslope from 414. The valley here was relatively open though asymmetric with a steep south slope and a gentle north slope. The gradient of the stream course at this point was 1 to 2 percent. Trinchera 414 had been completely cut through at one end by erosional agencies and the bedrock floor of the valley, upon which 414 had been built, exposed.

Slumped fill was cleared back for an extent of 4 feet from the cut portion directly behind the trinchera wall to expose the fill as shown in Photograph 21.

Unlike the trenches in Area A, the Trinchera 414 excavation showed no discernible strata or layers of fill. No observable soil had formed or was in the process of forming on the uppermost portion of the fill. The only color difference throughout the entire fill was a slight darkening of the top 0.3 feet. Samples of the fill were taken at three depths, 0.5, 1.5, and 2.5 feet; and all yielded the same textural grade of loam. No layers of gravel appeared; however, occasional small stones were noted.

Although time did not allow for more than one trench to be dug in Area B, fill samples taken with a soil auger from a representative number of other trinchera plots confirmed the above soil description as an apt generalization for trinchera soils of Area B. The homogeneous character and lack of textural and other observable variations in the trinchera fill of this area contrast strongly with the definite stratified appearance with definable layers of the soils in similar check dam plots of Area A. The possible explanation lies in the location of Sample Area B completely within a drainage basin eroded from the red volcanic ash. This material weathers rather rapidly into a coarse granular mantle which appears to vary little in character anywhere within the area. In Area A, on the other hand, there is a considerable variation in the character of the bedrock, both within any drainage area and in the sample area as a whole, a heterogeneity which has been mirrored in the stratified appearance of the depositional trinchera fill. The contrasting homogeneity of the fill in Area B does not stand in evidence of lack of water deposition but rather of the homogeneous nature of the volcanic ash parent material, which lacks any xenoliths or other complicating features.

H. Trinchera 319

As shown by Map 10, Trinchera 319 in Sample Area D is located in a short, steep ephemeral stream course that flows into the Rio Piedras Verdes. The trinchera wall, 54 feet long and 7.2 feet high, is in a state of complete preservation. Although one of the highest trincheras in this area, 319 is formed of relatively small stones, 1 to 2 feet on a side, which are well coursed. As in all of the higher trincheras, the wall of 319 rests upon bedrock, a light grey felsite. The mantle on the slopes is very thin and extremely stony (see Photograph 1).

Illustrated in Photograph 15, showing the base of Trinchera 319 and its contact with the underlying felsite bedrock, is an interesting phenomenon seen not only at 319 but also at other trincheras in Area D. It will be noticed that a small pool of water is accumulating at the contact of the trinchera and the bedrock, to be absorbed by the fill of the next lowest trinchera. This evidences the presence of soil moisture in the trinchera fill and the gradual movement of the moisture downslope through the fill to the bedrock contact of the trinchera wall. While this phenomenon had been observed before in Area D*, it was not observed to this extent in any other area in 1964.

The fill of all the trincheras in Area D being nearly at a state of field capacity at the time they were surveyed, no trenching of the fill could be carried out in this area. A soil sample taken by soil auger at a depth between 0.5 and 1.5 feet is described as to textural and other properties in Table 2. The trinchera fill in Sample Area D, as expressed by the fill of 319, was considerably more stony than in any other area. Stones varied in size from several tenths of a foot in diameter to 0.6 feet or more on a side.

* On an excursion into the area later in the rainy season, late August, in 1963.

I. Conclusions Concerning Trinchera Soils

Based upon the preceding data, conclusions can be made about the fill behind trinchera walls as follows:

1. Both transported and residual mantle are found behind trinchera walls. Many of the very long, low walls (1 ft. or less high often) seem to have been constructed for the primary purpose of stabilization of the residual mantle or reduction of the effects of sheet flood erosion upon the mantle.

2. There is no indication that the fill behind the trincheras was accumulated by any other process than the normal process associated with water deposition and mass wasting.

3. Much evidence indicates that the process of water deposition of mantle behind trinchera walls took place over some considerable period of time. This is evidenced by observable layers varying in texture, color, and structure, dependent upon environmental conditions at the time of the deposition.

4. There is evidence that in some cases fill material was allowed to cover and obscure the original residual mantle.

5. A sufficient period of time has elapsed since the accumulation of mantle in the trinchera plots for weathering to have significantly modified the uppermost 1 foot of the fill in most sample areas. There are observable textural, structural, and color differences with incipient horizons forming in the top portion of the fill.

6. The fill shows no indications of disturbance during the time the fill accumulated (as, for example, would have occurred as a result of soil mixing in cultivation, disturbing the stratified nature of much of the fill).

7. Some trinchera walls have been extended in height during their history. Coincident with such modifications are certain distinct levels in trinchera fill.

J. Soil Moisture*

On numerous exploratory trips into the study area it was observed that water seepage was present at the base of many of the higher

* This section was written by William A. Howard.

trincheras. Since these observations were made during the dry season, the question of the importance of trincheras as moisture storage devices was posed. It was thought that a method for getting at this question would be to take soil samples in those areas not immediately behind trincheras, such as in areas where the soils were thin, as on terraces and flats, and compare the moisture content with those samples taken directly behind the trincheras where the greatest mantle accumulations are found. Since the study was to commence during the dry season and extend into the rainy season, this period of time would facilitate a comparison of retention and absorption rates through the climatic extremes.

It was decided, after weighing the merits of various soil moisture determination methods, to use the so-called gravimetric method. Two factors favored this choice. First, a definite quantitative measure of moisture present results from its use; and second, the gravimetric method is amenable to field conditions, a factor quite necessary to the overall study. Unlike many other methods, the actual steps for carrying out the gravimetric method can be conducted in the field. There is no necessity to fall back to the laboratory, although facilities for weighing and drying the samples must be provided for. Briefly, the steps necessary in the gravimetric method are as follows:

1. Initially, it is important to obtain samples of soil that are representative of specific soil depths. Care must be taken to insure a minimization of moisture loss by evaporation. To facilitate this, samples are placed in nearly airtight containers. These containers are then accurately weighed, dried to constant weight, and an oven-dry weight derived.

2. Soil tubes are employed to obtain samples. Such tubes make it possible to obtain samples without any danger of contamination with other soil. Also, damage to a sample site is minimized through the use of tubes. Increments are marked on the tubes, and this allows soil cores to be obtained at any depth. In practice, the depth of samples should conform to soil horizons or layers so that a given sample does not include different types of soil material.

3. After samples have been collected, it is necessary for fresh weights to be determined, preferably as soon as the samples are brought in from the field. Once fresh weights have been obtained, the

samples are then dried to derive oven-dry weights. From this step certain computations are necessary to obtain soil moisture content in percent of oven-dry weight, percent by volume, and inches of water.

a. Net oven-dry weight = oven-dry weight (tare weight + weight of rock)

b. Weight of water = fresh weight - oven-dry weight

c. $Pw = \frac{\text{weight of water} \times 100}{\text{net oven-dry weight}}$

d. $Pv = Pw \times$ bulk density of soil

e. Inches of water = $\frac{Pv \times \text{inches of soil represented}}{100}$

Pw is moisture as percent of dry weight, and Pv is moisture as percent of volume. *

Ideally, daily soil samples for moisture determination should have been taken. This would have allowed for an optimum determination of moisture variance in the period of time the study covered. Unfortunately, the press of time and the division of labor ruled this out as a possibility. Rather, samples were taken periodically, when personnel could be released from other tasks, in the hope that some approximation of moisture variance could be derived. Beginning June 22 and continuing through August 10, samples were taken on an average of nine day intervals. Areas where samples were collected are found on Map 7. After these samples were subjected to the necessary treatment so that moisture content could be determined, the data derived were analyzed to see what moisture changes occurred over the period of time involved. Unfortunately, the results were quite inconclusive on the importance of trincheras as moisture storage devices. A number of factors may have worked in combination to have brought about this condition.

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* David F. Olson Jr. and Marvin D. Hoover (1954), "Methods of Soil Moisture Determination Under Field Conditions," Station Paper No. 38: U. S. Department of Agriculture - Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina, pp. 2-6.

First, the period of time elapsed from one sampling to another may have been too long for a proper accounting of precipitation that occurred during intervening periods. Another factor contributing to the lack of realism was the degree of stoniness and rockiness over the whole study area. During certain sampling periods, personnel actually thought it necessary to seek out samples commensurate in depth with previous samples. This task proved to be quite difficult because of the stoniness and rockiness of the areas being sampled as well as the thin character of almost all soils in those areas not directly behind trincheras.

It would seem reasonable that in those areas where soils are thin the retention and absorption rates should show some variance as compared to those areas directly behind trincheras where greater accumulations of mantle are found. Taken as a whole, there is some indication from the data collected that such a relationship does, in fact, exist. However, conclusive generalizations cannot be made at this time.

The importance of further attention to soil moisture and the hydrologic ramifications of trincheras is pointed up in the vegetation investigations conducted during the summer. In Area B there was an obvious control exerted on vegetation by trincheras as reflected through density and productivity. The most likely cause was soil moisture. In future work on the overall problem of trincheras, intensive work is needed on the hydrology of the type area, as well as continued work on this problem of soil moisture.

Table 27 gives a comparison of three test pits and the variance of moisture based on the inches of water actually contained in the soil sample at the time of collection.

TABLE 27

Representative Soil Moisture Data

Inches of Moisture Present at Certain Sampling Periods

	Natural Area I		Trinchera #29		Natural Area IV*	
Dates	Depth (Inches)	Inches of Moisture	Depth (Inches)	Inches of Moisture	Depth (Inches)	Inches of Moisture
June 22	(Surface)	0.10	(Surface)	0.13	(Surface)	0.07
	6	0.65	6	0.85	6	0.97
	10	0.74	12	0.76	12	1.76
			24	1.50	24	2.72
			36	1.11	36	2.98
			48	1.06		
July 2	(Surface)	0.68	(Surface)	0.67	(Surface)	0.30
	6	0.67	6	0.88	6	0.99
	11	1.14	12	0.97	12	1.02
			24	1.96	24	1.75
					36	1.15
July 10	(Surface)	0.52	(Surface)	0.64	(Surface)	0.60
	6	1.32	6	1.98	6	1.07
	12	0.45	12	0.81	12	1.46
			24	2.04	24	2.95
			36	1.34	36	1.44
July 22	(Surface)	0.36	(Surface)	0.56	(Surface)	0.66
	6	2.22	6	1.93	6	1.41
	8	0.83	12	0.54	12	1.32
			24	0.97	24	3.18
					36	2.34
July 29	(Surface)	0.48	(Surface)	0.77	(Surface)	0.53
	6	1.96	6	2.10	6	1.36
	12	1.42	12	3.84	12	1.44
	24	2.54	24	1.99	24	2.66
			30	0.49	36	2.22
August 10	(Surface)	0.25	(Surface)	0.15	**	**
	6	1.54	6	1.53		
			12	0.84		
			24	1.12		
			30	0.49		

* Natural Area IV does not appear on the map indicating the locations of moisture test pits. It was located at the north end of the cornfield across the stream from the campsite.

** Samples were not collected for this site on August 10 because of an intense storm that cut off the camp from the site.

VIII. POLLEN ANALYSIS

Eight soil samples were taken at various depths in the fill behind Trinchera 18a in Area A and Trinchera 414 in Area B for the specific purpose of pollen analysis. It was hoped that some further information would be gained about environmental conditions at the time the trinchera fill was being deposited, as well as about possible uses of these structures.

Five samples were collected in the fill of Trinchera 18a: at 0.75, 2.0, 2.5, and 4.4 feet. Also, a sample of surface soil was collected immediately adjacent to 18a. At Trinchera 414 the two samples collected were at 1.5 and 3.0 feet.

Since the University of Denver has no facilities for the analysis of pollen, the samples were sent to Dr. Paul S. Martin of the Geochronology Laboratory, University of Arizona, who so generously carried out the analysis. His report is presented below:

"Only . . . the surface soil adjacent to Trinchera 18a yielded enough pollen for a 200 grain count, as follows:

Tree pollen:	_Pinus_	99
	Quercus	38
	Juniperus	14
Non-tree pollen:	Cheno-ams	20
	Short-spine compositae	12
	Long-spine compositae	4
	Gramineae	9
	Ephedra	1
	Euphorbia	1
	cf. _Dodonaea_	1
	Unknowns	2
	Fungal spores	abundant
	Selaginella	1

Fungal spores and _Selaginella_ were also abundant in Trinchera 18a, 0.75 feet, which contained a few pollen grains of pine and oak. Pine and fungal spores were present but scarce at 2.0 feet and were very rare or absent in the other six samples."*

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* Paul S. Martin, Personal communication, January 22, 1965.

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IX. RELATIONSHIPS BETWEEN TRINCHERAS, TERRAIN, AND MANTLE

A. Introduction

This concluding section presents some of the most important aspects of the trinchera-physical environment interrelationship.

Four types of terrain are defined, and their distribution in the sample areas is described. In each type of terrain occur certain characteristic relationships between trincheras, terrain, and mantle. On the one hand, physiographic features influence and determine the placement of trincheras. On the other hand, trincheras exercise control: the effects of trincheras upon mantle are profound.

Since Area A was surveyed and described in greater detail than the other sample areas, it will be analyzed at greatest length. Portions of Area A were chosen for mapping of the trinchera-bedrock-mantle relationship (Maps 6a and 6b).

B. Definition of Terrain Types

Within the general region four terrain types were recognized. These types are defined by their surface configuration and relationship to the drainage pattern, as follows:

Type 1: gently sloping terraces and mesas. The slopes of these surfaces range from 1° - 4°, and they are largely structurally controlled. There is little stream dissection, although the surfaces are bounded by pronounced escarpments.

Type 2: short, steep gradient ephemeral stream valleys. Five to thirty feet deep, these valleys have been incised into the slopes of the mesas and mountain masses.

Type 3: narrow, often steeply sloping interfluves. Slopes vary from 9° - 30° and over. The surfaces are often interrupted by pronounced breaks of slope associated with the varying nature of the underlying volcanic rocks. The greatest proportion of the Study Area consists of this terrain type.

Type 4: flood plains and stream terraces of the permanent streams. Flood plains from 30 to 150 feet wide are occupied by the permanent streams. Rising 4 to 8 feet above each flood plain is a single, very discontinuous stream terrace, varying from a few yards wide to a maximum of 800 feet. A relatively small proportion of the Study Area lies in this terrain type.

C. Terrain Types of the Sample Areas

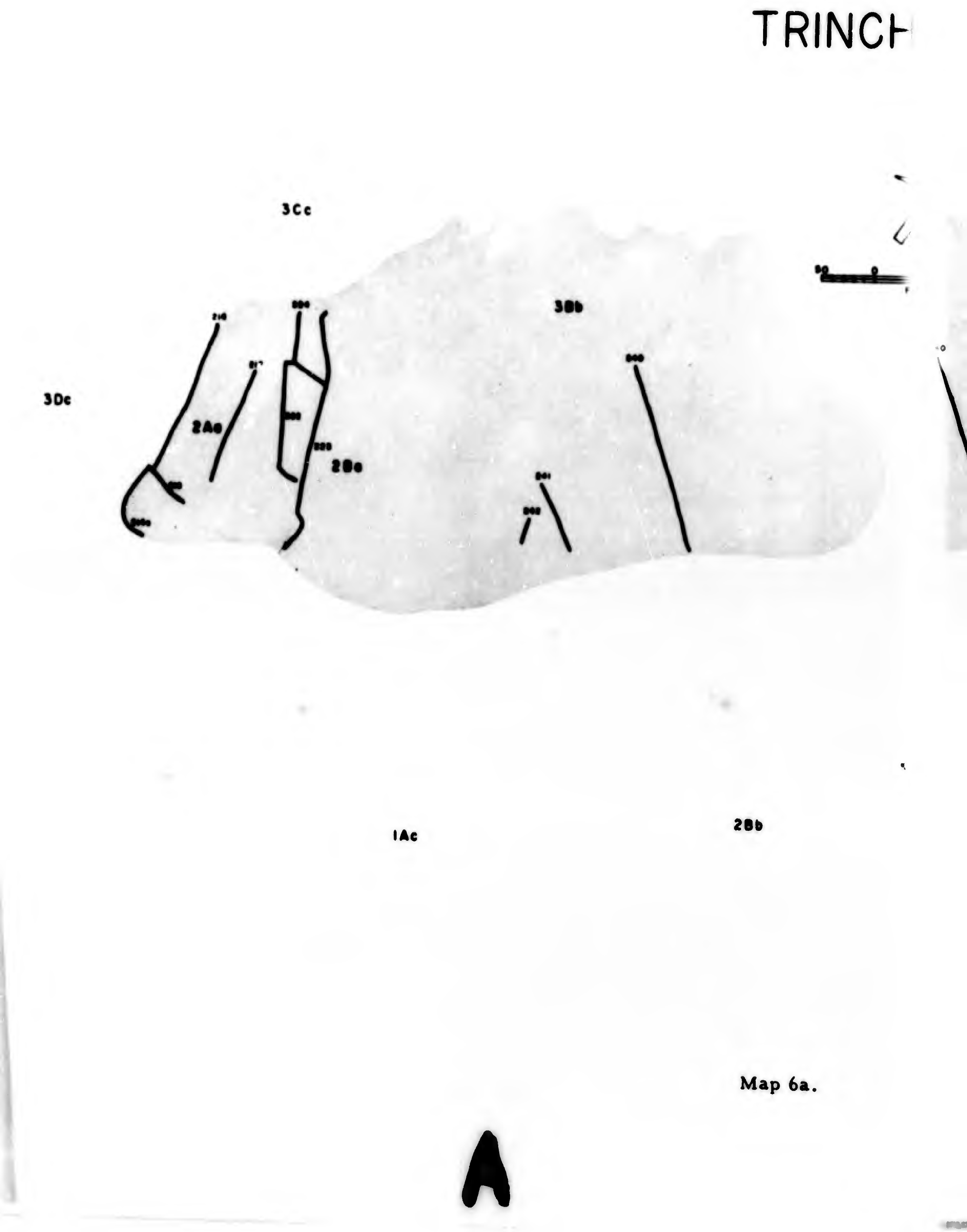
Drainage patterns and surface configurations vary over the Study Area so that the terrain of each sample area is distinctive.

Sample Area A. The bedrock in Area A is a gently dipping (5°) series of volcanic flows and ashes, striking S 88° E and dipping to the south (see geology inset on Map 6b). The flows are from 10 to 24 feet thick, with considerable textural differentiation from base to top. The basal portions are quite dense and massive, while the upper portions are typically vesicular or pillowy. Numerous escarpments and nick points characteristically occur at the point of this textural change within each flow rather than at the contacts between flows. The trace of these nick points and escarpments does not give a simple stair-stepped appearance to the terrain but is considerably complicated by the stream pattern, which has formed numerous embayments and has isolated knolls of bedrock. Terrain Types 2 and 3 are found in this geologic situation in Area A.

In the southeast portion of the area there is less dissection, and the relief is well-adjusted to the nearly horizontal attitude of the bedrock. In this geologic situation in Area A are found mesa and terrace flats, Terrain Type 1.

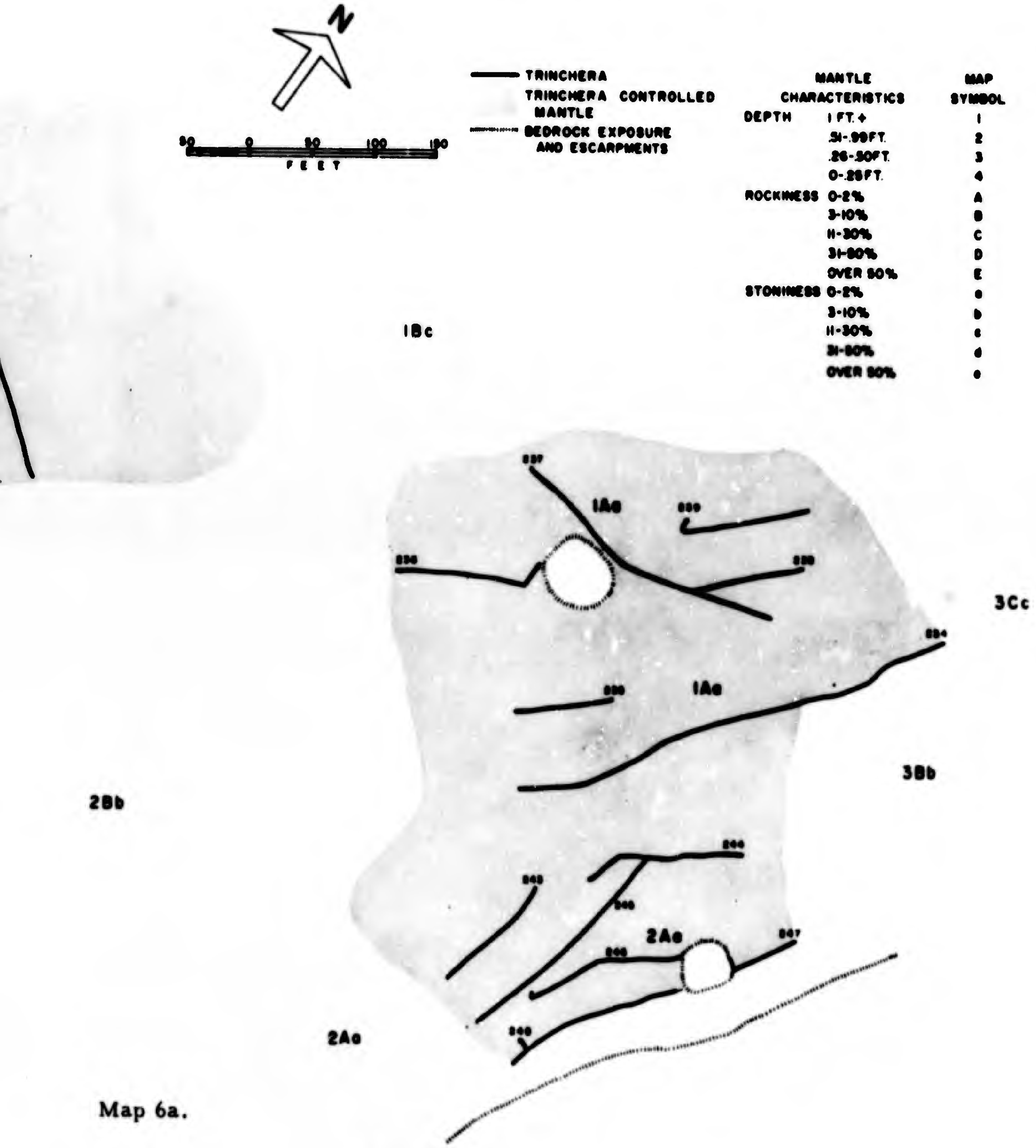
Sample Area B. The bedrock in Area B is entirely of red volcanic ash. Three terrain types are represented: stream valleys and interfluves (Types 2 and 3) and flood plain and stream terraces (Type 4). In contrast to Sample Area A, the gradients of the short ephemeral streams, which flow directly into the Rio Gavilan, are uninterrupted by pronounced escarpments or nick points. Exposed bedrock surfaces are not as numerous in these valleys as in Area A. The river occupies a relatively wide flood plain of 120 to 150 feet. Rising 6 to 8 feet above the flood plain and extending back several hundred feet is a well-formed stream terrace.

Sample Area C. Two terrain types are represented in this area: Type 2 (ephemeral stream valleys) and Type 3 (interfluves). The bedrock here is red volcanic ash, and upon it has formed a very sandy



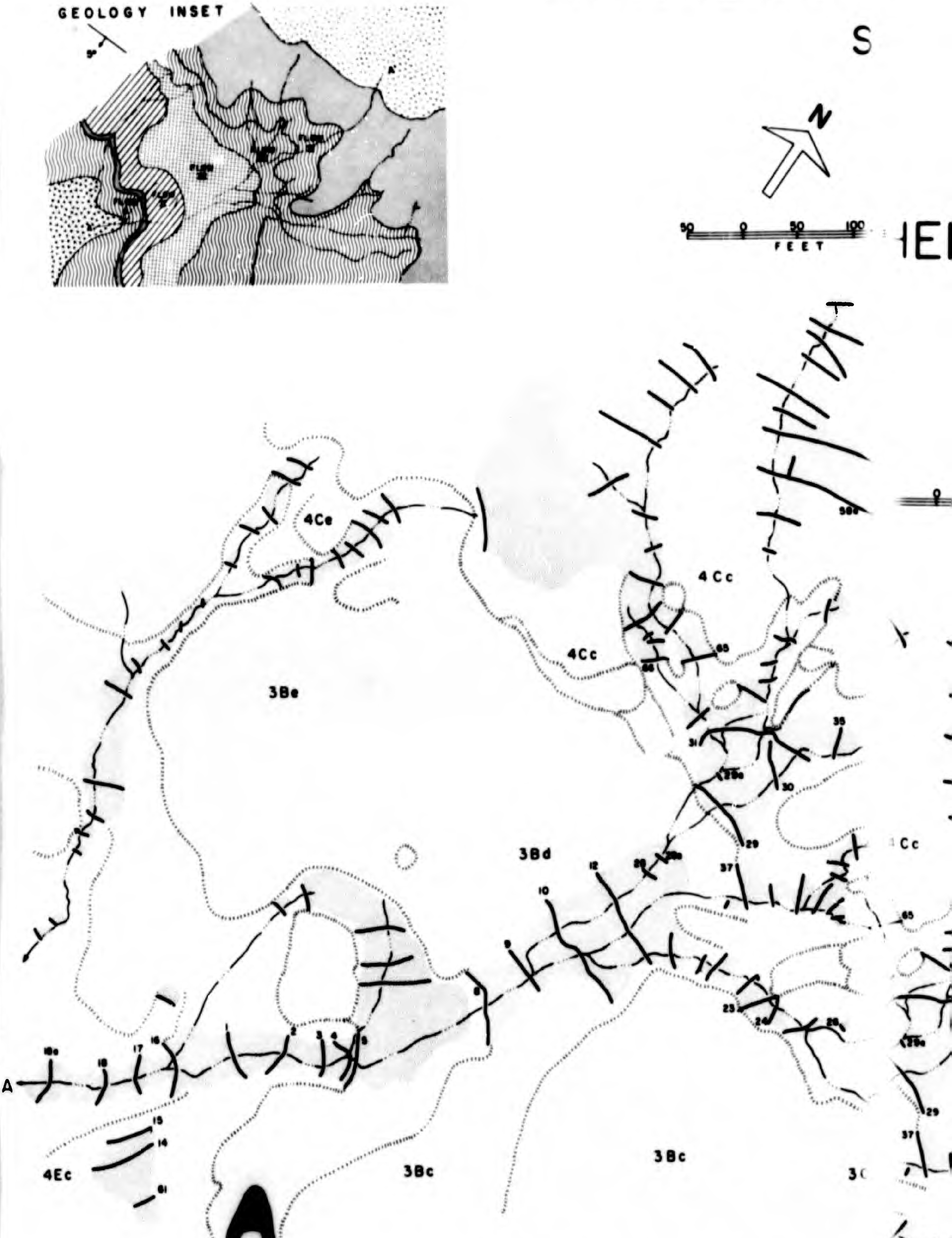
Map 6a.

TRINCHERAS AND TERRAIN TYPE 1
SAMPLE AREA A



Map 6a.

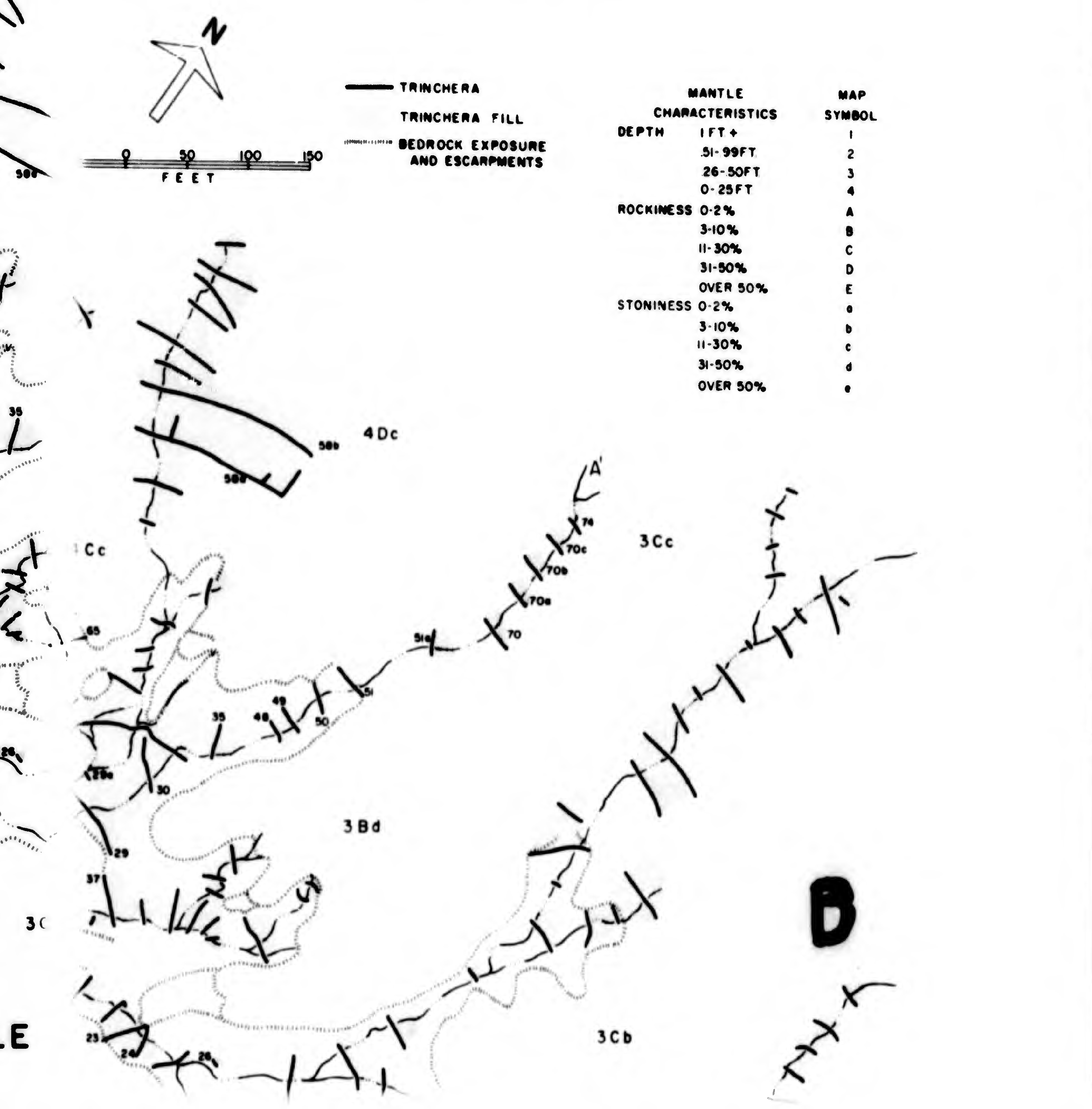
TRINCHERAS

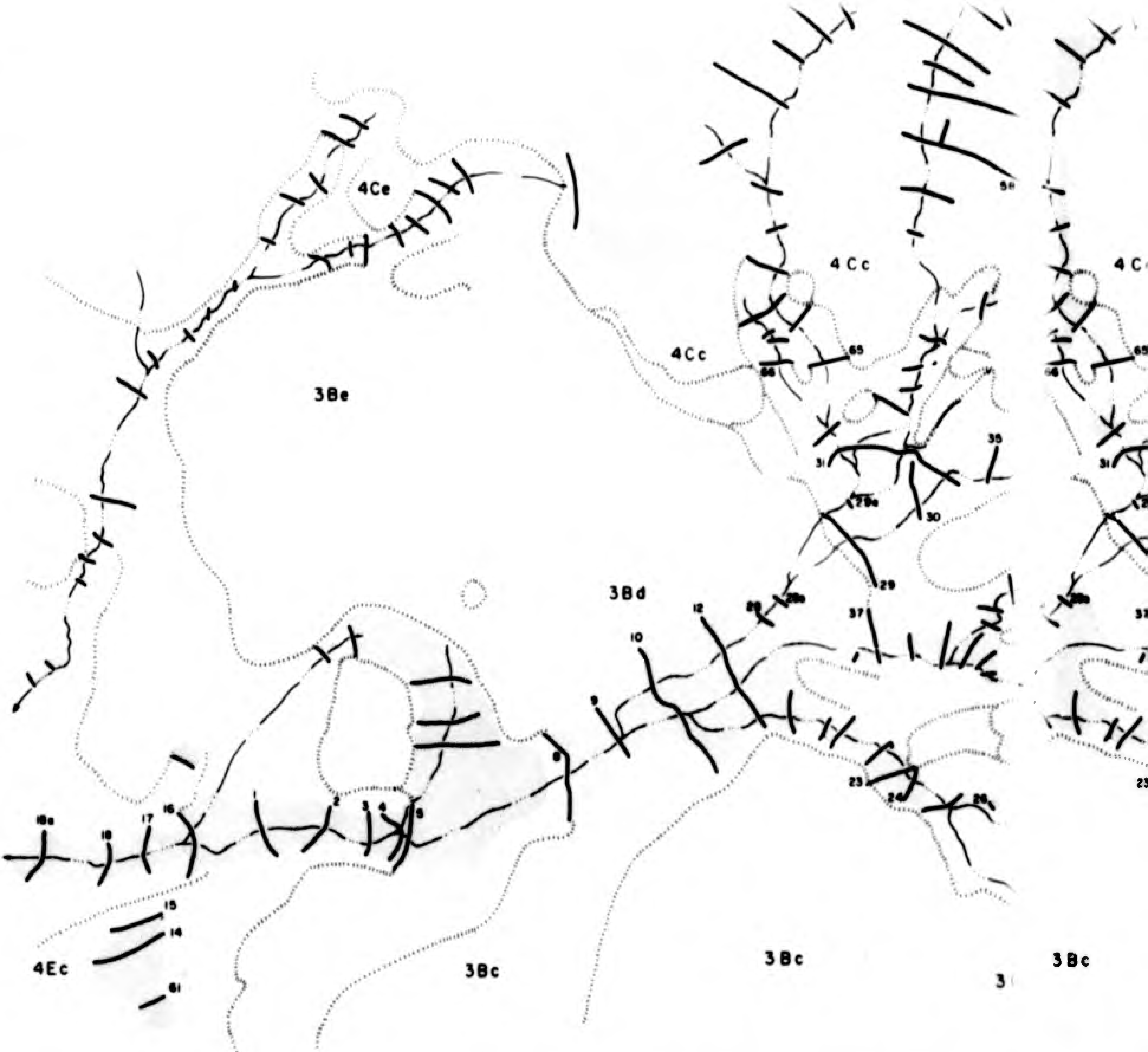


STRUCTURAL PROFILE

STREAM COURSE A-A'

...HERAS AND TERRAIN TYPES 2 & 3
SAMPLE AREA A





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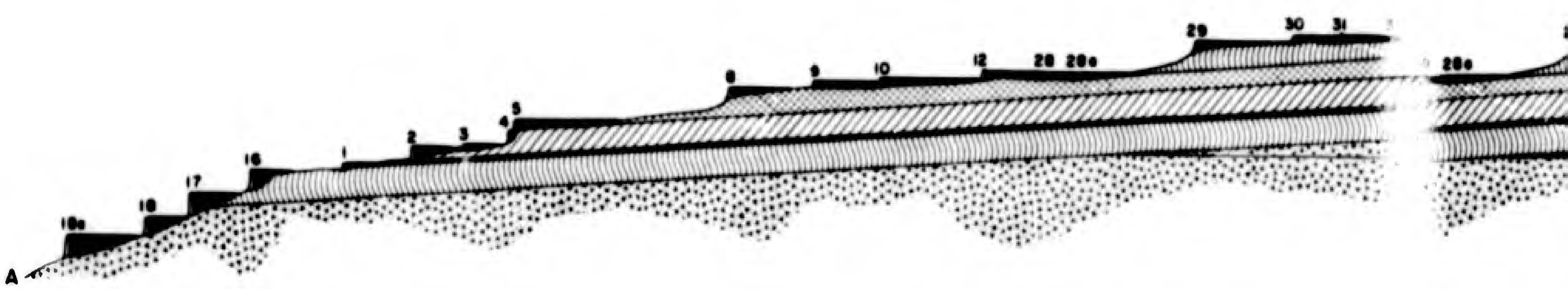
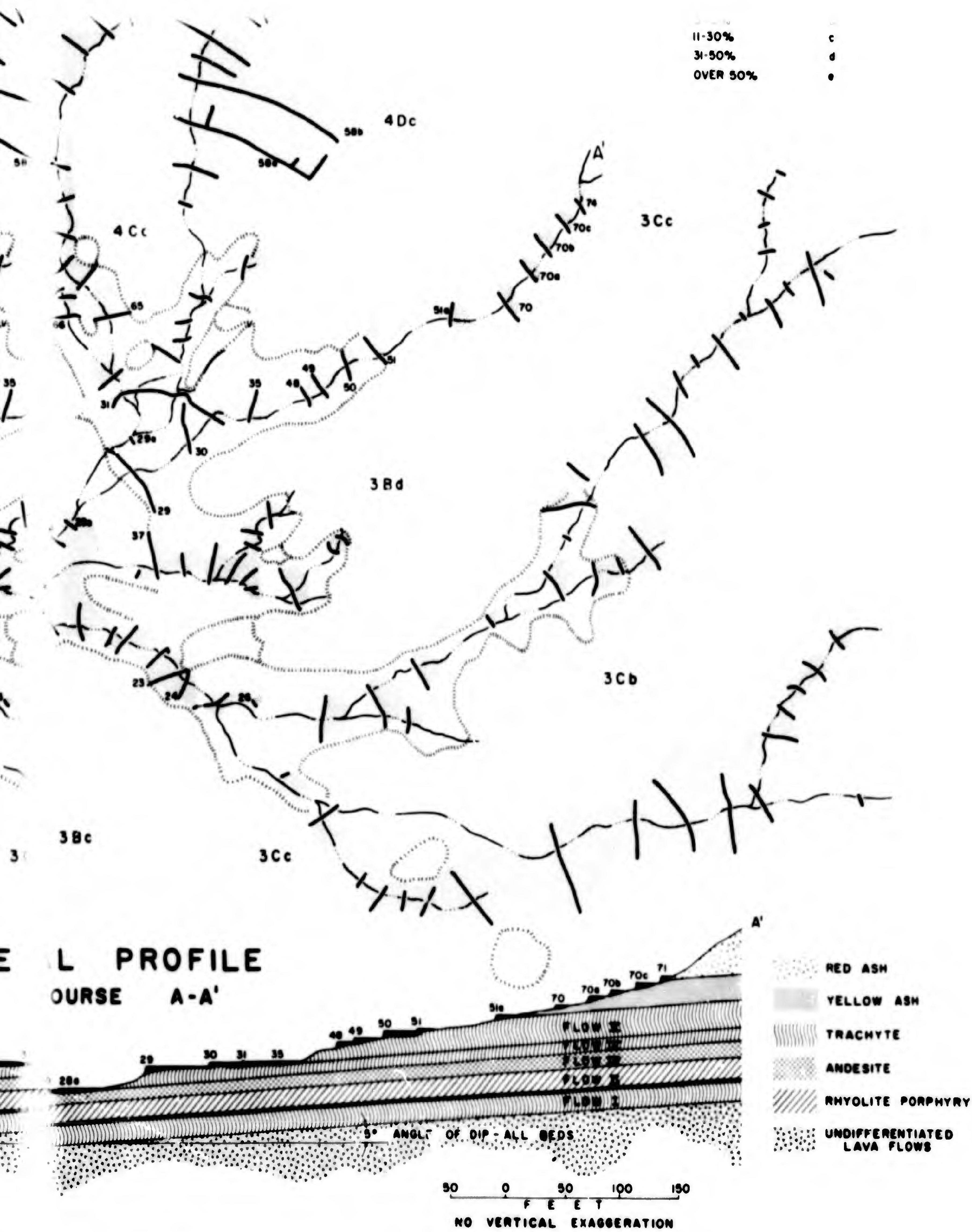
STREAM COURSE A-A' OURSE



Map 6b M

C



11-30% c
31-50% d
OVER 50% e
4Dc
4Cc
3Cc
3Bd
3Cb
3Bc
3Cc
A'
L PROFILE
OURSE A-A'
FLOW I
5° ANGLE OF DIP - ALL BEDS
RED ASH
YELLOW ASH
TRACHYTE
ANDESITE
RHYOLITE PORPHYRY
UNDIFFERENTIATED LAVA FLOWS
50 0 50 100 150
FEET
NO VERTICAL EXAGGERATION

Map 6b

D

mantle. The slope is about 10°. Adjacent to the sample area under slightly steeper slope conditions, 15° - 20°, the bedrock is completely exposed.

Sample Area D. Although 20 miles north of the principal study area, Area D lies within the same physiographic province and also is underlain by bedrock of volcanic origin, felsite in this case. A major permanent stream, Rio Piedras Verdes, has cut down 300 to 350 feet through a broad mesa, forming a river valley with steeply sloping sides (see Photograph 13). Two terrain types are found on the eastern valley slope: Types 2 and 3.

Of great importance in Area D is Terrain Type 4, for on the flood plain and stream terrace of the Rio Piedras Verdes are situated the unique riverside trincheras. The channel of this permanent stream is 60 to 150 feet wide. On the east bank of the river, a discontinuous stream terrace rises 4 to 6 feet above the flood plain and extends back 45 to 600 feet from the stream to meet the steep valley slope. The terrace alluvium is almost invariably under cultivation where it is extensive enough (see Photograph 12).

Sample Area E. Approximately one mile up the Rio Gavilan from Sample Area B lies Area E. This area is underlain by volcanic flows. Here a small structural terrace has formed, rising 35 feet above the river and extending back 250 to 350 feet from it. This terrace has a slope toward the river of 1° - 3°. Although the other terrain types are found here, only the major type--1, mesa and terrace flats--will be discussed.

D. Terrain Type 1: Trinchera Placement and Mantle Control

On gently sloping terraces and mesa lands are found only one type of trinchera--linear borders--whose long, low forms generally parallel the contours (see Part VI for the description of linear borders).

In Type 1 situations away from trincheras, the mantle* is from 0.6 to 1.5 feet deep (see the previous discussion of Soil Series C). Residual mantle has developed in place upon the lava flows. Variation from place to place is almost entirely of depth and stoniness, with reduced depth and increased stoniness closely correlated. The degree

* In the following discussion, mantle refers to all of the unconsolidated material resting on top of bedrock, which, of course, includes soil.

of rockiness is high: up to 30 percent of the surface has exposed bedrock and up to 30 percent of the surface is covered by rocks.* (See Photograph 5.)

Specific data about the placement of the linear borders and their effect upon the mantle come from Areas A and E.

Sample Area A. Map 6a shows the location of trincheras within the mesa and terraced flats of Sample Area A and features of bedrock and mantle. Only one type of trinchera is found in this portion of the area--linear borders. Two examples, Trincheras 247-248 and 214-214a, will illustrate the placement of trincheras and their effect upon mantle.

Trinchera 248 is poorly coursed, 140 feet long, and varies from 1.0 to 1.9 feet high (see Photograph 7). Similar in height, Trinchera 247 is 53 feet long; both are built 5 to 6 feet behind and parallel to the escarpment of this terraced surface so that immediately east of 247-248 the slope drops off steeply. Such a physiographic location--just upslope from and parallel to a major escarpment--is common for linear borders. To the west and behind 247-248, the terrace or mesa land extends with a gradient of 1.0° to 1.5°. Between 247 and 248 is an exposure of bedrock utilized by the two trincheras as a tie-in point.

The effect of these trincheras upon the terrain has been to stabilize the mantle and protect it from sheet flood erosion at this critical position where a break of slope occurs. The mantle behind 247-248 averages 0.8 feet deep, while in front of the wall downslope it averages 0.2 to 0.3 feet deep. No bedrock is exposed in 247-248 plots. The mantle is free of stones, although there is a fair amount of gravel in the mantle.

In contrast, to the southwest of the plots, although the mantle is the same depth, 10 to 20 percent of the terrace surface is covered by exposed bedrock and/or stones. To the north the mantle averages 0.4 to 0.6 feet deep and 30 to 50 percent of the surface is rock or stone covered.

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* Soil Survey Manual, U. S. Department of Agriculture Handbook No. 18, 1951, Washington, D. C., pp. 216-223. "Stoniness refers to the relative proportion of stones over 10 inches in diameter in or on the soil. . . Rockiness refers to the relative proportion of bedrock exposures either rock outcrops or patches of soil too thin over bedrock for use, in a soil area."

In the second example, linear borders 214-214a (Photographs 9 and 22), the combined length is 127 feet and height varies from 1.2 to 2.5 feet. The trinchera walls are two stones high, not well coursed. A cross-wall extends 48 feet from Trinchera 214, a common feature of linear borders. The slope upon which these trincheras are built is at the maximum for linear borders--3°. No irregularity of the bedrock occurs at this situation.

The mantle in the trinchera plot behind 214-214a varies between 0.6 and 0.8 feet deep and is essentially free of stones though slightly gravelly. To the south of 214-214a, however, a marked change occurs in the character of the mantle, as Photograph 22 shows. Here, below the control of 214-214a, the mantle averages 0.3 to 0.4 feet thick, and stones and bedrock cover 25 to 50 percent of the surface. To the west and northwest the mantle depth is 0.2 to 0.4 feet, and stones and bedrock exposures cover 30 to 60 percent of the surface. Upslope (northeast) where more linear borders are found (217, 222, etc.), mantle conditions improve and are similar to those found in Trinchera Plot 214-214a.

The relationship between linear borders and mantle characteristics in Terrain Type 1 of Area A, as illustrated by Map 6a and the above examples, can be summarized thus:

1. Linear border trincheras control in total 32.8 percent of the terrace and mesa mantle.

2. Trinchera-controlled mantle is somewhat deeper than that not behind trincheras. Of even greater significance is the smaller percentage of stones and the lack of exposed bedrock in trinchera-controlled mantle.

3. In several locations (247-248, 234, 236, 214-214a) linear border trincheras have been effective in protecting the mantle from erosion. However, in several other locations (244, 235, 239, 217) their control of erosion cannot be well established.

4. Although not proved conclusively, the lower degree of stoniness of trinchera-controlled mantle could be explained adequately by the systematic clearing of stones from these plots by the original constructors. By this means, two purposes could have been served, clearing of the plots and stabilization of the mantle.

Sample Area E. Two extremely long linear borders, 550 and 561, were surveyed on the terrace surface in Sample Area E. Trinchera 550 bounds the edge of the terrace escarpment for a distance of 350 feet, then at the eastern end it turns obliquely upslope about 25 to 30 feet on the terrace. This linear border, now in relatively poor condition, originally stood 1.5 to 2.0 feet high. It maintained and stabilized the mantle on the terrace, much as Trinchera 248 did in Sample Area A. Upslope 150 feet and roughly paralleling part of 550 is Trinchera 561, a linear border with similar functions.

The contrasting character of the mantle upslope in the trinchera plot and downslope from 550 is vividly shown in Photograph 23. The mantle surface behind 550, and thus controlled by the wall, is essentially free of stones; while downslope from 550 the surface is 60 to 80 percent stone-covered. No differences exist, however, in mantle depth or other mantle characteristics. Similar but less marked differences in stoniness were noted for Trincheras 552 and 553.

Mantle control by trincheras on the terrace surface in Area E, then, consists primarily of maintenance of mantle; and the clearing of stones from the plots was important in the wall construction also. The linear borders are so long and their plots so extensive that an extremely high proportion of the land in the area is under their control--about 3.2 acres, or 91 percent of Area E.

E. Terrain Type 2: Trinchera Placement and Mantle Control

The steep-gradient ephemeral stream valleys of the Study Area provide the situation for the overwhelming majority of trincheras, the check dams. Previous descriptions of check dams and their construction (Part VI) have shown that dimensions and form are extremely influenced by particular features of terrain. Terrain controls upon check dam placement will also be demonstrated below.

Functions of mantle control are more striking for check dams than for any other trinchera type. Where no check dams have been built in Terrain Type 2 and gradient is over 6° to 8°, the bedrock is normally exposed on the valley bottom and up the slopes for a distance of 3 to 15 feet. Under conditions of lower valley gradient, i.e., less than 6°, the floor of the valley may be covered with several tenths to 1 foot or more of alluvial and colluvial material. Whatever mantle is present tends toward a highly heterogeneous nature, with considerable quantities of rock, gravel, and sand. That trincheras have greatly altered these mantle conditions will be made clear by examples from Areas A, B, and D.

Sample Area A. Map 6b shows a portion of Terrain Type 2 in Sample Area A and presents the relation of the trincheras, bedrock, and mantle. In the mapped section, the one type of trinchera found in stream valleys is the check dam type, ranging in height from 0.5 feet (Trinchera 37) to 12.3 feet (18) and in length from 6 feet (26) to 121 feet (31). Most of the check dams were constructed in fairly deep valleys outlined by pronounced escarpments, the only exceptions being those placed on the upper two layers of volcanic rock (yellow and red ash).

It will be noted that check dams are placed to take the best advantage of rock outcrops to anchor the ends of the walls. In almost every instance the orientation of the ends of the walls is such that minor irregularities in the bedrock are used for support. Outstanding examples occur at Trincheras 65, 66, 22, 23, 24, 31, and 45. Wherever possible trincheras in stream valleys are located just above nick points in the valley gradient, examples being found in 4, 5, 8, and 29. In this way a maximum of fill could be controlled by a minimum of trinchera wall construction.

Under conditions of steep valley gradient, check dams were spaced according to the head-to-toe rule, which was also followed in the construction of check dams in Pike and San Isabel National Forests, Colorado, in the 1930's (Heede, 1960). This rule specifies that the sedimentary fill of a lower check dam will terminate just at the base of the next highest check dam. In the cross section on Map 6b, Trincheras 17, 18, and 18a well illustrate this principle. Where valley gradients are lower, this rule was not so strictly followed, thus allowing for more uniform fill depth but necessitating the construction of more and higher trincheras than absolutely necessary. In the cross section, Trincheras 30, 31, and 35 illustrate this variation from the head-to-toe rule.

In consideration of time and effort in construction and amount of fill possible, the building of such extremely large trinchera walls as the series 16 to 18a is somewhat puzzling. The return in cultivable area (if the plots were used for crops) for energy output was pitifully small. An equal expenditure of energy at some other location would have yielded far greater returns. However, it must be remembered that once such a complete trinchera system as that in Area A was initiated, protection of the lower plots by the construction of upstream check dams became necessary; and check dams did continue down the drainage course for nearly a half mile farther. Although not mapped or studied, in other areas the placement of extremely high trincheras did not necessarily protect lower, more vulnerable trinchera plots.

In marked contrast to mantle in valley situations under no trinchera control is the depth of mantle behind check dams, clearly delineated for representative plots in the cross section of Map 6b. The depth of mantle caught immediately behind each check dam equals the height of the wall, except insofar as it has been eroded; and the mantle becomes shallower toward the edges and higher in the plot. In character, also, trinchera fill differs greatly from uncontrolled mantle: whereas the latter is highly stony and heterogeneous, trinchera fill is almost completely free of stones and is composed of alluvial strata, each of which is homogeneous. The earlier analyses of soil trenches at 18a, 28, 29, and 414 detail the nature of this fill.

That check dams accumulate mantle (alluvium) is primary and has been pointed out abundantly before. An additional function of some dams probably was maintenance of original mantle in valleys and behind earlier check dams (see Soil Trench 28). As the plots fill and thereafter, maintenance of fill becomes a more important aspect of trinchera control over mantle. Considering their antiquity and the lack of any upkeep for hundreds of years, the effect of check dams even today in maintenance of mantle in ephemeral stream valleys is remarkable. However, in most all instances the remaining alluvial fill in trinchera plots is now in the process of being carried away by erosive agencies. Only behind Trincheras 16 through 18a is fill accumulating under present conditions.*

Of the 5.04 acres in Terrain Type 2 included in Map 6b, check dams control 2.26 acres, or 44.8 percent of the stream valley area. Thus, compared with the other types of trincheras in other terrains of Area A, check dams have had the greatest relative influence upon the depth and character of mantle.

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* The test trench at 18a described in Part VII was completely filled with alluvial deposits following the storm of 12 August 1964.

Sample Area B. As in Area A, one main type of trinchera was constructed within stream valley terrain--check dams. In part because of the more open nature of the valleys, trinchera walls were larger than in most areas. The more uniform gradient of the valley seems to have resulted in more limited range in trinchera heights. The arrangement of check dams is related to the much simpler geology, with fewer rock outcrops and nick points: the walls tend to parallel each other more closely, and the spacing of walls (distance apart) is much more uniform and dependent almost entirely upon the valley gradient, as for example in the spacing of 409-412 in comparison to 425-433.

Over most of the valley floors in areas of no trinchera control, 1 to 2 feet of gravelly mantle rest upon bedrock. The mantle behind check dams is deeper and less stony, but the contrasts are far less marked than in Area A. (See the discussion of Trench 414 in Part VII.) Check dams control a total of about 3 acres of land, which places them as by far the most influential type in Area B.

An interesting exception to the rule that only check dams occur in stream valleys is Trinchera 440, which is actually a terrace interrelated with Check Dams 439, 440a, and 486. Terrace 440 parallels the gentle valley slope just beyond the lowest part of the valley, which is presently being gullied. Perpendicular to the three check dams, 440 begins at about the top level of 439 and raises a height of 2.5 to 2.9 feet, a terrace plot this high thus being formed along the slope. The tops of Check Dams 440a and 486 are on a level with 440, as they are built higher on the stream course and rise with the gradient. Generally similar mantle is found behind both the terrace and the check dams. It appears that 440 functioned both to accumulate and maintain mantle and possibly to organize it into a more regular surface.

Sample Area D. Mapped in a steeply-graded drainage course (Terrain Type 2) flowing into the Rio Piedras Verdes was one of the best preserved of all systems of trincheras found (Photograph 13). Unique features of this series of check dams include extremely close spacing and several unusual wall and plot shapes (234, 235, 236).

More than any trinchera system studied, this one strongly controls the mantle in a drainage area. Considerable surface (about 70 to 90 percent) on the adjacent slopes is exposed bedrock and coarse stone litter, but bedrock exposures occur at no place in the drainage course except below the first check dam. Although several walls are completely cut through (Photograph 1), trincheras lower on the slope maintain the gradient to such an extent that large parts of the trinchera plots still remain. In most cases both walls and plots are essentially intact.

At the base of many trinchera walls where they come into contact with the bedrock, pools of water had accumulated from moisture percolating through the trinchera fill above (see discussion of soil test for 319 in Part VII). Thus, in this system of trincheras exists outstanding evidence of not only accumulation and maintenance of mantle but also conservation of moisture by the check dams.

Excellent as it is, the check dam system in Area D controls only 0.4 acres in total.

F. Terrain Type 3. Trinchera Placement and Mantle Control

A very small number of trincheras are situated in the terrain most common in the Study Area, steeply-sloping stream interfluves. The trincheras here are terraces, which parallel slopes and usually parallel each other in series. They are constructed on bedrock, but the relationship to local terrain features is not nearly so close as in check dams.

In Terrain Type 3 the mantle is 0.2 to 0.6 feet deep, with the smaller values being most frequent (see discussion of Soil Series B). The mantle is predominantly residual, although on the footslopes it is quite often transported. The character of mantle varies greatly from place to place, and combined rocks and stones may cover 30 to 90 percent of the surface of interfluve slopes (Photograph 4).

Sample Area A. That portion of Terrain Type 3 in Sample Area A which is mapped in 6b provides the situation for only five trincheras: Terraces 14, 15, 61, 58a, and 58b. The extreme stoniness of the mantle as well as its thinness in most places apparently all but precluded any development of trincheras here.

Trinchera 58a, which will serve as an example of an interfluve slope trinchera, is 136 feet long, 2 feet high, of poorly coursed rock. The westernmost 34-feet section of this wall has many of the attributes of a check dam as the slope here is interrupted by a small stream course, which is a common variation in the placement of terraces. Over its greatest extent 58a is a well-developed terrace, with several cross-walls on its almost level plot of nearly 60-feet width.

Mantle in the plot varies between 0.8 and 1.8 feet deep and is largely stone-free. Quite heterogeneous in character, it shows development in part from the weathering of the yellow volcanic ash upon which 58a is built. Most of the mantle, however, has resulted from weathering of the red ash that outcrops on the surface 150 feet further upslope, from where it has been transported downslope. Possibly, alluvial fill caught behind the check dam portion of this trinchera was spread out to add depth to the very minimal mantle originally found at this location.

Upslope from 58a, the smaller terrace plot of 58b has mantle to a depth of 0.6 to 1.0 feet. Downslope from 58a, outside of trinchera control, mantle is almost completely absent and bedrock is exposed on 80 percent of the surface.

Thus, the effect of the terraces in Terrain Type 3 has been toward both maintenance and accumulation of mantle; and the plots exhibit marked differences in depth, stoniness, and rockiness from slope areas not under trinchera control.

Relatively little mantle is controlled by trincheras in Terrain Type 3 situations mapped for Area A (Map 6b): of 7.44 acres total, only 0.52 acres, or 7.0 percent, is under trinchera control.

Sample Area B. The interfluves of Area B are similar in character to those found in Area A. Here occurs thin mantle with 30 to 50 percent of the surface in rock or stone cover.

Nine Area B trincheras are situated in Terrain Type 3 : terraces 401-408 and linear border 408a. The slope of the land surface here is 9° to 10°. The terraces average 2 feet high, with the mantle behind 0.1 to 1.5 feet deep. The terrace plots are covered with considerable quantities of small rounded rocks washed down from higher slopes.

The mantle on the slope adjacent to the trincheras is similar in rockiness and depth, though somewhat shallower. These terraces have accumulated little or no mantle. Their effect has been primarily to arrange the mantle into more usable surfaces, presumably for cultivation.

Sample Area C. Terraces 500-505 occur in a Terrain Type 3 situation in Area C. Behind the 2.5 to 4.0 feet high terrace walls (see Photograph 16), the mantle varies from 1 to 2 feet deep; while mantle on adjacent slopes varies between 0.5 and 0.7 feet deep. The mantle in the trinchera plots is markedly more free of rock (other than from fallen trinchera walls) than adjacent uncontrolled slopes.

The overall effect of these terraces, as those in Sample Area B, is the organization of the mantle into surfaces more suitable to cultivation than were the original slopes. The six terraces are substantially more important in mantle control than the check dams (506-513) located in a shoi , steep-gradient valley upslope from the terraces.

Sample Area D. Considerable surface of the stream interfluve slopes here has exposed bedrock and coarse stone litter, usually about 70 to 90 percent of the slopes. This terrain type contains only one linear border (331), constructed a few feet upslope from a steep escarpment. In contrast to most trincheras in Area D, this one has deteriorated greatly. The original mantle accumulated or maintained in a large plot behind the wall has been completely washed away.

G. Terrain Type 4 : Riverside Trinchera Control

Preliminary explorations in 1962 raised the possibility that trincheras of extremely massive structure, appearing to cross the permanent stream partially or possibly completely, were located on the Rio Piedras Verdes. Subsequently located (Sample Area D), riverside trincheras have been found to take the form of buttresses or groynes which may occur opposite each other on both banks of the river but which show no evidence of continuation across the stream itself. (See the complete description in Part VI.)

Seven riverside trincheras are built on the eastern bank in the flood plain of the river, spaced from 60 to 205 feet apart. Above the flood plain the stream terrace rises to near or more than the height of the trincheras, which are covered by the terrace mantle for unknown distances at their bank ends.

The area of stream terrace mantle between the river and the steep valley slope, totaling 1.3 acres, is under control by the riverside trincheras. The effect of the trincheras is to stabilize the bank on this outside bend of the river and to protect it from erosion. Also, like groynes along coasts, over a long period of time the trincheras have accumulated alluvium on both sides of the walls, to the extent that they have been partly covered.

The accumulation of the 1.3 acres of alluvial fill and its maintenance may well have been the main functions of these riverside trincheras, similar to the mantle control functions of other types of trincheras. Certainly any other possible functions, such as water control, are not indicated by the evidence available.

H. Extent of Mantle Control

Table 29 summarizes the amounts of mantle controlled by trincheras. The square footage in all trinchera plots (itemized in Appendix E) is given by type of trinchera, and total acreages under trinchera control are compared with totals surveyed in each area.

In keeping with its vastly greater number of trincheras and larger size than the other areas, Area A has more trinchera-controlled land: 10.6 acres, or 11.1 percent of the total 95 acres in Area A. Linear borders and check dams are about equally important, again showing the proportionately high return (at least in terms of mantle control) from the comparatively few but long trincheras on the mesa top.

Of the 58.8 acres in Sample Area B, 4.1 acres (7.0 percent) of mantle surface are under some degree of trinchera control. Although they are present, the differences in mantle which trincheras can effect are not nearly so marked here as in Area A.

A smaller proportion of mantle is controlled by trincheras in Area C than in any other area. In the 8.8 total, only 4.5 percent, or 0.4 acres, lies behind trincheras.

Well adapted to the terrain in most cases, the varied trincheras in Area D combine to form a system highly effective in mantle control. Trinchera-controlled mantle totals 1.7 acres, or 7.9 percent of the area. Most of this is stream terrace material around and behind the riverside trincheras.

The highest proportion of land--21 percent--is controlled by trincheras in Area E, for linear borders of great length and with large plots dominate this small area.

I. Conclusions

A definite interrelationship between trincheras, terrain, and mantle has been established. In particular, the following conclusions emerge from the data examined:

TABLE 28

Mantle Under Trinchera Control

Location	Check Dams Sq. Ft.	%	Linear Borders Sq. Ft.	%	Terraces Sq. Ft.	%	Riverside Trincheras Sq. Ft.	%	All Trincheras Sq. Ft.	%	Acreage* Trinchera Controlled	Area Total	Percent Controlled
Area A	205,808	44.5	212,650	46.0	43,800	9.5	-	-	462,258	100.0	10.6	95.0	11.1
Area B	134,250	75.1	950	0.5	43,350	24.3	-	-	178,550	100.0	4.1	58.8	7.0
Area C	3,850	22.7	-	-	13,100	77.3	-	-	16,950	100.0	0.4	8.8	4.5
Area D	16,500	21.8	1,950	2.6	-	-	57,200	75.6	75,650	100.0	1.7	21.5	7.9
Area E	1,800	1.2	138,700	91.3	11,400	7.5	-	-	151,900	100.0	3.5	16.5	21.2
Totals													
Sq. Ft.	362,208	41.0	354,250	40.1	111,650	12.6	57,200	6.4	885,308	100.0	20.3	200.6	10.1
Acres	8.3		8.1		2.6		1.3		20.3				

* 1 acre = 43,560 sq. ft.

1. Trincheras are situated in a variety of terrain types, including gently sloping terrace and mesa flats, steep gradient ephemeral stream valleys, generally steep slopes and interfluves, and permanent stream flood plains and terraces. Of these, the second terrain type provides situations for an overwhelming majority of trincheras, nearly all being the check dam type, and about 40 percent of the trinchera-controlled mantle. Terrace and mesa terrain is equally as important in area controlled, for although the number of trincheras (linear borders) here is small, their length is great. Flood plains and stream terraces are the site only of the few specialized riverside trincheras, which nevertheless account for a relatively large land area. The most irregular, steep, and poorly mantled terrain, the interfluve slopes, are also the most infrequently used for trincheras.

2. The specific placement of trincheras is influenced or determined by terrain features. Major examples are the location of linear borders and check dams at nick points and the tops of escarpments, the abutment of trinchera walls (especially check dams) with bedrock and outcrops, and the spacing of check dams in relation to the valley gradient.

3. The form of trincheras is influenced or determined by the terrain situation, as seen in the conformation of length and to some extent height of check dams to their valley sites, in the alignment of linear borders and terraces along slopes, and in the minimal height but maximal length of linear borders in their flat sites.

4. Trincheras of all types and in all situations have had important influence on mantle. Distinct differences in depth and character separate mantle in natural areas unrelated to trincheras from mantle in trinchera plots, with the latter being almost always deeper and less stony and rocky.

5. Trincheras function to control mantle in a variety of ways, depending on trinchera type and terrain situation. Accumulation of alluvium is primary in check dams and probably in riverside trincheras; thus, accumulation of mantle occurs mainly along stream courses. It also takes place to some extent in terraces and linear borders. This function could be stated as the formation of plots of soil more suitable to cultivation than surrounding areas.

6. Trincheras function, also, to maintain and stabilize mantle, either residual or transported. This is a primary function of trincheras

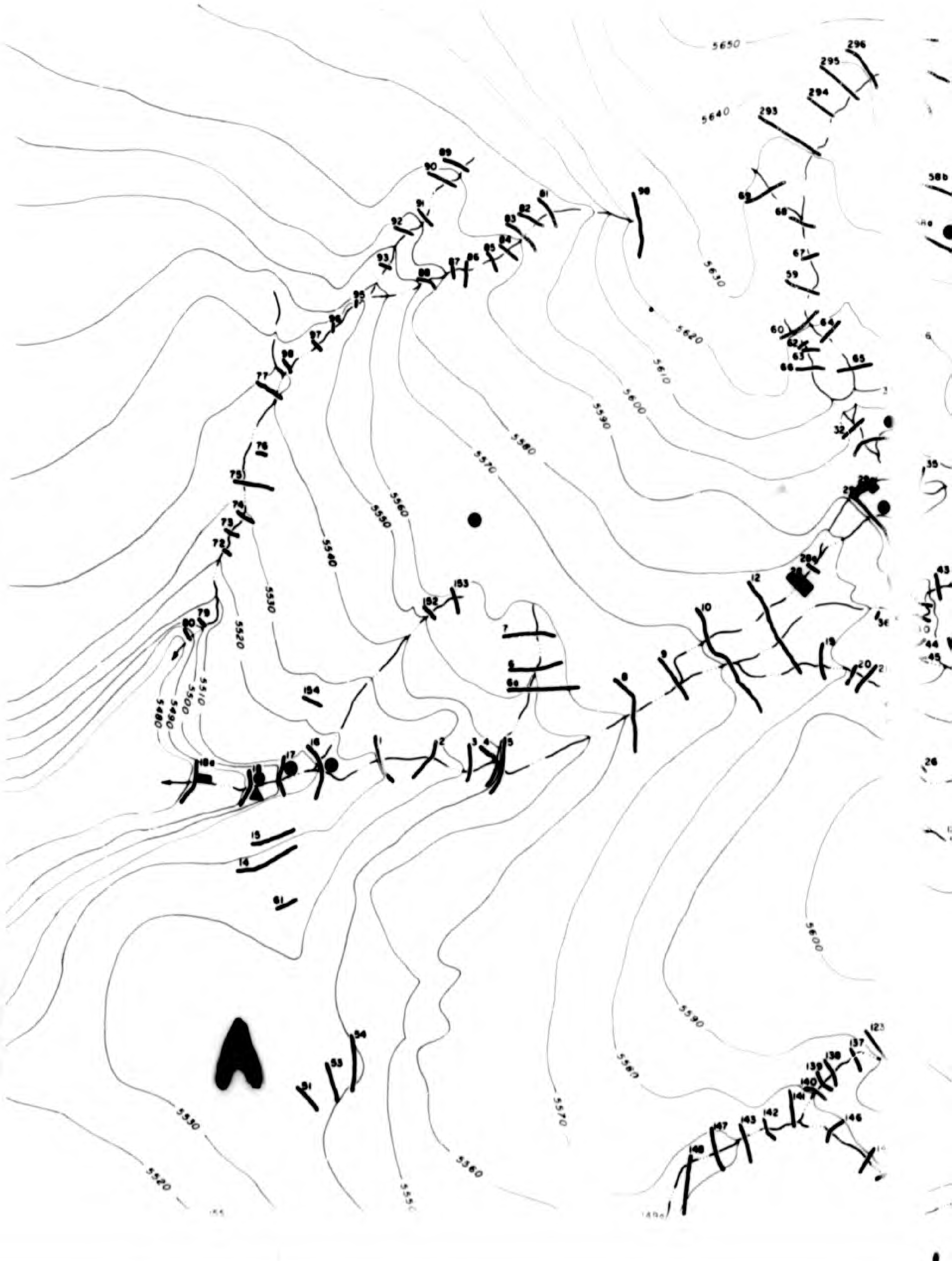
on gently sloping or flat surfaces. Although a secondary function generally in check dams, terraces, and riverside trincheras, maintenance of mantle continues in importance in preservation of walls, plots, and surrounding terrain to the present time. As parts of this function, trincheras reduce runoff and soil erosion.

7. Mantle is organized into more usable surfaces by the building of trinchera walls and their plots. Aspects of mantle organization are the levelling of surfaces behind walls, the clearing of stones which are added to the walls, and the marking of field boundaries.

8. The total acreage controlled by trincheras, approximately 20 acres, comprises about 10 percent of the land total surveyed. Controlled mantle ranges from 4.5 to 21.2 percent in the various sample areas, which are representative of varying degrees of trinchera-development of the terrain. Similar mantle control is reached on other hillsides and valleys where trinchera systems of at least moderate extent have been developed.

9. The above effects of terrain upon trincheras and trincheras upon mantle are of major importance in the whole trinchera-physical environment relationship. In this study it has been possible only to suggest other equally significant aspects of the relationship. The effect of trincheras upon the hydrological cycle, particularly the role of check dams as moisture reservoirs, promises to be a valuable topic for inquiry. Also, the place of trincheras in prehistoric farming patterns needs much attention.

Clearly, scientific inquiry along the Rio Gavilan and in all the trinchera country of the Sierra Madre Occidental can go far from the introduction provided by this study. The many applications of trinchera studies to problems of land utilization, soil conservation, and water conservation become ever more obvious. The most pressing need of all may well be that this search for knowledge be hastened lest it find itself without subject matter. Though they have resisted, blended with, and even buttressed the environment for centuries, the trincheras cannot long survive under the land use practices of today. Modern man once again is destroying the very things which can teach him so much about man's role in the physical environment.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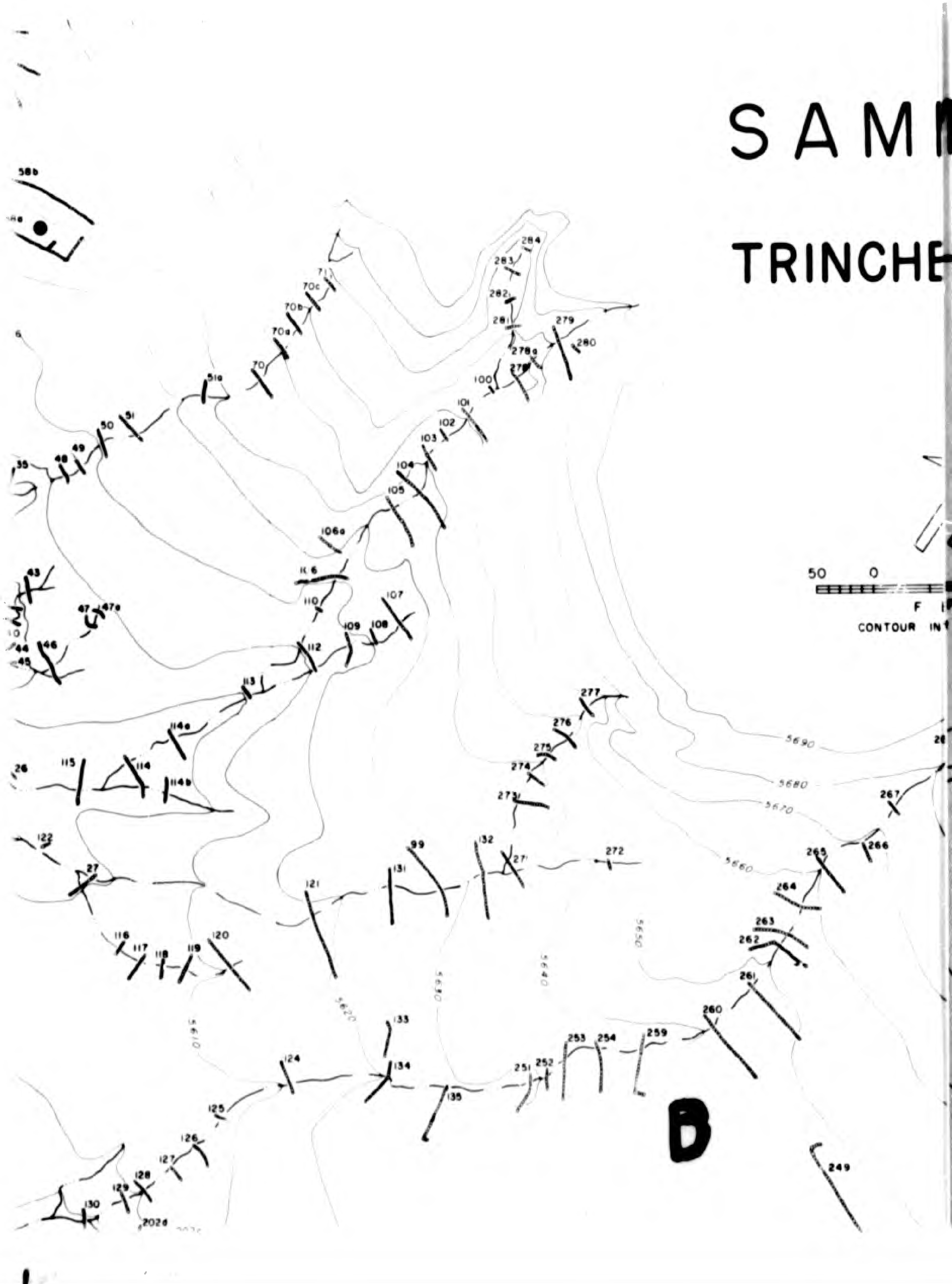

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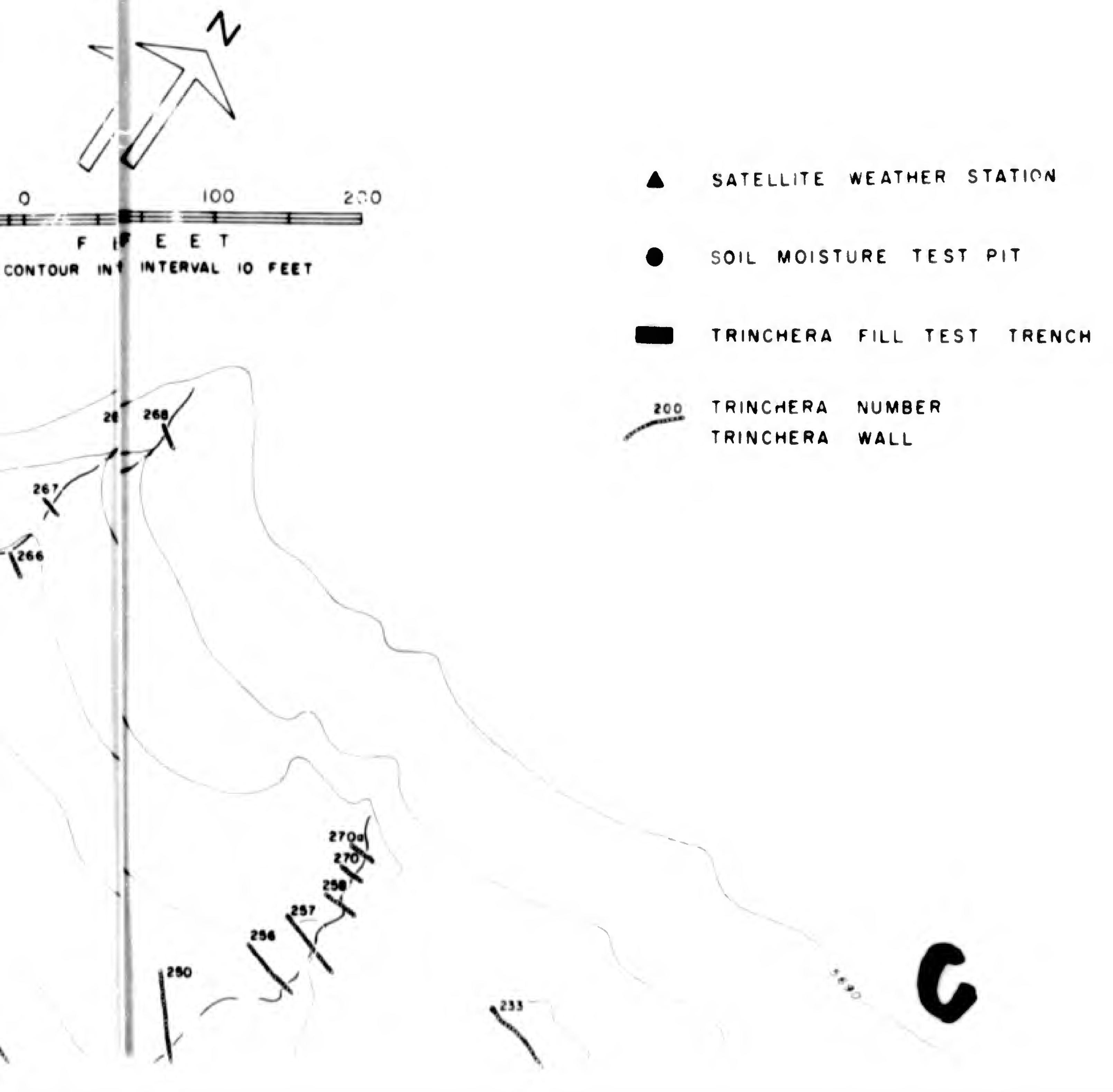

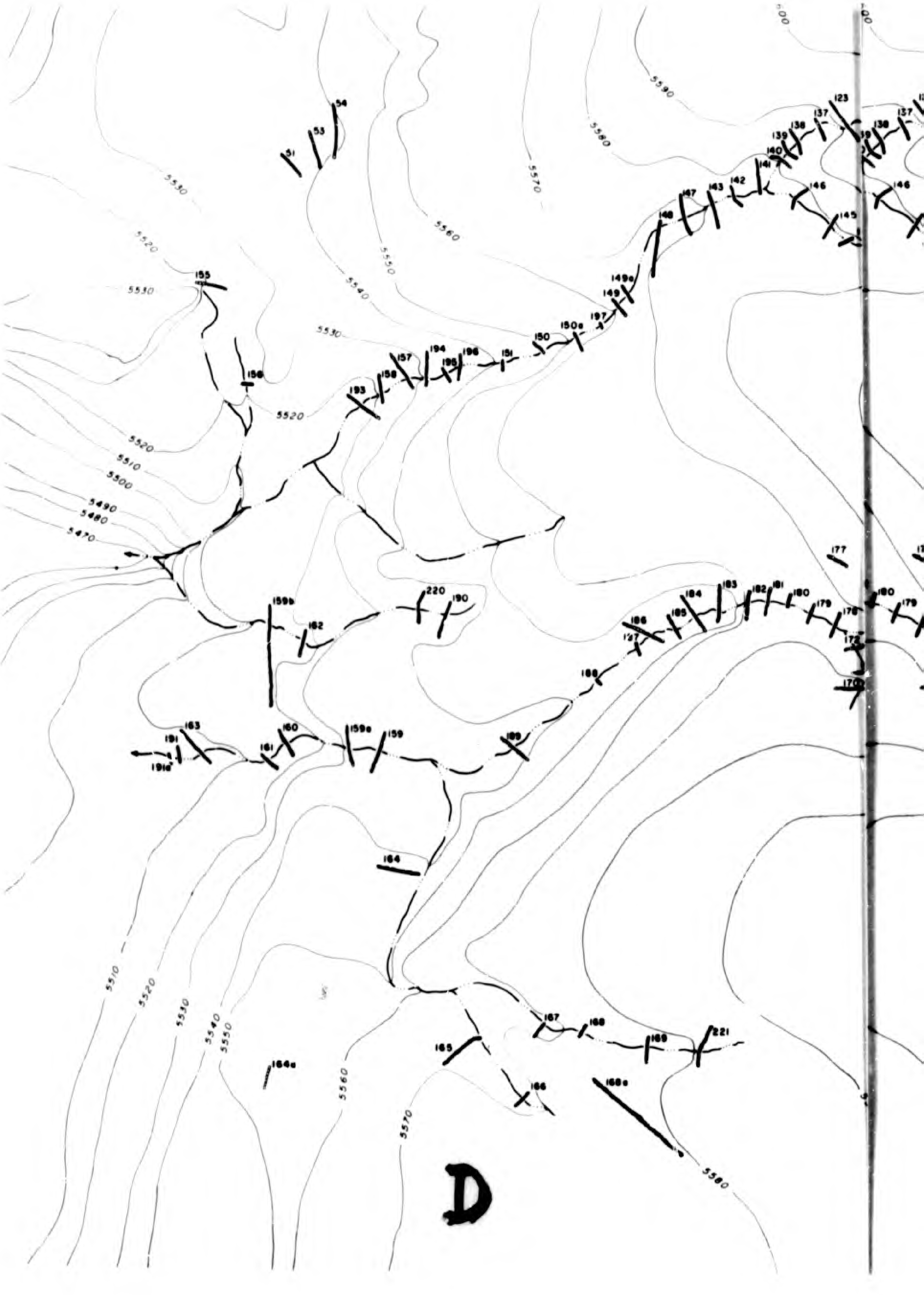
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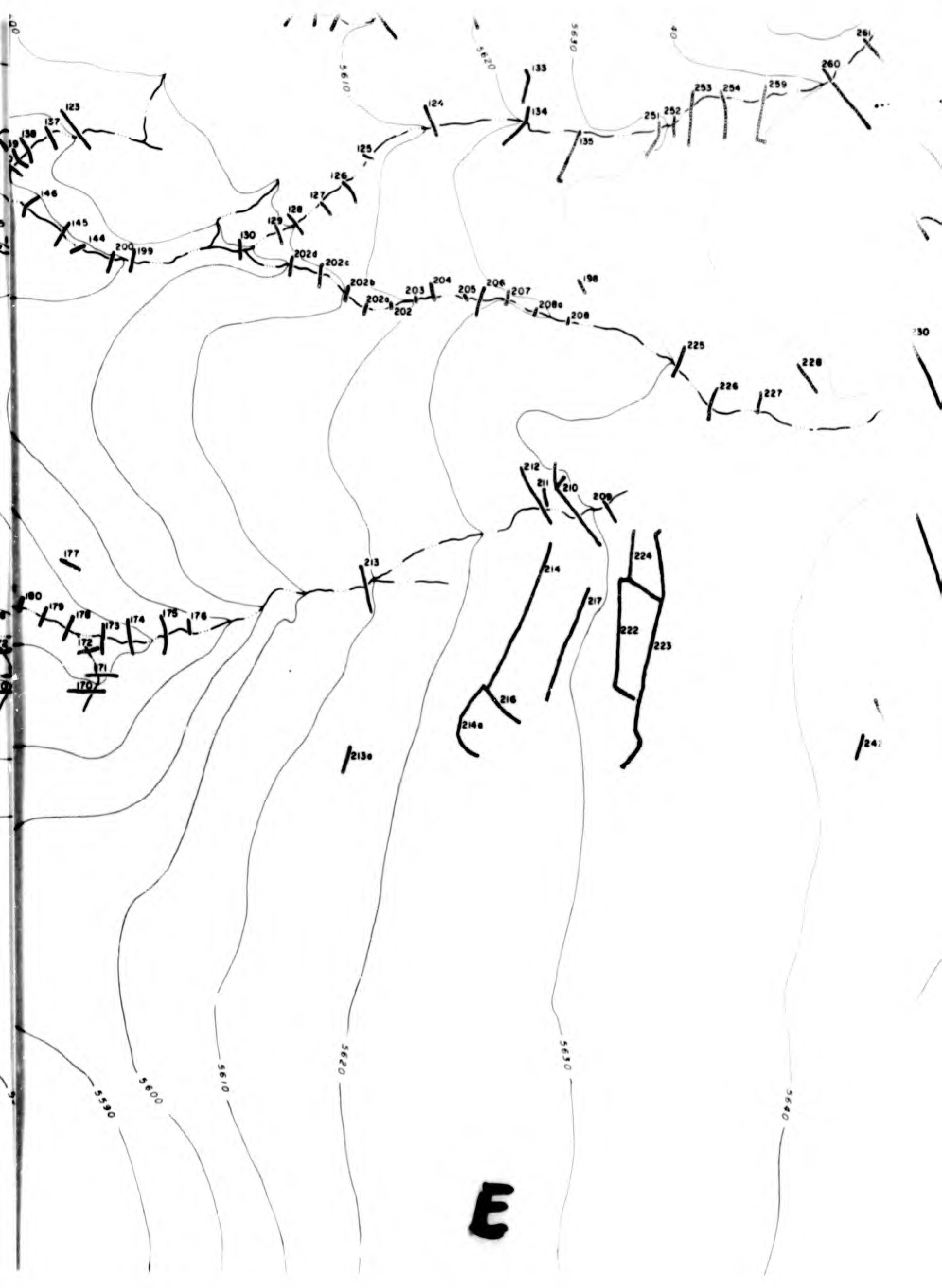

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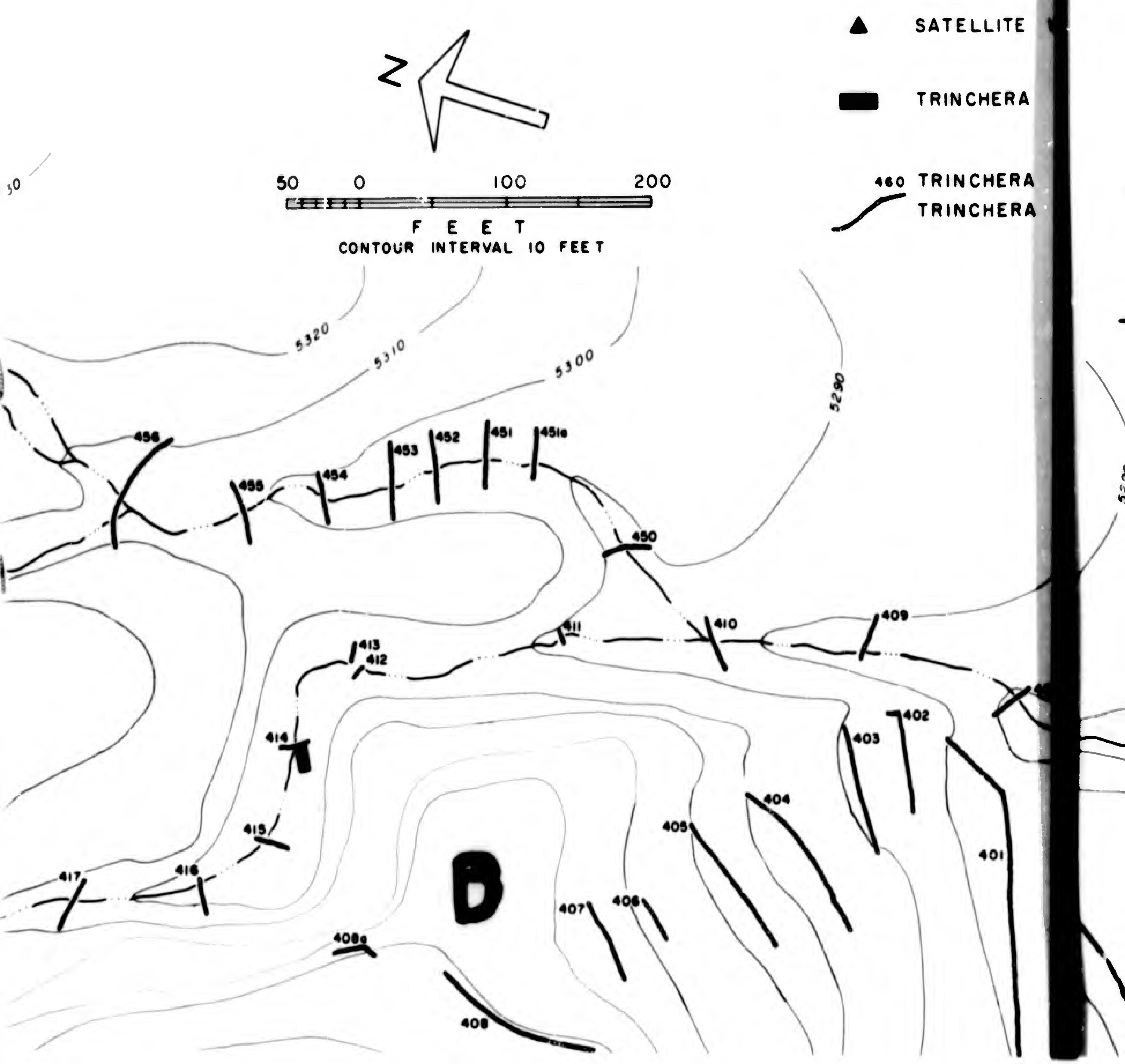

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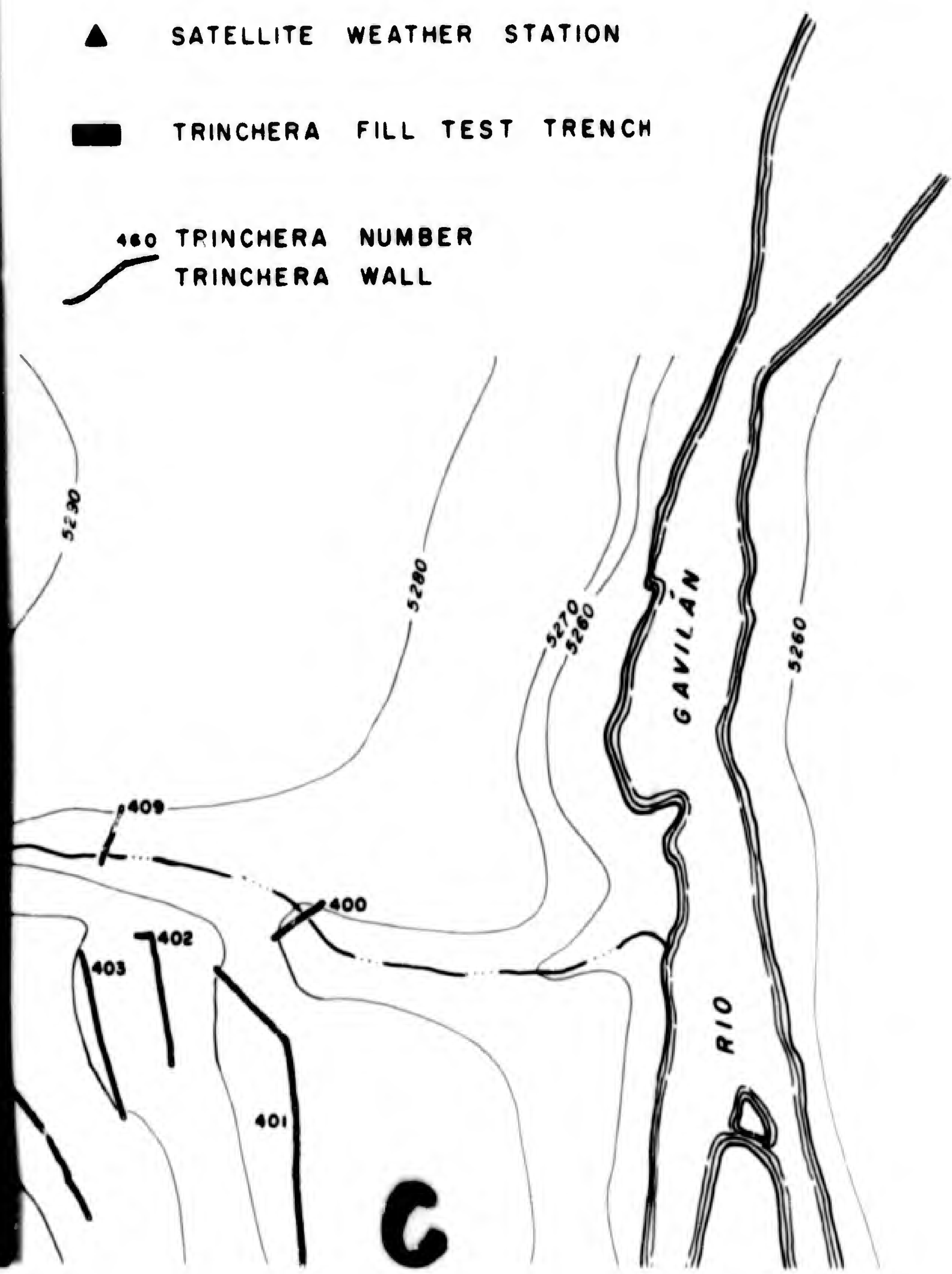

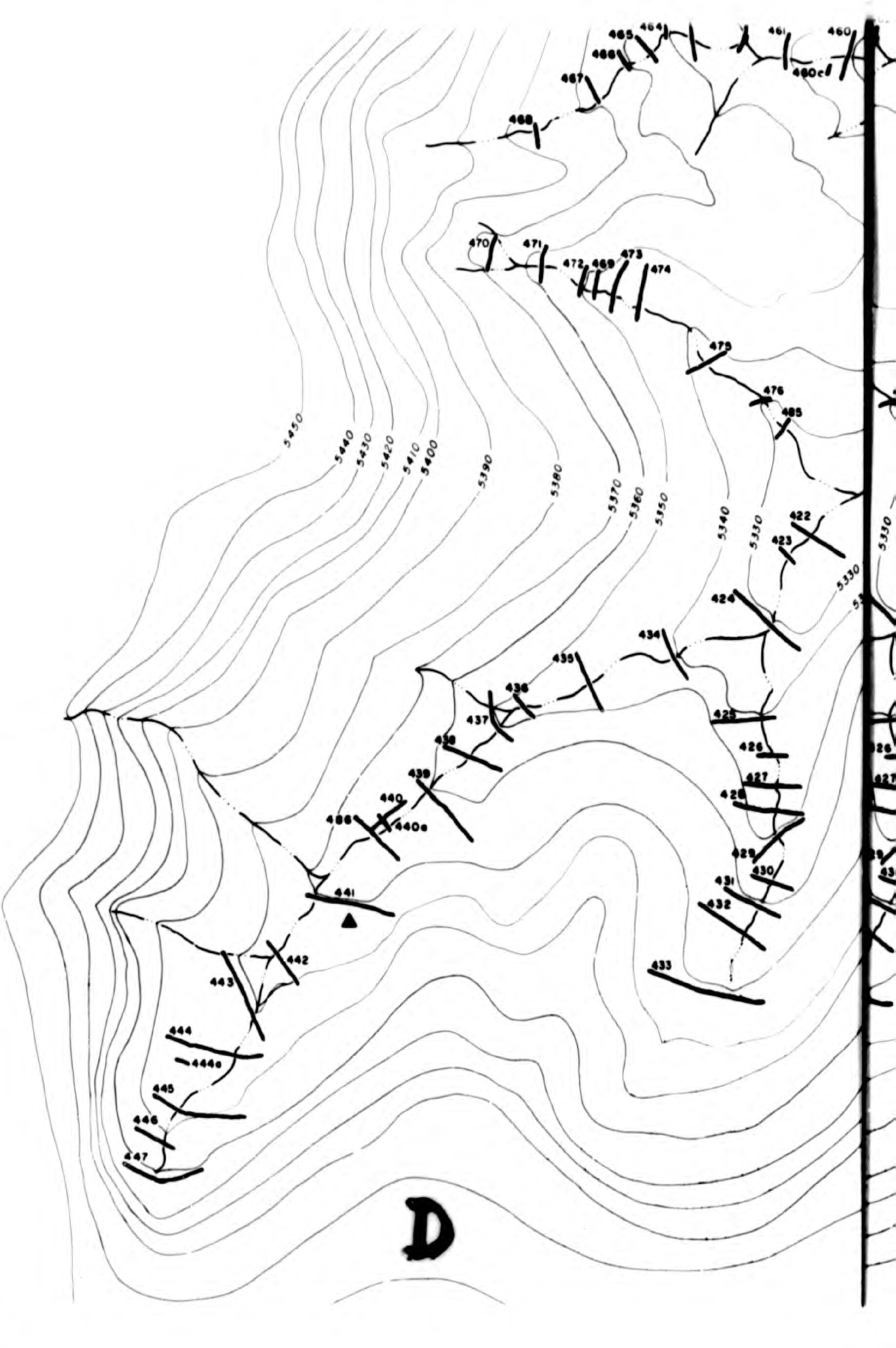
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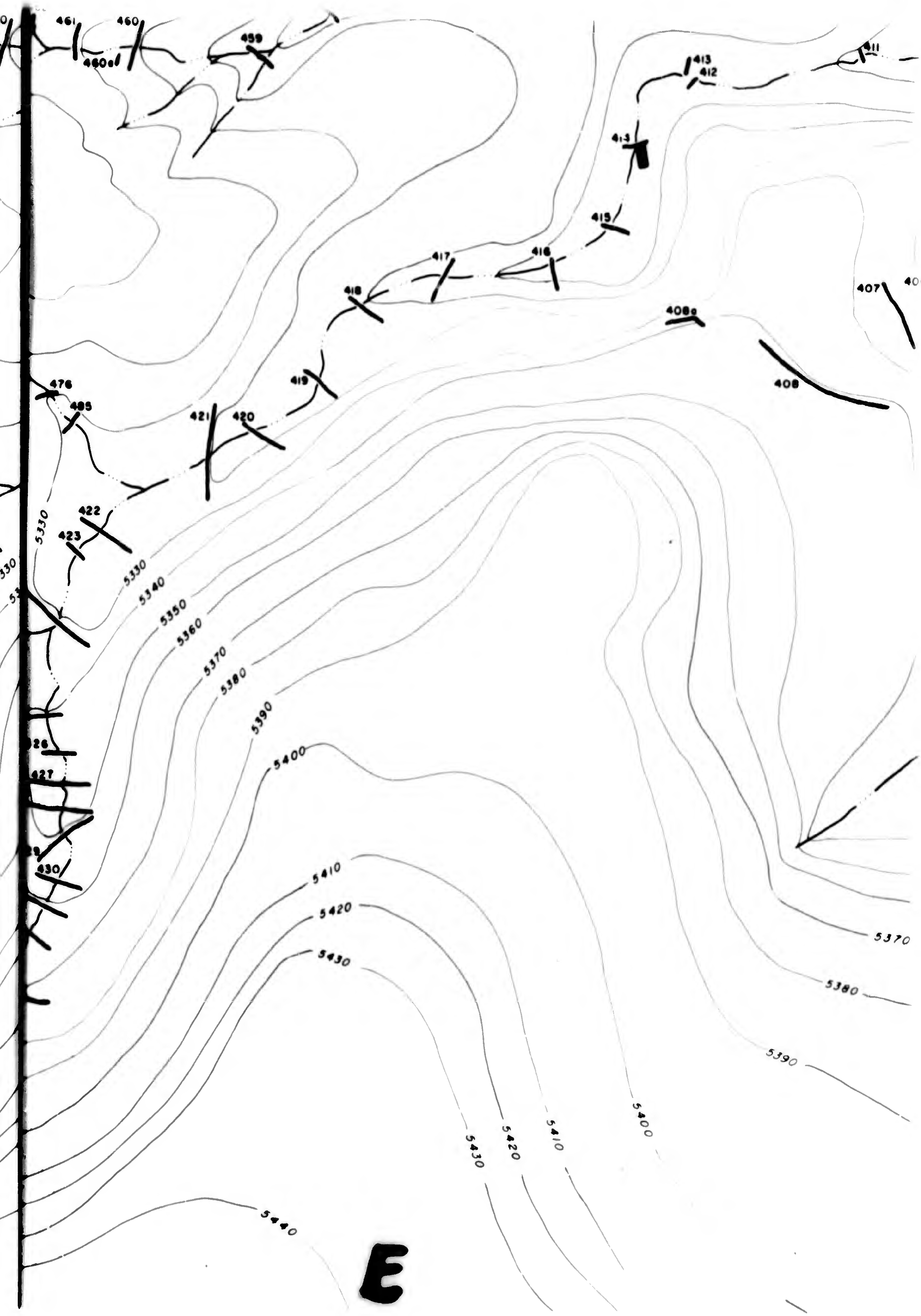
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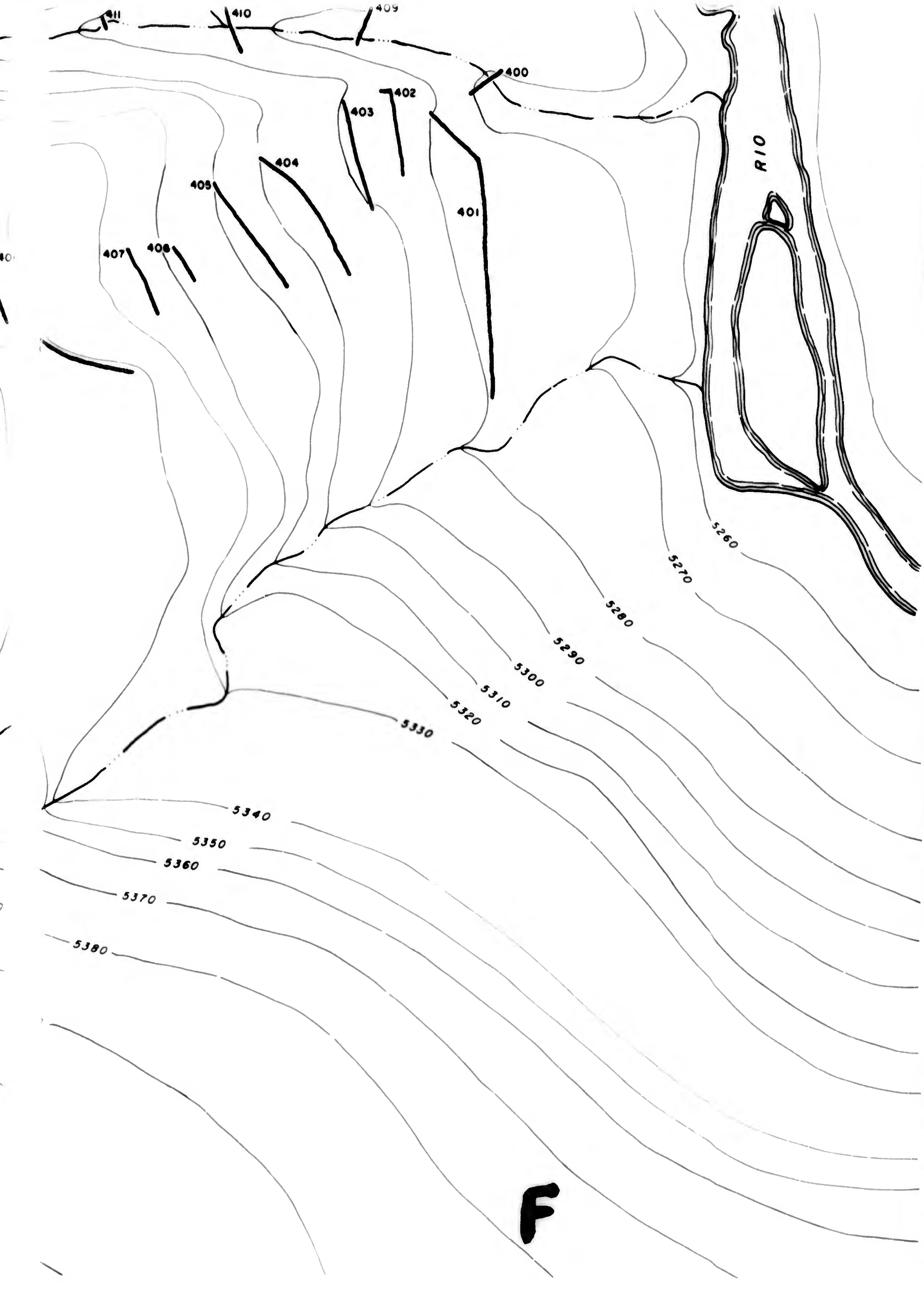
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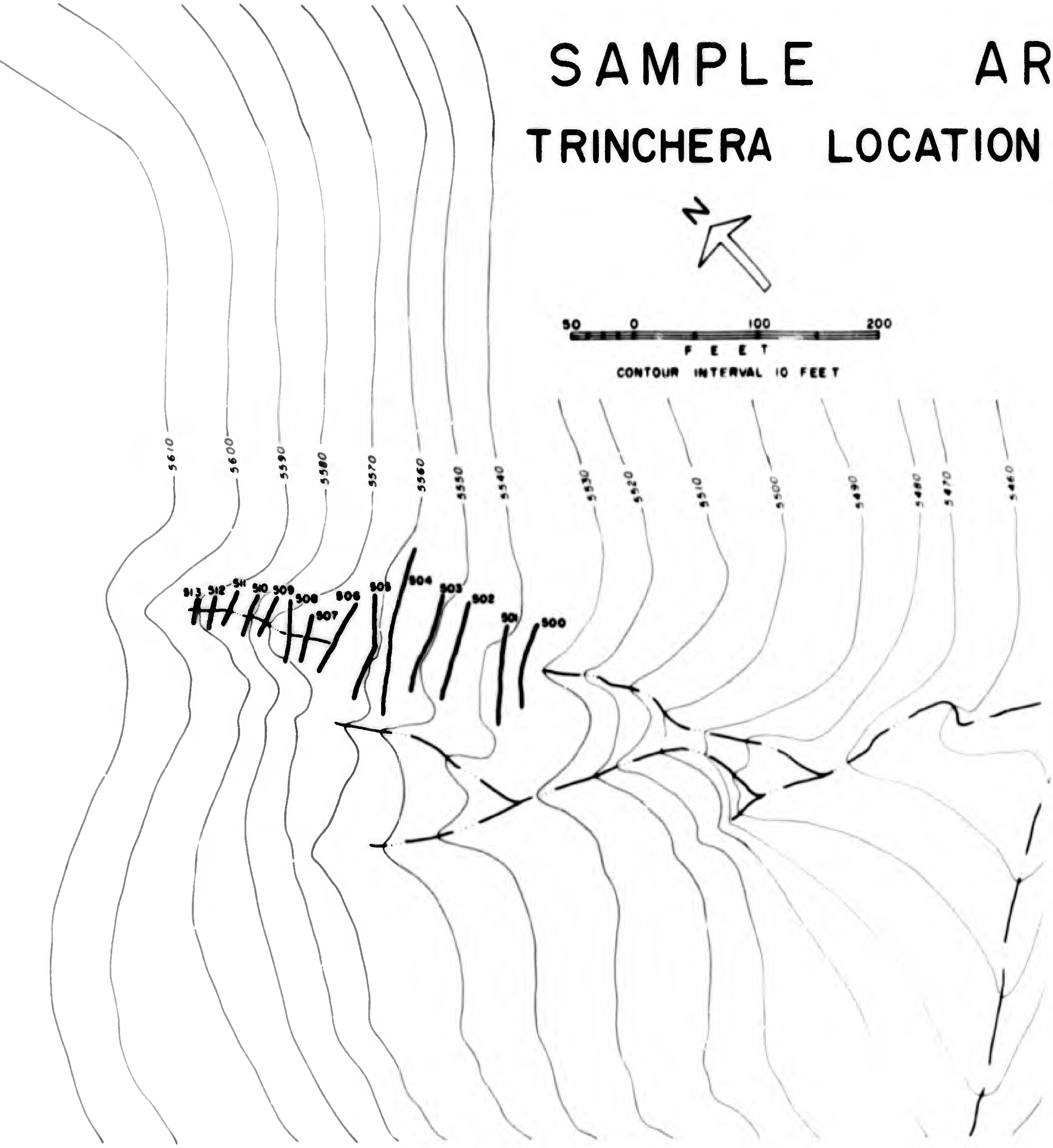
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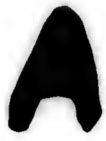

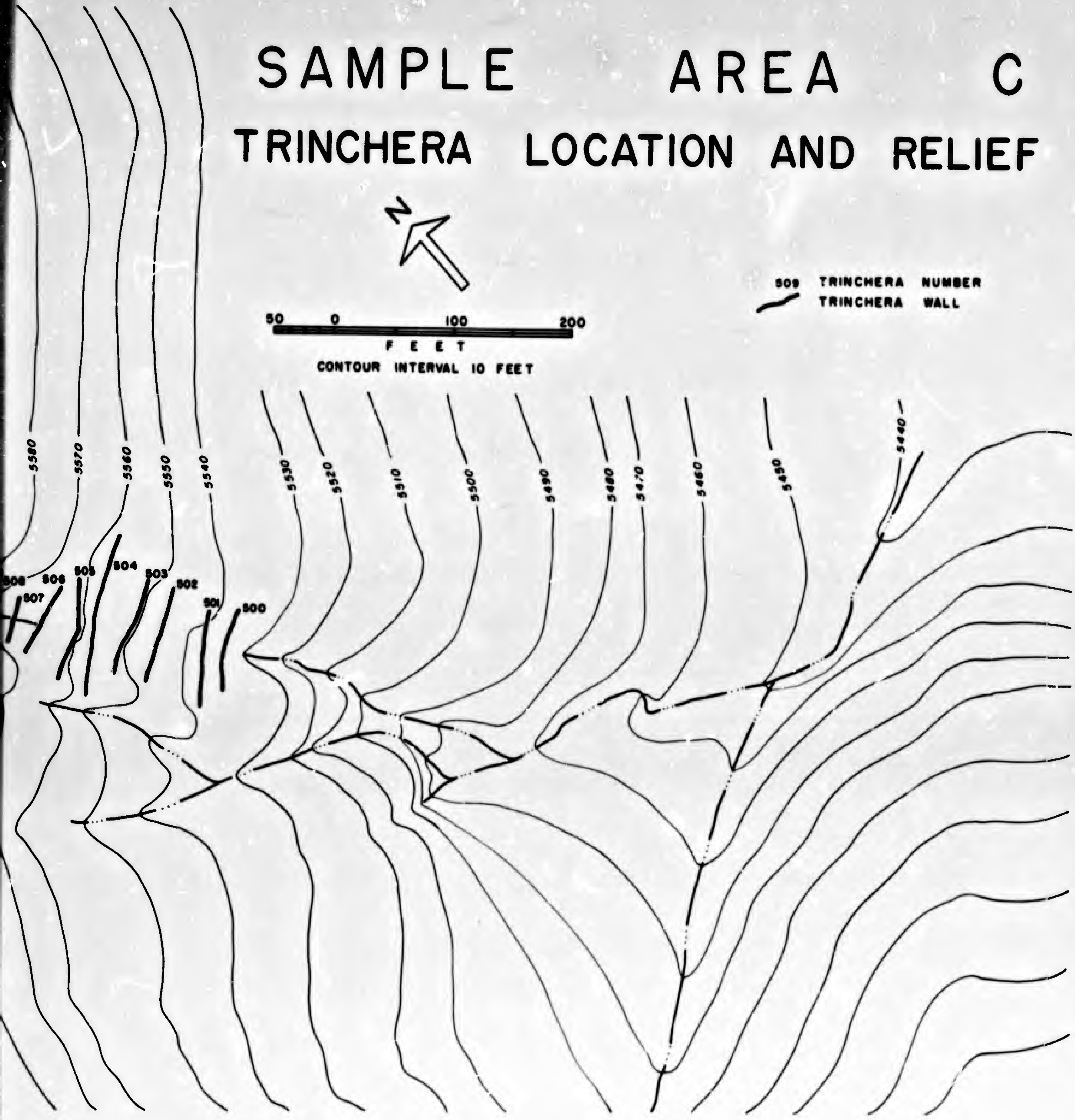
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Map 9

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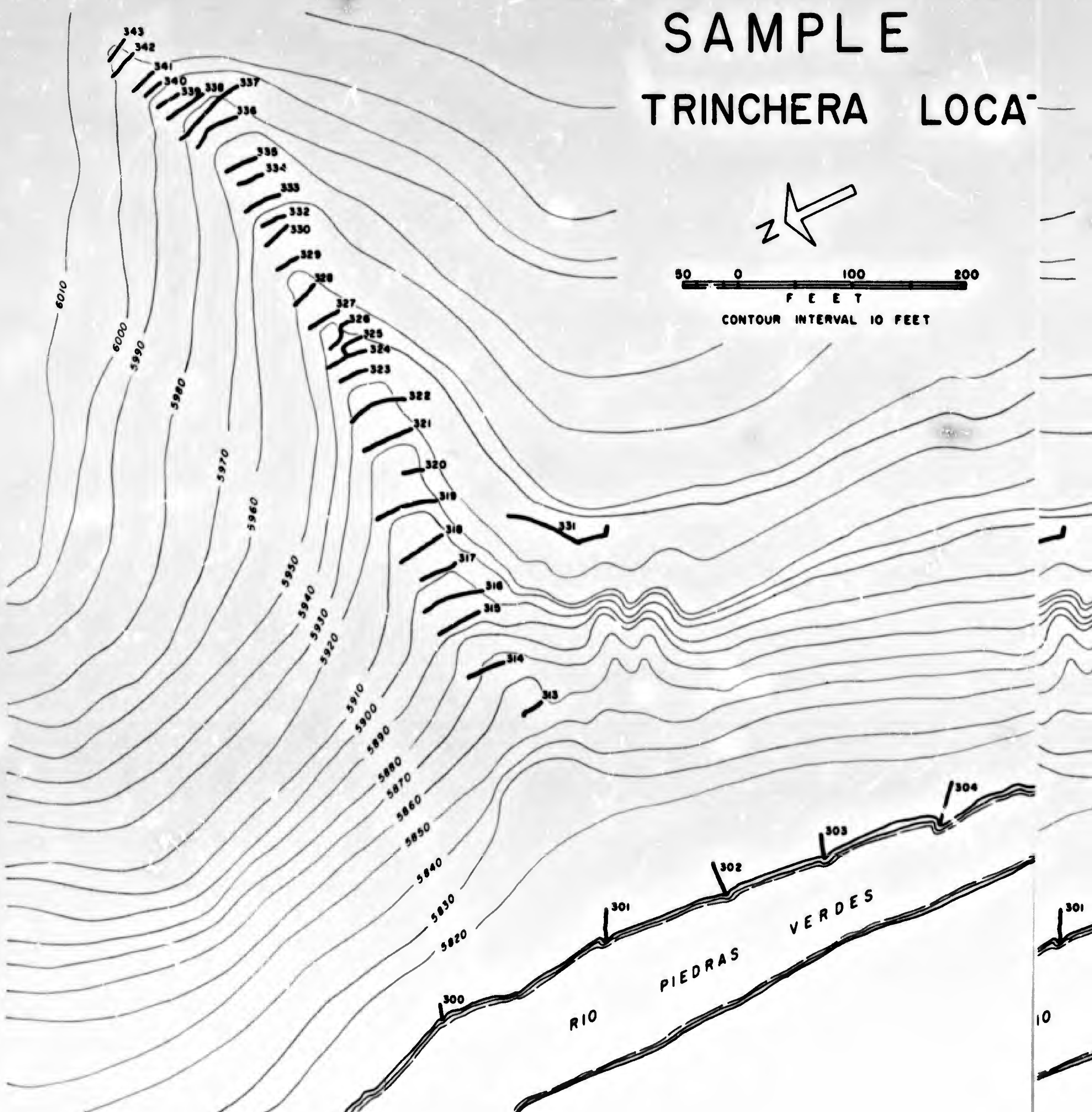
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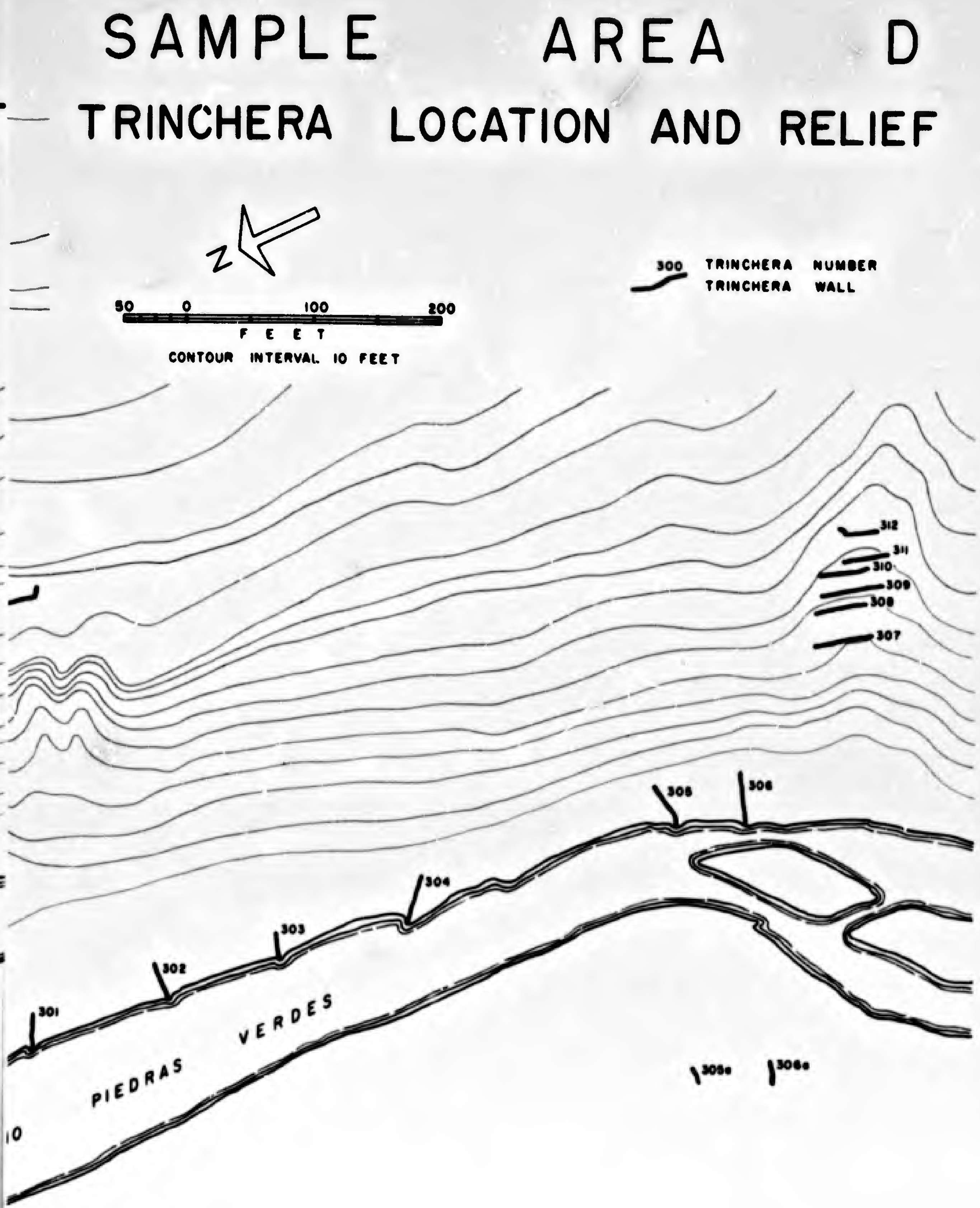
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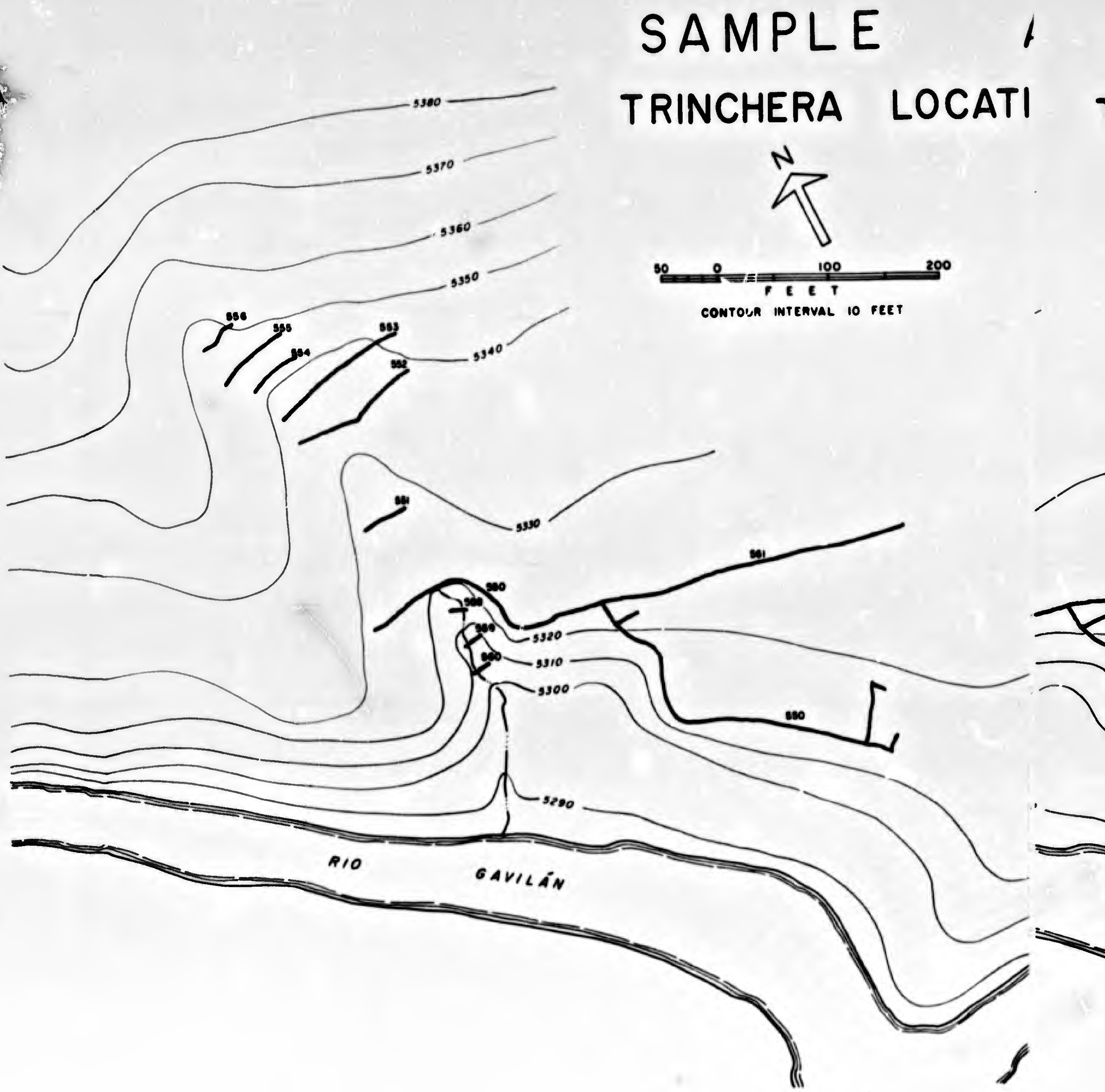
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Map 11

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SAMPLE AREA E
TRINCHERA LOCATION AND RELIEF

Map 11

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APPENDIX A

APPENDIX A

Minimum and Maximum Temperatures (°F) at Base Camp, Nuevo Casas Grandes, and Rancho Agua Salada

18 June - 12 August

	Base Camp		Nuevo Casas Grandes		Rancho Agua Salada	
Date	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
June						
18	56.0	88.0	60.8	93.0	50.0	79.0
19	52.0	89.0	--	--	52.0	77.0
20	49.5	90.0	64.4	95.0	46.0	81.0
21	52.0	91.0	62.6	97.0	54.0	79.0
22	46.0	94.0	62.6	97.0	46.0	79.0
23	38.0	97.0	57.2	93.0	39.0	84.0
24	52.5	90.5	66.2	91.0	46.0	81.0
25	50.5	85.0	62.6	88.0	45.0	77.0
26	53.0	85.5	59.0	90.0	48.0	72.0
27	58.0	90.0	64.4	90.0	54.0	75.0
28	54.0	86.9	60.8	93.0	55.0	86.0
29	48.5	90.0	62.6	97.0	48.0	75.0
30	52.0	97.0	69.8	100.0	52.0	82.0
July						
1	51.0	95.5	68.0	102.0	57.0	84.0
2	54.0	94.0	68.0	102.0	55.0	86.0
3	50.0	100.4	69.8	104.0	52.0	88.0
4	59.0	98.6	68.0	102.0	63.0	84.0
5	52.5	101.0	68.0	99.0	50.0	88.0
6	53.0	95.0	69.8	97.0	55.0	86.0
7	60.0	93.0	68.0	95.0	59.0	84.0
8	60.5	85.0	64.4	93.0	57.0	81.0
9	57.0	82.0	62.6	87.0	54.0	87.0
10	53.0	87.0	59.0	99.0	50.0	72.0
11	56.0	88.0	68.0	100.0	54.0	77.0
12	59.0	89.0	66.2	90.0	57.0	77.0
13	60.0	84.0	60.8	81.0	55.0	75.0
14	54.5	88.0	60.8	91.0	54.0	64.0
15	55.0	88.5	64.4	95.0	50.0	73.0
16	56.0	89.5	68.0	97.0	54.0	75.0
17	60.0	95.0	68.0	97.0	59.0	79.0

APPENDIX A (Cont.)

	Base Camp		Nuevo Casas Grandes		Rancho Agua Salada*	
Date	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
July						
18	61.0	93.0	66.2	95.0	57.0	79.0
19	60.0	89.5	69.8	97.0	59.0	75.0
20	60.0	87.5	64.4	93.0	57.0	79.0
21	57.5	87.5	62.6	93.0	50.0	75.0
22	59.0	89.0	69.8	93.0	55.0	77.0
23	60.5	85.0	64.4	90.0	54.0	77.0
24	56.5	77.0	66.2	88.0	54.0	73.0
25	59.0	87.0	64.4	86.0	55.0	70.0
26	56.0	89.5	62.6	95.0	48.0	70.0
27	56.0	89.5	62.6	88.0	52.0	81.0
28	55.0	89.0	62.6	95.0	54.0	77.0
29	55.0	89.0	62.6	93.0	52.0	79.0
30	59.0	80.0	66.2	91.0	54.0	81.0
31	60.5	74.0	66.2	87.0	54.0	72.0
August						
1	61.0	76.0	62.6	86.0		
2	59.0	82.0	59.0	84.0		
3	55.0	86.0	62.6	93.0		
4	57.0	87.5	62.6	93.0		
5	63.0	82.0	69.8	93.0		
6	57.0	92.0	64.4	86.0		
7	55.5	93.5	64.4	99.0		
8	59.0	89.0	66.2	91.0		
9	62.0	83.5	62.6	91.0		
10	57.0	87.5	64.4	95.0		
11	59.0	87.5	66.2	97.0		
12	57.0	86.0	62.6	99.0		

* No data available for Rancho Agua Salada after July 31

APPENDIX B

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APPENDIX B

Net Radiation, Dry Bulb, Soil Surface, and -.25 Foot Soil Temperatures
Base Camp

27 June to 12 August 1964

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25' Soil Temperature
27 June	0900	.1730	67°	80°	75°
	1000	.6101	74°	102°	74°
	1100	1.0733	84°	125°	74.5°
	1200	1.0871	85°	138°	76°
	1300	.8113	88°	137°	78°
28 June	1000	.4525	69°	84°	71°
	1100	1.2168	77°	106°	72°
	1200	1.3530	82°	117°	72°
	1300	.7325	83°	114.5°	73.5°
	1400	.2580	84°	116°	75°
29 June	0900	.3818	64.5°	78°	66°
	1000	.8555	72°	89°	66°
	1100	.7750	79°	103°	68°
	1200	1.3575	86°	115°	70°
	1300	1.5106	88°	124°	73°
	1400	.7171	86°	109°	75°
30 June	0800	.1179	59°	63°	68°
	0900	.5210	68°	84°	68°
	1000	.9055	78°	103°	68°
	1100	1.1207	86°	117°	70°
	1200	1.8269	90.5°	131°	73°
	1300	.9538	91°	127.5°	75°
	1700	.0994	82°	93°	81°
	1800	.4628	83°	99°	81°
	1900	-.0963	79°	82.5°	81.5°
	2000	-.0844	76°	79°	81°
	2100	-.1034	73°	74°	80°
	2200	-.1034	70°	72°	80°
1 July	0700	-.0700	56°	56°	72°
	0800	.0245	64°	73°	71°
	0900	.3482	71°	91°	70°
	1000	.7819	78°	109°	70°
	1100	1.0572	85°	125°	72°
	1200	1.1240	90°	137°	74°

APPENDIX B (Cont.)

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25' Soil Temperature
1 July (cont.)	1300	.9698	90.5°	137°	77°
	1700	-1.2071	81°	92°	82°
	1800	-.0300	78°	80°	81°
2 July	0700	-.0799	55°	56°	72°
	0800	.1315	62°	69°	71°
	0900	.4750	69.5°	80°	70°
	1000	.8521	76°	92°	70°
	1100	.8719	82°	104°	71°
	1200	.1379	91°	120°	73°
	1300	.7449	90°	115°	75°
	1600	.2380	86°	108°	79°
	1700	-.0522	80°	83°	79°
	1800	.0264	77°	81°	79°
3 July	0800	.1587	64°	67°	68°
	0900	.5245	70°	85°	67°
	1000	.9143	80°	104°	67°
	1100	1.1761	85°	121°	70°
	1200	1.2880	93°	132°	73°
	1300	1.0414	93°	132°	75°
	1400	.9891	94°	129°	78°
4 July	1000	.8719	82°	110°	72°
	1100	1.1296	90.5°	128°	73°
	1200	1.0515	93.5°	133°	74°
	1300	.9278	92.5°	129°	76°
	1400	.9268	96°	129°	79°
	1500	.5148	92.5°	124°	80.5°
5 July	0900	.5377	74.5°	96°	72.5°
	1000	.3999	79.5°	112°	72.5°
	1100	1.0967	86.5°	129°	74°
	1200	.8782	94°	134°	76°
	1300	.8295	94°	126°	77°
	1400	1.2039	94°	133°	79°
	1500	1.1262	98.5°	146°	81°
	1600	.9162	95°	142°	83°
	1700	.4379	95°	127.5°	84.5°
	1800	.3309	94.5°	122°	81°
	1900	-.1461	90°	96°	86°
	2000	-.1949	85°	85°	86.5°
	2100	-.2099	76°	78.5°	86°

APPENDIX B (Cont.)

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25' Soil Temperature
6 July	0800	.0696	66°	77.5°	75°
	0900	.3754	71°	95°	75°
	1000	.7521	80°	115°	75°
	1100	1.0606	86°	134°	76°
	1200	1.1855	91°	138°	77.5°
	1300	1.2195	91.5°	147°	79°
	1400	.0594	88°	113°	81°
	1700	.1614	72°	82°	83°
	1800	.1067	74°	81°	83°
	1900	.0368	75°	78°	82°
7 July	0700	-.0403	62°	63°	74°
	0800	.0781	65°	69°	73.5°
	0900	.2999	71°	86°	73°
	1000	.6533	81°	105°	73.5°
	1100	.4262	80.5°	103°	74.5°
	1200	.4634	81°	105°	75°
	1300	1.3576	84°	134°	76°
	1400	.9128	85°	130°	78°
	1500	.5709	86°	125°	79°
	1600	.2225	80°	105°	80°
8 July	0800	.0128	66°	70°	71.5°
	0900	.2890	66.5°	75°	71°
	1000	.5008	70°	82°	71°
	1100	.5740	74°	80°	71.5°
	1200	.7951	77°	91°	73°
	1300	.5320	79°	88°	74°
	1400	1.5970	82°	104°	75°
	1500	.6895	82°	100°	76.5°
9 July	0900	.1360	65°	79°	70°
	1000	.2534	66°	75°	70°
	1100	.5700	71°	83°	70°
	1200	.5875	74°	87°	71°
	1300	.9870	81°	93°	72°
	1500	.2405	78°	85°	74°
	1600	.0029	74°	77°	75°
10 July	0700	-.0401	54.5°	58°	68°
	0800	.0989	60°	68°	67°
	0900	.4098	65°	79°	66°

APPENDIX B (Cont.)

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25' Soil Temperature
10 July (cont.)	1000	.8296	70°	87.5°	66°
	1100	1.2090	77°	95°	67°
	1200	1.4724	81°	101°	71°
	1300	1.6228	85°	106°	73°
	1500	.4329	80°	90°	76°
	1600	.4838	83°	88°	77°
	1700	.1549	79°	81°	77°
	1800	-.0300	75°	75°	77.5°
	1900	-.0408	72.5°	73°	77.5°
11 July	0800	.1020	64°	69°	69°
	0900	.3347	69°	76°	69°
	1000	.5833	72°	85°	70°
	1100	.3509	76°	83°	70.5°
	1200	1.4389	82°	105°	71.5°
	1300	1.5727	88°	118°	72°
	1400	1.2587	82.5°	88°	74.5°
12 July	0900	.1794	65°	69°	69°
	1000	.8238	77°	85°	68.5°
	1100	.4634	79°	86°	70°
	1200	.9114	81°	92°	72°
	1300	1.4383	84.5°	110°	74°
	1400	1.0990	86°	121°	75°
	1500	.0160	80°	92°	77°
13 July	0800	.1247	67°	68°	69°
	0900	.3885	72.5°	77°	68°
	1000	.7359	74°	84°	69°
	1100	1.1232	79.5°	82°	70°
	1200	1.5677	82°	97°	73°
	1300	.8434	80.5°	91°	74.5°
	1400	.4129	80°	85°	76°
	1500	.0607	76°	80°	77°
	1600	.2473	73°	78°	77°
	1700	.1168	74°	79.5°	77.5°
	1800	.1045	73°	77°	77.5°
	1900	.0028	71°	74°	77°
	2000	-.0825	69°	68°	77°
	2100	-.1327	66°	66°	76°
	2200	-.1115	64°	64°	76°

APPENDIX B (Cont.)

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25' Soil Temperature
14 July	0800	.0569	63.5°	66°	68°
	0900	.4810	69°	77°	68°
	1000	.8467	75°	90°	70°
	1100	1.1969	80°	86°	71°
	1200	1.3899	83.5°	99°	72.5°
	1300	1.4839	84°	111°	74.5°
	1400	1.2316	87°	111°	76.5°
15 July	0700	-.0300	57°	60°	70°
	0800	.0984	61°	65°	70°
	0900	.2369	62°	72°	68°
	1000	.8216	67°	74°	67°
	1100	1.1972	74°	82°	68°
	1200	1.1518	77°	94°	71°
	1300	1.5870	79°	102°	72°
	1400	1.4464	83°	105°	74°
	1500	1.4543	84°	110°	76°
	1600	.4769	83°	95°	77°
	1700	.8185	85°	102°	78°
	1800	.5009	85°	98°	79°
	1900	.3678	85°	93°	79.5°
16 July	0700	-.0603	56.5°	62°	71°
	0800	.1688	61°	70°	70°
	0900	.6079	68°	80°	70°
	1000	.6594	73°	83°	70°
	1100	1.3458	77°	83°	71.5°
	1200	.6337	81°	86°	73°
	1300	.1672	79°	81°	75°
	1400	.7772	83°	105°	76°
	1500	.5369	84°	89°	77°
	1700	.3408	78°	87.5°	78°
	1800	.1316	78°	80°	78°
	1900	-.0300	75°	75°	78°
	2000	-.1259	72°	72°	78°
	2100	-.1236	69°	68°	78°
17 July	0700	-.0707	60°	61°	71°
	0800	.1342	64°	68°	69°
	0900	.3110	70.5°	78°	70°
	1000	.8322	77°	90°	71°

APPENDIX B (Cont.)

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25' Soil Temperature
17 July (cont.)	1100	1.2491	80°	87°	72.5°
	1200	1.4157	86°	101°	74°
	1300	1.0066	87°	102°	75.5°
	1400	1.6717	89°	121°	78°
	1500	1.3661	90°	121°	79°
	1600	1.1207	89°	118°	80°
	1700	.4748	87°	101°	81°
18 July	0700	-.0608	62°	64°	74°
	0800	.0700	68°	69°	73°
	0900	.4574	72°	82°	73°
	1000	.8817	76°	92°	73.5°
	1100	1.1491	81°	89°	75°
	1200	1.4267	83.5°	100°	76.5°
	1300	1.5058	84.5°	111.5°	78°
	1500	1.3448	88°	122°	81°
	1600	1.0812	90°	120°	82°
	1700	.7643	82.5°	108°	82°
	1800	.2247	80.5°	91°	83°
	1900	.0388	78°	75°	83°
	2000	-.0735	76°	79°	83°
19 July	1000	.8435	78°	93°	74°
	1100	1.2571	82°	90°	76°
	1200	1.4167	87°	111°	77.5°
	1300	.1578	80°	89°	79°
20 July	0700	-.0402	61°	64°	73°
	0800	.1963	71°	74°	74°
	0900	.5494	72°	82°	74°
	1000	1.0127	77°	90°	74.5°
	1100	1.2652	80.5°	90°	76°
	1200	1.7093	86°	108°	77°
	1300	1.0569	85°	114°	79°
	1400	.5432	80°	96°	81°
	1800	.3625	77°	81°	82°
21 July	0800	.0647	59°	63°	72°
	0900	.2573	60.5°	68°	72°
	1000	.8552	65°	74°	72°
	1100	1.2721	72°	79°	72°
	1200	1.7152	79°	90°	73°

APPENDIX B (Cont.)

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25' Soil Temperature
21 July (cont.)	1300	1.6197	82.5°	101°	74.5°
	1400	1.5927	86°	103°	76.5°
	1500	.5076	84°	83°	78°
	1600	.8947	85°	91°	79.5°
	1700	.1080	76°	80°	80°
	1800	.0030	73°	76°	81°
	1900	-.0408	72.5°	75.5°	81°
	2000	-.1242	70°	69°	80°
	2100	-.1030	69°	M	80°
	2200	-.0928	69°	M	79°
22 July	0700	-.0704	60°	59°	74°
	0800	.0701	65°	74°	73°
	0900	.4345	72°	91°	73°
	1000	.8552	76°	105°	73.5°
	1100	1.0884	80.5°	119.5°	75°
	1200	1.1362	84°	117°	76°
	1300	1.1275	85°	124°	77.5°
	1400	1.5601	87.5°	136°	79°
	1500	1.2397	88.5°	132°	81°
	1600	1.0687	86°	125.5°	82°
	1700	-.0300	76°	88°	82.5°
	1800	-.0300	73°	84°	83°
23 July	0800	-.0723	62.5°	68°	74°
	0900	.3694	68.5°	85°	73°
	1000	.8729	74°	100°	73.5°
	1100	1.1930	77.5°	104.5°	74°
	1200	1.2899	82.5°	121.5°	75°
	1300	1.3267	83°	132°	77°
	1400	1.4157	84.5°	133°	78.5°
	1500	1.0043	84°	115°	80°
	1700	.6753	84.5°	115°	81°
	1800	.3902	85.5°	97°	82°
	1900	-.0300	78°	83.5°	82°
	2000	-.1259	72.5°	77.5°	82°
24 July	0700	-.0403	60°	64°	65°
	0800	.0766	62°	67°	73°
	0900	.5967	68°	83°	73°
	1000	.8876	72.5°	92°	73°

APPENDIX B (Cont.)

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25' Soil Temperature
24 July (cont.)	1100	.6387	74°	96°	74°
	1200	.7745	76°	96°	75°
	1800	.0691	71°	86°	77°
	1900	-.0730	68°	71°	76°
27 July	0800	.1832	60°	68°	68°
	0900	.4829	65°	78°	68°
	1000	.9108	71°	89°	68°
	1100	1.3048	77°	99°	69°
	1200	1.4943	83°	104°	71°
	1300	1.6404	85°	108°	73°
	1400	.8369	85°	108°	75°
	1500	.9945	86°	100°	77°
	1600	1.0414	86°	111°	78°
	1700	.8871	87°	110°	79°
	1800	.2003	84°	88°	80°
	1900	-.0624	77°	78°	80°
28 July	0800	.0024	61.5°	65°	72°
	0900	.3371	69°	80°	71°
	1000	.7772	74.5°	96°	71°
	1100	1.1568	81°	111°	72°
	1200	1.4032	85°	124°	73°
	1300	1.7897	88°	127°	75°
	1400	1.2244	86.5°	130°	77°
	1500	.2920	84°	115°	78.5°
	1600	.0512	80°	98°	79.5°
29 July	0800	.0434	59°	65°	71°
	0900	.4396	69°	82°	71°
	1000	.7603	74°	99°	70°
	1100	1.1214	79°	112°	71.5°
	1200	1.0885	82.5°	114°	73°
	1300	1.0569	84°	132°	74.5°
	1400	1.4248	86°	136°	76°
	1500	1.4556	88°	130°	78°
	1600	.2460	78°	96°	79°
	1800	.3427	79°	90°	81°
	1900	-.0408	73°	79°	80.5°
30 July	0700	-.0809	59°	62°	73°
	0800	.0344	61°	67°	73°

APPENDIX B (Cont.)

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25' Soil Temperature
30 July (cont.)	0900	.3772	68.5°	83°	72°
	1000	.7667	71°	90°	72°
	1100	1.1114	74°	98°	72.5°
	1200	1.1809	78°	93°	73°
	1300	1.0364	79°	93°	74.5°
	1400	.0703	72.5°	78°	76°
	1700	-.0074	70°	78°	78°
31 July	0800	.0679	64°	68°	71°
	0900	.3734	69°	80°	71°
	1000	.5398	72°	83°	71°
	1100	.4110	72°	81°	71.5°
1 August	1000	.4446	68°	79°	70°
	1100	.4558	70°	84°	70°
	1200	.6709	72°	93°	71°
	1300	.6049	73°	87°	71°
2 August	1000	.2214	72°	91°	69.5°
	1100	.8382	75°	98.5°	70°
	1200	1.1580	75.5°	104.5°	71°
	1300	1.4537	78°	103°	72.5°
	1400	1.2249	79°	95.5°	74°
	1500	1.1930	79°	87°	75.5°
	1600	.5630	79°	88.5°	76.5°
3 August	0800	-.0513	61°	59°	69°
	0900	.3258	68°	81°	68°
	1000	.7628	73°	96°	68°
	1100	1.1214	80°	110°	69°
	1200	-.1102	81°	112°	71°
	1300	1.4235	84°	132°	73°
4 August	0800	-.0407	61°	66°	71°
	0900	.3647	68°	81°	70.5°
	1000	.6049	72°	88°	70.5°
	1100	.9684	79°	98°	71°
	1200	1.4389	82°	105°	71.5°
	1300	1.2409	83°	96°	73°
	1400	.9598	85°	106°	75°
	1500	1.3359	86°	104°	76.5°
	1600	.9450	86°	101°	78°
	1700	.2586	83°	86°	79°

APPENDIX B (Cont.)

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25' Soil Temperature
4 August (cont.)	1800	.0723	77.5°	81°	79.5°
	1900	-.0733	75°	75°	79°
5 August	0800	.0025	64°	69°	73°
	0900	.4259	68.5°	85°	73°
	1000	.8787	78°	96°	73°
	1100	.4821	78°	90°	78.5°
	1400	.6823	80.5°	123°	76°
6 August	0800	.0059	62°	65°	70°
	0900	.3734	68.5°	80.5°	69°
	1000	.8006	73.5°	91.5°	69°
	1100	1.2089	79.5°	106°	69.5°
	1200	1.4067	85°	115.5°	70.5°
	1300	1.5903	88°	127°	72.5°
	1400	.5507	85°	102°	74°
	1500	1.3191	88°	126°	75.5°
	1600	1.1099	88.5°	120°	77°
	1700	.7276	88.5°	108°	78°
	1800	.0625	84°	88.5°	78.5°
	1900	-.0520	80.5°	80°	79°
	2000	-.1259	75.5°	74°	79.5°
	2100	-.1131	70.5°	70°	79°
	2200	-.1330	68.5°	66.5°	79.5°
7 August	0800	.0021	62°	64°	71.5°
	0900	.3622	68.5°	81.5°	70.5°
	1000	.6709	69.5°	97°	70.5°
	1100	1.1214	81.5°	113.5°	71°
	1200	1.4248	86.5°	127.5°	71.5°
	1300	1.2571	88.5°	135.5°	73°
	1400	1.2817	88.5°	132.5°	75°
	1500	1.2689	88.5°	133.5°	76.5°
	1600	.9950	89.5°	124°	77.5°
	1700	.7573	86.5°	114°	79°
8 August	0800	.0679	64°	66°	72°
	0900	.3258	72°	81°	72°
	1000	.5474	74.5°	89°	71.5°
	1100	1.3676	78°	103.5°	72°
	1200	1.0709	80°	107°	73°
	1300	1.3359	84°	109°	74°

APPENDIX B (Cont.)

Date	Time	Net Radiation	Dry Bulb Temperature	Soil Surface Temperature	-.25'Soil Temperature
8 August (cont.)	1400	.4687	81.5°	95°	76°
	1500	1.3065	84°	114°	77.5°
	1600	1.0414	81.5°	111°	78°
9 August	0800	.0445	63°	67°	73.5°
	0900	.2802	67.5°	78°	73°
	1000	.5097	73.5°	85°	72°
	1100	.5780	75.5°	87°	72°
	1200	1.4175	80.5°	106.5°	72°
10 August	0800	.0324	58.5°	64°	70°
	0900	.1095	60.5°	68°	70°
	1000	.7114	66°	78°	70°
	1100	1.0009	72°	100.5°	69°
	1200	1.3433	81°	107°	70°
	1300	.5512	77°	100°	70.5°
	1400	1.4281	81.5°	120°	72°
	1500	.3700	80°	96.5°	73°
	1600	1.0849	83.5°	103°	74.5°
	1700	.2440	79.5°	95°	75°
	1800	.1174	80.5°	85.5°	76.5°
	1900	.0031	75°	80°	77°
11 August	0800	.0118	59°	64°	69°
	0900	.2254	63.5°	70°	69°
	1000	.7309	70°	79°	68.5°
	1100	1.1195	75°	94°	69.5°
	1200	1.3337	78°	100°	70°
	1300	1.5016	81°	105°	71°
	1400	1.5113	83°	106°	72°
	1500	1.3477	84°	105°	73.5°
	1600	1.1682	85°	99°	75°
	1700	1.4878	80°	84°	77°
12 August	0900	.0665	62.5	68°	68°
	1000	.5066	67°	75°	68°
	1100	.9976	71°	88°	68°
	1200	1.2567	78°	92°	69.5°
	1300	1.5308	81°	99°	70.5°
	1400		82.5°	101°	72°

APPENDIX C

APPENDIX C

Mean Hourly Surface and Sub-Surface Temperatures at Base Camp

19 June to 24 June

Time	Surface	Depth in Feet			
		0.25	0.5	1.0	2.0
0700	56.8	75.1	78.3	77.0	72.0
0800	77.5	74.4	77.7	77.0	72.0
0900	92.7	74.1	77.2	76.7	72.0
1000	112.5	74.8	77.2	76.8	72.0
1100	131.4	76.2	77.0	76.8	72.1
1200	137.7	77.8	77.0	76.8	72.1
1300	140.4	81.5	77.5	76.8	72.5
1400	140.4	82.1	77.8	76.8	72.3
1500	136.1	83.5	78.4	76.7	72.2
1600	133.2	85.1	79.0	76.5	72.3
1700	124.2	86.7	79.8	76.5	72.1
1800	108.0	87.4	80.7	76.3	72.0
1900	91.1	87.7	81.4	76.2	72.0
2000	83.1	87.1	81.8	76.1	72.1
2100	75.5	86.2	81.4	76.0	72.0
2200	71.5	85.2	81.8	76.0	72.0

APPENDIX C (Cont.)

16 July to 22 July

Time	Surface	Depth in Feet			
		0.25	0.5	1.0	2.0
0700	62.7	72.8	75.1	75.0	72.0
0800	71.7	72.1	75.0	75.2	71.8
0900	78.7	72.2	74.7	75.1	71.8
1000	89.5	72.7	74.2	75.3	72.1
1100	91.1	74.0	74.2	75.1	72.2
1200	101.8	75.3	74.6	75.1	72.1
1300	103.2	76.8	74.6	75.0	72.1
1400	110.8	78.5	75.1	75.0	72.1
1500	105.9	79.8	75.6	74.6	72.1
1600	111.1	80.4	76.1	74.3	72.2
1700	91.4	81.0	76.6	74.6	71.7
1800	84.8	81.2	76.9	74.1	71.8
1900	76.4	81.1	77.3	74.3	72.0
2000	73.0	81.0	77.7	74.6	72.0
2100	70.0	80.4	77.7	74.3	72.1
2200	68.2	80.0	77.7	74.3	72.1

APPENDIX C (Cont.)

6 August to 12 August

Time	Surface	Depth in Feet			
		0.25	0.5	1.0	2.0
0700	60.1	70.9	72.8	73.3	71.1
0800	65.0	70.6	72.6	73.1	71.3
0900	75.3	70.1	71.8	73.1	71.1
1000	84.9	69.9	71.9	73.1	70.9
1100	98.9	70.1	71.7	73.0	70.9
1200	108.0	71.0	71.6	73.0	70.9
1300	109.6	71.8	71.5	72.7	71.0
1400	108.4	73.6	71.1	72.6	70.9
1500	106.9	75.1	71.9	72.6	70.9
1600	106.6	76.3	72.4	72.3	70.8
1700	93.5	77.1	72.9	72.5	70.9
1800	80.5	80.3	73.3	72.4	70.9
1900	77.1	78.6	74.3	72.6	71.1
2000	73.0	78.7	74.8	72.6	71.0
2100	70.1	78.2	74.8	72.7	71.0
2200	68.3	77.8	75.1	72.3	70.8

APPENDIX D

APPENDIX D

Rainfall Intensity Per Storm

Date	27 June	28 June	1 July	1 July	1 July	2 July	6 July	7 July
Time Began	1350	1444	1450	2000	2300	0135	1455	1623
Time Ended	1900	1700	1730	2200	2330	0300	1545	2115
Hours								
	*	.04	*	.03	*	.01	.03	.30
	.04	.13	*	.02	*	.01	*	.29
30 min.	*	.07	*	.11	*	*	.02	.04
	*	.02	*	.02		*	*	.01
	*	*	*	*		*	*	.05
1 hr.	*	*	*	*		*		*
	*	*	*	*		*		*
	*	*	*	*		*		*
1 hr. 30 min.	*	*	*	*		*		.07
	*	*	*	*				*
	*	*	*	*				*
2 hr.	*	*	*	*				*
	*	*	*					*
	*	*	*					.07
2 hr. 30 min.	*		*					.07
	*							.03
	*							*
3 hr.	*							*
	*							*
	*							*
3 hr. 30 min.	*							*
	*							*
	*							*
4 hr.	*							*
	*							*
	*							*
4 hr. 30 min.	*							*
	*							*
	*							*
5 hr.	*							
	*							
Total Amount	.12	.27	.02	.22	.02	.02	.06	.93

*Less than .01 inch

APPENDIX D (Cont.)

Date	8 July	8 July	9 July	10 July	12 July	14 July	15 July	16 July
Time Began	0100	1610	1845	0500	1520	1433	1950	2200
Time Ended	0615	1900	2200	0630	1620	2000	2200	2230
Hours								
	.05	.20	*	*	.32	.18	.02	*
	*	.15	*	*	.12	.18	.05	.02
30 min.	*	.05	*	*	.06	.04	.03	*
	*	.02	*	*	.02	*	.06	
	*	.08	*	*	.02	.02	*	
1 hr.	*	.04	*	*	*	.02	*	
	*	.01	*	*		*	*	
	*	*	*	*		*	*	
1 hr. 30 min.	*	.03	*	*		*	*	
	.04	.01	.01			*	*	
	.03	*	.04			*	*	
2 hr.	.01	*	*			*	*	
	.02	*	.01			*	*	
	.01	*				*	*	
2 hr. 30 min.	*					*		
	*					*		
	*					*		
3 hr.	*					*		
	*					*		
	*					*		
	*					*		
3 hr. 30 min.	*					*		
	*					*		
	*					*		
4 hr.	*					*		
	*					*		
4 hr. 30 min.	*					*		
	*					*		
	*					*		
	*					*		
5 hr.	*					*		
						*		
						*		
Total Amount	.22	.61	.11	.05	.52	.46	.18	.04

APPENDIX D (Cont.)

Date	17 July	19 July	20 July	20 July	22 July	23 July	24 July	25 July
Time Began	2200	2215	1945	2245	2010	2110	1302	1650
Time Ended	0202	0130	2023	0200	2150	2133	1647	1830
Hours								
	*	.01	.12	.05	.03	.23	*	.03
	*	.01	.22	.02	*	.01	*	.18
30 min.	*	.01	.06	*	*		*	.02
	.02	.01	.01	*	*		*	.01
	.01	*		*	*		*	*
1 hr.	.01	*		*	.03		*	*
	.02	*		*	*		*	*
	.01	*		*	*		*	*
1 hr. 30 min.	.01	*		*	*		*	*
	.02	*		*			*	
	*	*		*			*	
2 hr.	*	.01		*			*	
	*	.02		*			*	
	*	.01		*			*	
2 hr. 30 min.	*	*		*			*	
	*	*		*			*	
	*			*			*	
3 hr.	*			*			*	
	.02			*			*	
	.01			*			*	
3 hr. 30 min.	.01			*			*	
	*			*			*	
	*			*			*	
4 hr.	*			*			*	
Total Amount	.14	11	.41	.11	.07	.24	.17	

APPENDIX D (Cont.)

Date	26 July	29 July	30 July	31 July	31 July	1 August	3 August	5 August
Time Began	1715	2008	1412	1200	1900	2050	1350	1835
Time Ended	1900	0100	1500	1545	2400	2100	1500	1845
Hours								
	.60	.02	.03	*	*	.04	.02	.02
	.15	*	.01	*	.02		.28	.01
30 min.	.04	*	*	*	.01		*	
	.04	.14	*	*	*		*	
	.02	.16	*	*	*		*	
1 hr.	*	.04	*	*	*		*	
	.04	*		*	*		*	
	*	*		*	*			
1 hr. 30 min.	.02	*		*	*			
	*	*		*	*			
		*		*	*			
2 hr.		*		*	.02			
		*		*	.02			
		*		*	.02			
2 hr. 30 min.		*		*	.02			
		*		*	.01			
		*		.02	*			
3 hr.		*		.02	*			
		*		.02	*			
		*		*	*			
3 hr. 30 min.		*		*	*			
		*		*	*			
		*		*	*			
4 hr.		*		*	*			
		*		.02	*			
		*		*	*			
4 hr. 30 min.		*		*	*			
		*		*	*			
		*		*	*			
5 hr.		*		*	*			
				*				
				*				
5 hr. 30 min.				*				
Total Amount	.94	.42	.05	.23	.26	.04	.34	.03

APPENDIX D (Cont.)

Date	7 August	8 August	8 August	8 August	9 August	11 August	12 August
Time Began	1545	1630	2030	2330	0200	0110	2430
Time Ended	1600	1640	2040	2410	0230	0415	0440
Hours							
	.20	.01	.03	.01	*	.30	1.05
	.02			.01	.01	.15	.80
30 min.				.01	*	.28	.15
				.01		.05	.10
						.02	.05
1 hr						.05	*
						.01	*
						.01	*
1 hr. 30 min.						.01	*
						.01	*
						.03	*
2 hr.						.02	*
						.04	*
						*	*
2 hr. 30 min.						*	*
						*	*
						*	*
3 hr.						*	*
							*
							*
3 hr. 30 min.							*
							*
							*
4 hr.							*
Total Amount	.22	.01	.03	.04	.02	.98	2.24

APPENDIX E

APPENDIX E

Characteristics of Trincheras

Legend:

Condition:

- C = Complete
- P = Partially complete
- F = Fragmentary

Type:

- CD = Check dam
- T = Terrace
- LB = Linear border
- R = Riverside trinchera

Design:

- A = Stone alignment
- F/R = Stone facing with rubble backing
- D = Double wall with rubble core
- R = Piled rubble

Trinchera	Condition	Length	Height	Width	Distance to Next Trinchera	Type	Design	Plot Size (Sq. Feet)
			(Feet)					
AREA A								
1	F	48	4.0	2.0	47	CD	F/R	1,200
2	P	37	4.0	1.5	40	CD	F/R	700
3	P	35	7.0	--	25	CD	--	500
4	P	47	5.0	--	6	CD	--	250
5	P	54	10.0	--	130	CD	--	7,100
6	P	62	1.5	--	31	CD	--	1,400
6a	F	65	0.5	--	35	CD	--	1,000
7	F	50	1.5	--	None	CD	--	1,200
8	P	75	5.0	1.5	41	CD	--	2,000
9	P	40	3.0	2.0	44	CD	--	2,100
10	P	109	3.0	2.8	57	CD	--	6,213
12	P	97	4.0	--	32	CD	--	4,900
14	P	65	3.0	--	38	T	--	1,900
15	P	42	3.0	--	15	T	--	900
16	C	49	9.2	--	58	CD	--	1,914
17	C	35	10.3	--	30	CD	--	660
18	C	41	12.3	3.0	31	CD	--	900
18a	C	39	12.0	2.0	44	CD	D	1,056
19	P	31	1.5	--	30	CD	--	350
20	P	16	3.0	--	12	CD	--	130
21	P	37	2.0	--	30	CD	--	350
22	F	23	1.0	--	17	CD	--	500
23	P	41	3.0	--	20	CD	--	400
24	P	33	1.5	--	33	CD	--	300
25	P	30	3.3	--	30	CD	--	350
26	P	6	1.5	--	60	CD	--	25
27	C	33	1.0	1.0	50	CD	A	1,750
28*	C	--	2.7	1.5	12	CD	D	--
28a*	C	--	3.0	1.5	None	CD	--	--
29	P	73	3.6	2.2	62	CD	D	4,500
29a*	P	--	1.5	1.1	46	CD	A	--

* Buried trinchera

APPENDIX E (Cont.)

Trinchera	Condition	Length	Height	Width	Distance to Next Trinchera	Type	Design	Plot Size (Sq. Feet)
			(Feet)					
30	P	45	2.5	--	10	CD	--	800
31	P	121	4.0	1.0	28	CD	--	3,100
32	C	26	3.0	1.3	45	CD	--	490
33	P	32	2.0	1.0	27	CD	--	400
34	P	18	3.2	1.0	15	CD	--	150
34a	F	20	3.0	1.0	10	CD	--	65
34b	F	8	2.8	1.0	10	CD	--	45
35	P	23	1.5	--	48	CD	--	400
36	F	5	2.0	--	16	CD	--	50
37	F	42	0.5	0.7	26	CD	--	650
38	F	22	1.0	0.7	25	CD	--	250
39	F	30	0.8	0.7	19	CD	--	350
40	F	33	1.0	0.7	13	CD	--	400
41	F	15	1.2	0.7	11	CD	--	90
42	F	20	1.5	0.7	20	CD	--	150
43	P	23	2.0	0.7	None	CD	--	200
44	F	21	2.7	--	12	CD	--	225
45	F	10	2.5	--	None	CD	--	100
46	F	40	2.5	--	49	CD	--	600
47	F	14	1.5	--	22	CD	--	125
47a	F	14	1.5	--	None	CD	--	40
48	P	16	2.0	--	16	CD	--	400
49	P	27	2.8	--	28	CD	--	500
50	P	24	3.0	--	25	CD	--	225
51	P	26	1.0	--	75	LB	--	500
51a	F	20	2.5	--	50	CD	--	300
52	P	28	0.5	--	27	CD	--	1,050
53	P	36	2.0	--	25	LB	--	1,100
54	P	49	1.5	--	None	LB	--	500
55	P	18	3.5	--	45	CD	--	125
56	C	22	3.1	3.0	None	CD	--	460
57	F	14	1.3	1.3	28	CD	--	900
58	F	40	0.2	--	33	CD	A	1,700
58a	C	136	2.0	2.0	35	T	F/R	4,700
58b	P	155	2.7	1.7	18	T	D	2,000
59	P	35	1.0	--	27	CD	--	600
60	C	50	0.8	--	35	CD	--	1,200
61	F	21	3.0	--	None	T	--	500
62	P	10	0.7	0.7	12	CD	A	300
63	P	14	0.7	0.7	10	CD	A	300
64	P	19	0.7	0.7	21	CD	A	400
65	F	35	2.0	--	37	CD	--	600
66	P	30	2.0	--	15	CD	--	500
67	P	12	0.3	0.9	30	CD	A	400
68	P	27	0.8	0.9	40	CD	A	250
69	P	36	1.0	1.0	None	CD	A	400
70	F	32	2.0	--	35	CD	--	400
70a	F	22	3.0	--	22	CD	--	150
70b	F	23	3.0	--	26	CD	--	200
70c	F	20	3.0	--	20	CD	--	150
71	F	18	3.0	--	None	CD	--	200
72	F	6	4.0	--	16	CD	--	50
73	F	8	4.0	--	18	CD	--	50

APPENDIX E (Cont.)

Trinchera	Condition	Length	Height	Width	Distance to Next Trinchera	Type	Design	Plot Size (Sq. Feet)
			(Feet)					
74	P	16	3.0	--	30	CD	--	825
75	P	36	3.0	--	27	CD	--	1,100
76	F	11	0.5	1.0	58	CD	A	1,500
77	P	31	1.5	--	25	CD	--	550
78	F	15	3.0	--	32	CD	--	350
79	P	10	4.0	--	65	CD	--	150
80	P	10	4.0	--	17	CD	--	150
81	P	33	2.0	1.0	None	CD	--	250
82	P	26	3.0	--	20	CD	--	300
83	P	38	2.2	--	16	CD	--	580
84	P	23	2.0	--	20	CD	--	650
85	P	20	1.2	--	16	CD	--	400
86	P	22	4.0	--	27	CD	--	550
87	P	12	--	--	12	CD	--	210
88	P	20	4.0	--	20	CD	--	300
89	P	25	3.0	1.0	None	CD	--	175
90	P	35	4.0	3.0	29	CD	--	450
91	F	25	4.0	--	35	CD	--	550
92	P	16	3.0	--	27	CD	--	200
93	P	11	4.0	--	37	CD	--	175
95	P	5	5.0	3.0	40	CD	--	10
96	P	7	4.0	2.0	27	CD	--	250
97	P	9	4.0	2.0	20	CD	--	200
98	C	55	2.4	1.2	None	LB	--	13,200
99	P	69	3.0	3.5	42	CD	D	4,400
100	P	10	4.0	--	25	CD	F/R	100
101	P	36	4.0	--	30	CD	--	900
102	P	10	2.4	--	30	CD	F/R	650
103	P	23	3.5	--	20	CD	F/R	400
104	P	65	5.0	1.8	27	CD	D	900
105	P	47	4.0	2.5	25	CD	D	1,500
106	P	54	4.0	--	30	CD	--	1,100
106a	F	25	--	--	None	CD	--	--
107	P	45	1.2	--	None	CD	--	900
108	P	16	3.0	--	24	CD	R	750
109	P	28	4.0	2.0	24	CD	--	500
110	F	8	--	--	40	CD	--	30
112	P	34	3.0	--	61	CD	--	500
113	P	11	4.0	--	40	CD	--	150
114	P	40	2.5	--	20	CD	--	800
114a	F	30	3.0	--	75	CD	--	600
114b	F	25	3.0	--	None	CD	--	300
115	P	28	2.4	--	48	CD	--	1,680
116	C	13	1.0	--	20	CD	A	430
117	C	28	1.0	--	23	CD	A	550
118	C	15	1.0	--	20	CD	A	400
119	C	27	1.5	--	27	CD	A	1,500
120	P	61	2.0	--	85	CD	R	5,700
121	F	80	1.0	--	70	CD	--	3,800
122	P	7	2.5	--	48	CD	--	600
123	P	45	1.6	--	None	CD	F/R	3,300
124	P	30	4.0	2.0	80	CD	D	4,100
125	P	10	2.0	--	70	CD	--	1,550

APPENDIX E (Cont.)

Trinchera	Condition	Length	Height	Width (Feet)	Distance to Next Trinchera	Type	Design	Plot Size (Sq. Feet)
126	P	21	1.0	--	37	CD	--	600
127	P	16	1.5	1.5	30	CD	--	550
128	F	24	2.5	--	30	CD	--	650
129	P	21	2.0	--	21	CD	--	400
130	P	15	3.0	--	37	CD	F/R	100
131	P	45	3.0	--	38	CD	--	1,900
132	P	68	3.0	2.5	25	CD	F/R	2,500
133	P	31	1.5	--	None	CD	F/R	600
134	P	45	2.7	1.7	54	CD	D	2,100
135	P	55	1.6	1.5	85	CD	D	1,900
137	P	19	1.8	1.2	21	CD	F/R	850
138	P	25	2.0	1.2	25	CD	D	450
139	P	20	1.5	--	27	CD	F/R	200
140	F	22	2.0	--	10	CD	--	250
141	P	32	2.0	--	12	CD	F/R	900
142	P	23	3.0	--	30	CD	--	500
143	P	35	3.0	2.2	20	CD	D	500
144	P	15	3.0	--	30	CD	--	75
145	P	26	3.2	--	20	CD	--	500
146	P	25	3.0	1.9	42	CD	D	400
147	P	37	3.5	2.0	30	CD	D	1,000
148	P	51	3.0	--	25	CD	--	1,700
149	P	20	2.2	--	15	CD	F/R	300
149a	F	20	3.0	--	40	CD	F/R	300
150	P	17	4.5	--	31	CD	D	500
150a	P	20	4.0	2.0	30	CD	D	200
151	P	10	1.5	--	42	CD	--	250
152	C	15	0.2	0.5	26	CD	A	125
153	P	19	2.5	--	None	CD	--	1,300
154	P	20	1.2	--	None	CD	--	200
155	P	31	1.5	1.5	None	CD	A	350
156	P	7	1.0	--	None	CD	--	350
157	P	38	4.8	2.1	25	CD	F/R	600
158	P	27	--	--	23	CD	--	500
159	C	37	2.5	--	25	CD	R	1,000
159a	C	40	1.0	--	None	CD	R	3,000
159b	C	92	2.0	1.5	35	CD	F/R	2,300
160	C	26	4.0	--	62	CD	--	400
161	P	20	1.5	2.0	17	CD	--	500
162	F	27	1.0	--	None	CD	A	500
163	P	42	2.0	2.0	75	CD	--	2,500
164	C	40	1.0	--	None	CD	--	1,700
164a	C	22	0.5	--	None	CD	A	1,200
165	P	45	1.5	--	63	CD	R	1,900
166	F	20	1.0	--	None	CD	R	750
167	P	17	1.5	--	40	CD	--	200
168	P	25	1.5	--	60	CD	F/R	1,700
168a	F	108	0.7	--	50	LB	R	5,800
169	C	25	1.8	2.0	50	CD	D	1,600
170	F	36	1.5	--	None	CD	F/R	400
171	P	30	1.8	--	14	CD	F/R	400
172	P	20	2.0	2.0	21	CD	F/R	450

APPENDIX E (Cont.)

Trinchera	Condition	Length	Height	Width (Feet)	Distance to Next Trinchera	Type	Design	Plot Size (Sq. Feet)
173	F	25	1.0	--	24	CD	--	700
174	F	33	2.0	--	35	CD	--	600
175	P	37	3.7	--	25	CD	--	400
176	P	11	3.0	--	None	CD	--	100
177	P	20	1.4	--	None	CD	F/R	600
178	P	23	2.4	--	33	CD	--	800
179	P	19	1.3	1.0	25	CD	F/R	600
180	P	3	1.2	--	23	CD	--	500
181	P	23	2.0	1.5	19	CD	F/R	325
182	P	31	1.3	--	18	CD	--	600
183	P	35	1.9	1.9	35	CD	A	900
184	P	37	2.0	1.0	26	CD	A	700
185	P	25	2.6	--	21	CD	F/R	225
186	P	40	3.0	--	30	CD	--	700
187	F	11	1.0	--	16	CD	--	125
188	P	7	3.1	--	48	CD	--	15
189	P	35	2.0	--	100	CD	R	700
190	C	37	1.5	--	None	CD	A	900
191	P	16	3.0	--	17	CD	--	525
191a	F	10	3.0	--	20	CD	--	25
193	F	39	2.0	--	22	CD	--	650
194	P	34	6.0	3.0	16	CD	F/R	400
195	P	15	5.4	3.0	9	CD	F/R	175
196	P	20	5.7	3.0	46	CD	F/R	280
197	F	4	1.0	--	22	CD	--	20
198	P	13	1.5	--	None	CD	F/R	75
199	P	22	2.5	--	100	CD	F/R	300
200	P	20	2.0	--	20	CD	D	300
202	F	6	2.0	--	25	CD	--	30
202a	F	--	1.0	--	25	CD	--	--
202b	F	15	3.0	1.5	21	CD	D	100
202c	F	25	2.5	--	30	CD	D	200
202d	F	20	3.0	--	30	CD	--	150
203	P	5	2.4	--	17	CD	--	25
204	P	17	3.2	--	30	CD	--	150
205	F	6	3.0	--	15	CD	--	30
206	P	26	3.0	--	27	CD	--	200
207	P	15	2.5	--	27	CD	F/R	100
208	P	6	2.4	--	None	CD	F/R	30
208a	F	6	2.4	--	32	CD	--	30
209	P	23	0.5	1.0	35	LB	A	800
210	C	90	1.0	1.5	32	LB	D	1,700
211	P	15	2.0	1.5	15	LB	D	400
212	P	59	2.0	1.5	7	LB	D	500
213	P	45	2.0	--	180	CD	--	1,300
213a	P	25	1.9	--	None	LB	--	200
214	C	150	1.2	--	50	LB	R	7,600
214a	C	77	2.5	--	45	LB	R	2,050
216	C	45	1.5	--	None	LB	R	--
217	F	111	1.0	--	50	LB	--	3,000
220	P	30	2.0	--	25	CD	R	700
221	C	40	1.0	2.0	None	CD	--	1,800
222	P	87	1.3	1.5	32	LB	D	2,900

APPENDIX E (Cont.)

Trinchera	Condition	Length	Height	Width (Feet)	Distance to Next Trinchera	Type	Design	Plot Size (Sq. Feet)
223	C	222	1.5	2.0	216	LB	D	24,300
224	C	45	1.0	1.8	26	LB	D	1,200
225	P	30	1.4	--	50	CD	--	1,400
226	P	32	1.3	--	45	CD	--	1,400
227	P	20	1.2	0.7	51	CD	A	1,500
228	P	31	0.5	0.5	175	T	A	9,800
229	C	50	1.0	--	50	T	--	3,100
230	C	87	1.5	--	110	T	--	9,600
231	C	51	0.6	0.5	87	CD	R	4,200
232	C	41	3.5	1.5	95	CD	F/R	6,400
233	P	85	2.0	--	None	CD	--	1,700
234	P	370	1.1	--	63	LB	F/R	21,700
235	F	111	1.0	2.0	112	LB	R	13,900
236	P	124	1.1	2.0	None	LB	D	10,400
237	P	238	1.1	2.5	47	LB	D)	
238	P	88	0.5	0.5	43	LB	A)	15,600
239	F	100	0.6	2.0	None	LB	F/R	5,000
240	P	175	1.5	1.5	None	LB	F/R	19,800
241	P	67	0.8	0.7	114	LB	A	9,100
242	P	22	0.3	0.5	30	LB	A	1,000
243	C	[illegible]8	1.1	--	None	LB	--	11,600
244	C	131	0.5	1.4	45	LB	F/R	15,600
245	C	194	1.1	1.2	90	LB	F/R	6,300
246	C	117	1.2	1.2	23	LB	F/R	5,900
247	P	53	1.0	--	86	LB	F/R	5,800
248	C	140	1.6	2.5	36	LB	F/R	5,200
249	P	125	1.4	1.0	95	T	A	8,000
250	C	90	1.7	1.4	87	CD	D	5,700
251	P	34	2.0	1.0	17	CD	A	350
252	P	20	0.9	--	15	CD	A	450
253	C	52	2.0	--	38	CD	F/R	1,400
254	P	43	2.0	--	33	CD	F/R	1,300
256	P	43	2.0	--	38	CD	--	700
257	P	50	3.0	3.0	33	CD	--	950
258	P	25	1.0	--	20	CD	A	225
259	C	52	2.0	--	80	CD	F/R	4,600
260	P	73	1.0	--	50	CD	F/R	3,500
261	P	70	0.9	--	45	CD	F/R	2,400
262	P	60	2.0	--	10	CD	F/R	500
263	P	52	2.5	1.2	27	CD	D	850
264	P	47	2.0	--	41	CD	F/R	850
265	P	40	2.0	1.5	38	CD	D	1,400
266	P	20	1.2	--	41	CD	F/R	500
267	P	17	2.5	--	70	CD	--	125
268	P	18	2.0	--	None	CD	--	0
269	F	35	1.0	--	87	CD	--	5,200
270	F	17	1.0	--	15	CD	--	150
270a	F	20	2.0	--	None	CD	--	200
271	P	35	2.0	1.5	82	CD	F/R	500
272	P	8	1.6	1.5	None	CD	D	30
273	P	34	2.0	1.5	23	CD	F/R	400
274	P	17	2.0	1.5	22	CD	F/R	250
275	P	20	2.0	1.5	21	CD	F/R	200

APPENDIX E (Cont.)

Trinchera	Condition	Length	Height	Width (Feet)	Distance to Next Trinchera	Type	Design	Plot Size (Sq. Feet)
276	P	26	3.0	1.5	32	CD	F/R	300
277	P	20	2.0	1.5	None	CD	F/R	200
278	P	28	5.0	--	22	CD	--	450
278a	P	15	1.2	--	27	CD	--	200
279	P	48	2.8	--	20	CD	--	600
280	F	--	2.0	--	None	CD	--	--
281	P	13	2.0	--	22	CD	--	100
282	P	10	3.0	--	25	CD	--	50
283	C	16	4.0	--	20	CD	--	100
284	P	10	2.4	--	None	CD	F/R	40
287	P	40	1.5	--	15	CD	A	750
288	P	76	3.0	2.2	37	CD	D	1,600
289	P	38	1.6	--	17	CD	F/R	300
290	P	57	2.9	--	12	CD	--	500
291	P	55	2.5	--	24	CD	F/R	550
292	F	25	2.4	--	12	CD	D	200
293	P	67	1.3	--	35	T	A	2,400
294	P	30	2.0	1.5	30	T	D	900
295	P	48	2.0	--	25	CD	D	500
296	P	43	1.7	--	--	CD	F/R	300
AREA B								
400	C	29	8.7	2.7	105	CD	D	1,450
401	P	242	2.0	0.8	45	T	F/R	11,500
402	C	67	2.0	--	37	T	D	5,500
403	C	88	2.0	5.0	50	T	R	6,200
404	C	120	2.0	--	54	T	R	5,000
405	C	100	2.0	--	58	T	R	3,700
406	C	38	2.5	--	35	T	R	1,000
407	C	55	2.8	1.0	97	T	F/R	550
408	C	115	2.2	1.5	28	T	D	6,800
408a	P	27	1.5	--	None	LB	--	950
409	F	30	3.5	--	105	CD	--	3,500
410	P	38	4.0	3.1	90	CD	D	3,500
411	F	12	8.0	--	135	CD	--	200
412	P	10	9.0	--	8	CD	D	600
413	F	11	3.0	--	80	CD	D	200
414	P	20	4.6	2.6	65	CD	D	2,050
415	P	21	2.7	2.1	62	CD	D	1,400
416	P	21	5.0	3.8	90	CD	D	2,300
417	P	39	9.3	2.0	60	CD	D	3,400
418	P	34	5.5	--	68	CD	F/R	3,200
419	P	38	2.5	--	60	CD	D	1,700
420	P	38	2.0	--	60	CD	--	2,050
421	P	74	5.0	3.0	95	CD	D	9,600
422	P	51	2.9	--	22	CD	D	3,900
423*	P	17	--	--	51	CD	--	--
424	P	72	4.4	2.6	60	CD	D	5,200
425	P	52	7.0	2.9	30	CD	D	2,900
426*	P	26	2.0	--	25	CD	A	--

* Buried trinchera

APPENDIX E (Cont.)

Trinchera	Condition	Length	Height	Width (Feet)	Distance to Next Trinchera	Type	Design	Plot Size (Sq. Feet)
427	P	50	4.0	1.5	19	CD	F/R	950
428	P	60	2.6	--	30	CD	--	1,300
429	P	55	1.7	--	25	CD	D	1,300
430	P	38	4.0	--	22	CD	F/R	900
431	P	55	4.5	--	24	CD	F/R	950
432	P	65	7.0	--	58	CD	F/R	3,700
433	P	100	4.5	--	None	CD	F/R	2,200
434	P	45	4.8	2.1	70	CD	D	3,400
435	C	50	5.6	2.0	105	CD	D	1,600
436	P	22	2.0	--	27	CD	D	700
437	P	50	3.0	--	26	CD	F/R	1,400
438	P	52	3.0	2.0	53	CD	D	2,200
439	P	66	3.0	1.4	45	CD	D	2,100
440	P	41	2.9	2.1	None	T	D	700
440a	P	15	3.4	2.6	12	CD	D	300
441	P	74	6.6	3.3	128	CD	D	2,900
442	P	40	5.0	1.6	40	CD	D	2,200
443	P	76	5.0	--	57	CD	--	3,200
444	P	92	3.6	3.8	15	CD	D	4,100
444a*	P	--	2.0	--	36	CD	--	--
445	P	102	4.2	--	28	CD	--	2,500
446	F	36	2.0	--	28	CD	--	1,300
447	P	73	2.5	--	None	CD	--	1,000
450	P	31	6.0	--	85	CD	--	1,700
451	P	47	3.0	--	35	CD	--	1,500
451a	P	35	0.7	0.7	32	CD	A	1,200
452	P	50	2.5	1.0	30	CD	F/R	1,800
453	P	51	3.0	1.0	49	CD	F/R	2,600
454	P	38	2.5	--	55	CD	F/R	2,600
455	P	43	3.0	--	87	CD	F/R	1,900
456	P	88	3.0	1.5	85	CD	D	11,800
457	P	25	3.2	--	45	CD	--	1,150
458	P	18	2.5	--	65	CD	D	1,200
459	C	24	3.0	--	100	CD	F/R	250
460	P	41	2.0	--	20	CD	--	1,250
460a*	F	8	2.0	2.0	40	CD	D	--
461	P	30	2.7	--	35	CD	F/R	950
462	P	22	2.7	--	40	CD	F/R	550
463	P	45	3.0	--	22	CD	--	550
464	P	11	2.3	--	18	CD	F/R	100
465	P	25	1.5	--	20	CD	--	250
466	P	17	2.0	--	33	CD	--	250
467	P	24	2.0	--	59	CD	--	250
468	P	19	2.0	--	None	CD	--	300
469	P	27	3.0	--	11	CD	--	250
470	P	25	2.5	--	None	CD	--	350
471	P	31	2.9	1.6	40	CD	D	400
472	P	27	1.8	--	36	CD	--	350
473	P	42	2.6	1.0	15	CD	D	400
474	P	47	1.3	1.0	20	CD	D	750
475	C	36	2.9	1.6	80	CD	D	4,000

* Buried trinchera

APPENDIX E (Cont.)

Trinchera	Condition	Length	Height	Width (Feet)	Distance to Next Trinchera	Type	Design	Plot Size (Sq. Feet)
476	C	17	2.1	1.0	50	CD	--	900
477	P	30	3.0	--	55	CD	--	800
478	F	10	2.0	--	20	CD	--	150
478a	F	15	2.0	--	12	CD	--	100
478b	F	15	2.0	--	35	CD	--	150
478c	F	10	4.0	--	60	CD	D	100
479	F	24	1.8	--	57	CD	--	350
480	F	18	1.0	--	30	CD	--	300
481	P	27	--	--	None	CD	F/R	350
482	P	47	3.0	--	50	CD	--	1,900
483	P	34	2.5	2.0	16	T	F/R	800
484	P	70	2.5	2.0	None	T	F/R	1,600
485	P	17	1.0	--	28	CD	--	450
486	F	50	2.5	--	50	CD	F/R	2,700
AREA C								
500	P	68	3.0	--	22	T	D	1,400
501	P	78	3.0	--	36	T	D	3,100
502	P	80	3.0	--	21	T	D	1,700
503	P	87	3.0	--	38	T	D	2,500
504	P	135	3.0	--	12	T	D	2,400
505	P	87	4.0	--	30	T	D	2,000
506	P	60	3.0	--	21	CD	D	1,300
507	P	36	3.0	--	15	CD	D	400
508	P	48	3.0	--	20	CD	D	700
509	P	33	3.0	--	15	CD	D	350
510	P	33	3.0	--	16	CD	D	350
511	P	28	3.0	--	14	CD	D	300
512	P	26	3.0	--	12	CD	D	250
513	P	19	3.0	--	None	CD	D	200
AREA D								
300	F	10	2.3	3.0	160	R	--	
301	P	24	7.0	6.0	112	R	--	
302	P	27	4.1	3.5	98	R	A	
303	P	18	3.5	--	115	R	A	
304	P	36	5.7	5.0	205	R	--	57,200 total
305	P	36	4.0	10.0	60	R	A	
305a	F	10	2.6	3.0	60	R	--	
306	P	40	6.0	8.0	None	R	--	
306a	F	10	2.4	3.0	None	R	--	
307	C	48	5.5	--	24	CD	--	600
308	C	42	5.0	3.0	11	CD	F/R	300
309	C	50	5.5	--	15	CD	--	400
310	C	40	2.5	--	9	CD	--	200
311	C	38	5.0	--	20	CD	--	400
312	C	25	5.0	2.5	None	CD	F/R	250
313	C	20	7.5	--	50	CD	F/R	200
314	C	35	9.0	--	45	CD	F/R	350
315	C	40	5.5	--	23	CD	F/R	800
316	C	56	5.0	--	23	CD	F/R	800

APPENDIX E (Cont.)

Trincheras	Condition	Length	Height	Width (Feet)	Distance to Next Trincheras	Type	Design	Plot Size (Sq. Feet)
317	C	37	7.0	--	25	CD	F/R	600
318	C	43	5.0	--	40	CD	--	650
319	C	54	7.2	--	26	CD	--	600
320	C	17	3.5	2.5	33	CD	D	200
321	C	47	6.2	2.5	31	CD	F/R	600
322	C	59	6.4	3.0	30	CD	D	700
323	C	27	3.9	--	15	CD	F/R	200
324	C	37	3.0	--	13	CD	F/R)	
325	C	33	2.0	--	5	CD	F/R)	550*
326	C	31	3.0	--	22	CD	--	500
327	C	34	5.8	2.0	26	CD	F/R	600
328	C	25	3.0	3.5	30	CD	D	400
329	C	21	4.3	4.0	25	CD	D	500
330	C	26	6.0	2.5	13	CD	--	200
331	P	95	1.0	--	None	LB	A	1,950
332	C	24	3.0	2.0	18	CD	F/R	600
333	C	33	4.0	2.0	20	CD	--	500
334	C	24	2.5	--	15	CD	F/R	350
335	C	31	3.0	2.5	39	CD	D	1,300
336	C	48	4.0	--	11	CD	--	600
337	C	69	4.3	--	17	CD	--	650
338	C	40	2.5	1.5	13	CD	F/R	250
339	C	22	4.1	--	15	CD	F/R	200
340	P	18	4.0	--	10	CD	--	200
341	C	25	4.3	3.0	21	CD	--	450
342	C	30	7.0	2.0	12	CD	F/R	300
343	C	37	2.5	--	--	CD	F/R	500
AREA E								
550	C	555	3.0	3.0	140**	LB	D	102,500
551	P	43	1.5	--	87	CD	F/R	700
552	C	112	1.0	--	45	T	R	4,400
553	C	130	1.0	--	36	T	R	3,700
554	C	50	1.0	--	23	T	R	1,600
555	C	67	1.0	--	28	T	R	1,700
556	C	38	1.0	--	None	CD	R	600
558	P	13	3.5	2.5	26	CD	D	150
559	P	16	4.0	--	30	CD	D	200
560	P	15	3.0	--	25	CD	--	150
561	C	280	2.5	2.0	None	LB	F/R	36,200

* In one with 324.

** 140 ft. on E, 75 ft. on W

PHOTOGRAPHS

PHOTOGRAPHS

Photograph 1. Check Dam Trincheras Near Rio Piedras Verdes. Area D. 335-9.

Photograph 2. Check Dam Trincheras Near Rio Gavilan, Outside Study Area.

Photograph 3. Aerial View in the Eastern Portion of the Sierra Madre Occidental. West of Nuevo Casas Grandes, Chihuahua, Mexico.

Photograph 4. Representative Slope Land, Area A.

Photograph 5. Representative Mesa Land, Area A.

Photograph 6. Aerial View of Base Camp. The Weather Shelter can be Seen in the Fenced Enclosure at Lower Left. Unsurveyed Trincheras Are on the Slope Above.

Photograph 7. Trinchera 248. Linear Border. Max. Height 1.9 Feet.

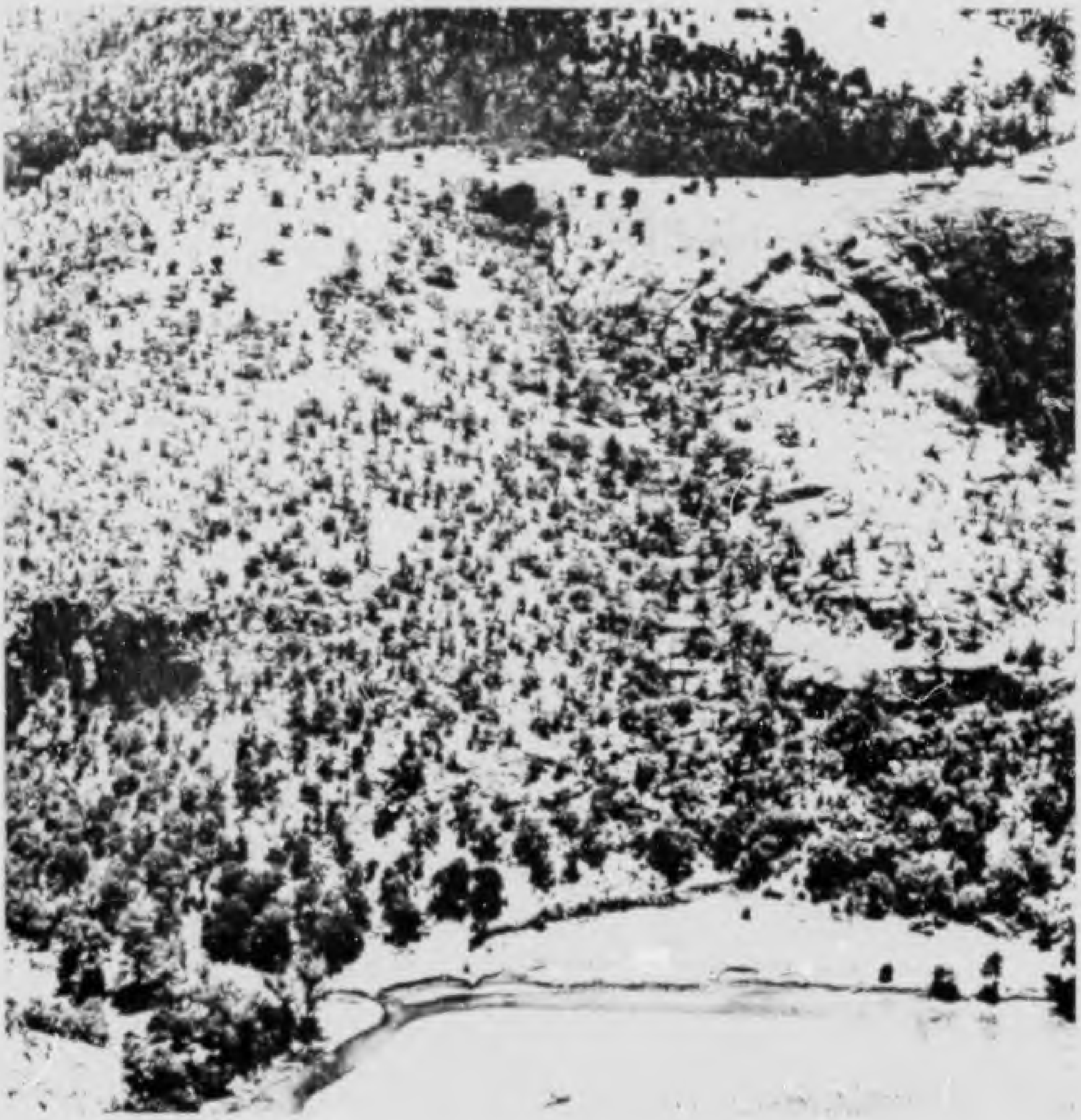
Photograph 8. Trinchera 18. Check Dam. Max. Height 12.3 Feet.

Photograph 9. Aerial View of Trincheras 212, 214, 214a, 217, 223, etc. Linear Borders.

Photograph 10. Terrace Trinchera 305, West End. Max. Height 4 Feet.

Photograph 11. Riverside Trincheras 305 and 306.

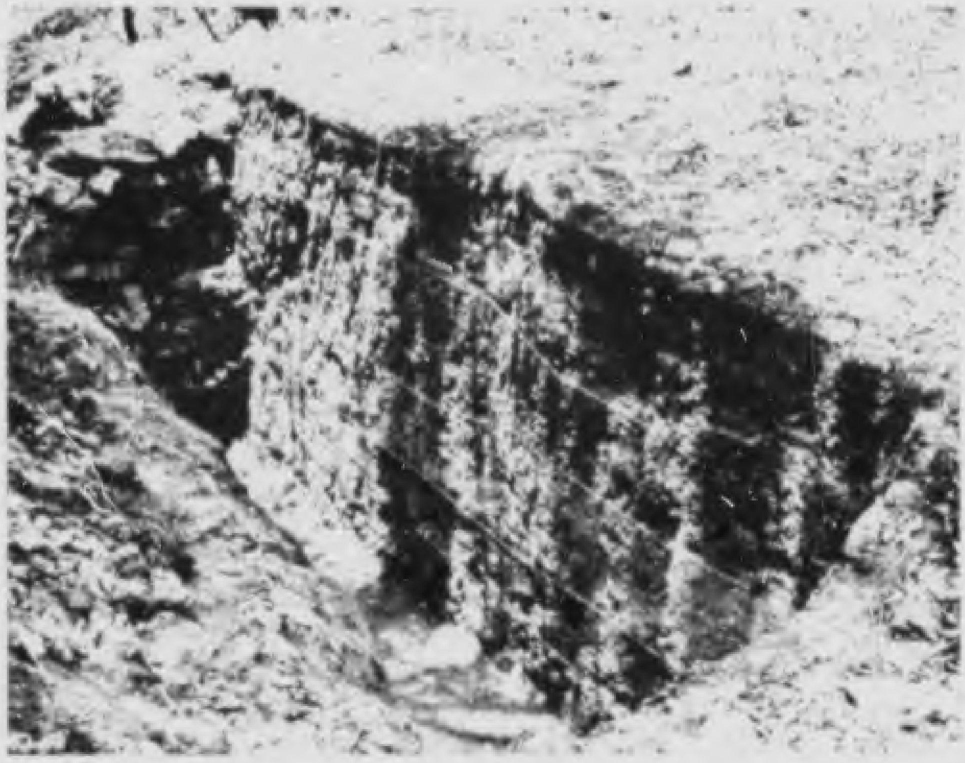
Photograph 12. Aerial View of Riverside Trincheras on the Rio Piedras Verdes.



Photograph 13. Aerial View of Sample Area D, Showing Riverside Trincheras in Foreground, Check Dams at Center, and Linear Border at Right Center.

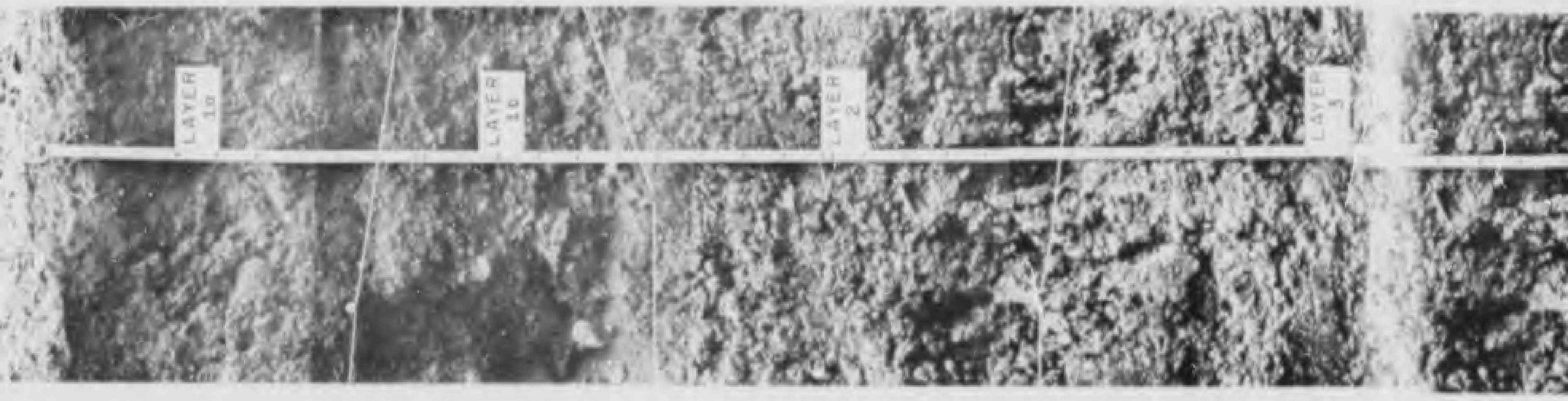
Photograph 14. Abutment of Check Dam 434 with Bedrock Outcrop. Height 4 Feet.

Photograph 15. Contact of Base of Trinchera Wall 319 with Bedrock. A Small Pool of Water has Collected Here.



Photograph 16. Aspect of Trinchera Plot and Trench at 18a. Layers 1-4 are Outlined.

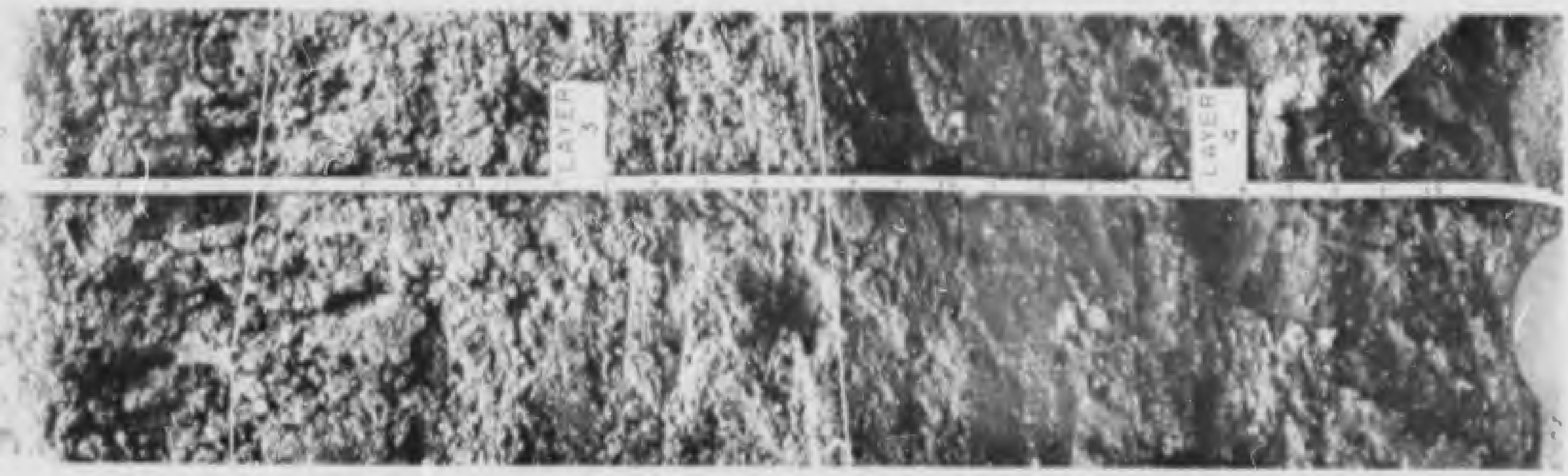
Photograph 17. Aspect of Trinchera Plot and Trench at 29. Trowel Rests on Buried Trinchera 29a.



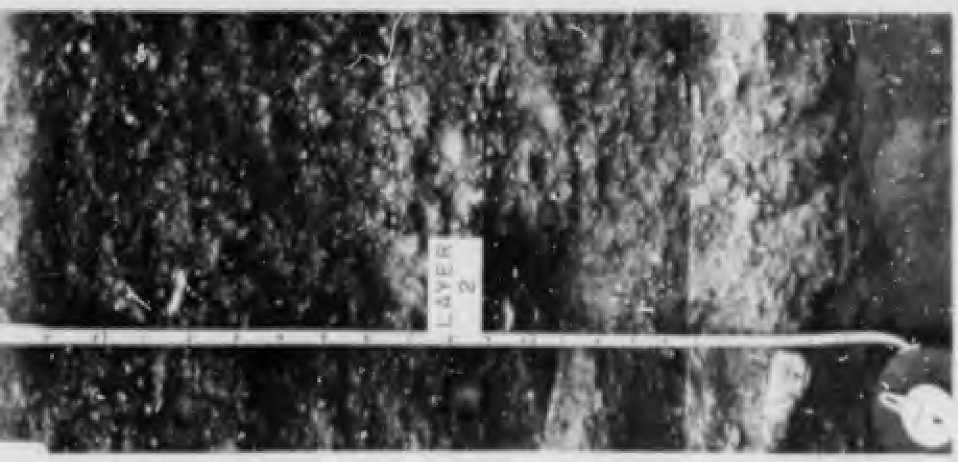
Photograph 18. Profile of Trinchera Fill, 18a, 9 Feet Be[illegible] Trinchera

Photograph 19. Profile of Trinchera Fill, 29, 15 Feet Be[illegible] Trinchera

A



Trinchera Fill, 18a, 9 Feet Behind Trinchera Wall.



Trinchera Fill, 29, 15 Feet Behind Trinchera Wall.

B

Photograph 20. Buried Trinchera 29a. Layers 1, 2, and 3 are Outlined. Trowel Rests on Bedrock.

Photograph 21. Trench at 414. Tape Rests on Bedrock.

Photograph 22. View from Trinchera Plot 214, Over 214a, and Toward the South.

Photograph 23. Linear Border 550, Eastern End.

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