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TERRAIN STUDY  
of the  
YUMA TEST STATION AREA  
ARIZONA

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ABSTRACT CARD

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Purdue University, Lafayette, Indiana  
TERRAIN STUDY OF THE YUMA TEST STATION AREA ARIZONA, by  
J. R. Shepard, J. G. Johnstone, A. A. Lindsey, R. D. Miles,  
and Robert E. Frost

March 1955, 176 pp illustrated. (2 maps in envelope on  
back cover)

Contract No. DA-22-079-eng-134

DA R&D project No. 8-97-10-004, Unclassified Report.

The report presents data on the terrain features of the Yuma Test Station Area, Arizona, obtained from field and literature surveys, study of maps and aerial photographs, and other sources. Description of the natural setting includes physiography, geology, vegetation, hydrology, climate and relationship to deserts of the southwestern United States. Terrain is classified into three major relief-land form groups: mountains, hills, and plains. Surface materials, surface conditions, degree of dissection, and vegetation are correlated with the land form units.

UNCLASSIFIED

1. Physical geography
2. Soils
3. Vegetation
4. Climate

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**TERRAIN STUDY  
of the  
YUMA TEST STATION AREA  
ARIZONA**

Contract No. DA-22-079-eng-134

DA Project No. 8-97-10-004

Between

**WATERWAYS EXPERIMENT STATION**

for

**OFFICE CHIEF OF ENGINEERS**

And

**AIRPHOTO INTERPRETATION LABORATORY**

**Joint Highway Research Project**

**Engineering Experiment Station**

**Purdue University**

Prepared by

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**Alton A. Lindsey, Robert D. Miles**

**Robert F. Frost, in charge**

**March, 1955**

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TABLE OF CONTENTS

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	Page No.
List of Figures	
List of Tables	
Abstract	
PREFACE	1
Authority	1
Purpose	1
Scope	1
Field Trips	2
Office and Field Study Procedures	4
Acknowledgments	6
CHAPTER I. YUMA TEST STATION AREA	8
Natural Setting	8
Location	8
Area covered by this report	10
Physiography	14
Geology	18
Hydrology	21
Climate	23
Relation to deserts of southwestern United States	26
Land Use	32
Road and Trail Network	33
Yuma Test Station and Test Programs	34
Signal Corps	35
Chemical Corps	38
Quartermaster Corps	39
Corps of Engineers	39
Ordnance	40

	Page No.
<b>CHAPTER II. CLASSIFICATION OF YUMA TERRAIN</b>	<b>45</b>
Scope and perspective	45
Basis for classification and mapping	45
Relief-land form units	46
Mountains	47
Hills	49
Plains	51
Degree of dissection	52
Method of development	53
Soils-Surface Conditions	53
Soil-rock types	53
Surface conditions	54
Vegetation	56
Methods of vegetation analysis	66
<b>CHAPTER III. MOUNTAINOUS TERRAIN OF YUMA TEST STATION AREA</b>	<b>72</b>
Rugged mountains	72
Rounded mountains	79
Flat-topped and single peaked mountains	82
<b>CHAPTER IV. HILLS AS A TERRAIN UNIT OF THE YUMA TEST STATION AREA</b>	<b>85</b>
Hills (Unclassified)	85
Inselbergs	91
Sand dunes	94
<b>CHAPTER V. PLAINS AS A TERRAIN UNIT OF THE YUMA TEST STATION AREA</b>	<b>105</b>
Introduction	105
Alluvial Fans	106

Page No.

Alluvial Aprons	112
Terraces	127
Flood plains	130
Playas	141
Washes	144
<b>CHAPTER VI. MILITARY SIGNIFICANCE OF THE YUMA TEST STATION ENVIRONMENT</b>	151
Cross country movement	151
Trafficability	153
Air drops	153
Site selection	154
Road construction	155
Water supply	156
Cover and concealment	156
Survival	158
<b>CHAPTER VII. CONCLUSIONS AND RECOMMENDATIONS</b>	162
Evaluation of the Yuma Test Station	162
Use of other deserts	163
Suggested research programs	164
Airphoto mapping and interpretation program	164
<b>APPENDIX</b>	
Folio of maps	167
Soil Test Data	168
Definitions	170
Bibliography	175

## LIST OF FIGURES

Figure No.	Page No.
1. Yuma Test Station and vicinity	9
2. Photo-map, Laguna Reservoir	11
3. Index of photo-maps	12
4. Government Reservations in the vicinity of Yuma	13
5. Geologic map of Yuma Test Station Area	19
6. Arid and semi-arid climates of the United States	28
7. Map showing roads, trails, and land use	30
8. Headquarters Area	37
9. Research and Development Area	37
10. The hill course	42
11. The cross-country course	42
12. Muggins Mesa test track	43
13. Dynamometer course	43
14. The artillery range	44
15. Artificial sand slope	44
16. Erosional cycle in arid climate	50
17. Vegetation along washes dissecting aprons	60
18. Physiographic correlations with chief plant species	63
19. Castle Dome Peak and Mountains	74
20. Rugged topography of Castle Dome Mountains	74
21. Dissected volcanic rocks in Muggins Mountains	75
22. Trigo Mountains	75
23. Vegetation along a mountain-wash	77
24. The Middle Mountains are mostly rounded	80
25. Flat-topped mountains of the Chocolate Range	83

26. Hills in the Miggins Mountain area	88
27. Hills in the Laguna Mountain area	88
28. Hills supporting palo verde trees	90
29. Inselbergs east of the Castle Dome Range	93
30. Texas Hill, an inselberg	93
31. Heavy shadows outline the dunes	98
32. Low altitude oblique of sand dunes	98
33. Basin enclosed by sand dunes	99
34. Alignment of intersecting transverse dunes	99
35. Photo-index of the Sand Hills	102
36. Jeep on the slip face of a dune	103
37. Slip face of a dune	103
38. Fans along the Miggins Mountains	108
39. Fans along the Chocolate Mountains	108
40. Gullied alluvial fan	111
41. Ground view of head of gully on fan	111
42. High altitude view of Castle Dome Plain	114
43. Alluvial apron east of Castle Dome Mountains	114
44. Desert pavement with shallow washes	116
45. Detail of materials beneath desert pavement	116
46. Mound which houses small burrowing animals	117
47. Detail of entrance to a burrow	117
48. Vegetation on a finely dissected alluvial apron	120
49. Pure creosote bush community	121
50. Airphoto of vegetation along wash	123
51. Dust stirred up on desert pavement	125



52. Smooth surface of desert pavement	126
53. Tracks on desert pavement	126
54. Aerial view of terrace	128
55. Flood plain of the Colorado River	131
56. Flood plain of the Gila River	131
57. Common reed on the Colorado flood plain	135
58. Picklebush	135
59. Dome-like masses of saltbush	137
60. Salt-cedar	137
60-A. Irrigated fields near Bard	140
61. Playa south of Stoval	143
62. Surface texture and cracks in playa	143
63. Broad wash bordered by vegetation	146
64. Indian wash	146
65. Base level wash	149
66. California mistletoe	149
67. Days of expected survival	161

LIST OF TABLES

Table No.		Page No.
I	Perennial plant species	61
II	Dominant plant species within principal terrain types	65
III	Density values of vegetation	70
IV	Per cent ground coverage by plants	71

## ABSTRACT

The terrain and environmental features of the Yuma Test Station Area are the subject of this study. This area in western Arizona and southeastern California from Yuma to Death Valley is the hottest and driest part of the United States.

Twenty-six per cent of the Yuma Test Station Area consists of mountains, most of which are rugged and difficult to traverse. Hills comprise 17 per cent of the Test Station Area. The terrain is rolling to rough, although local elevation differences are usually not great.

Plains make up fifty-seven per cent of the Test Station Area and provide the most suitable locations for most of the various activities that are being conducted at the Test Station. Forty-four per cent of the total area is alluvial aprons. Much of the surface consists of desert pavement, a firm mosaic of pebbles that make a smooth surface. Desert varnish is a dark coating that has formed on exposed rock surfaces, both pebbles and bedrock. Except on the floodplains and along the washes, vegetation is very sparse in the area.

In the opinion of most of the personnel of the test teams that were interviewed, environmental conditions at the Yuma Test Station offer conditions that are suitable for conducting most of the desert testing programs.

## PREFACE

This report covers a study of the terrain at the Yuma Test Station in Arizona. It is a part of the evaluation of the Yuma Test Station as a desert testing site for the Department of the Army.

### AUTHORITY

The work on this program was accomplished under the terms of Contract No. DA-22-079-eng-134 between the Engineering Experiment Station of Purdue University and the Waterways Experiment Station, dated 15 June 1953, as Project 8-97-10-004 "Military Evaluation of Geographic Areas", which was assigned to Waterways Experiment Station by the Office of the Chief of Engineers.

### PURPOSE

The purpose of the Purdue study is to study, evaluate, and map the terrain of the Yuma Test Station area with particular emphasis placed on the environmental factors which are known to affect military operations. The data thus developed and contained in this report are to be used in evaluating the suitability and adequacy of the Yuma Test Station Area for testing materiel, equipment, and personnel for operations in desert areas in other parts of the world.

### SCOPE

This report presents data on the environmental and terrain features in the vicinity of Yuma, Arizona. Most of the field work was done within the limits of the military reservation of the Yuma Test Station. Some work was done in the surrounding regions, including parts of the Kofa Game Range, the Imperial Wildlife Refuge, and a test course across the Sand Hills in Imperial County, California.

For the purposes of this study the Yuma Test Station Area, which is essentially that included in this report, is defined as that area covered by the series of thirty-two photo maps which were furnished for use on the project (see Figure 1).

Data for the study and report are the result of three field surveys, study of the aerial photographs, review of literature and existing maps, and conferences with authoritative sources.

The report is limited to development of a classification system of terrain and surface conditions, a discussion of desert ecology at Yuma Test Station, detailed discussion of terrain units found at Yuma Test Station, a discussion of military significance of the terrain and associated environment, and recommendations and conclusions.

#### FIELD TRIPS

Field data for this report were obtained during three field trips. The first field trip was conducted during December, 1953, and January, 1954. Professor R. E. Frost, the university representative in charge of the survey, and Professor J. G. Johnstone arrived at the Yuma Test Station on 8 December 1953. Arrangements for support of the field work were made with officers of the Test Station, Colonel W. W. Abbey, Commanding. Upon the recommendation of the Waterways Experiment Station, the period from 9-12 December was spent on a trip to Los Angeles for conferring with Dr. Thomas Clements, Professor of Geology at the University of Southern California. Dr. Clements had been working on a contract for the Quartermaster Corps which involved the classification of desert terrain. He has been conducting private studies in Death Valley and other southwestern deserts for 25 years and is considered to be an authority on deserts. Dr. Clements not only made available his desert reports but also gave considerable first-hand information about many of his observations.

On 20 December, Dr. A. A. Lindsey, Purdue Biology Department, joined the field party for the period 20 to 31 December for the purpose of obtaining data about desert vegetation under winter conditions. During this period he was able to inspect vegetation in representative areas both on the ground and from the air. Professor Johnstone completed his portion of the field survey and left Yuma on 22 December. Mr. J. R. Shepard joined the group on 28 December and remained until completion of the field work. From 27-30 December, Mr. R. D. Miles joined a field trip conducted by Dr. Clements (University of Southern California) for a study of Death Valley. He then joined the field party for the remainder of the work at Yuma.

Representatives from the Waterways Experiment Station (Dr. J. R. Schultz, Geologist, and Mr. Robert Turner, Engineer) and Purdue University (Professor K. B. Woods) met for two days with the field party and the Chief of the Engineer Test Team at the Yuma Test Station (Mr. Edward Uhl, Jr., Civil Engineer) to discuss a desert classification and to make plans for the summer survey.

In addition to the study in and adjacent to the Test Station, two trips were made twenty miles to the west of Yuma to the large sand dune area in Imperial County, California. Here is found one of the largest areas of sand dunes in the country. A two-day trip was made to the Salton Sea area to study some of the features of that area.

The second field trip consisted of a short trip to Yuma Test Station by Dr. A. A. Lindsey from 21-27 April, 1954. The purpose of this trip was to study spring vegetation conditions at Yuma Test Station.

-4-

The third trip was conducted during the period 28 May to 30 June 1954. Field party members were Professor Robert E. Frost, Professor James G. Johnstone, and Mr. James R. Shepard. Mr. Charles Koib, geologist of the Waterways Experiment Station, joined the field party for the period of 2-4 June for conferences and terrain inspection purposes.

The purpose of the last field trip was to obtain additional data during the summer period. Many of the original sites and study areas were revisited during the summer trip, and additional sites were also visited. In addition to field study, many flights were made over the area for purposes of reconnaissance and obtaining low altitude oblique photographs of the various terrain features.

#### OFFICE AND FIELD STUDY PROCEDURES

Prior to departing on the first field trip, a preliminary study of the Yuma Test Station area was made by reviewing the literature and studying the available aerial photography, which had a scale of 1:40,000. The airphotos were assembled into mosaics and major boundaries between the surface materials were drawn. The mosaics were then photographed, and 14 x 20 inch prints were made for use in facilitating the field work. The airphotos were then filed in envelopes to be taken into the field.

Field survey of the Yuma Desert area consisted of detail study of topography, soils, rocks, and vegetation at locations considered to be representative of desert terrain in the Yuma area. Samples were obtained for moisture content, mechanical analysis, and Atterberg limits from many locations. At some locations field density tests were run. Notations were made concerning topography, soil or rock type, vegetation, dust, "pavement" condition, desert varnish, and any other items that were considered to be important.

Upon arrival at the Yuma Test Station, the field party made arrangements with the personnel of the Station for the use of their facilities in making the field survey. The Yuma Test Station Headquarters furnished transportation facilities -- the use of jeeps, a weapons carrier, helicopter, and L-19 observation plane. Members of the Engineer Climatic Test Team from Fort Belvoir under the direction of Mr. Edward Uhl, Jr., actively assisted in many of the field activities.

After an area had been selected for study, a small mosaic was assembled along the proposed route. The airphotos were studied stereoscopically to locate areas that should be tested. The mosaics were taken into the field for further use. Field trips were made in a jeep or weapons carrier. These vehicles with four-wheeled drive and low gear ratio can traverse some very rough country where there are no roads.

At the principal test sites, considerable data were obtained: moisture samples were sealed in cans to be returned to the Soils Laboratory at Purdue University, samples of the surface materials were taken for grain size analysis, the vegetation was described and sometimes sampled, the topography and surface features were described, and ground photographs were taken.

Attempts were made to visit representative sites in all the major terrain types in the Yuma area. Additional desert features were studied in Death Valley and the Salton Sea Basin.

The same general procedure was followed on subsequent field trips. At sites which were being observed for the second time, any changes in environmental features were noted. Aerial oblique photos



were taken from liaison type aircraft belonging to the Test Station.

Final maps were prepared after the return from the last field trip. Original boundaries developed in the airphoto analysis were modified to conform to the known conditions as they were observed in the field.

#### ACKNOWLEDGMENTS

The completion of this study is the result of a great deal of cooperation by the many individuals and groups with whom contact was made by the field parties from Purdue. Particular thanks and appreciation are extended to the personnel of the Yuma Test Station for their hospitality and assistance which was so freely offered. Colonel W. W. Abbey, the commanding officer, and Lieutenant Colonel Raymond Young, the executive officer, put the facilities of the base at the disposal of the field parties. It is understood that the primary mission of the Yuma Test Station is to provide facilities for desert research activities; and from the experiences of the Purdue field parties, it is evident that the personnel of the Test Station are doing all they can to provide the facilities and any assistance for the various test teams.

Mr. Edward Uhl, Jr., and members of the Engineer Climatic Test Team deserve special mention for their active participation in much of the field work. It is not possible to list here the many individuals who contributed to the activities of the field parties.

Mr. C. R. Kolb (geologist) and Mr. A. R. Compton, both of the Waterways Experiment Station, gave invaluable assistance in planning the program and organizing the material. The guidance of Professor

K. B. Woods, Head of the School of Civil Engineering at Purdue, and Professor H. L. Michael, Assistant Director of the Joint Highway Research Project, is also acknowledged. The maps were prepared by Mrs. David Nelson, Mrs. Ward Watson and Mr. Steve McLaughlin. Photographic work was done by Mr. Murray Raymond and Mr. Emmet Black. The final copy was typed by Mrs. Richard Miller, and the ozalid copies were reproduced by Mr. Steve McLaughlin.

## CHAPTER I

### YUMA TEST STATION AREA

This chapter discusses the general regional environmental factors which exist at the Yuma Test Station and the test programs which were active during 1954.

#### NATURAL SETTING

The landscape of the Yuma Test Station Area owes its existence to complex development processes in an arid region. The desert and its problems cannot be understood or evaluated properly without an insight to the natural setting and the factors responsible for its condition.

#### Location

Yuma is located in the southwestern part of Yuma County, which in turn is in the southwestern corner of Arizona. It is situated on the banks of the Colorado River, opposite Imperial County, California, and a few miles north of the Mexican border.

Yuma is located on the main east-west line of the Southern Pacific Railroad. The area is served by U. S. Highway 80 and State Route 95. The Bonanza Airlines provide air transport service to Yuma on its route from Phoenix to San Diego and Los Angeles. Yuma Air Force Base is on U. S. 80 three miles southeast of Yuma.

Headquarters of the Yuma Test Station is about 20 miles northeast of Yuma and about two miles from Imperial Dam. A map of the area surrounding Yuma is presented in Figure 1. It shows the locations of the towns, major transportation routes, topographic features, and the limits of the Yuma Test Station Area. It also includes the Sand Hills to the west in Imperial County.

MAP OF  
YUMA TEST STATION  
AND VICINITY

MILES  
0 5 10

- LIMITS OF YUMA TEST STATION AREA
- RAILROADS
- ==== PAVED ROADS
- ==== GOOD UNPAVED ROADS
- POOR ROADS & TRAILS

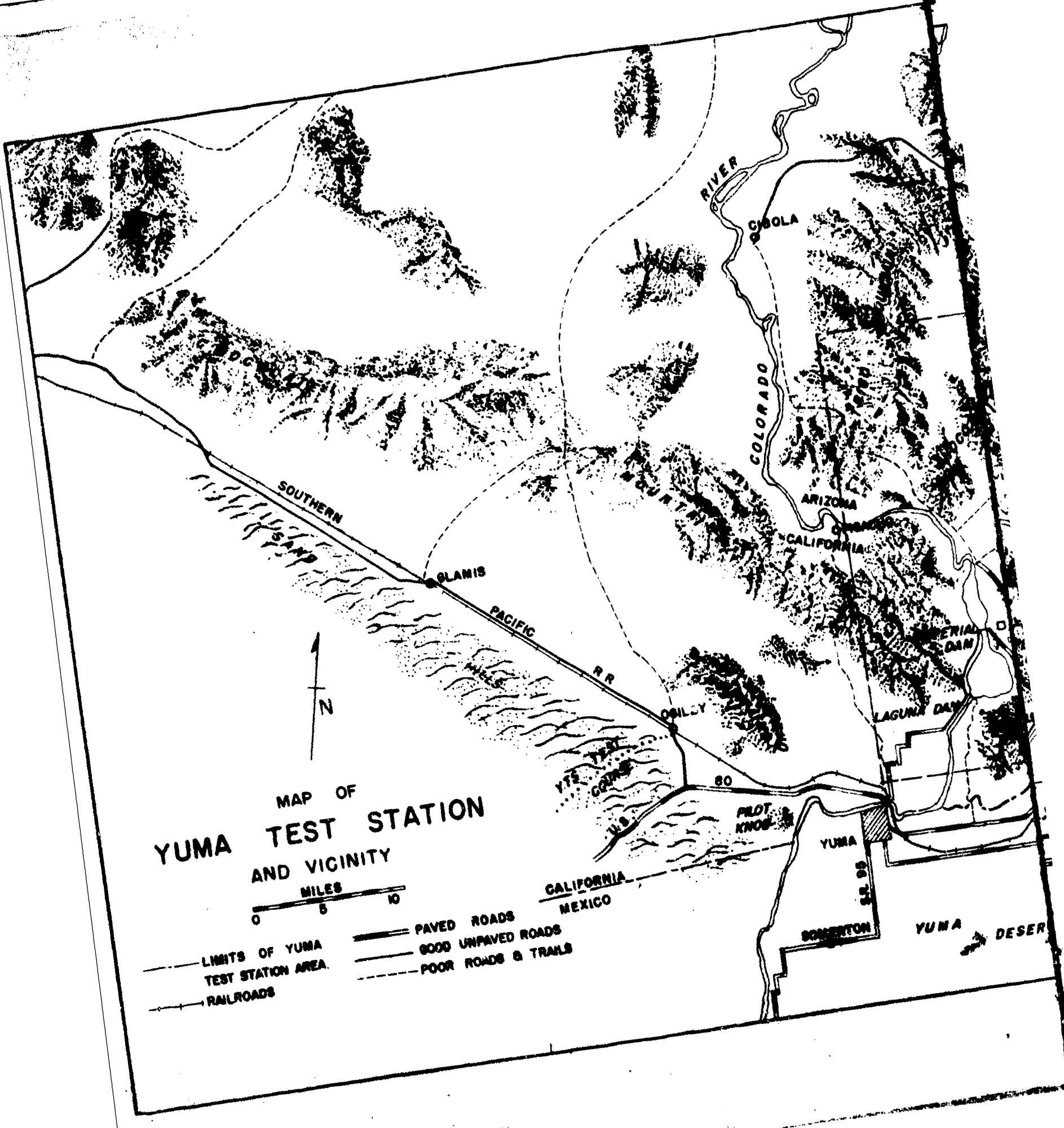
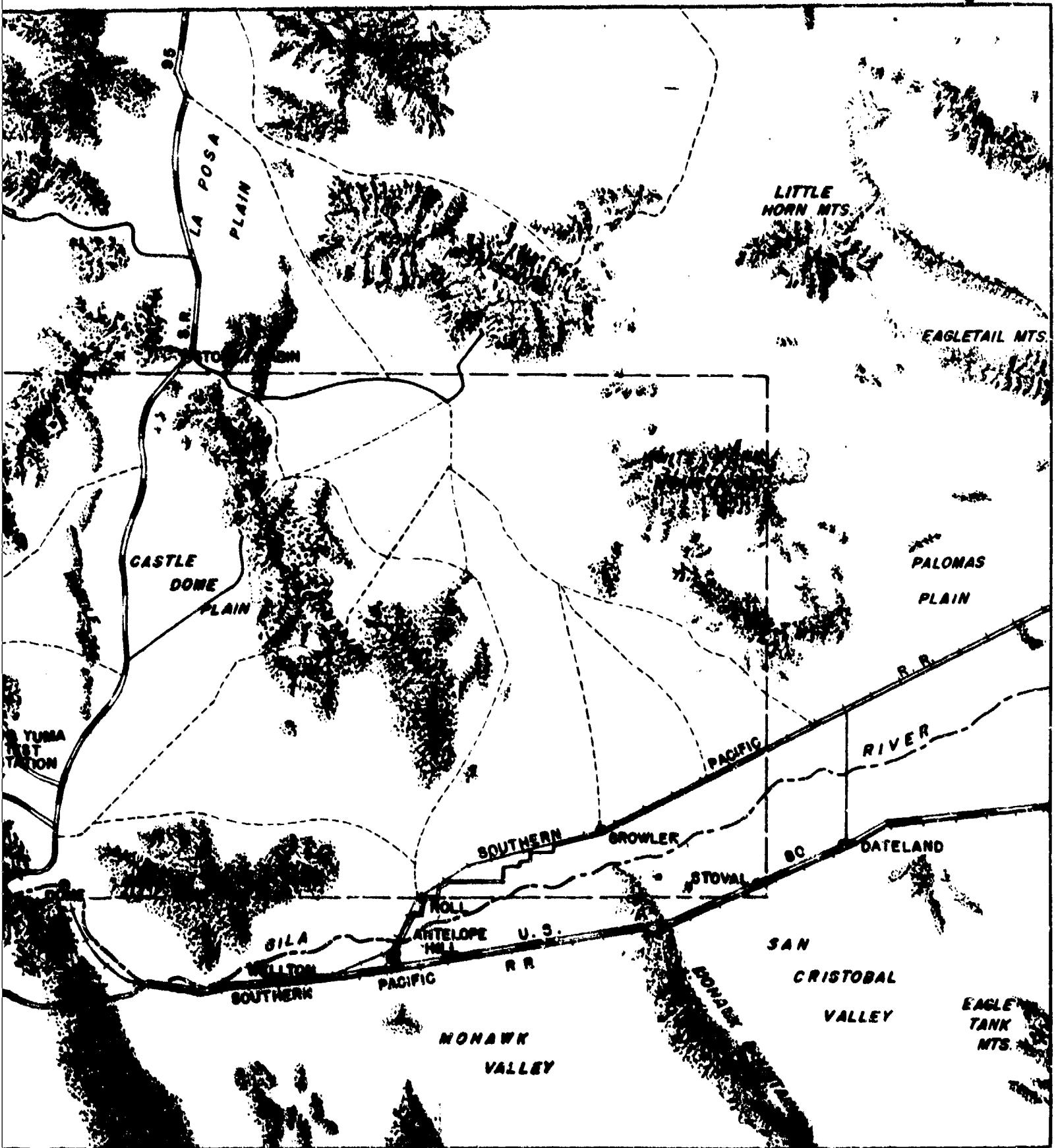


Figure 1



Area Covered by this Report

This report covers the Yuma Test Station and the surrounding area as limited by the 32-sheet set of photo maps, AMS series V095G and V098B. The maps on Plates I, II, ~~III, and IV~~ (see the Appendix) cover the same area that the photo maps do. This area covered by the photo maps is referred to herein as the Yuma Test Station Area. A small size copy of one sheet of the photo maps is shown in Figure 2. An index of the entire series has been prepared for Figure 3.

Besides the Test Station, which is a military reservation, the Test Station Area includes parts of the Kofa Game Range and the Imperial Wildlife Refuge. These are under the supervision of the Department of the Interior. Figure 4 shows the boundaries of these government reservations in the Test Station Area.

The Yuma Test Station Area as shown on Plate I covers about 1,240,000 acres, or 1938 square miles. Over a third of this is outside the boundaries of the Test Station.

The Kofa Game Range is a refuge that has been established for the preservation of wild life: the Kofa sheep, deer, and other animals. It is under the supervision of the Department of the Interior. By agreement between the Departments of Defense and Interior, none of the activities of the Test Station are to be conducted within the limits of the Kofa Game Range. However, permission can be obtained to make studies of a scientific nature that do not disturb the wild life.

This report includes information on the southern part of the Kofa Game Range that is included on the photo maps, since the surface features are similar to those of the Test Station. The total area of the range is approximately 627,000 acres, but less than one-third of it is within the area that was studied.



Fig. 2. One of the 32 photo-maps that comprise the Yuma Test Station Area. The lines of the One Thousand Meter Universal Transverse Mercator Grid System are shown.



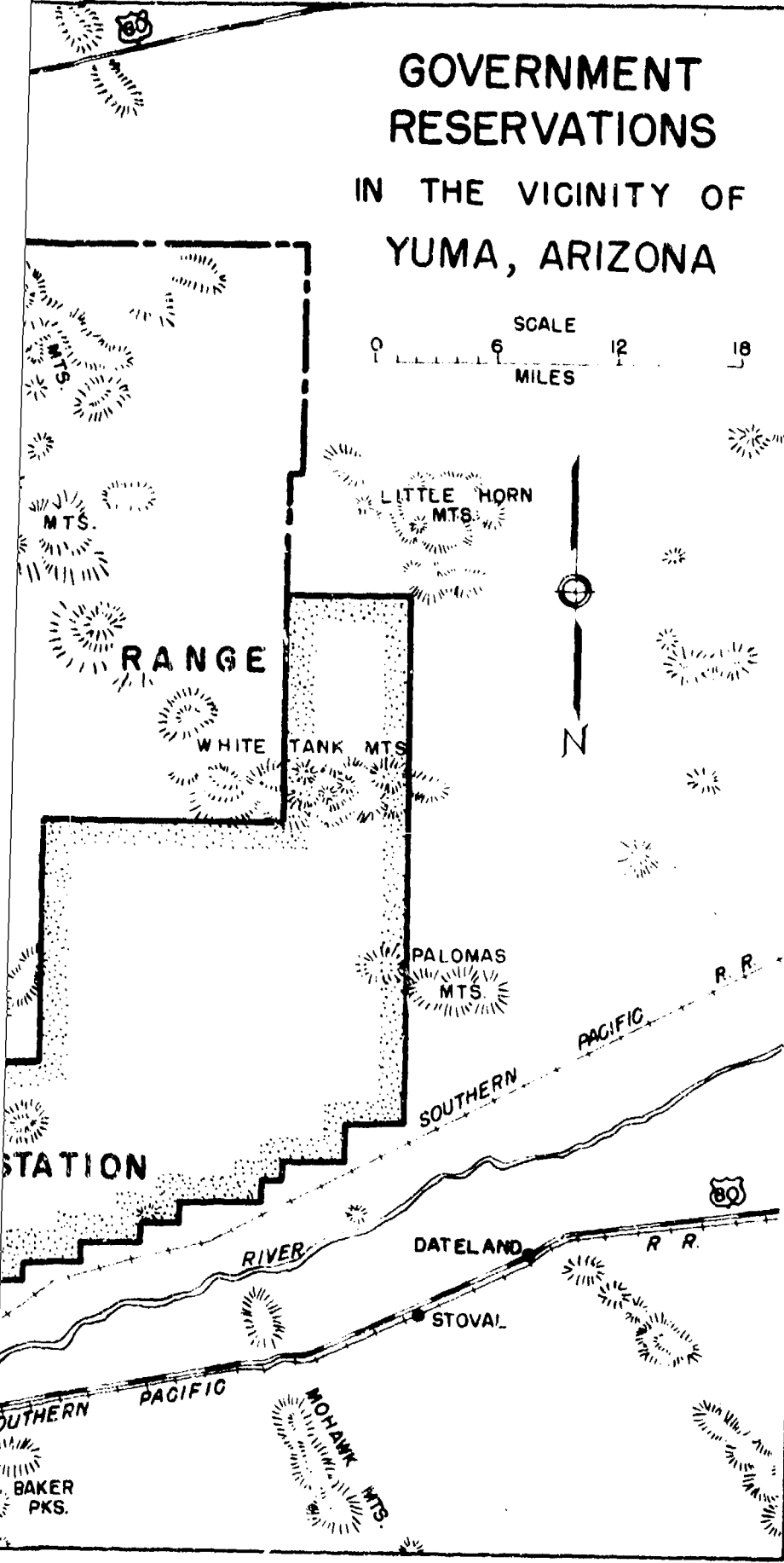




Figure 4

# GOVERNMENT RESERVATIONS IN THE VICINITY OF YUMA, ARIZONA

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The Imperial National Wildlife Refuge occupies a long narrow strip along the Colorado River. The Department of the Interior supervises the refuge, which covers an area of about 60,000 acres; approximately 40,000 acres of this is located within the area that has been mapped for this study.

In addition to the Yuma Test Station Area, the report also discusses the Sand Hills in Imperial County, California, about twenty miles west of Yuma. These dunes extend from the Mexican border northwestward for about fifty miles toward the Salton Sea. Personnel from the Test Station regularly use a test course that runs west from Ogilby across the dunes. This provides a course for testing vehicles on loose sand that is common in desert areas throughout the world. The Sand Hills are not included when the term Yuma Test Station Area is used, however.

#### Physiography

The Yuma Test Station Area lies within that section of the Basin and Range province known as the Sonoran Desert. The Sand Hills near Ogilby in California, which are used as an outlying test course, do not fall into this physiographic section. They are a part of the Salton Trough (sometimes called the Colorado Desert section) of the Basin and Range province.

Unlike the Great Basin section to the north and the Salton Trough to the west, the Sonoran Desert section presents an "open basin" condition, i. e., there are few, if any, enclosed basins or bolsons containing playas. The alluvial plains which surround the many ranges are interconnected, and under other climatic conditions surface drainage would reach the sea. In general, these range-studded alluvial plains rise from the Gulf of California more or less uniformly until some

portions attain an elevation of 3000 feet. However, more than half the plains lie below 2000 feet. These plains are more or less continuous and from one-half to twenty-five miles wide.

It is recognized that about one-fifth of the province consists of ranges. The ranges vary in size from low-lying hills to mountainous proportions, some over 4000 feet above sea level. They vary from an eighth of a mile to about sixteen miles in width and from eight to thirty-six miles in length.

North of the Gila River the ranges are generally irregular in shape and consist of blocky buttes, spires, and steep-sided mesas with local relief of a few tens to several hundreds of feet. The plains here are cut by broad desert washes varying from 3 to 20 feet deep.

South of the Gila River the ranges are more narrow and steep-sided with sharp crests. The plains are noticeably less dissected except in the parts situated near the base of the ranges.

As the province name implies, the topography consists primarily of alluvial plains and ranges of hills and mountains. The ranges do not have a uniform trend. Although a southeast-northeast<sup>west</sup> trend predominates, there are many exceptions, some of great magnitude.

The valleys of two major stream systems cross the Yuma area: the Colorado River and the Gila River. Both have sources beyond the borders of the Sonoran Desert section. The presence of through streams is a major distinction of this area from the Great Basin section to the north.

Of these two streams only the Colorado, which crosses the area from the north to south, has a large continuous annual flow of water. The headwaters of the Colorado River lie in the Rocky Mountains and

embrace a large watershed. Here melt-water from snow and general precipitation contribute to an abundant water supply. The quantity of water is sufficient to allow the stream to reach the sea despite the fact that it crosses hundreds of miles of some of the most arid terrain on the North American continent.

The Colorado River has been termed the "Nile of America." The resemblance begins with the similar nature of their headwaters with their abundant supply. In addition, the greatest flow comes at the time of year when the water is useful for irrigation. Finally, the Colorado and the Nile both carry large quantities of silt which contributes to the formation of a large delta at the mouth of each river.

The Gila River valley crosses the area from east to west, joining the Colorado just above Yuma. Its headwaters are also outside the borders of the Sonoran Desert, but there the similarity ceases. One branch rises in the Mexican Highlands section while another major tributary, the Salt River, taps the southern margin of the Colorado Plateau province. Both of these areas are semi-arid and therefore produce only a limited supply of water. Although the Gila formerly reached the Colorado more or less regularly, the construction of several dams along its course for irrigation purposes has reduced the discharge to an occasional trickle. There are times following heavy local rains when the Gila's discharge is high, but this is exceptional. Based on these considerations, the lower Gila River is no longer perennial in character.

The alluvial plains are crossed by hundreds of branching and braided ephemeral washes. These washes deliver to the Colorado and Gila those surface waters which have escaped evaporation, alluvial absorption, and vegetative transpiration during and after periods when it does rain. The washes may head in mountain gullies or rills on the plains. Locally the drainage pattern developed by the washes is parallel in character, i. e., they trend in the same general direction as the regional slope until they are intercepted by a transverse wash usually lying at the base of one of the ranges lying athwart the regional slope.

The Salton Trough is a depressed basin, much of which is below sea level. It lies between the Coast Ranges on the west and the Chocolate Mountains in California to the east (see Figure 1) and represents an extension of the Gulf of California. The lowest point of the basin surface lies more than 250 feet below sea level. The basin rises to an elevation of about 40 feet above sea level on the south. To the north the alluvial plain reaches 400 to 1000 feet elevation at the mountain margin.

The topography of the Salton Trough is generally a plain surface depressed at the center like a great saucer or bowl. There are a few irregularities on this sloping surface. The most important are the nearly buried Superstition Mountains, the Sand Dunes of Ogilby trending north-south along the eastern portion, the gullies associated with the streams entering the basin, and the benches which have been cut out at the position of former shorelines.

One of the outstanding features is the delta of the Colorado River which is the immediate cause of the formation of the Salton Trough. The delta is situated athwart an elongated depression, cutting off the Gulf of California from the Salton Trough to the north.

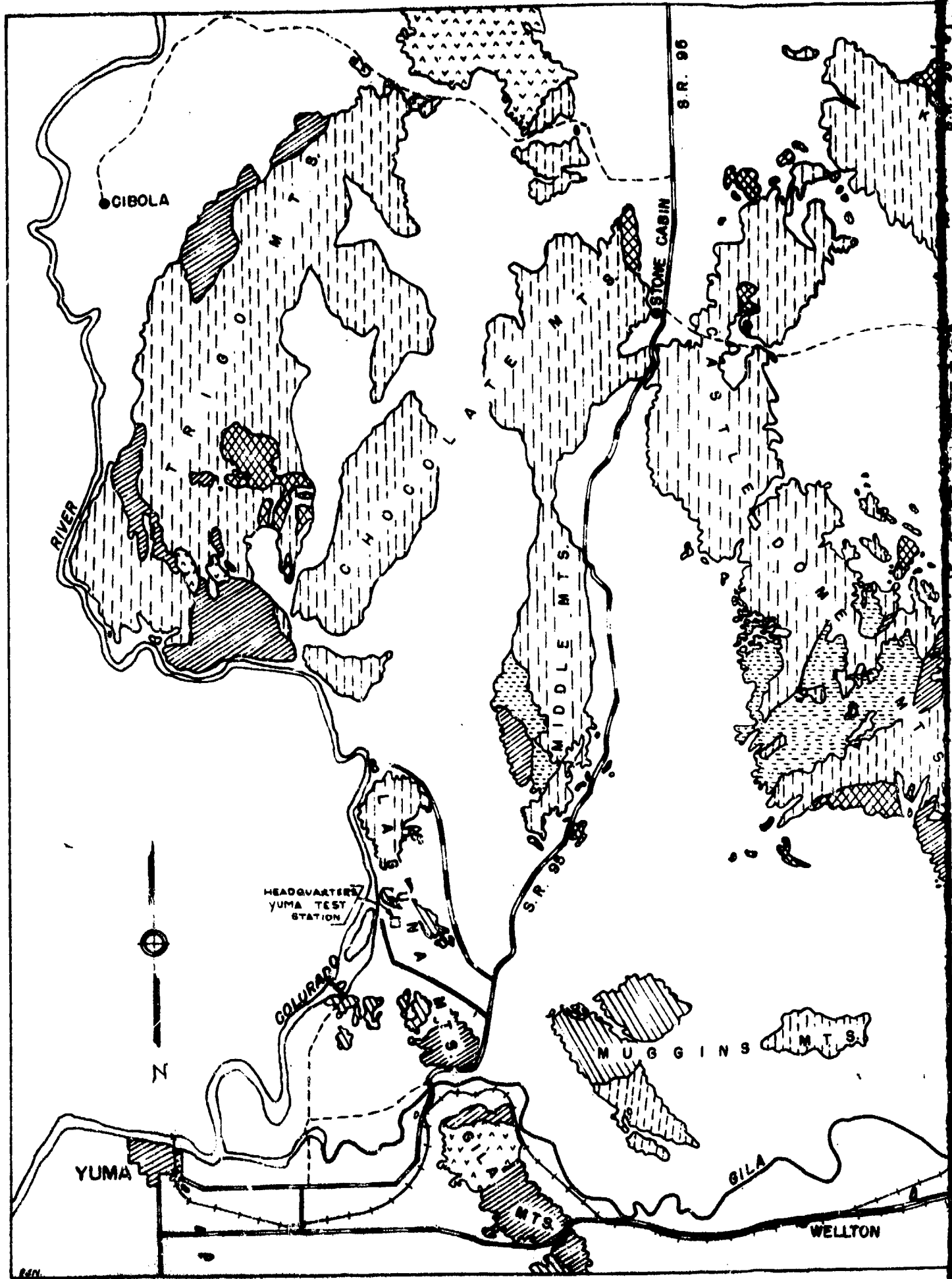
The dune area along the eastern portion of "the Trough" is one of the finest examples of massive sand dune formations to be found on the North American continent. This area called the "Sand Hills" is being used for tests by the Yuma Test Station because no large expanse of dune sand exists within the Yuma Test Station east of the Colorado River.

#### Geology

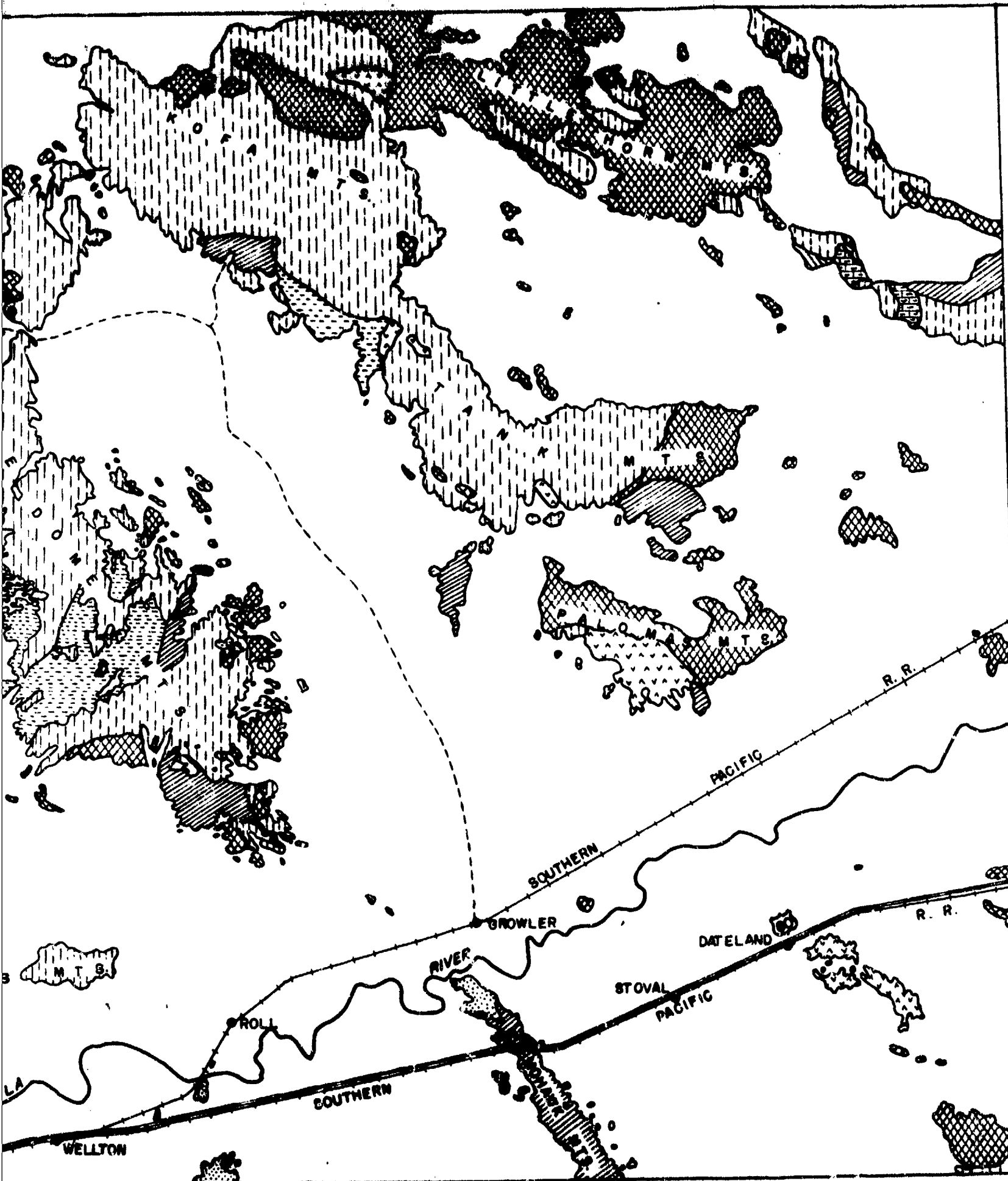
Exposures of bedrock are limited to the ranges proper and to the pediments at their margins. Examples of each of the major rock classes (igneous, sedimentary and metamorphic) are exposed in the area.

Stratigraphy. The stratigraphy of the area has never been studied in great detail. The outlines of stratigraphy presented here are based on maps accompanying the Arizona Bureau of Mines Bulletin No. 134, "Geology and Mineral Deposits of Southern Yuma County, Arizona." (23) A portion of the map from this report has been reproduced as Figure 5. Included in the area are rocks of pre-Cambrian to Mesozoic, Tertiary, and Quaternary-Tertiary ages. The vast majority of the area is mantled by Recent alluvium which has considerably impeded stratigraphic studies.

Lithology. Of the pre-Cambrian to Mesozoic deposits, metamorphosed igneous and sedimentary rocks are the most widely recognized. Considerable masses of granite have a dominant place in the area. The former are usually mapped as schists and gneisses, and the schists are generally older than the gneisses.







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PACIFIC

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GROWLER

DATELAND

R.R.

STOVAL

PACIFIC

ROLL

SOUTHERN


RIVER

WELLTON

M.T.S.


### LEGEND

#### QUATERNARY AND TERTIARY

 GRAVEL, SAND AND SILT; ALSO MARINE MIOCENE OR PIOCENE BEDS IN OIBOLA REGION.

 BASALT AND TUFF.

#### TERTIARY

 VOLCANIC ROCKS: MAINLY ANDESITE, RHYOLITE, DACITE, TUFF, AGGLOMERATE, AND MINOR INTRUSIVE MASSES.

 ARKOSIK SANDSTONE, SHALE AND CONGLOMERATE.

#### MESOZOIC OR TERTIARY

 CHERTY LIMESTONE AND SHALE OF GLANTON REGION.

#### MESOZOIC

 SHALE, LIMESTONE, SANDSTONE AND CONGLOMERATE.

#### PRE-CAMBRIAN TO MESOZOIC

 GRANITE

 GNEISS

 SCHIST

#### ROADS

 PAVED

 UNPAVED

### GEOLOGIC MAP

of the

### YUMA TEST STATION AREA

from

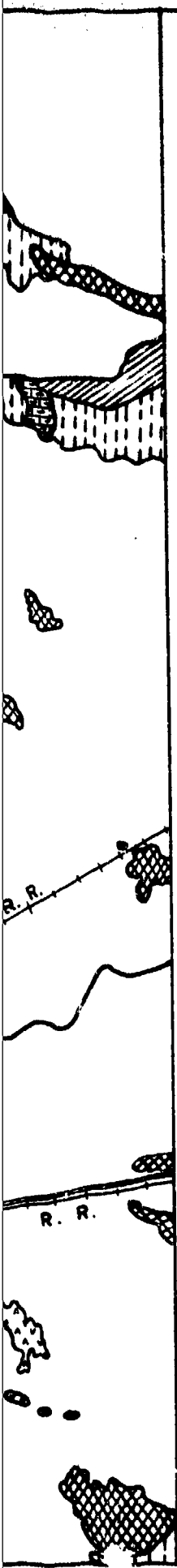
"GEOLOGY AND MINERAL DEPOSITS OF SOUTHERN YUMA COUNTY, ARIZONA"

BY ELDRED D. WILSON  
ARIZONA BUREAU OF MINES, 1933

SCALE



SURVEYED IN 1929-1932



Some local sedimentary rocks have been assigned to the Mesozoic; they consist of shales, limestones, sandstones, and conglomerates. These are localized in the southwestern part of the Middle Mountains and the Castle Dome Mountains and to the central west portion of the Kofa Mountains.

Two groups of tertiary rocks are recognized. There are the volcanics which consist mainly of andesite, rhyolite, dacite, tuff agglomerate and minor intrusive masses. These materials make up the bulk of the ranges lying north of the Gila River. To a lesser degree Tertiary beds of arkosic sandstone, shale and conglomerate are found almost exclusively south of the Gila River.

There are local beds of basalt and tuff in the ranges which are assigned to Quaternary or Tertiary. The vast majority of the area constituting the plains are gravels, sands and silts of Quaternary or Tertiary origin. In the Cibola region marine beds exist that are either Miocene or Pliocene in age.

Structure. The attitude of the exposed rock is highly variable, and most structural forms may be found. The major exception is that of folding which seems to be nearly absent. Slight folding exists as may be expected near fault planes.

The absence of large-scale folding indicates that the metamorphic rocks have been formed by regional compression of their precursors. The lamination of the metamorphics indicates that this compression acted in a northwest or southeast direction.

Most of the present day ranges appear to be horsts or fault blocks with associated grabens forming the base for the plain areas. Practically all formations of rocks from pre-Cambrian to Quaternary have been faulted

at one time or another. The major faulting appears to have occurred after the early Tertiary lava flows, and there is evidence of renewed uplifting as late as Quaternary which has raised and exposed pediments and mountain valleys. The older periods of faulting have produced marked monoclinial tilting while the more recent activity has tilted the Quaternary basalt flows less than ten degrees.

Most of the faults have very steep dips, and there is a conspicuous absence of faults of reverse character. The amount of movement varies from a few feet to several hundred feet.

#### Hydrology

In 1923 the U. S. Geological Survey published Water-Supply Paper 498: "The Lower Gila Region, Arizona." (18) This gives a geographic, geologic, and hydrologic description of the area around the Yuma Test Station.

Ground Water. The best source of ground water is in the valley fill materials, particularly along the Colorado and Gila River Valleys. Some ground water has been found in all the valleys that were prospected prior to 1923 (18). As practically all the valleys in the Yuma Area are open, the ground water drains slowly out of them into the Colorado or Gila valley, instead of being stored as they would in enclosed basins.

Surface Water. The Colorado River is the only permanent stream in southwestern Arizona. It furnishes an adequate source of water for extensive irrigation and water supply. The water for the great irrigation system of the Imperial Valley of California is taken from the Colorado at the Imperial Dam and carried seventy miles through the All-American Canal into the Salton Basin. For many years the region in the vicinity of Yuma has been irrigated. In 1952 the Wellton-Mohawk Canal was opened. This canal carries water for some distance up the Gila Valley to fields

which are now being leveled for irrigation. A hundred miles north of Yuma at Parker Dam the Colorado River Aqueduct carries much of the municipal water supply to Los Angeles.

There has evidently been a considerable change in the character of the Gila River during the last several hundred years. Early explorers write of the Gila that contained considerable water. Father Kino in 1700 reported that all the inhabitants near the present town of Wellton were fishermen, fishing being their main occupation all the year. In 1846 Emory wrote of the Gila a hundred yards wide with much vegetation and game along its banks, and he contrasted the sea-green waters of the Gila where it flowed into chrome-colored hue of the Colorado. In 1849 a flatboat made the trip down the lower Gila to Yuma. In 1889 near Powers Butte, which is about 100 miles east of Yuma, the river had a well-defined channel with clear water five or six feet deep, containing many fish.(25)

In his report which was published in 1923 (25), Ross wrote that fish, although not plentiful, still existed in the Gila River and that "the river can be forded by horses in many places in this vicinity (Wellton) without difficulty except during times of unusually high water." He pointed out that the flatboat of 1849 could not be floated with passengers down the river at any season in 1923 because during floods the current is too swift and there is insufficient water during the rest of the year.

This resume of the recent history of the Gila River has been included to show how much the Gila has changed during the short time that Arizona has been settled. Most of the course of the lower Gila is now dry throughout the year. Green vegetation and occasional pools of water are found

near the McPhaul bridge, which is close to the valley of the Colorado. Undoubtedly, the chief cause of the absence of water in the lower Gila today has been the construction of several dams and vast irrigation systems to the east. The possibility of floods still exists, however; in 1949 the lower parts of Yuma were flooded by waters from the Gila, which resulted in considerable damage to the business district.

It is common to find water in depressions in the rock along the rivers in the Southwest. Water can often be found by digging into the sands of the dry river bed.

The only other source of surface water is that associated with the natural rock tanks that are found in the mountains. The largest tanks are those that are due to irregularities in the rocky beds of streams, particularly the plunge pools at the foot of falls. Some of these are ten to twenty feet in diameter and three to ten feet deep. These usually contain water except during extremely dry seasons. The locations of these tanks were shown on signs posted along the routes or trails many years ago as they were sources of water for drinking and for automobile radiators.

In June 1954 the Purdue field party visited Horse Tanks in the Castle Dome Mountains and found the largest one empty. A small cleft in the rock did contain a small amount of water. McPherson Tank was completely dry at the time it was visited.

#### Climate:

The Yuma Test Station is situated in one of North America's most pronounced desert areas. Here the climate is characterized by intense heat in summer and warm winters with occasional sharp chills. Long periods of aridity are separated by violent storms which often yield cloudburst rainfalls.

A rather thorough analysis of the climatic data for the Yuma Test Station has been presented in the "Handbook of Yuma Environment" (28). Only a brief summary of climatic conditions will be included here. The long-term averages are those from the Weather Bureau Station in Yuma, which is less than twenty miles away. Temperatures at the Test Station average about a degree lower than those at Yuma.

Precipitation. The average annual rainfall at Yuma is 3.38 inches. Of all the official Weather Bureau stations having data listed in "Climate and Man" (27), only Greenland Ranch in Death Valley and several towns in the vicinity of the Salton Sea have a lower annual rainfall. The average distribution of precipitation in inches at Yuma for a period of 71 years is as follows (28):

January	0.39
February	0.41
March	0.32
April	0.09
May	0.03
June	0.01
July	0.19
August	0.57
September	0.40
October	0.27
November	0.23
December	<u>0.47</u>
Annual	3.38

Although these are average values, it should be borne in mind that there are many extremes. Areas may go for many months more without rainfall and then be deluged by a great cloudburst.

During 1953 the rainfall was extremely low at Yuma; there was only 0.31 inches of precipitation recorded during the entire year by the Yuma Weather Bureau, which is a record minimum for the location. Records show that 0.53 inches fell at the Test Station during the year.

Rainfall is the least during April, May, and June. Summer precipitation almost always occurs as local thunderstorms. During the winter, general rains over a large area are more likely to take place.

Humidity. The relative humidity is generally low at Yuma. A 25-year record shows that the average relative humidity at 5:30 A.M. is from 50 to 60 percent, except in August and September when it averages 65. At this time the humidity should be near the daily maximum, whereas the humidity at 5:30 P.M. should be only a little above the minimum. At 5:30 P.M. the average is about 15 percent during April, May, and June, between 25 percent and 30 percent from July to November, reaches 35 percent in December, and decreases during the winter until it drops to 20 percent in March. The average annual evaporation at the Yuma Citrus Station is 120 inches, which is more than thirty times the yearly rainfall.

Temperature. The area of southeastern California and western Arizona, from Death Valley to Yuma, is the hottest part of the United States. Death Valley has the highest temperatures in the nation and is the only location where the temperatures consistently exceed those at Yuma and several other towns in this area.

Southwestern Texas is probably the next hottest section of the country, but a check of the records shows that temperatures at Presidio and Del Rio are significantly lower than those in the Yuma-Death Valley area.

A summary of monthly temperature data at Yuma is given in the following table (28).



TEMPERATURES IN DEGREES (F.)						71 YEAR PERIOD							
Yuma	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Abs Max	84	92	100	107	120	118	120	119	123	108	97	83	123
Mean Max	67	72	78	87	93	102	106	103	100	88	77	66	
MEAN	56	59	64	70	77	85	91	90	86	73	62	56	
Mean Min	42	46	49	53	60	67	78	78	78	58	48	43	
Abs Min	22	25	31	38	39	50	61	58	50	38	30	22	22

During the summer, soil temperatures at Yuma often exceed 140 degrees in the afternoons. At night they usually drop to about 80 degrees.

Sunshine and Cloudiness. Records show that Yuma receives 90 percent of the possible sunshine for the area. Data from 180 cities throughout the United States shows that Yuma leads the nation in this respect. Other leading cities and the percentages of possible sunshine that they receive are: Phoenix 84%, Fresno 80%, El Paso 79%, Los Angeles 72%, Salt Lake City 69%, San Diego 68%, Tampa 67%, Denver 67%, and Miami 66%. Yuma has an average of 294 clear days a year; 55 days are partly cloudy, and 16 days are cloudy.

Winds. The wind speed at Yuma averages about 5 or 6 MPH throughout the year. During the fall and winter the winds are from the north, in the spring the westerly winds are dominant, and during the summer the winds are predominantly from the south.

#### Relation to Deserts of the Southwestern United States.

Most of the western portion of the United States has arid or semi-arid climatic conditions. In particular, the regions between the Rocky Mountains and the Coastal Ranges are noted for low annual precipitation. The most extreme conditions extend from Central Washington southward

through Oregon, California, Nevada, Utah and Arizona into Sonora and eastward into New Mexico and Texas. The map, Figure 6, shows the extent of arid and semi-arid regions of the United States (21). Boundaries on this map are based on the precipitation-evaporation indices, which are computed on the effectiveness of precipitation as evaluated in terms of the temperature at the time it occurred.

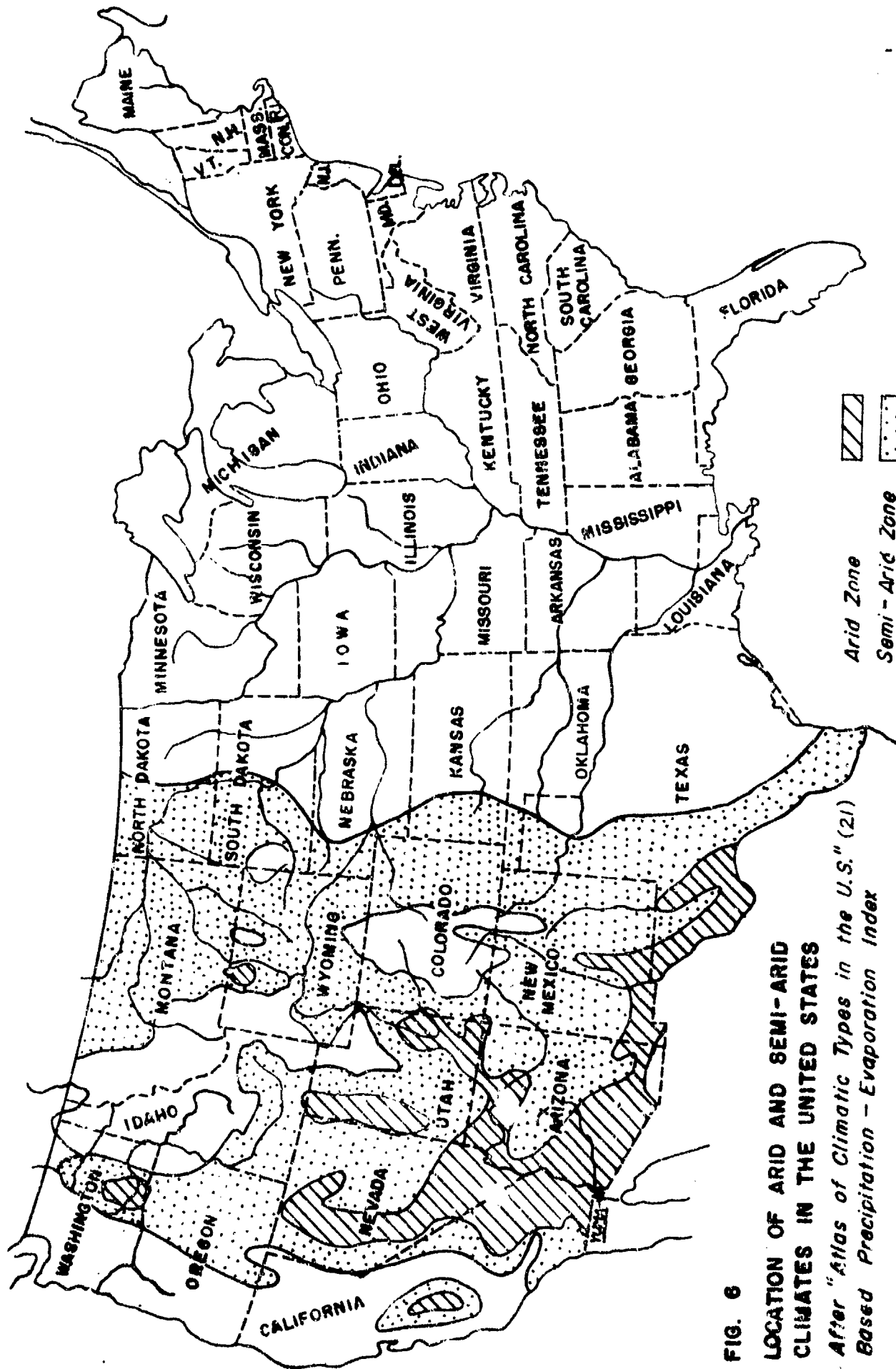
Arid conditions in the West are the result of several natural processes. As air masses move eastward from the Pacific Ocean, they lose most of their moisture on the western slopes of the mountain ranges along the Pacific coast. Inland ranges remove still more moisture from the air, creating a rain shadow.

This rain shadow is found on the eastern slopes of all the mountains in the western United States. In central Washington and central Oregon the annual precipitation averages about ten inches. In western Nevada, eastern California, and western Arizona it is five inches or less.

The major deserts of Arizona and southern California are shown on the map in Figure 7, which was taken from "Deserts" by Gayle Pickwell (17).

Sonoran Desert. The Sonoran Desert is the name used to refer to the great desert area of northwestern Mexico and portions of Arizona and California. It includes the Yuma Test Station. The term is usually used to include the Colorado Desert, the Yuma Desert, southwestern Arizona, northwestern Mexico and other locally named areas. A search of the literature reveals that none of these smaller deserts includes the Yuma Test Station Area.

Yuma Desert. On many maps the Yuma Desert is shown in the extreme southwestern corner of Arizona. It appears, however, that the Yuma



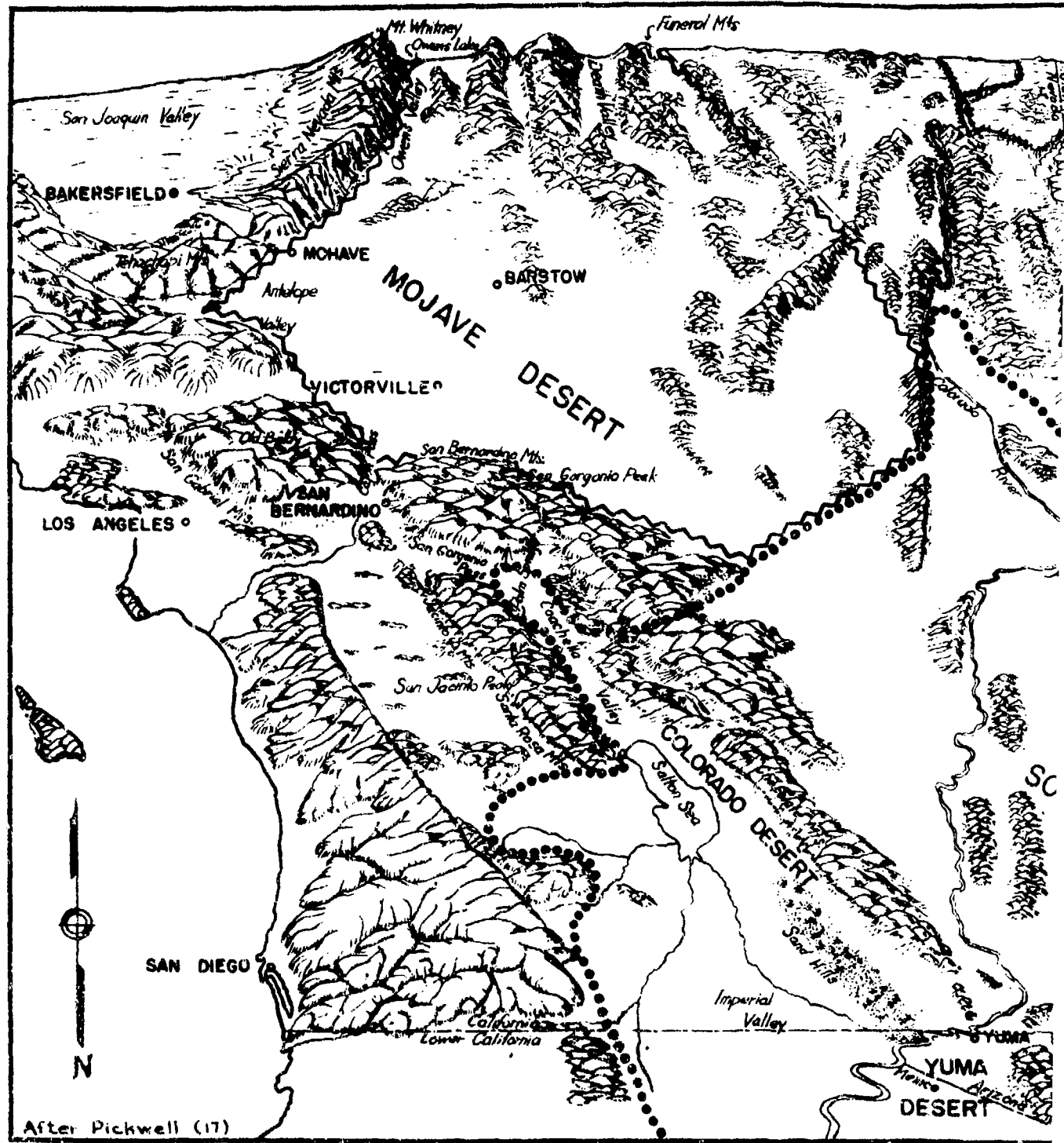
**FIG. 6**  
**LOCATION OF ARID AND SEMI-ARID**  
**CLIMATES IN THE UNITED STATES**  
*After "Atlas of Climatic Types in the U.S." (21)*  
*Based Precipitation - Evaporation Index*

Desert occupies the area south of the city of Yuma and U.S. Highway 80, between the Gila Mountains and the Colorado delta. No references have been seen which would indicate that it includes any part of the Test Station.

Colorado Desert. According to W. P. Blake, who explored and named the region in 1853, the term "Colorado Desert" was originally applied to "The typical desert area of the lacustrine clays and the alluvial deposits of the Colorado where extreme desert conditions prevail, such as arid, treeless plains, old lake-beds, and sand hills -- such conditions as are found in the Sahara of Africa and in the delta regions reached by the deposition of the silt of the Colorado, whether in the form of deltas or at the bottom of ancient lakes. I should also include the bordering detrital slopes from the contiguous mountains. So restricted, the area is practically coterminous with the ancient beachlines and terraces of the lakes which occupied the valley" (12, p. 6).

These limits include the areas below the beach lines along the Salton Basin and the alluvial deposits northward along the Colorado River to the Imperial Dam. This excludes the Sand Hills and all the Yuma Test Station except the western edge which is along the river.

Later writers have often extended the Colorado Desert to cover the rest of the southeast corner of California, including the Sand Hills and the Chocolate Mountains. It has not been used to include any of Arizona, however, except a narrow strip along the river below Imperial Dam that is considered as a part of the Colorado delta.



..... Approx. Limits of Sonoran Desert

~~~~~ Approx. Limits of Mojave Desert

## DESERTS OF SOUTHWEST

Figure 7



ERTS OF THE  
THWESTERN UNITED STATES

Mojave Desert. The Mojave Desert is a northern extension of the Sonoran Desert. It includes that part of the desert in southeastern California which is north of the Colorado Desert and also the southwestern corner of Nevada. Except for a small area along the Colorado River, there is no external drainage from the Mojave. It includes many playas and mountain ranges. It is bounded on the west and south by the Sierra Nevada, San Gabriel, and San Bernardino Mountains, and a rather indefinite boundary with the Colorado Desert. Just inside Nevada the distinctive characteristics of the Mohave begin to disappear, and the Nevada Desert of distinctive basins and ranges emerges.

Death Valley. Death Valley is a part of the Mojave Desert, but it bears special discussion since it presents the desert under its most extreme conditions in the United States. Much of Death Valley is below sea level, the lowest point at Badwater being 280 feet below sea level. During the summer it is the hottest place in the United States, and for several years it held the record of 134 degrees for the highest officially recorded temperature in the world. The present world record is 136 degrees at Azizia in Libya.

Temperatures at Death Valley frequently exceed 120 during the summer, but they seldom reach 125. Averages for 36 years show that during July the temperature reaches 115 or higher on 17 days; they reach 120 or higher on 6 days; and it gets to 124 or above on 1 day. It exceeds 125 degrees once in seven years.

The mean July temperature is 102 degrees. In July 1953 the average of the daily maximum temperatures was 117.4 degrees. The mean temperature in January is 52 degrees.

The average annual precipitation in Death Valley is 1.49 inches, which is probably the lowest in the United States. By desert standards, however, Death Valley is well supplied with ground water. There are a number of springs that furnish water that is suitable for drinking. Moisture can usually be found by digging only a few feet.

#### LAND USE

Except for testing purposes, little use has been made of most of the land in the Yuma Test Station. This is also true of the surrounding area outside the limits of the Test Station. The Kofa Game Range and Imperial Wildlife Refuge have been set aside as a refuge for wild life, and activities in the Range are limited by the Department of the Interior.

There are small areas of irrigated fields at the southern edge of the mapped area along the Colorado and Gila Rivers. The irrigation system is very extensive to the south of the limits of the Yuma Test Station Area. The irrigation program is being extended along the Gila River since the opening of the Wellton-Mohawk Canal in 1952.

Mountains consist mainly of bare rock, and vegetation on them is extremely sparse. Most of them are so rugged that they are of no economic value except for the minerals that may be found in them. There are a number of mines in the mountains, although a few of them are in the hills adjacent to the mountains. Many of these mines that were actively operated fifty years ago have been abandoned and are no longer in operation.

Some grazing is permitted in the area, but very few cattle are seen except along one river where there is considerable vegetation.



#### ROAD AND TRAIL NETWORK

State Road 95, from Yuma to Quartzite, crosses the area from south to north and provides the main route between the Test Station and Yuma. It is the only paved road that crosses the area. Access to Yuma is also possible by crossing the Colorado River at the Imperial Dam, then recrossing at Yuma. This route is several miles shorter than going by S. R. 95, although almost half the route is not paved.

U. S. Highway 80 lies just south of the southern edge of the mapped area except where it crosses the southeast corner of the map through Stoval.

There are a number of unimproved roads and trails traversing the Yuma Test Station Area. Most of these are the roads that connect the old mines with the towns, railroad stops, and Colorado River stops of earlier days.

A few years ago the main road between Yuma and Quartzite connected Dome and several of the mines on the west side of the Castle Dome Mountains. The route traversed a pass in the Castle Dome Mountains then closely followed the present route from Stone Cabin to the north. At present travel on this road is restricted to small vehicles with four-wheeled drive.

Several roads from stops along the Southern Pacific Railroad extend northward and meet on the Kofa Plain and provide access to mines in the Kofa Mountains and a route to Stone Cabin. Most of these can only be traversed with four-wheeled drive vehicles.

There is a paved road from S. R. 95 to Castle Dome Landing. An unimproved extension of this road extends northwestward through the Trigo Mountains and goes to Cibola. This, too, is a road usable only by vehicles with four-wheeled drive. The best route to Cibola is the road that heads west from S. R. 95, about five miles north of Stone Cabin. This road is well maintained and can be used by ordinary passenger cars.

Many of these old roads through mountain passes and dry washes are passable only in trucks or vehicles with four-wheeled drive because of loose sand, loose gravel, washouts, rough terrain, boulders, and deep ruts. Ordinary passenger cars cannot be used on many desert roads.

Large areas of desert pavement are easily traversible even though there is not a regular road across them. The desert pavement presents a smooth, firm surface that allows the passage of almost any vehicle (see Figures 17 and <sup>19</sup>23). Slight difficulty may be encountered in crossing shallow washes. Where the washes are deep, cross country travel is restricted. From the air, the tracks of a single vehicle can often be seen extending for miles across the desert pavement.

#### YUMA TEST STATION AND TEST PROGRAMS

The Yuma Test Station is a military base under the command of the Sixth Army. The mission of the Station is to provide facilities and support for the teams of the various Technical Services in testing the performance of military equipment and personnel under desert conditions.

An operating staff of both military and civilian personnel is maintained throughout the year. Facilities are available for the use of test teams and research groups who are authorized to work at the Station. These facilities include quarters, mess facilities, transportation, office space, and many types of equipment.

The Yuma Test Station was originally established during the World War II; the main area at that time was situated on the flood plain just below the Imperial Dam. It was relocated shortly after the war to its present location. Operations were suspended for a period of about two years, but the Station was reactivated in 1951. At the present time additional facilities are being constructed for the accommodation of more personnel.

The Technical Services of the Army send test teams to the Yuma Test Station for conducting tests on equipment and personnel relative to their particular type of activity. Several teams are stationed at the Station throughout the year, but some of the teams operate at Yuma for only several months during the summer. Most of the work at the Test Station is being conducted to determine the performance of equipment under desert conditions, but there is some routine testing that is not concerned with the environmental conditions.

An aerial view of the Headquarters Area is shown in Figure 8. The administrative offices, housing facilities, and service facilities are located here. Figure 9 shows Laguna Airfield and the Research and Development Area, which is shown on Plate I as the R and D Area about three miles southeast of the Headquarters Area. Most of the test teams have office space and other facilities available in the Research and Development Area, although much of their activities are conducted on courses and ranges in other parts of the Test Station. The Laguna Airfield has two paved runways which are approximately 6900 and 4700 feet in length. During 1954, an L-19 observation plane and an H-23 helicopter were available for use by personnel working at the Station.

Some of the activities of the various test teams at the Yuma Test Station are described briefly on the following pages. This information was obtained from interviews with members of the test teams. There was no team from the Transportation Corps at Yuma when the Purdue field parties were there.

#### Signal Corps

The Signal Corps has had a test team at the Yuma Test Station for the past three summers. The Signal Corps also operates a meteorological station at Y.T.S. throughout the year.

The Signal Corps team tests radio and land line carrier equipment, meteorological instruments and shelters, and mobile enclosures. The personnel are interested in climatic and environmental conditions and how these conditions affect their equipment. They are not interested in the soil or rock type except as it may affect the grounding of their circuits.

Erratic results have been obtained from some of the equipment tested at Yuma. The terrain has more effect on the use of radio equipment than was anticipated. FM is generally used for military radio, but it does not work well at Yuma because of the topography and the dryness of the ground.

The testing is done primarily to observe the performance of equipment under desert environmental conditions. Practically no routine tests are run on equipment at Yuma by the Signal Corps. The effect of dust on the operation of equipment has been found to be important. A dusty area east of Ogilby in California is used to study this problem. Although some "isolated tests" have been conducted at other sites in deserts in the United States, most of the desert testing is done at Yuma. Some testing has been done on photographic material -- effects of temperature, effects of storage of film, etc.

A micro-meteorology study is planned to start in 1955 to last from 1½ to 6 years. One hundred temperature masts at various heights are to be placed in a square-mile area. Continuous readings will be made at various heights and under other specified conditions. The data will be evaluated by personnel of the Massachusetts Institute of Technology.

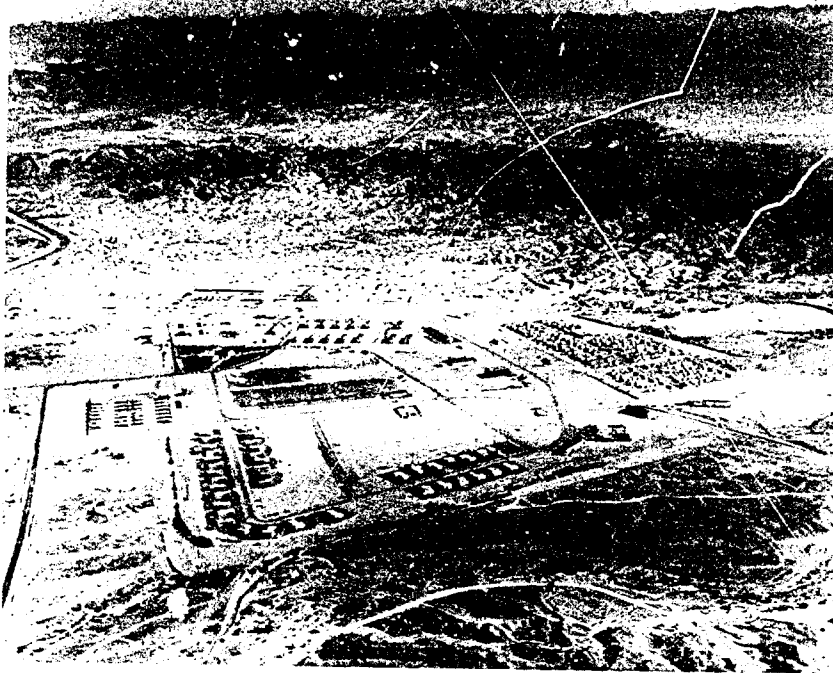


Fig. 8. Headquarters Area of the Yuma Test Station, Looking northwestward.



Fig. 9. The Research and Development Area with Laguna Airfield in the Background.

Chemical Corps

A Chemical Corps test team has been at the Test Station since August, 1952, and has personnel at the Station all year. A four-year program was originally set up, and it has been extended for another four years, so the program is currently planned until 1960.

Practically all the work is concerned primarily with the effects of desert conditions on chemical warfare activities. There are no limitations on the operation of the test team because of environment. In fact, desert areas are well suited to the routine testing activities of chemical warfare agents, although most of this is done at proving grounds in the east at the present time.

All chemical agents and decontaminating agents that the Chemical Corps has developed have been tested at the Yuma Test Station. The Chemical test team has several primary activities at the Test Station:

- (a) To test the various chemical agents, decontaminating agents, mixtures, and fuels.
- (b) To determine the use, detection, and consistency of various agents.
- (c) To determine the effect of the storage of chemical warfare agents in the Yuma area.
- (d) To test equipment that is used in chemical warfare activities.
- (e) To determine if CW teams can operate in the terrain around Yuma.

The Chemical Corps also conducts some tests at Dugway, Utah. The test area there is a marshy flat with a salt crust. Precipitation is only about five inches per year, but Dugway does not get the long, hot summers that Yuma does. There is also some biological warfare testing done at Dugway, which has not been done yet at Yuma.

### Quartermaster Corps

The Quartermaster Corps test team is interested in the desert environmental conditions as they affect the soldiers, their uniforms, and their equipment. For example, they are working on load-carrying and foot problems, such as: energy expenditure tests, determination of pack shifting, human trafficability, swelling of feet and its effect on footgear, absorption of heat through the feet, and the absorption of solar radiation heat.

The color of the uniform has been a subject of study. Tests have been made to determine if uniforms of different colors have significant effects on bodily functions of the soldier. A current test is being run on the fungicidal treatment of leather. A petroleum laboratory, operated by the Quartermaster team, acts primarily as a support group for the Ordnance testing.

### Corps of Engineers

The Engineer climatic test team is a unit that operates at Yuma throughout the year. Its work is concerned primarily with the effect of desert environment on engineering activities and equipment.

The team is interested in various surface types as sites for locating test tracks. One recent project was to determine some of the effects of dense clouds of dust that were blown over moving vehicles by mobile "dust machine". Another test was to determine the performance of engineering equipment under overloaded conditions. The team also acts as a service unit for other Engineer test groups that visit the Station periodically. For example, the team runs all the soil tests that are made, and the personnel contributed invaluable assistance in obtaining field data for this report.

### Ordnance Corps

The Ordnance test team started operations at the Yuma Test Station in the summer of 1951. It was originally set up to test equipment and personnel under the extreme desert conditions during the summer, but operation is now continued throughout the year. Many of the projects at Yuma have no direct relation to the desert environment, for example: acceptance tests of arms and ammunition produced on the West Coast, and quality control of automotive equipment manufactured or stored on the West Coast. The tests on arms and ammunition are made at the Artillery Range (Figure 14).

Several of the environmental features that affect the use of ordnance equipment are listed below:

- (a) Dust and sand "gum and abrade" the equipment, which shortens the operational life.
- (b) Washes and loose sand surfaces affect mobility.
- (c) Slopes and other surface conditions are important.

During each of the last two summers a group from the Yuma Test Station has been sent to Death Valley for several weeks for some special tests during the period of the highest temperatures. A course was laid out over terrain that changes from low to high elevation in a short distance, with accompanying changes in temperature with elevation. Vehicles are given a gruelling run for 2000 miles.

The Ordnance team has set up a number of test courses for observing the performance of vehicles under various conditions: the Miggins Mesa test track (Fig. 12); a flat cross-country course at the north edge of the Laguna Mountains (Fig. 11); a new hill test course for track-laying



vehicles that was being laid out in the summer of 1954; a vapor lock course; a mid course about  $1\frac{1}{2}$  miles south of the Headquarters Area that can be flooded from the canal; a hill course northwest of the Research and Development Area (Fig. 10); a tank dust course which crosses one corner of the hill course, and a dynamometer course (Fig. 13). In addition, a route across the Sand Hills and the artificial sand slopes (Fig. 15) are used for testing vehicles on loose sand.



Fig. 10. The Hill Course that is located northwest of the R. & D. Area at Loc. 363.7 - 74.3.



Fig. 11. The Cross-Country Course at the north edge of the Lagunas at Loc. 363.4 - 74.3.



Fig. 12. Miggins West Test Track, looking southwest at Loc. 363.2 - 75.0, with the Miggins Mountains in the background.



Fig. 13. The Dynamometer Course at Loc. 364.3 - 74.8. This view, looking northeastward, also shows S. R. 95 and Castle Dome Peak.

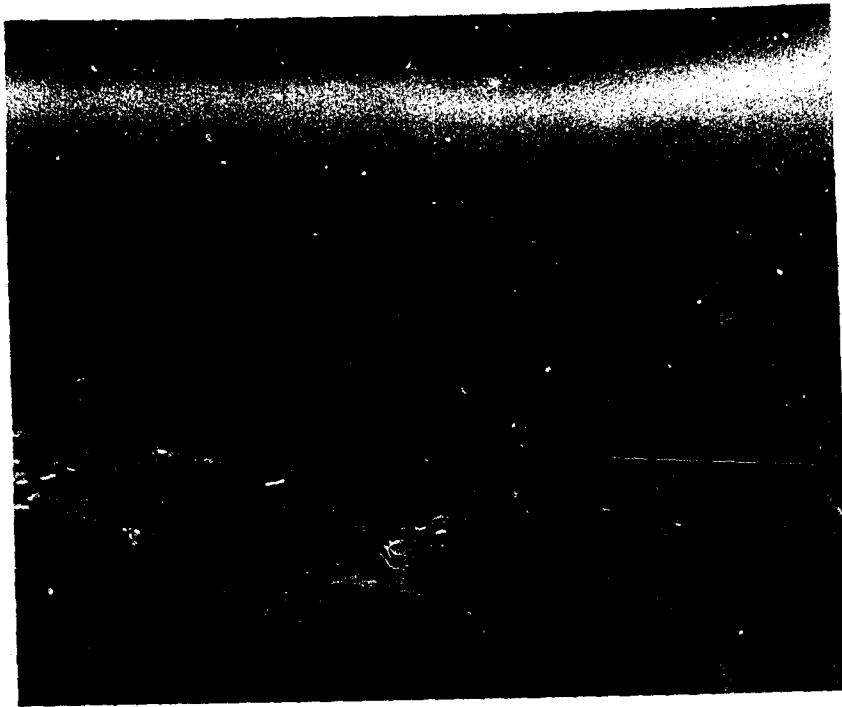


Fig. 14. View looking east at the Artillery Range. The buildings are at Loc. 363.9 - 75.0.

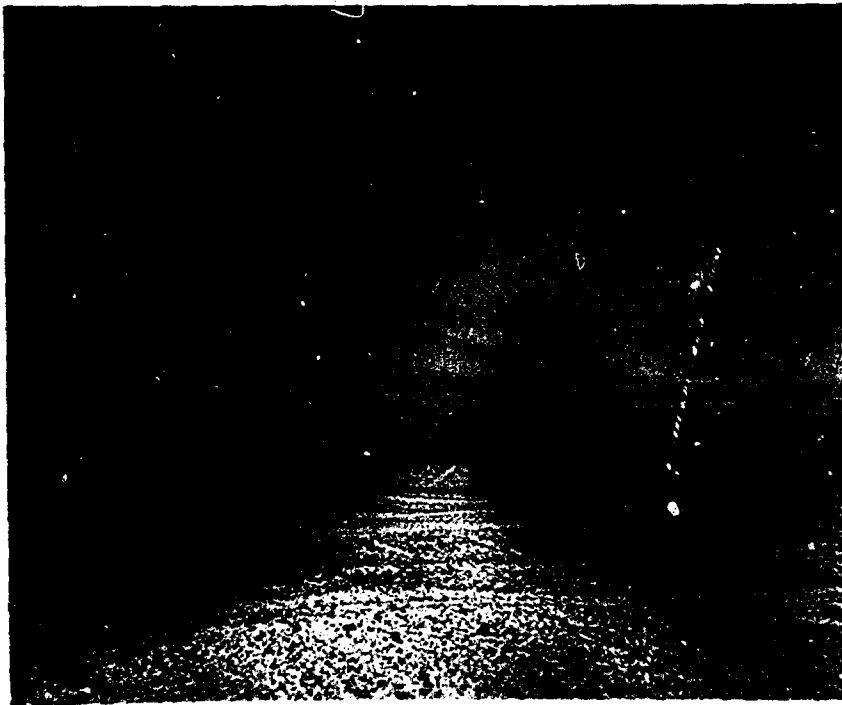


Fig. 15. The artificial sand slopes (Loc. 363.3 - 74.5) were prepared by bull-dozing the sand from the plain into a hill.

## CHAPTER II

### CLASSIFICATION OF YUMA TERRAIN

The Yuma Test Station Area has been covered rather thoroughly in the field, and aerial photographs of the area have been studied carefully. The area has been classified primarily on the type of the land form as a basis for discussing the natural features in this report.

#### SCOPE AND PERSPECTIVE

This report and the classification of surface features is essentially limited to the Yuma Test Station Area, which is that area covered by the set of 32 photo maps which was issued by the Army Map Service in 1953, and the Sand Hills in Imperial County, California.

In this chapter the major environmental conditions and terrain features are described. Features such as land forms, surface conditions, and vegetation are discussed as separate subjects. In the following chapters these various features are related to the land form units which are used as a basis for mapping the area. The land form units are introduced here, but in subsequent chapters they are described in detail and correlated with the other environmental features.

#### BASIS FOR CLASSIFICATION AND MAPPING

The land form is used as the basis for classifying the area. The three major land forms in the Yuma study area are mountains, hills, and plains. These are sub-divided into more specific forms that are described in considerable detail.

The one thousand meter universal transverse mercator grid system, which is superimposed on the photo-maps, has been used for control in preparing the maps for Plates I <sup>and II</sup> ~~III~~. Zones 11 and 12 meet near the

center of the plates and overlap at a slight angle to each other. The scale of the plates (~~1 to 125,000~~) was selected so the plates would be large enough to show considerable detail, but the <sup>plates</sup> ~~folie~~ would be small enough to be easily used.

The coordinates, using this grid system, are often used in the text to locate illustrations and sites. The first number is the vertical reference, and the second is the horizontal reference.

#### RELIEF-LAND FORM UNITS

The major physiographic units have been subdivided into a number of types and assigned the more common land form names. It should be kept in mind that there are many land forms associated with deserts which will not be discussed. Only those which are known to exist within the limits of the Yuma Test Station Area (plus the Sand Hills) are considered in this report. It is the purpose of this section to define and outline the broad character of the major units. The land form types comprising the major units are briefly discussed here and will be taken up in greater detail in the succeeding chapters.

The land forms of the Yuma Test Station Area have been mapped on Plate ~~II~~<sup>I</sup>. The relative degree of dissection is also shown.

An arbitrary distinction had to be made in a number of cases on whether to classify an area as mountains or hills. Generally, if the land mass was less than about 500 feet above the adjacent plain, it was classified as hills. Elevations were not available in all parts of the area, so in some cases it was estimated from the aerial photographs. The type of material making up the land mass was also considered in

making the decision on the "border-line" land forms. The mountains consist primarily of bedrock, while most of the hills are the dissected remnants of former plains that consist of unconsolidated materials.

Similar difficulties were also encountered in separating some of the hills from plains that have been well dissected. If there was a substantial portion of the original plain surface remaining, the area was classified as a plain. If dissection had progressed to the stage where there was little or none of the original plain surface remaining, the area was classified as hills.

#### Mountains

The term mountain as used in this report refers to land masses of small summit area which rise conspicuously above their surroundings. In this area it refers to those masses of bedrock exposures which rise to considerable heights above the plains surrounding them and which, due to the arid climate, are practically devoid of a soil cover.

To properly type the mountain land forms, one could get involved in many physiographic details, some of which are of little or no concern to the purpose of this report. Only four major types of mountain situations are considered here, based on their physical appearances.

- a. Rugged mountains
- b. Rounded mountains
- c. Flat-topped mountains,
- d. Single-peaked mountains

Most of the mountains at Yuma are the rugged type with steep slopes and deep canyons. There are some rounded mountains, but flat-topped mountains are almost unknown in the area. There are a number of isolated peaks, or

inselbergs. Some of these are mapped as single-peaked mountains, and the smaller ones are shown as hills.

The mountains of the area consist primarily of igneous and metamorphic rocks of various types. To a minor degree they contain sedimentary rocks. On the basis of surface exposure igneous rocks are the most widespread. The Tertiary volcanics, consisting of flows and ashfalls, appear to mantle the greatest part of the mountain situations.

The mountains of this area are associated closely with block faulting and for the most part represent horsts. Evidence of their faulted origin can be found locally, but the encroachment of alluvial material on the flanks of most ranges has buried most of the evidence which may exist. Figure 16 graphically illustrates the changes that have occurred in the topography after faulting to bring about the present condition.

Following the development of the fault scarp as shown in (a) of Figure 16, the weathered products of the block mountains are carried to the scarp base forming small fans. As the mountain gorges cut deeper, more material was carried to the adjacent plain which already is encroaching on the flank of the fault scarp, leaving truncated spurs exposed. These triangular faces eventually become buried and alluvium begins to be deposited within the gorges as the alluvial plain continued to rise (c,d). Eventually the alluvial deposits in opposing gullies join to form a narrow plain through the range as in (e). Continuous activity buries the block completely in its own debris or leaves only the highest part exposed as an inselberg or isolated peak (f).



In the Yuma Test Station Area stages (d) and (e) are the most common with stage (e) becoming more pronounced south of the Gila River valley. Almost all the isolated peaks are closely associated with adjacent ranges as shown in (e) of Figure 16.

### Hills

The term "hill" is a very elusive one, but for the purpose of this report it is necessary for describing some of the surface features in the Yuma area. As used in this report, the term "hills" refers to elevations of land of limited extent, generally rounded rather than peaked or precipitous in shape. The hills which are recognized have been subdivided into three groups:

- a. Dunes
- b. Inselbergs, buttes, and other isolated peaks
- c. Hills (Unclassified)

The dunes are sand hills that have been formed as the result of wind action. The sand dunes of Ogilby are the principal dunes located in the vicinity of Yuma. A route across these dunes is used as a test course by the Yuma Test Station. There are no dunes within the limits of the Test Station Area, although an "artificial dune" has been prepared by bull-dozing material from the sand plain into a hill at Loc. 363.3 - 74.5.

Isolated peaks, such as inselbergs and buttes, are mapped as hills when their heights are relatively low. Higher isolated peaks are mapped as mountains.

Except for the inselbergs and buttes, all the hills in the Test Station Area have been grouped into the category of "unclassified hills". These hills are usually the extremely dissected remnants of alluvial fans and aprons which have been eroded to the extent that little or none of the original surface remains.

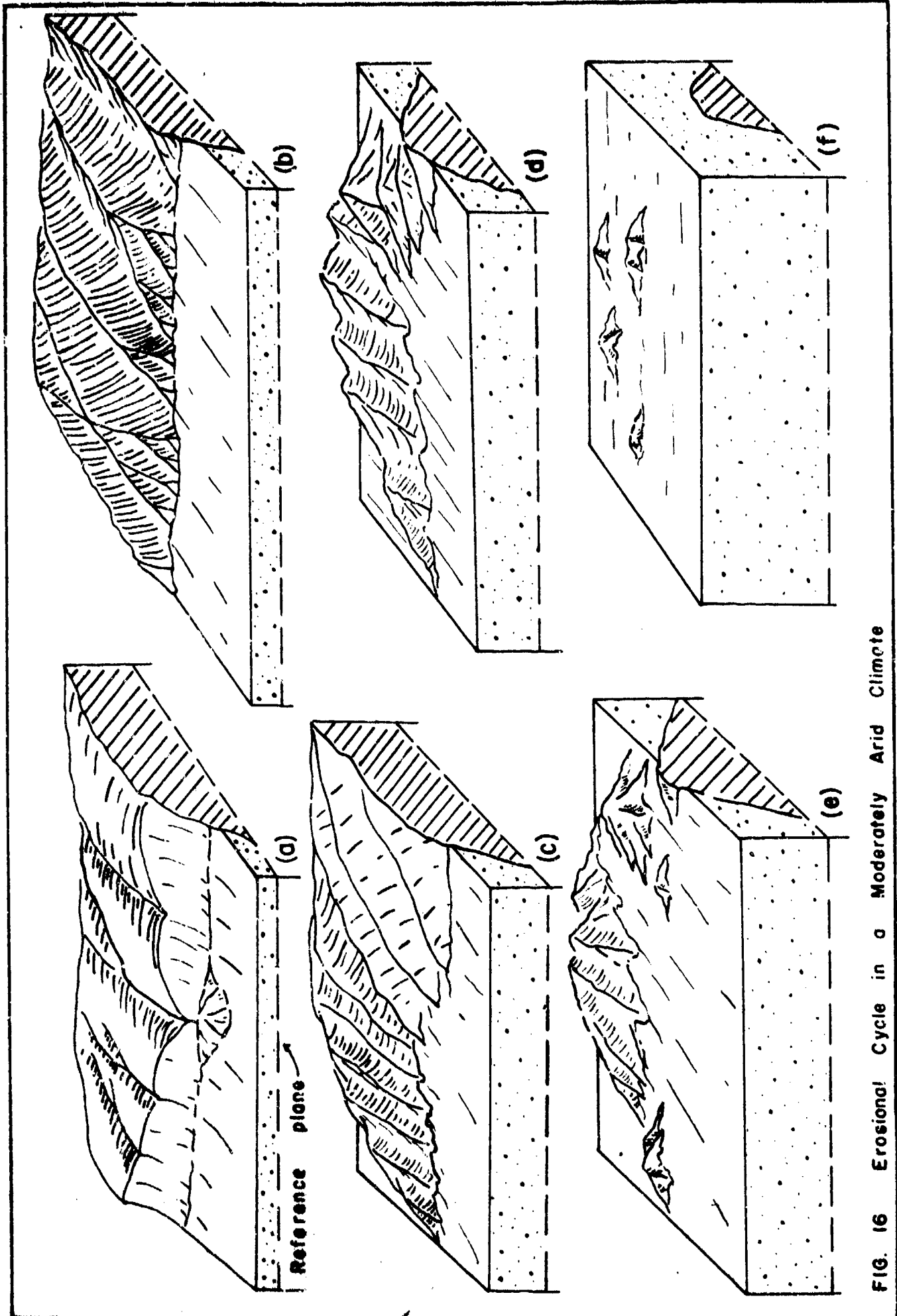


FIG. 16 Erosional Cycle in a Moderately Arid Climate

### Plains

The term "plain" in this report refers to the comparatively flat to gently undulating surfaces of the area. In using the term plain as such, no connotation is implied other than that indicated above. In the consideration of plains, subdivisions have been based partly on origin and partly on the dissection features which are associated with them in this area. Plains have been classified into the following units:

- a. Alluvial fans
- b. Alluvial aprons
- c. Terraces
- d. Floodplains
- e. Playas
- f. Washes

Although such features as alluvial fans may not be true plains in the strictest sense, they fit more nearly under the general heading of plain than under any of the other major units used. Similarly, the washes have been included under the heading "plains." They represent varying degrees of dissection, and they vary in width from a few feet to several hundred feet. They are most commonly found crossing the larger plains. Included also under this major unit are such land forms as terraces, flood plains, and alluvial aprons. Although playas are conspicuously absent, the presence of a small one south of Stoval warrants inclusion in the discussion.

The great majority of the plains of this area have had their origin in the destruction and burial of the block mountains. Again referring to Figure 16, the grabens which formed the troughs between the upthrown blocks became the resting place for the debris carried down from the

mountain heights. The abrupt reduction in gradient of streams leaving the mountains caused the debris-laden waters to deposit their load at the mountain base in the form of fans at the mouths of mountain gullies and canyons. As these fans continued to grow outwardly, they coalesced to form an apron of material about the mountain flanks. It is likely that the encroachment of such aprons from adjacent mountains produced enclosed basins or bolsons and their accompanying playas. As they continued to build up and encroach, these alluvial basins gradually filled until the material from one spilled over into the next, forming an interconnected plain from the individual basins. Today, surface drainage is practically continuous across them and would reach the Colorado and Gila valleys were the water not lost in the process of crossing the plain either by evaporation or absorption into the soil.

#### Degree of Dissection

Relief features are found in various forms that may be smooth or extremely rough. The degree of dissection of a given land form may vary considerably. Alluvial aprons may have the smooth surface of desert pavement that is broken only by occasional shallow washes, or the apron may be dissected by gullies which are deep enough to impede vehicular traffic.

The relative degree of dissection is shown on the land form map, Plate <sup>I</sup> II. Dissection is rated on the following scale:

- a. Severe
- b. Moderate
- c. Slight

Severe dissection has left practically none of the original surface remaining. Moderate indicates that there has been much dissection, the washes are at least several feet deep, but there are some flat surfaces remaining. Slight dissection means that the washes are shallow and little material has been removed, although the washes may be numerous. Some intricate patterns have been developed by some of these shallow washes. The slightly dissected surfaces are the best for cross-country movement.

#### SOILS - SURFACE CONDITIONS

The type of soil or rock that makes up the surface material and the condition in which it is found are important features. Plate <sup>II</sup> III is a map showing the soil and rock types and their methods of development, together with the degree of firmness of the surface materials.

#### Method of Development

The present condition of the soils and rocks of the Yuma area are the result of three geologic processes. The various surface materials were formed as a result of one of these methods of development:

- a. Residual
- b. Alluvial
- c. Aeolian

Some materials of very limited extent, which could not be mapped, are the result of weathering and the action of gravity. Other methods of surface development are not found in this area.

#### Soil - Rock Types

An attempt has been made to map the soils and rocks of the Yuma Test Station Area. Identification has been based on field inspections and study of the aerial photographs. Samples were taken at many sites throughout the area. Usually the borders between the soil-rock types could be drawn as a result of the study of the airphotos.

The following types of surface materials have been used as units for mapping the area:

- a. Bedrock
- b. Stony and Bouldery surfaces
- c. Gravel
- d. Sand
- e. Silt
- f. Combinations

Bedrock makes up most of the mountains. The surface of desert pavement is made up of gravel-size pebbles. When the gravel symbol on Plate ~~III~~<sup>II</sup> is widely spaced, it indicates the probability of desert pavement, in contrast with the gravel symbol which has been closely spaced in the washes. ~~The surface in several places contains~~<sup>A</sup> a chemical precipitate, usually a salt deposit, is found on the surface at several places which are too small to be mapped. Combinations of the materials listed are shown by combining the soil symbols.

#### Surface Conditions

The use that can be made of an area depends to a large extent on the degree of firmness of the surface material. This is especially true in evaluating the trafficability of the soil.

Degree of Firmness. Firmness of the surface material has been evaluated in six categories:

- a. Firm. Consolidated material, such as bedrock, has been called firm.
- b. Compact. Compact surface consists of unconsolidated materials that are well compacted and rate high on the firmness scale.
- c. Intermediate. Unconsolidated material that is not well compacted; it may be slightly soft.

- d. Soft. Material which has little supporting ability; it may be wet.
- e. Crusted. The surface has a hard, thin crust which may be underlain by soft or loose material.
- f. Loose. Material with no cohesion or little stability, such as sand, dry silt, dust.

Other Surface Considerations. Dustiness is a problem caused by the movement of very fine soil particles in the air. Strong winds pick up particles which are mostly of a silt-size and carry them to great heights and distances. The dry soil of deserts is more easily moved by the wind than soils in humid climates. The cross country movement of vehicles loosens the soil particles and raises clouds of dust along the route. Figure 51 shows the dust that can be raised by a vehicle in crossing desert pavement areas.

Dust is a serious problem for several reasons. Dust in the air decreases visibility. The dust cloud behind a moving vehicle is visible for much greater distances than the vehicle itself. Dust has been found to be harmful to the moving parts of vehicles as some of the mineral particles are extremely hard and abrasive.

Desert varnish is a dark brownish coating of iron and manganese oxides that has been formed on rock surfaces. It may be found on bedrock, boulders, or pebbles. Rocks with the dark surface may be light colored beneath the paper-thin coating of desert varnish.

Among the theories regarding the development of iron and manganese oxides on the rock surfaces are the following: desert varnish is formed by the weathering of rocks (6); lichens are an important factor in the formation of desert varnish (10); iron and manganese oxides are derived

from pollen that adheres to the rock surfaces (22); the varnish may be a precipitate from water running over the surface. Hunt (6) reports that staining similar to desert varnish is also found in humid regions and is found on nearly all types of rocks, although it is less common on quartz and limestone. He suggests that such stains throughout the world may have various origins: the stain may have been transported a considerable distance to its present surface; it may be derived from the weathering of the minerals in the rock beneath it; some stain was deposited by physical chemical processes while other staining appears to have been deposited biochemically. These methods require active moisture. Hunt theorizes that the desert varnish was developed when the area had a more humid climate.

#### VEGETATION

The Yuma Test Station lies within the Sonoran Desert, one of the four North American Deserts recognized in the biological sense: the Chihuahuan, the Great Basin, the Mojave, and the Sonoran (19). This desert is not only a biological unit but is distinguished also by many features of climate, physiography, soils and hydrography.

The outstanding feature of the vegetation of deserts in general, in contrast with non-desert regions, is the lack of dominance by a particular life form. This is illustrated at the Yuma Test Station Area by the mixing or shared dominance of a number of distinct life forms, especially trees, evergreen shrubs, deciduous shrubs, and stem succulents. Another life form, the annual, is of small size and conspicuous by reason of numbers only for brief periods when moisture conditions permit germination of seeds and rapid development to maturity.



The Sonoran Desert differs from the other three North American deserts most conspicuously in the greater importance of small trees, relative to that of the shrub life forms and in the variety and development of plant communities. Despite this fact, the observer standing at any particular site within the Yuma Test Area is impressed by the extreme simplicity of the plant community there, in regard to the number of plant species composing it. Not only are there few dominant species, but these generally can be distinguished readily by the non-botanist because of striking differences in appearances. Such extreme variation within the small group of species in a stand makes this region peculiarly favorable for successful use of large-scale color airphotos in vegetational analysis. The primary subdivision of the local vegetation is between the strictly desert types and those dependent upon the high water table near the Colorado and Gila Rivers.

Ecological science has established that the mature plant community when undisturbed by man is an excellent indicator of the environmental conditions. The vegetation provides a single expression into which are integrated all the significant physical, chemical, and biological factors brought to bear upon it. The fully developed plant community is in dynamic equilibrium with the prevailing combination of factors operating largely by way of the climate and the soil. Thus, the vegetation is a living record, the resultant of the effective environment throughout the year. It expresses the environmental complex better than would the data derived from any combination of various recording instruments. This is true because it is not known how to integrate the various physical measurements into a single meaningful expression that gives each factor its proper weight and represents the resultant of all environmental influences.

In the extreme desert environment the moisture factor is significant above all others, yet it is intricately related with heat energy, slope, soil porosity, texture, etc. If separated areas possess similar environmental conditions, this may often be most readily recognized by the similarity of their plant communities. But when two undisturbed parts of an area support different vegetation, this indicates diverse physical conditions, usually in moisture relations. Two communities may differ in that different species constitute them. However, in deserts especially, two stands may have exactly the same species, yet indicate habitat differences by the varying density and coverage values of these species.

A study of Marks (13) on the relationship between plants and plant communities in the Lower Colorado desert and the soils on which they grow, applies rather directly to the Yuma Test Station Area. By use of Marks' paper and the dominant plant cover on a specific site, interpretations of soil conditions are feasible.

In interpreting plant communities, the recent history of the area must be taken into account. Natural disturbances, especially flash floods, greatly affect the vegetation in this desert region. Runoff "washes," nearly always dry, occur throughout all the general terrain types from bedrock mountains to floodplains of the major rivers. These range from high elevation rocky gullies with steep gradient and V-shaped cross section, through the extremely common washes of gentle gradient crossing the broad alluvial aprons, to the great trunk wash areas a mile or two broad which separate two different alluvial apron slopes between parallel mountain ridges. For vegetational descriptions, such great trunk areas of surface drainage are here termed "base-level washes."

Since plant cover follows and parallels the dry washes, especially the borders of the wash channels, and is excluded from the uneroded desert pavement surfaces of alluvial aprons, it is evident that plant dispersal cannot be random. Random dispersal means scattered over the surface as dictated by chance alone, and neither uniformly regular in any way nor in clusters (aggregated). Because they are determined to a considerable degree by the pattern of washes, the stands and the separate plants illustrate a type of dispersal best termed "linear aggregation." A tree-like branching or dendritic pattern is common. A young aggrading alluvial fan has the "trunk" wash on the uphill edge whence the materials are contributed. However, most alluvial fans and aprons in the test area are being eroded down faster than they are being added to from above (desert pavement areas are being eroded only); these have the open branch ends on the upper side and the main stems downstream (Figure 17). Nearer base level several or many wash channels interjoin into a "braided" or reticulate (network) pattern. This is most characteristic of the large base-level washes. In the gentle sloping alluvial aprons, the degrading dendritic and reticulate types merge considerably.

Table I presents the common and botanical names of all the important plants of the area and shows the life form of each.

Figure 18 is a diagram intended to express the general physiographic-vegetational relationships for the principal terrain types and dominant species. It necessarily reflects rough altitudinal correlations also.

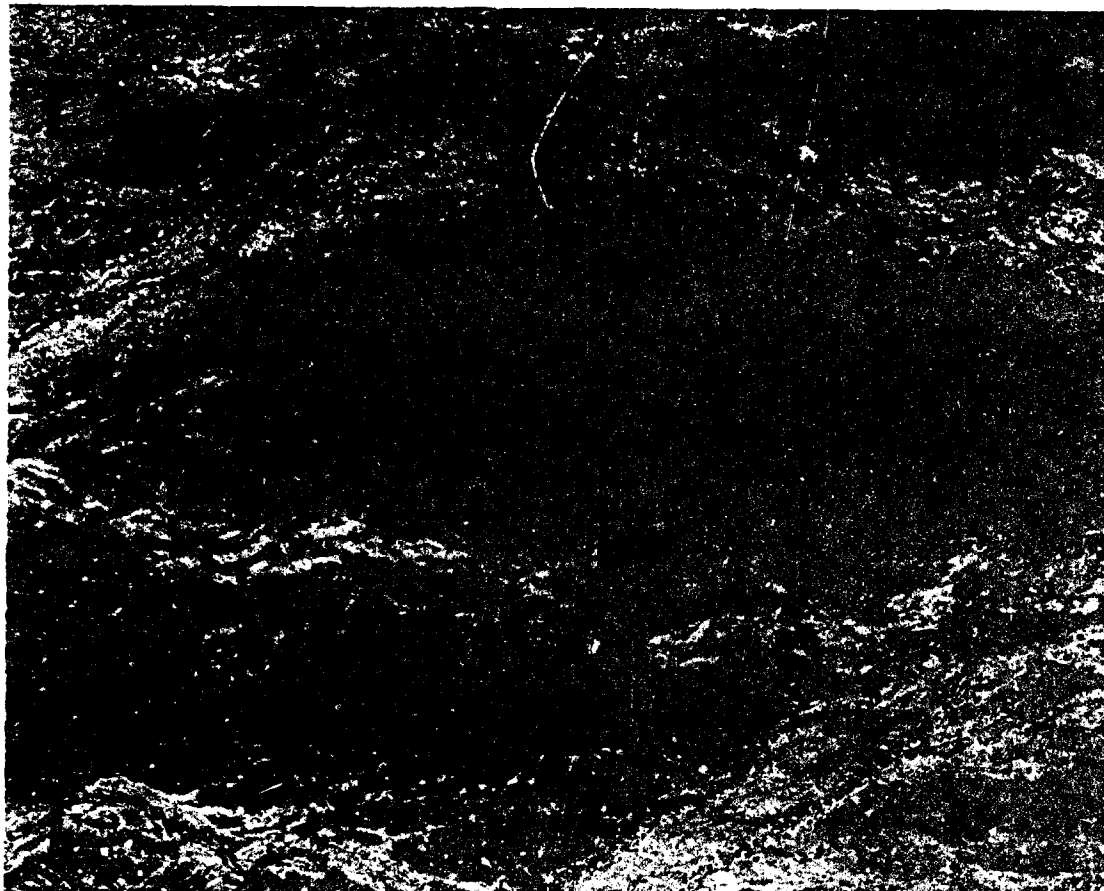


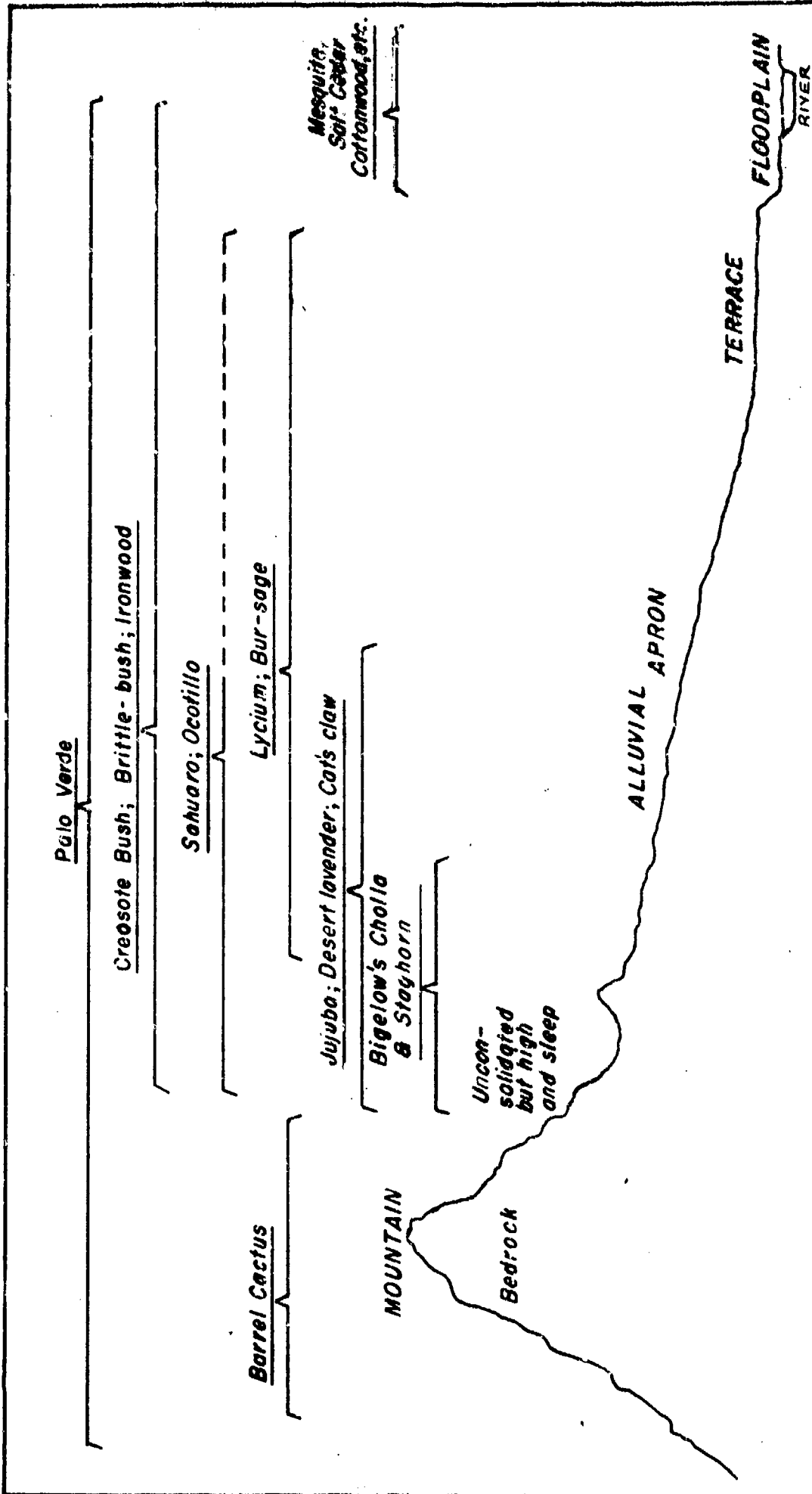
Figure 17. Vegetation along the washes that dissect the alluvial aprons. The dark areas are desert pavements. This site is at Loc. 366.5 - 22.3.

Table I. Nomenclature, life form, and thorniness of the perennial plant species. (Dunes along Route 80 west of Yuma are not included.)

| <u>Common Name</u>           | <u>Scientific Name</u>        | <u>Life Form</u> | <u>Thorns or Spines</u> |
|------------------------------|-------------------------------|------------------|-------------------------|
| Arrowweed                    | <u>Pluchea sericea</u>        | Tall shrub       | No                      |
| Bebbia                       | <u>Bebbia juncea</u>          | Medium shrub     | No                      |
| Brittle bush                 | <u>Encelia farinosa</u>       | Low shrub        | No                      |
| Bulrush, great               | <u>Scirpus validus</u>        | Rush             | No                      |
| Bunchgrass                   | <u>Hilaria sp.</u>            | Low shrub        | No                      |
|                              | <u>Franseria ambrosioides</u> | Shrub            | On seeds                |
| Bur sage                     | <u>Franseria dumosa</u>       | Low shrub        | On seeds                |
| Burrobrush                   | <u>Hymenoclea salsola</u>     | Shrub            | No                      |
| Cactus Group                 |                               | Stem-succulents  | Yes                     |
| Barrel cactus                | <u>Echinocactus sp.</u>       |                  |                         |
| Beavertail cactus            | <u>Opuntia basilaris</u>      |                  |                         |
| Bigelow's cholla             | <u>Opuntia bigelovii</u>      |                  |                         |
| Sahuaro                      | <u>Carnegiea gigantea</u>     |                  |                         |
| Staghorn cactus              | <u>Opuntia versicolor</u>     |                  |                         |
| Cat's-claw Acacia            | <u>Acacia greggii</u>         | Small tree       | Yes                     |
| Cat-tail                     | <u>Typha latifolia</u>        | Rush             | No                      |
| Cottonwood                   | <u>Populus fremontia</u>      | Tall tree        | No                      |
| Creosote Bush                | <u>Larrea tridentata</u>      | Shrub            | No                      |
| Desert-lavender              | <u>Hyptis emoryi</u>          | Tall shrub       | No                      |
| Encelia<br>(or Brittle bush) | <u>Encelia farinosa</u>       | Low shrub        | No                      |
| False-mesquite               | <u>Calliandra eriophylla</u>  | Low shrub        | No                      |
| Furstrum                     | <u>Furstrum heterophyllum</u> | Climbing herb    | No                      |

(Table I. Cont.)

| <u>Common Name</u> | <u>Scientific Name</u>                                  | <u>Life Form</u>   | <u>Thorns or Spines</u> |
|--------------------|---------------------------------------------------------|--------------------|-------------------------|
| Hop-sage           | <u>Grayia spinosa</u>                                   | Low shrub          | No                      |
| Ironwood           | <u>Olneya tesota</u>                                    | Tree               | Small                   |
| Jujuba             | <u>Simmondsia chinensis</u>                             | Tall shrub         | No                      |
| Lycium             | <u>Lycium sp.</u>                                       | Tall shrub         | Yes                     |
| Mesquite           | <u>Prosopis juliflora</u>                               | Tree or shrub      | Yes                     |
| Ocotillo           | <u>Fouquieria splendens</u>                             | Tall canes         | Yes                     |
| Falo verde         | <u>Cercidium microphyllum</u><br>and <u>C. floridum</u> | Tree               | Usually none            |
| Picklebush         | <u>Allenrolfea occidentalis</u>                         | Low stem-succulent | No                      |
| Reed, common       | <u>Phragmites communis</u>                              | Grass              | No                      |
| Saltbush           | <u>Atriplex lentiformis</u>                             | Tall shrub         | No                      |
| Salt-cedar         | <u>Tamarix pentandra</u>                                | Tall shrub         | No                      |
| Saltgrass          | <u>Distichlis sp.</u>                                   | Grass              | No                      |
| Smoke-tree (rare)  | <u>Dalea spinosa</u>                                    | Tree               | Yes                     |
| Tornillo           | <u>Prosopis pubescens</u>                               | Tree               | Yes                     |
| Willow             | <u>Salix goodingii</u>                                  | Tree               | No                      |



**ROUGH ALTITUDINAL & BROAD PHYSIOGRAPHIC CORRELATIONS WITH CHIEF PLANT SPECIES**

Plants on the same line above don't necessarily occur close together, e.g. ocotillo is often found with no accompanying sahuaro. Conversely, plants may characteristically occur together, even though one extends (at one or both ends) beyond the altitude range of the other. E.g., creosote bush & bur-sage.

FIG. 18

The range of a species or group of species is shown by a horizontal line over the terrain types where they are characteristic. That this is highly generalized is evident; actually several distinct habitats may occur within a single terrain type and show vegetational differences. For example, within the alluvial apron type occur washes having channels, channel borders, and farther out is wash terrain subject to occasional flooding. Bordering this habitat, there is desert pavement with essentially no plant cover except where the gravel mosaic is disturbed by burrowing animals or incipient erosion adjacent to gully heads. Thus, a single general terrain type may show a diversity of habitats ranging from those incapable of supporting plant life to the channel-border habitat with a practically continuous mass of coalesced plant crowns. The wash channels are barren because of the mechanical action of deep rushing floodwaters, abrasion by their suspended mineral particles, and the surface instability due to erosion and deposition. The other barren habitat, the desert pavement beyond reach of stream water, lacks plants because soil moisture is deficient and the temperatures reached by the surface rock fragments, with increased heat absorption due to the blackness of the "desert varnish," are likely sufficient to kill seedlings.

Table II shows the characteristic grouping of plant species, taking into account the minor habitat differences within the general physiographic or terrain type. An attempt has been made in each block to arrange the names in order, so that the plant most typical of the particular habitat heads the list.



Table II. Dominant plant species of the habitats within the principal terrain type.

| Erosional Stage or Feature                            | Residual Mountain Cores                              | Colluvial (rare) & steep, high alt. alluvium, mainly coarse textured in mtn. canyons & gullies | Upper Alluvial Apron                                                | Lower Alluvial Apron                              | Bottomland along Colorado River             |
|-------------------------------------------------------|------------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------|---------------------------------------------|
| Solid bed-rock; not transported                       | Barrel Cactus, very sparse Palo verde in some places |                                                                                                |                                                                     |                                                   |                                             |
| Wash-channels borders                                 |                                                      | Palo verde, Ironwood, Cat's claw, Desert-lavender, Jujuba                                      | Palo verde, Ironwood, Jujuba, Lycium                                | Palo verde, Ironwood, Lycium                      |                                             |
| Wash-flooded area (lateral to channel borders)        |                                                      | Cholla & Staghorn, Ocotillo, Samsara, Brittle-bush, Palo verde, Desert-lavender                | Creosote bush, Brittle-bush, Bur sage, Palo verde, Cholla, Staghorn | Creosote Bush, Brittle-bush, Bur sage, Palo verde |                                             |
| Desert Pavement (edges & animal disturbed parts only) |                                                      | Cholla, Ocotillo, Creosote bush, Bur sage                                                      | Bur sage, Creosote bush, Brittle-bush, Cholla                       | Creosote bush, Bur sage, Brittle bush             |                                             |
| Wind disturbed sandy-silt (hummocky)                  |                                                      |                                                                                                |                                                                     | Ocotillo, Creosote bush, Bur sage, Bunch grass    | Mesquite                                    |
| Silt or clay Alluvium (in situ)                       |                                                      |                                                                                                |                                                                     | Creosote bush, (Bur sage)                         | Salt cedar, Saltbush, Picklebush, Arrowweed |

A <sup>data on</sup> ~~Vegetation map~~ of the Yuma Test Station Area is <sup>also</sup> presented on Plate IV. <sup>I</sup> ~~Primarily, the map was prepared by correlating the vegetation with the land forms as shown on the chart in Figure 18, with some modifications as the result of field observations.~~ It should be noted that vegetation conditions are very generalized. Several species grow on more than one type of land form, although they may be very sparse, and cover wide ranges of altitudes.

An occasional barrel cactus or sahuaro may be found on the mountains, but they are so widely scattered that the mountains must be mapped as barren. Other areas, such as those with desert pavement, approach the condition that could be called barren. Most of the vegetation within the Yuma Test Station Area is found along the washes and on the flood plains.

#### Method of Vegetation Analysis

Quantitative studies of plant communities were made on the ground and from airphotos. In only the former studies were plant species distinguished, since the 1:20,000 scale of the airphotos supplied is not suitable for species identification. Also, it was felt that from the principal military standpoint, species separation is not essential. The practical significance of desert plant cover would appear to be largely attributable to those individuals exceeding ten feet in crown diameter. These plants are large enough to impede such vehicles as jeep or weapons carrier and to make it worthwhile to turn aside to avoid them. Also the cover that such plants provide may be of value in concealment of foot-soldiers or even of low vehicles. Therefore, plants of ten feet diameter and larger were studied quantitatively, by means of a 10 power binocular

microscope, on fourfold enlargements from original 1:20,000 scale air-photo contact prints. The various species were lumped into one analytical group. Thus grouped indiscriminately are trees, tall shrubs, and to a lesser extent the coalesced crowns of crowded medium-sized shrubs which usually exceed five feet in height. The plants included are largely palo verde, ironwood, cat's-claw, lycium, desert-lavender, and jujuba.

For determining density per acre for the group of large plants, a 5-acre sampling template, accurately calibrated by ocular micrometer to the scale of the airphoto prints used, was produced on a glass slide. Counts were made within 311 sample plots of 5 acres each, an aggregate sample area of 2.4 square miles in various terrain types. Since 10 per cent of the area being sampled is usually enough to include within sample plots, the statistically tested airphoto vegetation data applies directly to approximately 24 square miles of terrain typical of much of the remainder of the Test Station Area. It would not be at all feasible to make a study of this scope by laying out sample plots on the ground. The sample plot was an L-shaped, elongated unit with arms of equal length; it is the strip component of an "elb" (24). Because it gives low variance, this is the most efficient form of sample plot for desert vegetation. The sample unit was 2178 feet by 100 feet, to include 5 acres.

In eight selected portions (sampling stations) of the area, all but one confined to a single terrain type, an average of 35.5 five acre plots per station were distributed at random. Counts were made through the low power microscope. Since cross-country vehicular travel or foot marches

(except in the higher altitude terrain types) would take roughly the shortest route to a destination irrespective of the orientation of the shallow washes, all the habitats within one type, such as alluvial apron or base-level wash, were included in the same random sample. Thus, these varied habitats, with their differing vegetation, are represented in proper proportion as they would be encountered in cross-country movement during a military operation. This approach averages in the bare desert pavement, the densely vegetated wash borders and all other habitats, and yields an overall figure for mean density for each station in the particular terrain type. In contrast, ground studies in the field distinguished species, and restricted consideration to a particular well-vegetated habitat, to determine maximum concentrations of plants that would be encountered.

The adequacy of airphoto sampling was judged as follows. At each station the mean number of trees per plot was subjected to the statistical test for standard error. The per cent standard error was also calculated, i. e., the standard error times 100, divided by the mean. If the per cent error does not exceed 15, the sampling is considered entirely adequate.

Table III presents the results of the airphoto vegetational analysis for average density per acre of large plants. The per cent error ranged from 3.1 to 13.4. Therefore, the sampling adequacy was statistically established as fully acceptable.

The stations are tabulated in a series from higher to lower elevations. Since the residual mountain surfaces are practically devoid of plant cover, this terrain type is omitted.

Table IV gives per cent coverage with its standard error and the per cent of the former represented by the latter. The sampling unit for coverage is not areal plots, but lines (each 2,725 feet long and bent in the middle at a right angle) laid down randomly and in large numbers at a station. The total length of lines at seven sampling stations was 28.17 miles. The low per cent errors indicate very satisfactory reliability of sampling.

Table III. Density (number of plants per acre) values for all plants with crown diameters of ten feet or more. These were taken from sample plots on airphotos. Standard errors of mean density at the station, and per cent errors, are shown.

| Accompanying Illustration | Total Acres Within Sample Strips | Terrain Type                                 | Density         | Per cent Error |
|---------------------------|----------------------------------|----------------------------------------------|-----------------|----------------|
| Figure 28                 | 170                              | Hills                                        | 17.8 $\pm$ 5.5  | 3.1            |
|                           | 240                              | Hills                                        | 7.1 $\pm$ 0.38  | 5.3            |
| Figure 48                 | 190                              | Alluvial apron, all newly eroded surface     | 6.8 $\pm$ 0.37  | 5.5            |
|                           | 300                              | Alluvial apron, uniformly eroded plain       | 3.9 $\pm$ 0.28  | 7.2            |
|                           | 175                              | Alluvial apron, uniformly eroded plain       | 4.1 $\pm$ 0.55  | 13.4           |
|                           | 230                              | Base-level wash                              | 5.3 $\pm$ 0.27  | 5.2            |
|                           | 200                              | Base-level wash                              | 12.8 $\pm$ 0.59 | 5.4            |
|                           | 50                               | Floodplain-edges, pure mesquite on low dunes | 6.8 $\pm$ 0.37  | 9.2            |

Table IV. Per cent ground coverage by all plants having crown diameters of ten feet or more, taken from stations on airphotos by numerous unit sampling lines, each 2,725 feet long. Standard errors of mean per cent coverage at the station and per cent errors are shown.

| Accompanying<br>Illustration | Total line<br>length at<br>station | Terrain Type                                                     | Per cent<br>coverage | per cent<br>error |
|------------------------------|------------------------------------|------------------------------------------------------------------|----------------------|-------------------|
| Figure 28                    | 35,000 feet                        | Hills                                                            | 7.8 $\pm$ 0.58       | 7.5               |
| Figure 17                    | 76,300 feet                        | Alluvial apron, 3/4<br>desert pavement<br>dendritic gullies      | 6.4 $\pm$ 0.49       | 7.7               |
|                              | 54,500 feet                        | Alluvial apron, 1/2<br>desert pavement                           | 4.4 $\pm$ 0.37       | 8.4               |
|                              | 81,750 feet                        | Alluvial apron, 2/5<br>desert pavement<br>finely dissected       | 3.4 $\pm$ 0.25       | 7.5               |
|                              | 81,750 feet                        | Transition, alluvial<br>apron (1/5) to base-<br>level wash (4/5) | 5.5 $\pm$ 3.1        | 5.7               |
|                              | 68,125 feet                        | Base-level wash                                                  | 9.9 $\pm$ 0.62       | 6.3               |
|                              | 68,125 feet                        | Base-level wash                                                  | 10.2 $\pm$ 0.81      | 7.9               |

CHAPTER III

MOUNTAINOUS TERRAIN OF YUMA TEST STATION AREA

INTRODUCTION

Mountains form the most conspicuous features of the landscape in southwestern Arizona. The mountain ranges are usually separated by broad plains which are made up of material that has been washed down from the mountains. Material is being eroded from the mountains and building up the intermontane areas which, in effect, means that the mountains are being buried by their own materials.

Most of the mountains near Yuma are very rugged. There are some rounded mountains, a limited amount of flat-topped mountains, and a few isolated peaks. Twenty-six per cent of the Yuma Test Station Area consists of mountains:

|                                        |           |
|----------------------------------------|-----------|
| Rugged mountains                       | 20%       |
| Rounded mountains                      | 5%        |
| Flat-topped and singlepeaked mountains | <u>1%</u> |
| Total percentage of mountains 26%      |           |

RUGGED MOUNTAINS

Distribution

There are a number of important ranges in the area which consist almost completely of rugged mountains; Trigo, Chocolate, Castle Dome, Miggins, and Laguna. They are well distributed throughout the area. Rugged mountains make up 20 per cent of the area.



### Topography

The mountain ranges that are named in the preceding paragraph reach heights from 2000 to 3000 feet above sea level, rising from 1000 to 2500 feet above the surrounding plains. The term "serrate" aptly describes most of them. Briefly, Wilson (23) describes some of these ranges as follows: Trigo - "----extremely rugged...series of sawtooth ridges;" Middle - "rough, irregular ridges;" Castle Dome - "Spires and dome-capped towers adorn the skyline of this blocky, ragged mass."

Most of the other ranges approach similar degrees of ruggedness. The mountains are made up of irregular ridges, buttes, and spires, with practically no level surface remaining. Deep canyons and dry gulches dissect the rugged mountains. Examples of some of the extreme topography are shown in Figures 19 to 22.

The rugged portions at the eastern and western parts of the Miggins mountains are separated by rounded topography of relatively low relief which has been mapped as hills. A large part of the Laguna Mountains was also classified as hills.

### Geology and Composition

The rugged mountains consist predominantly of Tertiary volcanic rocks which are underlain largely by schists and gneisses, with some granites and sedimentary rocks. These underlying materials outcrop at numerous locations near the base of the mountains.

A series of lava flows covered much of this portion of Arizona during the Tertiary period. Probably most of the eruptions were of the fissure type, and the flows covered most of the hills then existing. Some of the individual flows were several hundred feet thick, and the total thickness of the lavas exceeds 2000 feet in the Castle Dome and Kofa Mountains.



Fig. 19. Castle Dome Mountains, with Castle Dome Peak projecting above the rest of the range. This view is to the northeast.



Fig 20. Aerial view showing the rugged peaks and topography in the Castle Dome Mountains.



Fig. 21. Dissected volcanic rocks in the northeastern Miggins Mountains overlie tilted sedimentary strata.



Fig. 22. Rugged topography of the Trigo Mountains.

Portions of the Laguna, Chocolate, and Trigo Mountains probably escaped the general volcanic flooding of the region (18).

One of the most remarkable dike swarms in the United States is found in the Castle Dome Mountains, particularly in the vicinity of Castle Dome peak. The outcrops of these dikes, principally of dioritic and porphyritic composition, may form ridges up to fifty feet high (23).

In Figure 21 is shown the tilted sedimentary strata that underlie the andesitic lavas in the northeastern part of the Miggins Mountains.

#### Surface Characteristics

Practically all of the surfaces consist of bare rock. Slopes are steep to precipitous. In places, the surface rocks have been broken down into angular fragments by weathering processes. These may vary from a few inches to two or three feet in size. Much of the exposed rock surface has been darkened by the coat of desert varnish.

#### Vegetation

The bedrock habitat of desert mountains supports practically no plant cover, only an occasional barrel cactus or scrawny palo verde that has managed to take root in a crevice. However, just above the alluvial fans are some fairly broad mountain washes (Figure <sup>23</sup>~~25~~) containing considerable plant cover growing on coarse alluvial deposits. The general aspect of this vegetation is not much different from that of washes of comparable width in the upper third of the alluvial apron terrain type. However, the cat's-claw and the large shrub desert-lavender are more important in mountain washes, and Lycium is less so. The abundance of cholla cactus and jujuba distinguishes this type from the lower alluvial apron, and both these plants are much more abundant (relative to other plants) in mountain washes than in alluvial fan gullies or upper alluvial apron washes.



Fig. 23. Vegetation along a mountain wash at the southwestern edge of the Castle Dome Mountains. Stand of cholla cactus and ocotillo paralleling the wash, with the tree community in the background below the mountains.

Species counts were made in a mountain wash at 1500 feet elevation. The smaller plants, brittle bush and cholla, although abundant along the less frequently and less drastically flooded edges, were not counted. (Since the plants counted usually exceed 10 feet in crown diameter, this is the same class studied as a whole from airphotos for density and cover.) The per cent numerical abundance, based on 350 plant crowns is:

|                 |       |
|-----------------|-------|
| Palo verde      | 34.0% |
| Desert-lavender | 17.7% |
| Ironwood        | 16.6% |
| Cat's-claw      | 11.7% |
| Jujube          | 8.6%  |
| Lycium          | 6.8%  |
| Sahuaro         | 1.7%  |
| Others          | 2.9%  |

#### Military Significance

Movement through the rugged mountains is limited primarily to the major washes. There are several old roads crossing the Castle Dome range. These follow washes most of the way and cross low divides to washes on the other side. Vehicles with tracks or four-wheeled drive are required for travel on most of these mountain roads. Ordinary passenger cars usually cannot get through the loose, granular material in the washes, clear the large boulders, or climb some of the steeper slopes.

Most of the canyons and washes reach a dead-end at their upper extremities, where a vehicle can go no farther. It is even difficult for a man to climb up the sides of many of the canyons.

The rugged mountains are a barrier to military activity; in fact, except for a very few routes, they cannot be crossed by military vehicles. Since most of the mountain ranges in southwestern Arizona are relatively short in length, they can normally be by-passed. In defensive operations the mountains would make strong positions maintaining control over the surrounding plains.

#### **ROUNDED MOUNTAINS**

##### Distribution

Most of the rounded mountains in the Yuma Test Station Area are found in the Chocolate Mountain Range in California and the Middle Mountain Range (Figure 24), with smaller areas in the Trigos, White Tank, Palomas Mountains, and very small areas along the eastern edge of the Castle Dome Mountains. Much of the rounded topography in parts of the Miggins and Laguna Mountains is relatively low in elevation, so these areas were mapped as hills. Rounded mountains make up 5 per cent of the Yuma Test Station Area.

##### Topography

Elevations of the rounded mountains are not as high as the peaks in the adjacent rugged mountains. The highest peaks are volcanic plugs that are very steep and rugged. In fact, several rugged volcanic plugs are surrounded by rounded mountains.

Slopes of the rounded mountains may be fairly steep, but they do not rise vertically. Erosion has not been extremely severe as it has in the rugged ranges. There are very few level surfaces in the rounded mountains.

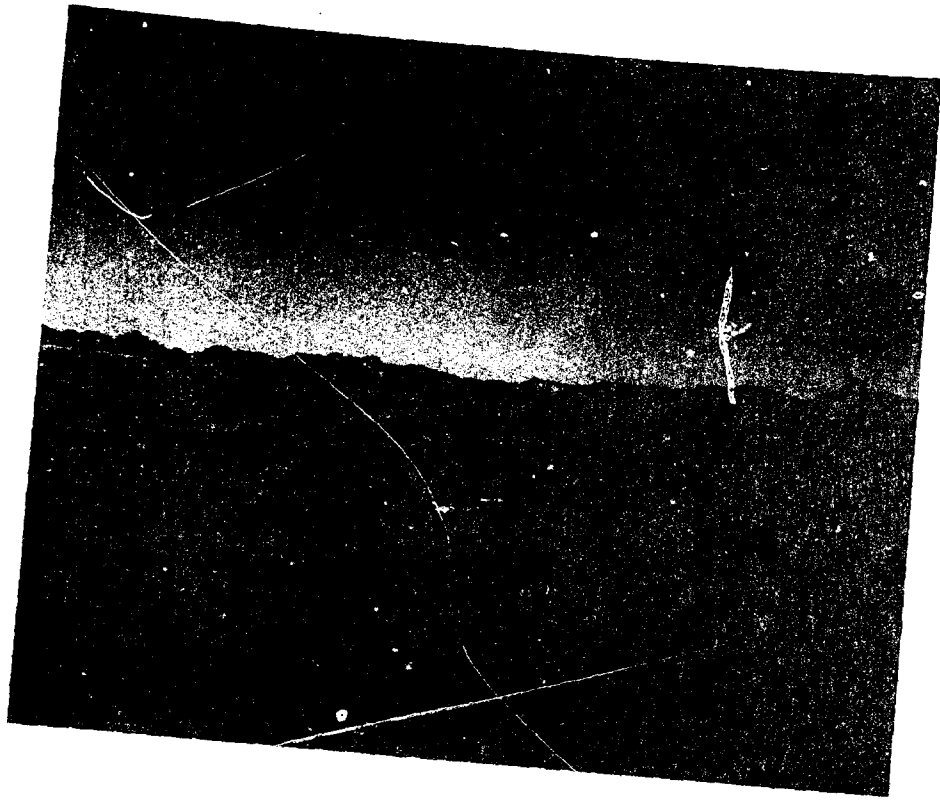


Fig. 24. The Middle Mountains are mostly rounded, with some rugged sections. This view is looking eastward; Castle Dome Peak at the right edge of the photograph.



### Geology and Composition

Much of the rounded mountains, particularly in the Chocolate, White Tank, and Palomas ranges, consist of basalt, the dark-colored basic volcanic rock. The deposition of the basalt occurred as a part of the volcanic activity that took place during the Tertiary period. The basalt has not eroded as severely as the acidic volcanic rocks, which are usually more rugged. The basalt shows rather prominently on the aerial photographs because of its very dark tone and more rounded appearance.

Although most of the Middle Mountains are rounded, there is little basalt found. The rocks are similar to those in the rugged Castle Dome Mountains.

### Surface Characteristics

The mountain surfaces consist of bare rock with no soil development. In places, the surface may consist of loose rock fragments and boulders. Both the bedrock and boulder surfaces have been coated with desert varnish.

### Vegetation

There is practically no vegetation on any of the mountains. The little vegetation that is found is confined mainly to the washes. The discussion of vegetation under the section on rugged mountains also applies to the rounded mountains.

### Military Significance

The slopes of the rounded mountains are probably too steep for vehicles to climb, although a man on foot would probably have no great difficulty. Traversing the rounded mountains would not be quite as difficult as crossing the rugged mountains.

## FLAT-TOPPED AND SINGLE-PEAKED MOUNTAINS

Since the flat-topped and single-peaked mountains cover a very small portion of the area, they were combined as a mapping unit. Single peaks that are high enough to be classed as mountains are extremely scarce. Many of the numerous inselbergs that protrude above the alluvial aprons were classified as hills, since they rise only a few hundred feet above the surrounding plains. The only single-peaked mountains are those that rise to considerable heights above the surrounding mountains and are isolated from other mountains.

### Distribution

Less than 1 per cent of the total area has been mapped as flat-topped mountains. This small proportion is well scattered through the area: in the Chocolate Mountains in California (Figure 25) at the southeast end of the Castle Domes, and in the White Tank Mountains. Larger areas of flat-tops are found to the east of the mapped area in the White Tank and Palomas Mountains.

Only three peaks in the mapped area were classified as single-peaked mountains. These were all at the southeast end of the Castle Dome range. Just beyond the main body of the range, they rise above the adjacent hills. These constitute a very small portion of one per cent of the area.

### Topography

The most obvious features of flat-topped mountains are the fairly level surfaces on their summits. The side slopes may be steep, but usually they are not excessively so. Most of these "flat-tops" have characteristics similar to those of the rounded basaltic mountains. There are a few mountains with volcanic caps that have vertical slopes at the summit.

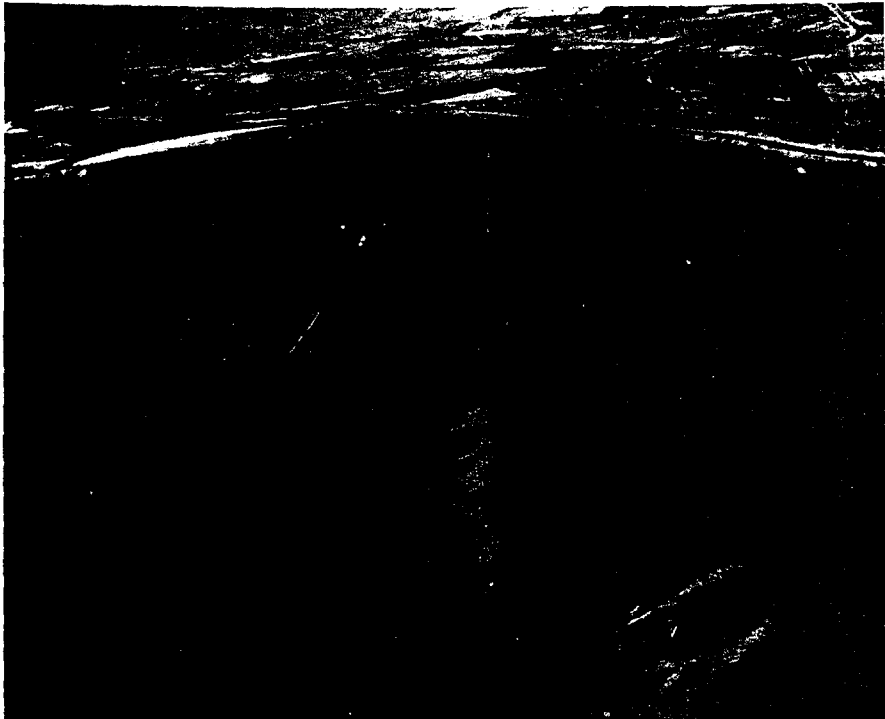


Fig. 25. Flat-topped mountains at the southern end of the Chocolate Range are shown on the right. This view, looking SSE, shows hills on the left. In the distant center, the All-American Canal can be seen bearing westward away from the Colorado River.

Of the three mountains classified as being single peaks, two are volcanic plugs that are surrounded by hills, and the third is an elongated cone. The two plugs are rugged and steep, while the cone has features resembling the rounded mountains.

#### Geology and Composition

Basalt is the rock making up most of the flat-topped mountains. The "flat-tops" are usually found adjacent to some rounded mountains, the difference between them often being the degree of dissection. Erosion processes in the basalt seem to develop rounded features rather than steep, rugged slopes and canyons. As erosion progresses, the "flat-tops" develop rounded mountain features.

#### Surface Characteristics

The surfaces consist of bare rock with little or no soil development. A coating of desert varnish is found on most of the exposed rock. Loose rock fragments cover many of the slopes.

#### Vegetation

Like the other mountains, these are also practically bare of vegetation. The little vegetation in the mountains is found along the gullies. This has been described in the Vegetation section under rugged mountains.

#### Military Significance

Like the other mountains, the flat-topped ones and inselbergs are probably too steep for vehicles to climb. Most of the flat-tops are of such small area that they are of little importance. The isolated peaks provide good positions for observing activities on the surrounding plains.

## CHAPTER IV

### HILLS AS A TERRAIN UNIT OF THE YUMA TEST STATION AREA

In this report the term "hills" refers to land forms of rolling to rough topography with relatively small differences in elevation, having very little level surface. They are generally rounded rather than peaked or precipitous in form. Some types may aptly be described as "low mountains." It is often difficult to distinguish hills from low mountains. Generally in mapping the Yuma area, elevations rising less than five or six hundred feet above the adjacent plain were classified as hills.

Hills in the Yuma area have been grouped into three types: dunes, inselbergs, and "unclassified" hills. About 17 per cent of the Yuma Test Station Area has been mapped as hills. Dunes are almost non-existent within the mapped area; inselbergs comprise less than 1 per cent of the area; the unclassified hills are practically the entire 17 per cent.

Since the other two types of hills (dunes and inselbergs) have specific names and occupy such a small percentage of the area, the term "hill" may be used in referring to the unclassified hills. Anytime that reference is made to dunes or inselbergs, they are referred to specifically by name.

#### HILLS (UNCLASSIFIED)

As used in this report, unclassified hills refers to extremely dissected surfaces of former plains that have been dissected so excessively that there is little, if any, of the original plain surface left. The topography is rolling or rough; few level surfaces remain.

A few of these formations have been referred to as badlands, resulting from severe erosion of shales. Other areas are the remains of excessively dissected portions of alluvial aprons and fans. These rough surfaces are most likely to be found adjacent to the mountains where the slopes are steeper, where erosion is most severe.

#### Distribution

About 17 per cent of the Yuma Test Station Area consists of the unclassified hills. They are found throughout the area. Many of them are located adjacent to mountains. They are most common in the western half of the Test Station Area, close to the Chocolate, Trigo, Laguna, Middle, and Muggins Mountains. Smaller groups of hills are found along the Castle Dome, White Tank, and Palomas Mountains. Extremely dissected portions of alluvial aprons are found close to the Gila River bed and in other locations. Figures 26 and 27 illustrate several of the areas that are classed as hills.

#### Topography

The hills have rolling to rough topographic features. Originally most of these surfaces were fairly level plains, but severe erosion has dissected the land into its present form, with little or no level surfaces remaining. Local topography in such instances can be measured in tens of feet. Larger hills, adjacent to mountains where dissection has been more severe can often be measured in terms of hundreds of feet locally from a relief standpoint. Slopes are generally not excessive except where severe erosion has been active recently.

### Geology and Composition

For the most part, the hills which flank the mountains consist of stratified alluvial outwash sediments which have been severely dissected. The hills northwest of McPhaul Bridge in the Laguna Mountain area, shown in Figure 27, consist mainly of a thick series of poorly stratified, weakly consolidated gravels that are combined with smaller amounts of sands and silts. The coarser textured material is usually found near the outcrops of bedrock. Similar gravels constitute the central portion of the Muggins Mountain area. These gravels overlie clays and silts and overlap the schists, gneisses, and lavas that form the rugged parts of the Muggins Mountains (23). Erosion has dissected these unconsolidated deposits into their present form.

Other hilly areas were formed by dissection of alluvial aprons and fans. These are mapped as hills only when the dissection is so severe that there is little or none of the original plain surface remains. Many of these are found adjacent to the mountains where the increased slopes accelerate the erosion.

Some of the hill areas consist of bedrock that is the same as those in the mountains; in fact, they might be readily called low mountains. Those extending along the Colorado River from the Headquarters Area northward to Castle Dome Landing are pictured in Fig. 8. On the eastern side of these bedrock hills are other hills that are made up of dissected alluvial material.

### Vegetation

The hills are not a step in the characteristic physiographic series from mountains through the alluvial fans and aprons derived from them, so the classification of vegetation on hills represents a

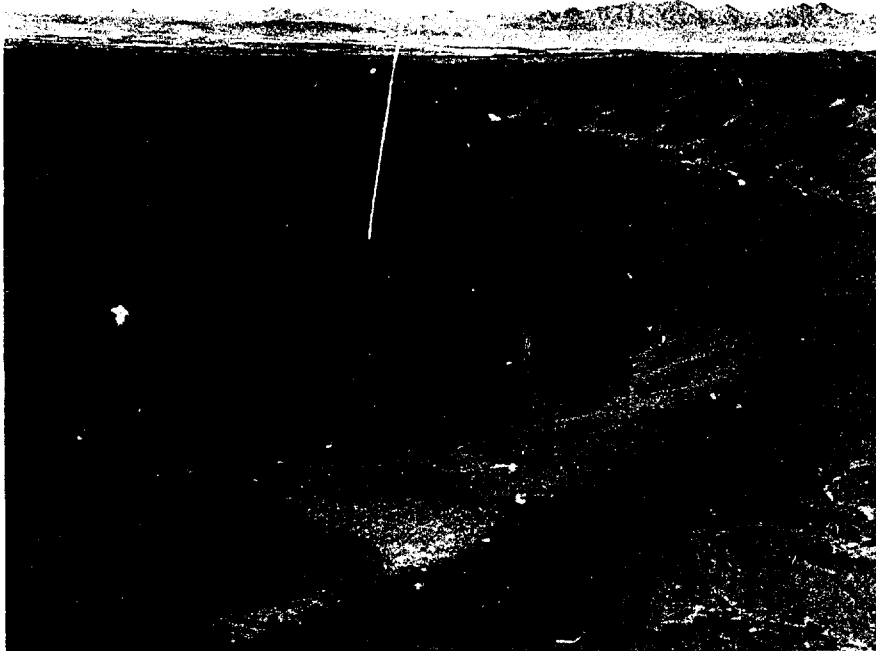


Fig. 26. Hills in the Muggins Mountain area. Region is well-dissected, but slopes are not too steep.



Fig. 27. Hills in the Laguna Mountain area. In the foreground is an inselberg where S.R. 95 crosses the Gila River bed on the McPhaul Bridge. The flood plain consists of sandy silt.



somewhat unnatural interpretation in the study of plants.

The only plant contributing important cover in the hill topography of V-shaped valleys and ridges is the palo verde tree. Despite the irregular terrain, the trees are rather evenly dispersed over the inter-fluves (Figure 28) and are not excluded from them as they are from desert pavement flats in the alluvial apron terrain. Both density and coverage (Tables III and IV) are higher than they are on the alluvial apron type at lower elevations; probably this is determined by the slightly higher precipitation, cooler temperatures, and hence lower evaporation-transpiration stress in the hill environments. In addition, the substratum is coarse and rocky, therefore, the small water supply from rains is not dissipated everywhere as in the finer textured materials but concentrated into crevices where the plant roots also occur. Shrubs appear to be inconsequential except on the borders of the washes or gullies.

#### Surface Characteristics

A substantial portion of the hills, like those in the Laguna and Miggins Mountain areas, are composed primarily of gravels which are mixed with sands and silts. Silts and clays are exposed in some places where badland erosion has occurred. The hills that are composed of rock may have bedrock exposed at the surface or the surface may be broken down into angular fragments by weathering processes. Desert varnish has darkened the surfaces of both the bedrock and the angular fragments.



Fig. 28. Hills supporting a rather uniform stand of palo verde trees at Loc. 368.1 - 23.7.

### Military Significance

In general, the slopes of the hills are not excessive, and many of them can be traversed by military vehicles with little difficulty. The hills are not nearly as easily traversed as the alluvial aprons. A limited degree of concealment is available in hills that is not usually found on the plains, however.

The use of FM radio equipment is restricted in hilly areas. This difficulty in maintaining communications is one problem on which the Signal Corps test team has been working.

### INSELBERGS

An inselberg is an isolated remnant of an old mountain whose peak rises above the surrounding plain. In the vicinity of Yuma, most of these old isolated mountains now rise only a few hundred feet above the alluvial fans and aprons, so they have been classified as hills.

### Distribution

Less than one per cent of the Yuma Test Station Area consists of inselbergs. They are many in number, but each one covers such a small area that they make up only a small portion of the surface.

Several inselbergs are located very close to State Road 95. Two of these by the McPhaul Bridge are shown in Figure 27. Most of them, however, protrude above the plain that is east of the Castle Dome Mountains; see Figure 29. Others on the other side of this same plain are found close to the White Tank and Palomas Mountains.

Several other inselbergs near the Gila River are farther removed from mountains. Texas Hill, the most conspicuous of these, is pictured in Figure 30. Antelope Hill, which is just outside the mapped area to the southwest of Roll, is easily accessible.

### Topography

The inselbergs near Yuma usually consist of a single peak or hill that is fairly steep, although not vertical. Level surfaces are scarce, although there are very small areas that may be fairly level on a few of the inselbergs. Many of them might readily be classified as low, rounded mountains; only a few of them are rugged.

### Geology and Composition

The inselbergs consist of the same types of rocks that make up the mountains of the area: basalt, volcanics, granites, gneiss, schists, sedimentaries. The inselberg at the south end of McPhaul Bridge was found to be andesite porphyry shot through with aplite dikes. Antelope Hill is composed of coarse-grained, gray arkosic sandstone, which has been quarried for use as railroad ballast. On a peak near S.R. 95 loose fragments of red volcanic rocks mantle the slopes of the peak. Basalt forms several of the inselbergs east of the Castle Dome range. Near the southwest edge of the Palomas Mountains, weathered granite can be easily crushed by hand.

The development of the inselbergs has been similar to that of the mountains in the area, since the inselbergs are the remnants of mountains that no longer reach elevations sufficient to remain in that category. Erosion has been wearing down the mountains and inselbergs, and the eroded material has been filling the valley and slowly covering the mountains. The inselbergs, besides being isolated, do not rise as high above the plains as most of the mountains. Undoubtedly, some have already been covered by the valley fill materials, and a fairly level alluvial apron now covers former mountain peaks.

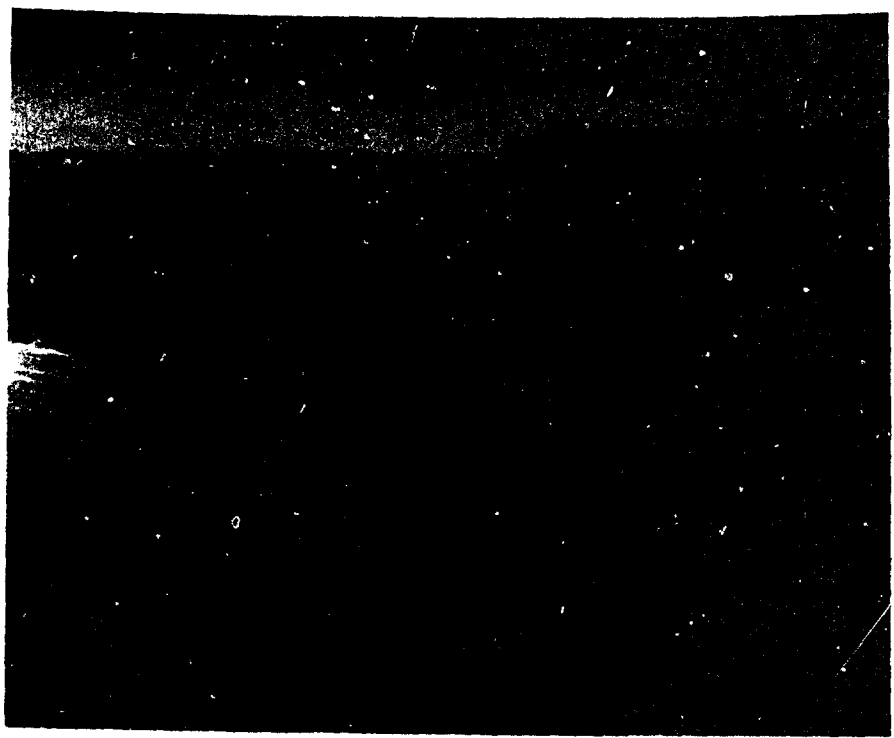


Fig. 29. Inselbergs near the east side of the Castle Dome Range in the vicinity of Loc. 366.3 - 78.0.

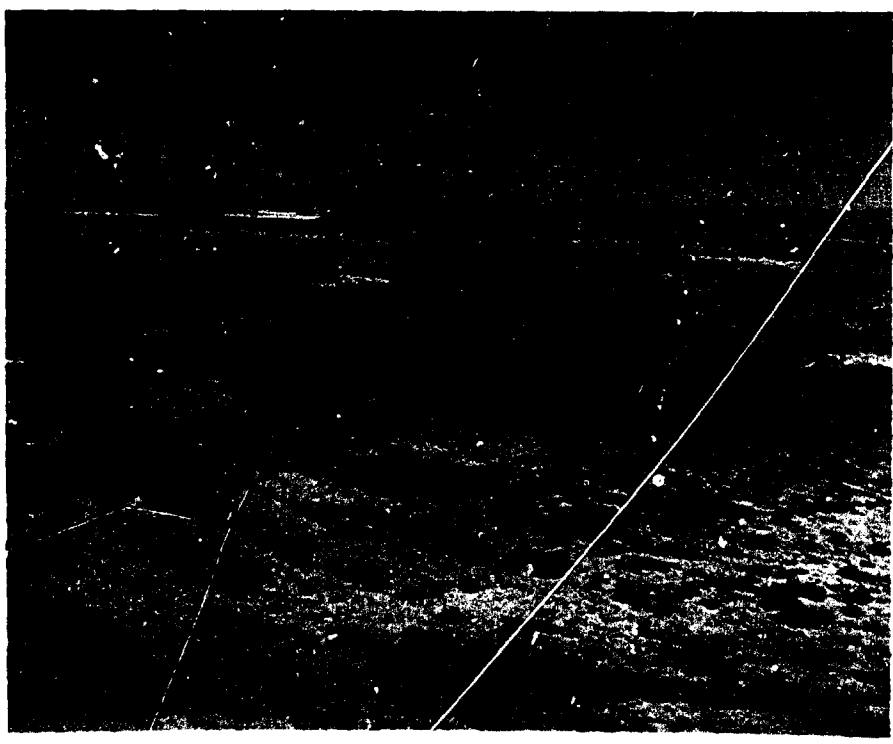


Fig. 30. Texas Hill, an inselberg at the edge of the Gila Valley, which is on the left edge of the peak. This view is looking west. (Loc. 363.8 - 24.8)

### Surface Characteristics

The slopes commonly consist of loose rock fragments, or possibly the bare bedrock, which has been darkened by the ever present desert varnish.

### Vegetation

The inselbergs are practically bare of vegetation, like the mountains in the area. An occasional sahuaro or small barrel cactus may be seen.

### Military Significance

The fairly steep slopes and the loose rock fragments make it almost impossible for vehicles to ascend the sides of the peaks. As an obstacle, however, they are no problem, since they are small enough that it is no problem to go around them.

Inselbergs can usually be climbed easily on foot since they are not too high. They present good positions for observation, usually in all directions except where mountains block the view, since the observer can usually reach the highest point. Natural concealment, other than a rocky surface, is lacking, however.

### SAND DUNES

There are no dunes located within the Yuma Test Station Area. On the sand plain near the intersection of the paved road to the Headquarters Area with State Road 95 (Loc. 363.3 - 74.5), an artificial sand hill has been prepared by bull-dozing the sand from the plain into a hill. These prepared sand slopes, shown in Figure 15, are used for some tests with vehicles. The remainder of this sand plain is rather level, perhaps undulating in places where there is a tendency

toward transverse dune formation. A similar sand plain is found on the terrace at the southeast corner of the mapped area.

The following discussion of dunes refers specifically to the Sand Hills in Imperial County, California. The area of the Sand Hills was not included in computing the total area of the Yuma Test Station Area.

Sand dunes are an important land form that is found in deserts throughout the world. Because they are formed by wind action, the range of sizes of the individual particles is limited, and, therefore, sand dunes in different parts of the world probably have more common characteristics than other surface forms.

Only ten per cent of the Sahara Desert is sandy (26). The Arabian Desert has more sand, but the Gobi has less sand than the Sahara. Although dunes cover only a small percentage of world desert areas, they are important because they are found in almost all deserts, and the crossing of great sand dune areas is an important military problem.

#### Relationship of Sand Hills to Yuma Test Station

The Sand Hills extend in a belt averaging about five miles in width from below the Mexican border northwestward for about fifty miles into Imperial County, California. Via highway through Yuma, the dunes are about forty-five miles from the Headquarters of the Yuma Test Station. Figure 1 shows the location of the Sand Hills with respect to Yuma.

The Yuma Test Station has a test course across the dunes that is used as a routine course for testing all types of military vehicles for their performance on sand. The test course starts just west of Ogilby and crosses the Sand Hills about four or five miles north of US 80.

These dunes are familiar to many as the setting for numerous movies ostensibly about the Sahara and other deserts. In 1908 a plank road was constructed across the Sand Hills. Remnants of this road occur at scattered locations. In 1928 the concrete pavement of US 80 replaced the old one-lane corduroy road, and in 1933 the All-American Canal between the Colorado River and the Imperial Valley was completed through the dunes. Constant maintenance is required to keep the highway and canal clear of sand.

#### Topography

Some of the dunes reach as much as three hundred feet above the base plain. Locally, however, most of them present elevation differences of thirty to fifty feet from the crests of the dunes to the depressions between.

This dune surface is sometimes referred to as "peak and fulje" topography. Fulje is an Arabic term for the depressions between the dunes. The surface consists of fairly shallow slopes to the windward side of the dunes and the steep slip faces on the lee side. Figures 31 and 32 show excellent examples of the dune forms.

There are a number of enclosed basins of level silty plain in the middle of the Sand Hills, as shown in Figure 33. Most of these seem to be bordered on the north or northwestern side by a steep sand slope. One of these steep slopes was observed to be rising abruptly for about 150 feet above the north edge of the silt plain.

#### Geology and Composition

The winds responsible for the formation of the Sand Hills have come chiefly from the southwest, west, and northwest (2). The dunes probably developed from the beach that was formed when Lake Cahulla



occupied the Salton Basin. The dunes may have moved eastward to their present position at that time or later. Land surveys made in 1856, however, show little difference in the shape and position of the present dune field (2).

Samples taken from the crests of the dunes show that only 1 or 2 per cent of the particles are finer than the No. 200 sieve. All the material passes the No. 10 sieve, and 97% of it passes the No. 40 sieve. There is more silt content in the depressions between the dunes. In fact, a hard crust had formed on some of the shallow depressions on the east side of the dune field. There is distinct evidence that water has been ponded in some of these.

At one of the level "islands" in the middle of the dunes which is known as Bitterscup Valley (Figure 33) the soil consists of a sandy silt which in places is covered with poorly developed desert pavement. A rim of stratified sand and silt outcrops around the valley, particularly along the east end. This is found six or eight feet above the base level of the valley. The material is slightly indurated.

#### Natural Divisions of the Sand Hills

Melton (14) has presented a system of classifying sand dunes. In the description under an oblique aerial photo of the dunes similar to looking northwestward across the Sand Hills, similar to the view in Figure 33, he has these comments: "A surface of complex sand dunes formed by conflicting winds... The surface is best described as 'intersecting transverse dune series,' though it is apparent that more than two intersecting sets may be present. It is impossible to detect the order which usually exists on surfaces of this nature without the use of vertical aerial photographs. The ground observer

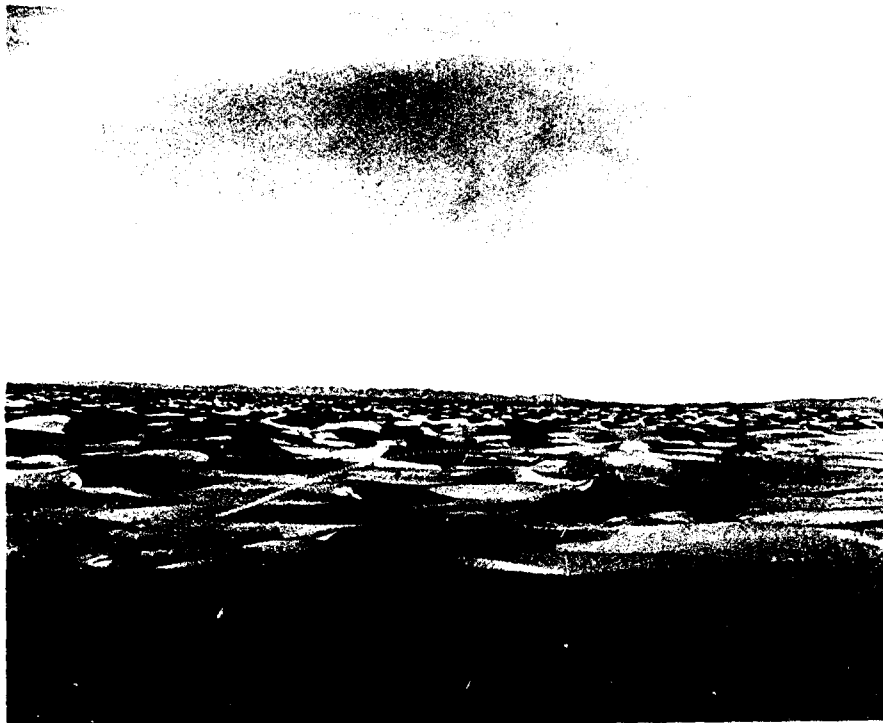


Fig. 31. Heavy shadows help outline the dunes with light from a low sun angle.

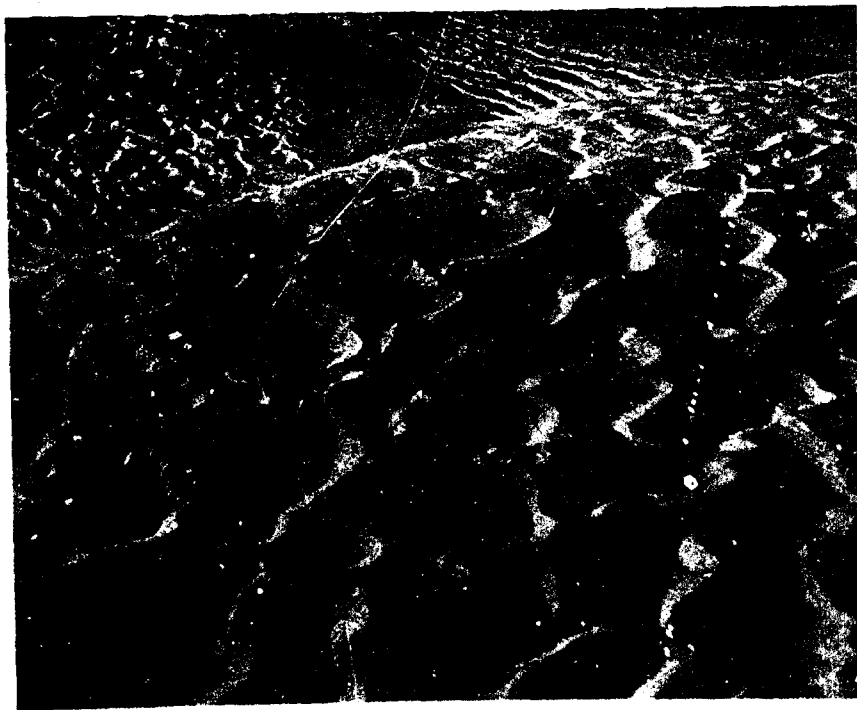


Fig. 32. Low altitude oblique of sand dunes in Imperial County.



Fig. 33. Basin enclosed by sand dunes. The one in the center is known as Buttercup Valley.



Fig. 34. Alignment in two directions of these intersecting transverse dunes can be seen. These low dunes are on the east edge of the Sand Hills.

is usually lost in a maze of topographic peaks, basins (fuljes), and saddles. In certain places where the sand supply is meager, barcan dunes have formed."

The aerial oblique photo in Figure 34 is near enough to a vertical view that the alignment of the dunes can be seen in two directions. This view is on the eastern side of the dunes, which are not as high as those to the westward. These dunes are also classified as "intersecting transverse dune series," but they do not appear to be as complex as the higher dunes.

A low sharp ridge can be seen along the crests of the dunes in Figure 32. This is due to an approximate reversal of the wind direction. The steep faces of dunes are on the lee side. If the direction of the wind is reversed, the dunes start adjusting themselves to the new conditions. As the wind starts blowing the sand up the steep slope, a new slip face starts forming on the new leeward side. If the wind direction continued unchanged for a long enough period of time, the original dune forms will be altered so the steep face will be on the right instead of the left.

Practically all the Sand Hills fall into Melton's classification of the intersecting transverse dune series. A few barcan dunes are found where the supply of sand is limited, usually at the edge of the dunes or at the edge of one of the silt plains within the dunes. The level plains within the dune field is a third surface type that is found within the Sand Hills.

From an analysis of an airphoto index sheet of the Sand Hills based on field observations, it appears that small dune forms are built up on the shallow slopes of the huge dunes which are several hundred feet high. A short distance from the summit, usually southeast, the huge dunes drop abruptly a hundred feet or more to the plain below. This huge wave-like appearance can be seen on the index sheet which is shown in Figure ~~37~~<sup>35</sup>, with the Sand Hills extending in a strip from the upper left to the lower right edge of the photograph. Some of these aerial photographs were ordered for study, but they had not been received at the time this report was prepared.

#### Surface Characteristics

A characteristic feature of wind-blown sand is the rippled surface that is formed. These ripples can be seen in two of the photographs, Figures 36 and 37. The coarsest material collects at the crests of the ripples, and the finest material is in the troughs (1).

On the shallow windward slopes of the dunes the sand was usually found to be relatively firm, as near as such a term can be used in referring to dry sands. Sometimes there are local spots where the sand is more loose, but the driver who has had experience in sand areas can usually detect these. The tops of the dunes were in the same condition, except for the sands adjacent to the slip face. On the slip face the sands are loose and unstable, and little supporting capacity is available, as shown by Figure ~~37~~<sup>37</sup>.

#### Military Significance

Tests that have been conducted by the Ordnance test team in these dunes have shown that practically all types of military vehicles can be used to cross areas of sand dunes. The major exception has been a



Fig. 35. Photo-index of the Sand Hills in Imperial County, California.

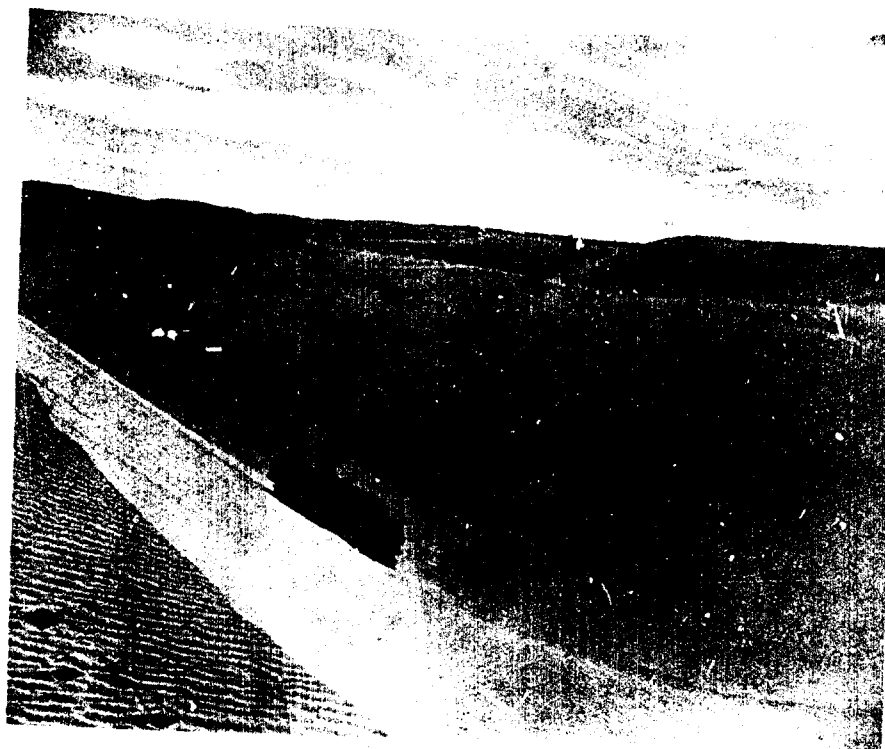


Fig. 36. Jeep moving down the slip face of a dune.

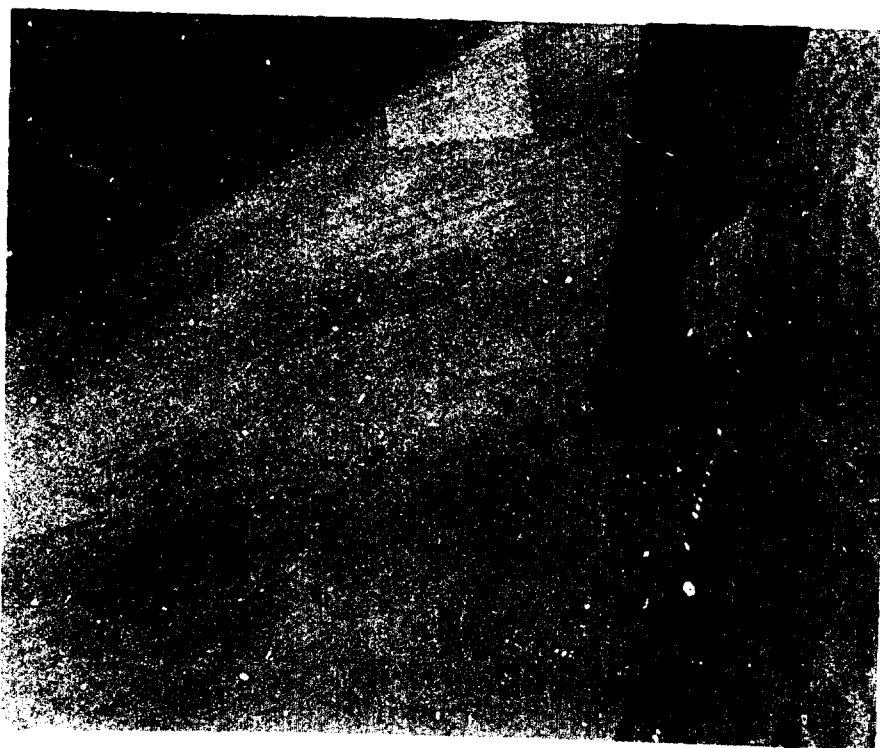


Fig. 37. The slip face of a dune is loose and unstable.

truck equipped with hydramatic drive. Wheeled vehicles require four-wheeled drive for use in the dunes, and the pressure in the tires needs to be reduced to less than ten p.s.i.

Although the dunes can be crossed, the route must be carefully selected as one travels along. Vehicles cannot climb the steep faces of the dunes, but they must be taken up one of the shallow slopes on the ends or windward side of the dunes. After arriving at the crest of a dune, the vehicle should be brought to a stop before proceeding down the steep face, as it could turn over very easily.

A running start is often needed to go up many of the sand slopes. Sometimes a vehicle cannot get up at a certain place, but it can usually be backed down and taken up at another location. Often it is best to follow along the crest of an elongated dune, keeping back from the slip face as the sand for several feet back from the break is unstable and may slide under the weight of a vehicle.

Drifting sand is a major problem in sandy deserts. Constant maintenance may be required to prevent aeolian sand from accumulating on a road, airfield, camp, or any other area where sand deposits would be undesirable. Sand must often be stabilized around telephone poles and other structures to prevent the sand from being blown away, which would leave the structure unsupported.

#### Vegetation

There is very little or no vegetation on the unstable dune sand, but a sparse cover is supported on the lower-lying sand between the series of dunes. The few species include a sand-binding grass (Panicum urvilleanum), the sand paper plant (Petalonyx linearis), joint fir (Ephedra trifurca), Coldenia plicata, and creosote bush.



CHAPTER V

PLAINS

INTRODUCTION

A plain is a land form that has, or formerly had, a fairly level surface. Erosion may have dissected much of the plain. In this study, when dissection has reached the stage where there is very little or none of the original plain left, the extremely dissected areas were classified as hills.

Plains occupy the filled-in portion of the valleys between the mountain ranges. They are largely composed of alluvial sediments that have been washed from the mountains to fill in the intermontane valleys.

Plains make up 57 per cent of the total area of the Yuma Test Station area:

|                 |           |
|-----------------|-----------|
| Alluvial fans   | 4%        |
| Alluvial aprons | 44%       |
| Terraces        | 3%        |
| Flood Plains    | <u>6%</u> |
| Total           | 57%       |

The playa which is described is outside the Test Station area. The area of washes has not been tabulated separately, but it is included mainly with the fans, aprons, and mountains.

Comparison of Alluvial Fans and Aprons

Because the development of alluvial aprons is a later stage in the formation and coalescence of alluvial fans, a comparison of the two land forms should be made at this point. It is often difficult to classify definitely whether a surface adjacent to the mountains is a fan or an apron. By definition, however, an apron is made up of coalescing fans, and most of the fans have reached this stage of development.

Since alluvial aprons consist of coalescing fans, the distinction between the two is often difficult to make. There are several distinctive features about an alluvial fan: its form resembles a fan, its slope is steeper than the adjacent apron, its material has usually come from a single mountain wash. The alluvial apron commonly extends from one side of the valley to the other. The only areas that were mapped as fans are those where the fans could be identified from aerial photographs based on the features mentioned above.

Along the southwest face of the Castle Dome Mountains, in particular, an impression is gained that a series of fans exist. However, study of airphotos reveals that the characteristic fan-shape is absent, and no break can be seen that would indicate that both fans and aprons are present. Thus, if a fan could not be definitely identified and its limits outlined, the area was mapped as an apron. In several cases, two or three which had joined together were mapped as fans instead of aprons because they still retained the features of individual fans.

#### ALLUVIAL FANS

Alluvial fans, in the strictest sense of the word are not truly plains; however, for the purpose of this study their characteristics are more in common with those of plains than with the other major land units in the Yuma area.

An alluvial fan is a sloping, fan-shaped mass of loose rock material deposited by an ephemeral stream at the place where it emerges from an upland into a broad valley or plain (3). As commonly used in this report, it refers to the true fan areas which are situated at the mouths of mountain washes and extend on to the adjacent alluvial aprons.

There are, however, several fans at the edge of the Gila valley where washes originating in the aprons cross a narrow terrace and deposit material on the lower flood plain.

#### Distribution

Alluvial fans cover four per cent of the Yuma Test Station Area. They are well-scattered throughout the area. Several of the best fans are pictured in Figures 38 and 39. These are located on the north side of the Miggins Mountains and in the Chocolate Mountains in California. The most outstanding fan that was observed in the vicinity is just north of the mapped area. This large fan, adjacent to the Kofa Mountains, can be seen to the north of the road about five miles east of Stone Cabin.

#### Topography

Alluvial fans slope downward from the mouths of mountain canyons to the adjacent alluvial aprons. Many of the fans in the Yuma area are somewhat dissected. In some instances, very little of the original surface remains. Deep gullies, often 10 or 15 feet deep, trend down the sloping surface toward the alluvial apron where they merge into the broad washes of the apron. There is a sharp break between the slope of alluvial fans and the aprons. In several cases the fans have lost their characteristic fan-shape because they are restricted by adjacent land forms.

#### Geology and Composition

The discussion in the introduction of this chapter of the comparison and differences between alluvial fans and aprons touches briefly on their development. The present fans are the most recent deposits of materials that have been eroded from the mountains and moved to the

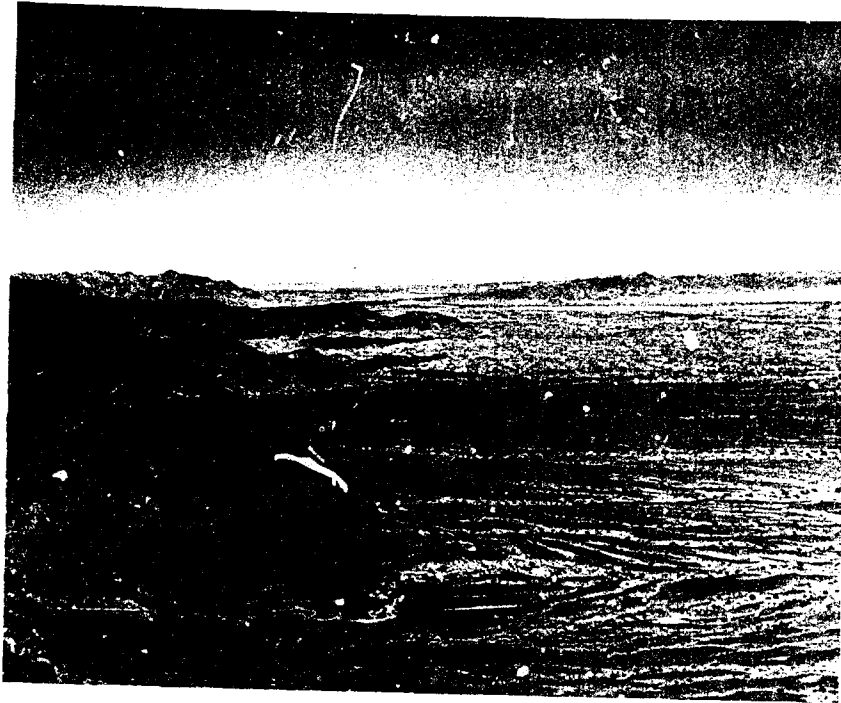


Fig. 38. Fans along the northern edge of the Miggins Mountains.

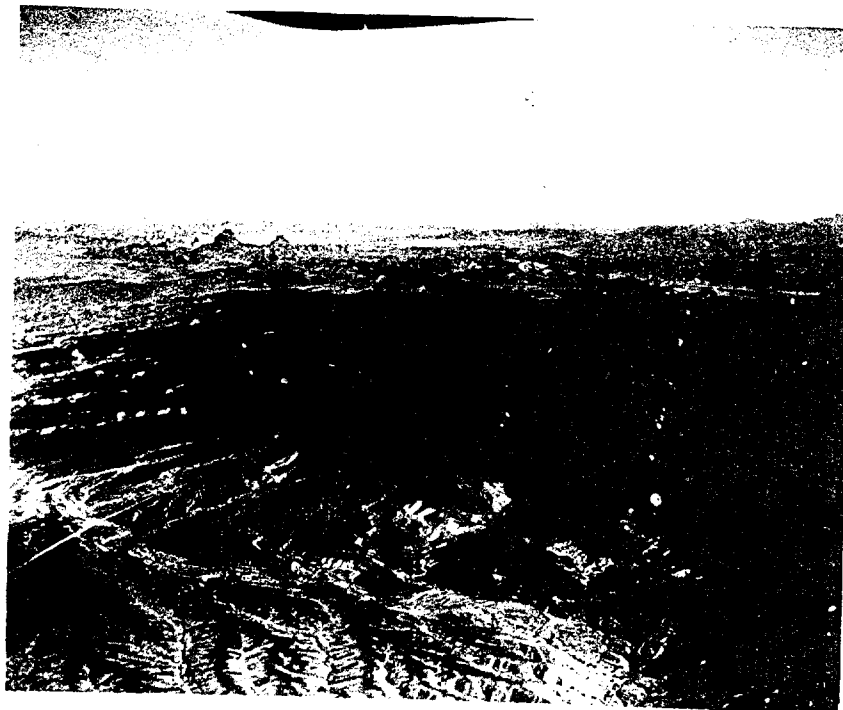


Fig. 39. Fans along the southern end of the Chocolate Mountains in California.

edges of the adjacent plains. In addition to the loss in gradient from the steep mountain washes, there is a loss of water; both of these conditions have contributed to deposition. This results in a characteristic braided condition below the discharge point. Permanent channels cannot be established during deposition since they become immediately choked, causing water and sediment to spread out over the surface of the fan.

In this desert, as in other arid areas, the fans are largely the result of a large run-off in a short period of time. This results in the aggrading character of the fan. However, the aggradation is sporadic.

The fans that are adjacent to the mountains are made up largely of coarse materials: boulders, cobbles, and sand particles. The finer materials: have been carried farther out to the alluvial aprons.

The fans along the flood plain of the Gila are composed of finer sands and silts. These are found at the lower end of the alluvial apron, where the materials are not as coarse as they are near the mountains.

#### Surface Characteristics

The surfaces of fans adjacent to the mountains are made up of loose, coarse materials, many of them boulders a foot or two in diameter. This produces a rough surface. Dissection is fairly severe on fans, too, so there are not too many level surfaces available. Some small areas of desert pavement surface are found.

On the fans along the Gila flood plain, the surface materials are loose sand and silt, with more dense vegetation.

Vegetation

Most alluvial fans are old and in process of degradation; they merge below with the general alluvial apron derived from the elongated mountain unit. The old fan shown in Figure 40 is being bypassed on both sides by the present drainage from the adjacent mountains; it is being eroded by dendritic gullies to which plant life is confined. The oldest surfaces of both alluvial fans and alluvial aprons show the dark tone of varnished "desert pavement."

The most unfavorable habitat where plants can exist is at the very heads of the gullies, since there the substratum is driest. The sequence of appearance of plant species (Figure 41) as the gully head erodes upward provides a series of species according to their tolerance to extreme drought. These fall into three groups. The most drought tolerant group consists of bur sage, Bigelow's cholla (cactus), creosote bush, and brittlebush. Somewhat less so are the ocotillo, palo verde, staghorn cactus, and beavertail cactus; consequently, these do not occur at the extreme tips of the gully branches. Still farther down the gullies are found the sahuaro cactus, ironwood, and jujuba. From the gully heads downward there is a cumulative occurrence of different species; i.e., within the gully head sections only the first group occur, farther down the first and second groups, and still lower, the species of the first, second, and third groups. In addition to this definite lengthwise zonation of plants along the gullies, there is a less distinct but nevertheless real lateral zonation. For example, in the wider but still V-shaped portions where all three plant groups are found, there is a tendency for the most tolerant species to concentrate on the two outside strips where the flat dark interfluvial surface first changes through lateral gully

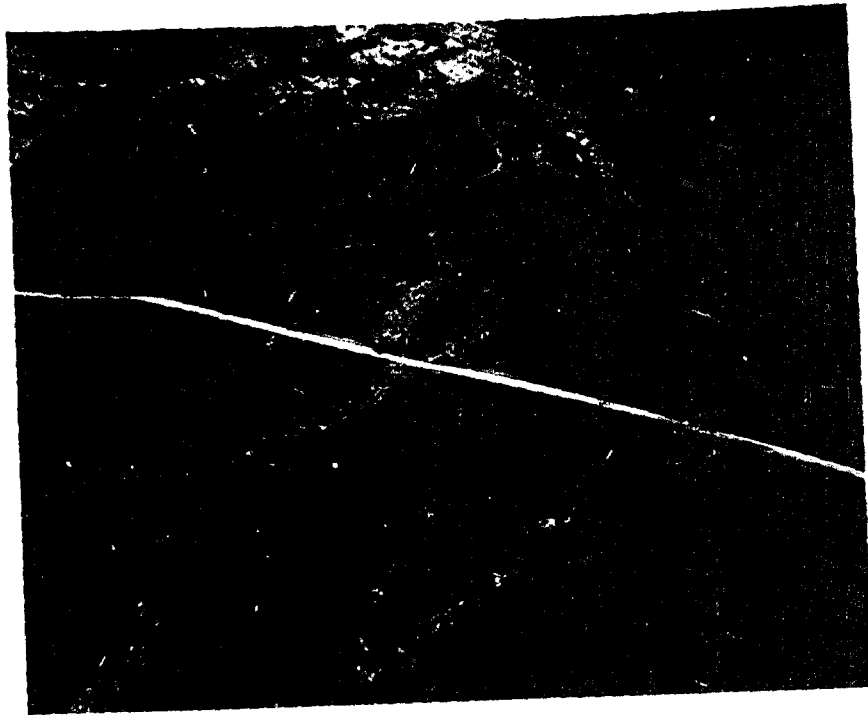


Fig. 40. Gullied alluvial fan at foot of a draw in mountains, with vegetation in gullies.

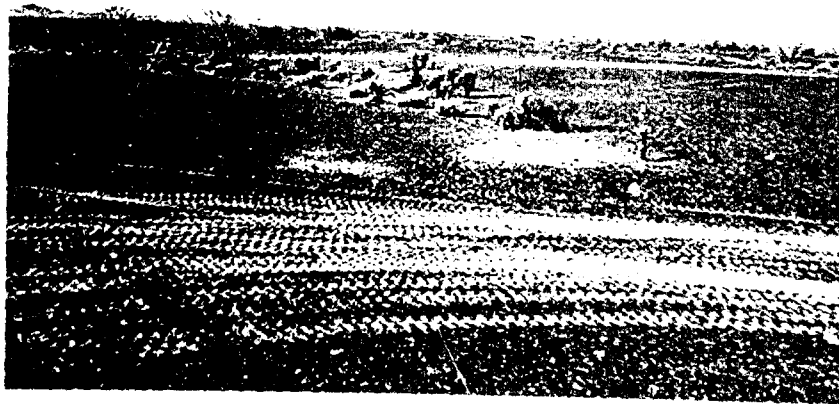


Fig. 41. Ground photo of head of the gully which crosses the road and ends a little to the left of center in Figure 40. The most drought-tolerant plants invade the advancing gully head: cholla, creosote bush, and bur sage.

widening into the lighter surface of the rocky slope. The other two expected bands are not so well differentiated from each other.

#### Military Significance

Travel across alluvial fans is rather difficult. The bouldery surface and the dissection make it difficult to travel across fans, particularly transverse to the gullies. As long as one can follow the washes, cross country movement is not difficult.

Dust is not as much of a problem on the fans as it is on the aprons. Considerable flow of water is likely to occur following a cloudburst in the mountains, as the fans are usually located at the mouths of the largest canyons.

#### ALLUVIAL APRONS

The broad alluvial aprons are one of the outstanding features of the landscape in southwestern Arizona. These may also be called bajadas (Spanish for "go down") or sloping desert flats.

#### Distribution

About 44 per cent of the Yuma Test Station area consists of alluvial aprons. This includes the area of the washes that dissect the aprons, which has been roughly estimated at about six or seven per cent of the total area.

There are several aprons covering large areas that deserve mention. The apron west of the Middle Mountains is dissected by several broad deep washes that lead to the Colorado flood plain. Castle Dome Plain, which is southwest of the Castle Dome Mountains, is shown in Fig. 42. It is crossed by many shallow washes that converge and diverge in a



braided network that drains in a southwesterly direction into the Gila. The broad plain with the Castle Dome Mountains on the west and the White Tank and Palomas Mountains on the east extends from the pass between the Kofa and Castle Dome ranges down to the Gila valley at Texas Hill and Growler (Figure 43).

#### Topography

The surfaces of alluvial aprons slope gently from the land forms above, usually mountains or fans, down to base level of the valley. Along the edge of Indian Wash the average slope over a ten-mile distance, based on U.S.G.S. bench marks, is one per cen. In other areas of the Southwest, shallow basins with no surface drainage outlet have been formed, but the proximity of the Colorado and Gila Rivers have led to the development of drainageways through the aprons in the Test Station Area.

Surfaces are fairly level, broken only by the washes which cross these plains. In most cases, dissection is not severe, and the washes are shallow. In some places, however, much of the original surface has been eroded away, leaving topography that approaches that of hills, but there are still considerable level surfaces on the tops. The most severe erosion has occurred in the higher portions of the aprons near the mountains.

#### Geology and Composition

As mentioned in the introduction of this chapter, the alluvial aprons have been developed as the fans coalesced with adjacent fans along the mountain faces and across the valleys. As the rushing water



Fig. 42. High altitude view of Castle Dome Plain, looking NNE along State Road 95 in the lower left. The Middle Mountains are in the left center, and Castle Dome Peak is in the distance.



Fig. 43. The alluvial apron east of the Castle Dome Mountains. The Kofa Mountains are at the right in the distance. This view is northwest from near Loc. 366.0 - 23.0.

debouched from the restricting walls of the mountain canyons, the water spread out and deposited the coarser debris as its velocity decreased. Finer materials were carried farther out on the plain.

The materials that comprise the aprons are pebbles mixed with silt and sand. Erosion has removed the silt and sand from the surface, leaving the layer of pebbles on the surface that forms the desert pavement. Beneath this surface of the desert pavement which is perhaps an inch thick, the original soil materials are found. The level surface of the pavement is shown in Figure 44, and a detail view of the underlying materials is shown in Figure 45.

#### Surface Characteristics

Desert pavement makes up the major portion of the surfaces on alluvial aprons. The surfaces of the mosaic-like pebbles, and other rocks that may be present, are coated with the dark stain of desert varnish.

The desert pavement surface is firm and smooth, broken only by the dry washes. The washes are shallow in the lower portions of the aprons, but they have eroded more in the high portions near the mountains.

The dark surface of the alluvial apron throughout most of the Yuma area is dotted with many light-toned circular patches. These are small mounds built by communities of burrowing animals. The light unvarnished subsoils are brought to the surface and scattered about by the small animals. These are easily seen on the airphotos, as shown in Figure 44, largely because of the sharp contrast in tone. Some are 40 to 60 feet across, but not more than a foot or two high and may contain 15 or 20 burrows. Figures 46 and 47 illustrate this condition on the ground.

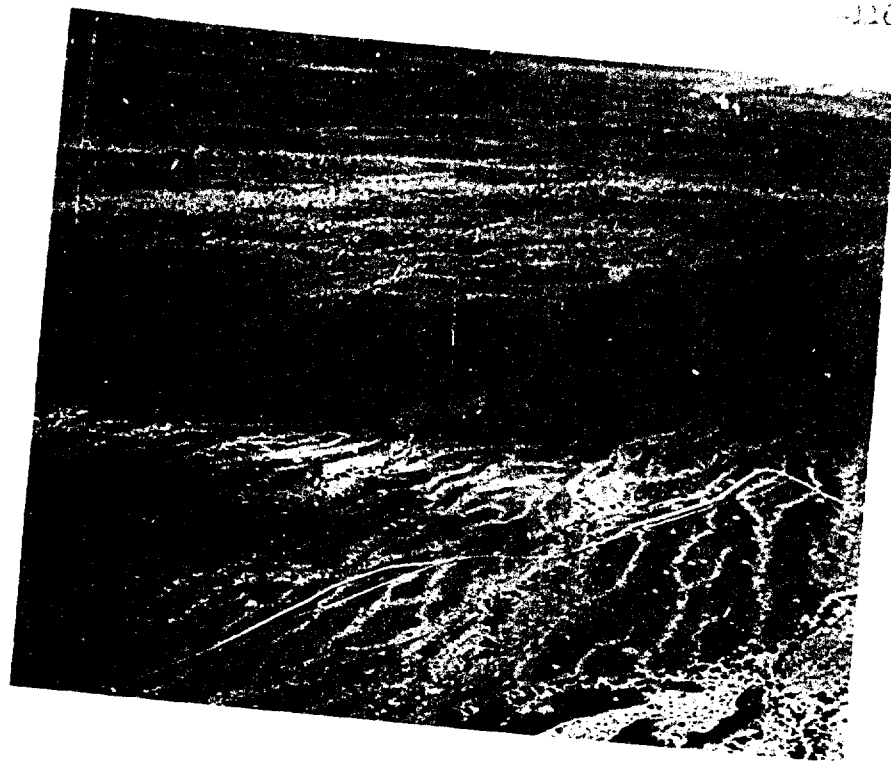


Fig. 44. The smooth desert pavement surface with shallow washes on the Castle Dome Plain. The light-colored spots are the low animal mounds.



Fig. 45. Detail view of the pebbles, sand, and silt beneath the desert pavement surface.



Fig. 46 General view of a light colored mound which houses small burrowing animals. This one is less than a foot high.

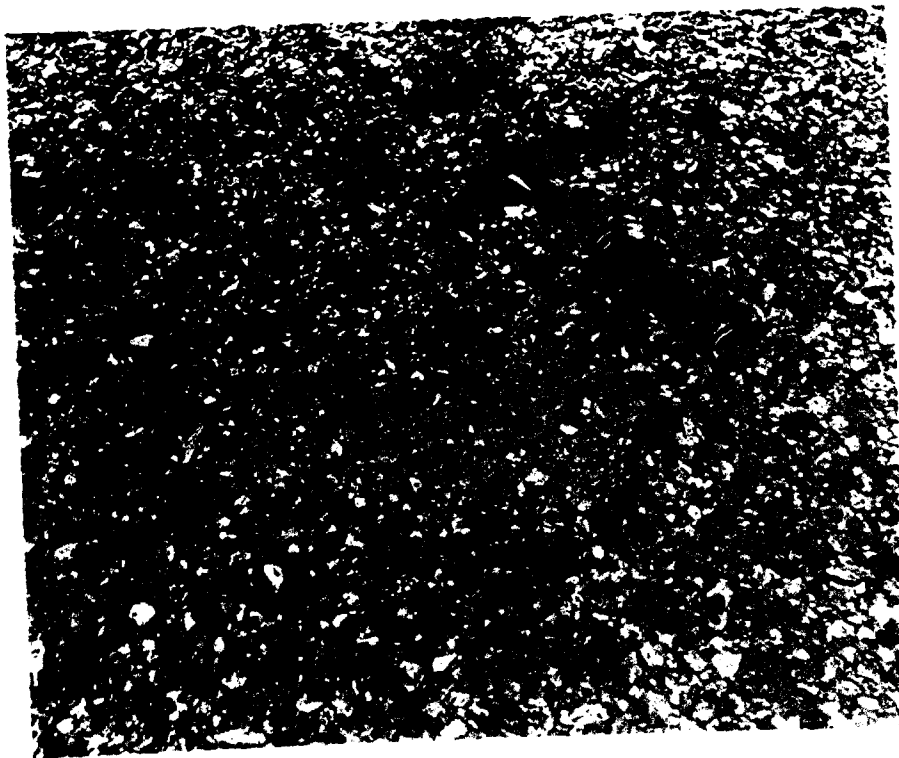


Fig. 47. Detail view of the entrance to a burrow.

### Vegetation

This discussion includes the vegetation of transgressive washes across alluvial aprons; in fact, it is only the surfaces eroded by water (or less commonly by wind) which have any appreciable amount of plant cover. Since the alluvial apron is the dominant land form of the Yuma Test Station Area, it supports the most widespread and important of the plant communities. The several habitats traversed in a cross section through the microtopography taken at right angles to a typical wash channel have been outlined in another section.

The airphoto reproduced in Figure 17 shows an upper altitude portion of an alluvial apron with much of its surface black and unaffected by erosion. The trees scattered along the narrow young gullies in single file, and forming often continuous lines of coalesced crowns on the borders of large wash channels, are palo verde and ironwood. This is a part of the enlargement from which the 6.8 density figure (Table III on page 70) was obtained. Had the washes alone been considered, obviously the plant density figure would have been very much greater.

A lower altitude alluvial apron is shown in Figure 48. Nearly all of the dark pavement surface has been removed by erosion, so that much more of the terrain has been colonized by plant invaders. Although their dispersal follows the braided-dendritic drainage pattern, this is much less evident to an observer on the ground. The vegetation approaches that of a gently sloping featureless plain dominated by creosote bush and bur sage which scarcely show on the airphotos. The occasional shallow washes support lines of palo verde, ironwood, and a few shrubs of larger size than the interfluvial dominants.

Tables III and IV (on pages 70 and 71) list stations in the alluvial apron type in series; those having much uneroded surface are listed first, and the fractions indicate approximate proportions of undisturbed vs. water-disturbed surfaces. The data show that the large plants decrease in abundance and coverage as erosion progresses in alluvial aprons toward a terrain of uniformly level topography. Both absolutely and relatively, the importance of small shrubs on the interfluves increases markedly during this process of land form evolution.

Detailed measurements of vegetation on the ground were made on a high elevation alluvial apron supporting creosote bush in an almost pure stand. The airphoto appearance was even more uniform than that shown in Figure 48. A ground photograph of this area is reproduced as Figure 49. The density of creosote bush is  $106 \pm 2.86$  individuals per acre, so that the error is 2.7 per cent of the mean density. The low per cent error with only 11 sample strips (each 400 feet x 20 feet) indicates great regularity of spacing of the individuals. The plants cover 2.5 per cent of the total ground surface, or only 1,089 square feet per acre.

Approximately halfway down the alluvial apron, per cent abundance of the plants in a wash of medium width showed palo verde 41.1 per cent; ironwood 36.8; ocotillo 16.0; sahuaro 4.9; and jujuba 1.2 per cent.

The cholla, beavertail, and staghorn cacti extend down the aprons from higher elevations to a lower limit at about 1,050 feet altitude. Their lowest altitudinal occurrence is in gullies, where moisture

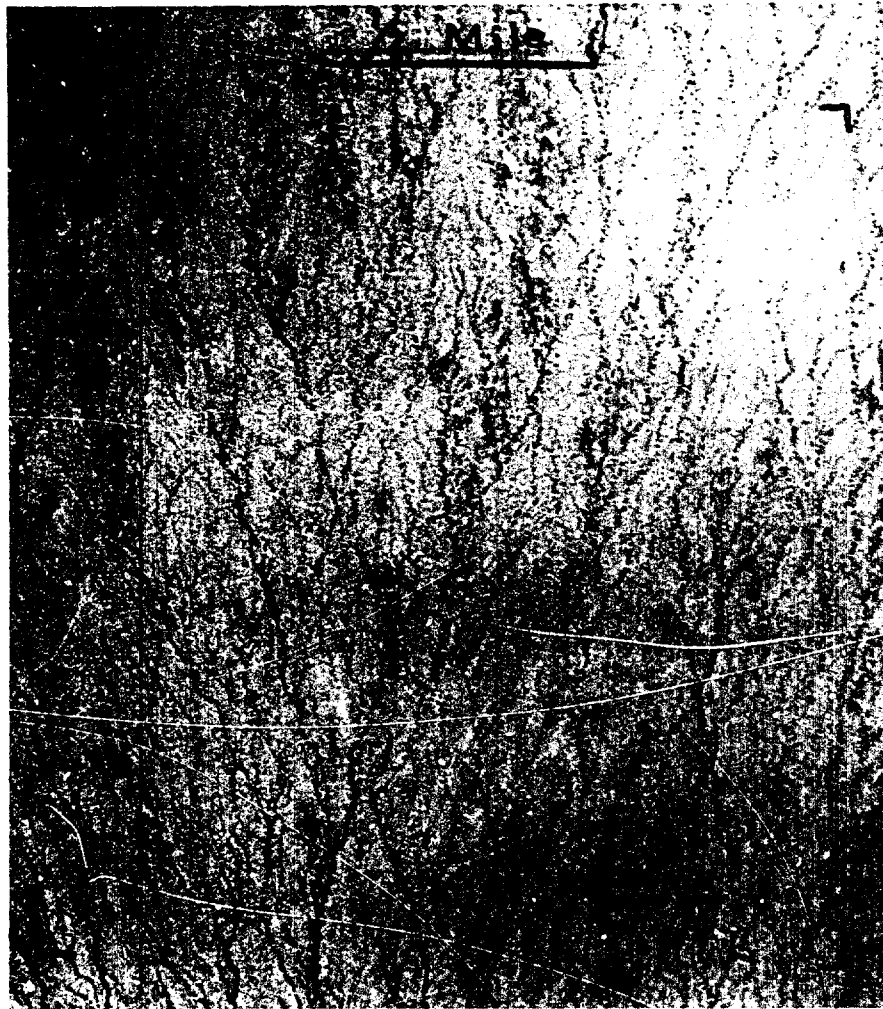


Fig. 48. Vegetation on a finely dissected alluvial apron, with trees in the narrow washes and shrubs between them. This site is at Loc. 368.0 - 77.8.



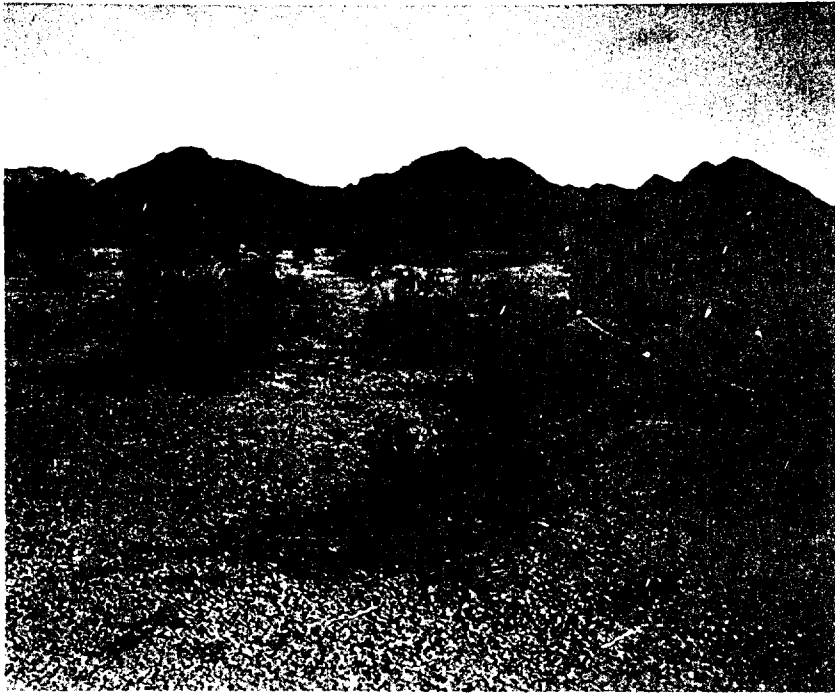


Fig. 49. Pure creosote bush community, with these shrubs openly and rather regularly spaced. This is a ground view taken at the same site as the airphoto in Fig. 49 at Loc. 368.0 - 77.8.

conditions remain favorable farther down slope than on the inter-fluves. Although sahuaro occurs generally, it is much more abundant on aprons above the 1100-foot contour.

In a lower alluvial apron site of interbraided washes represented in Figure 50, an 800 foot elongated plot, 100 feet wide was laid out on the ground to parallel and include just one border of wide and medium wash channels and some of the flood-worked lateral areas. The results obtained were as follows:

|                 | <u>Density</u> | <u>% Abundance</u> |
|-----------------|----------------|--------------------|
| Palo verde      | 10.1           | 51.6               |
| Ironwood        | 4.4            | 22.7               |
| Lycium          | 2.1            | 11.0               |
| Desert-lavender | 1.6            | 8.6                |
| Jujuba          | 0.8            | 4.3                |
| Cat's claw      | 0.3            | 1.5                |

Of the two commonest large shrubs, Lycium appears to be more important than desert-lavender in lower apron washes, while the reverse applies in mountain washes. Of possible interest in this connection is the thorny, stiff, impenetrable nature of Lycium, in contrast to the thornless desert-lavender.

#### Military Significance

Alluvial aprons represent the most stable soil areas throughout the desert around Yuma. This is because they are relatively firm, the soils are granular, and the smooth surface is relatively uninterrupted except by shallow broad washes. Trafficability is no problem



Fig. 50. Large-scale vertical airphoto of palo verde-ironwood-lycium community bordering larger wash channels and creosote bush (smaller) elsewhere. This is on the alluvial apron at Loc. 367.6 - 77.3. The absence of desert pavement and desert varnish is apparent.

on the apron surface for either wheeled or tracked vehicles. However, some of the washes which cross the aprons may offer an obstacle to movement, particularly if they have steep slopes on their banks. This is more serious for wheeled vehicles than for tracked vehicles. The washes themselves contain loose sand and gravel which may make crossing of wheeled vehicles a problem. Washes are definitely to be avoided during a rainstorm when flash floods may occur. The upper surface of the aprons are safe during a rainstorm, particularly on the dark varnished portions which do not exhibit a braided surface pattern.

Dustiness is a problem of considerable magnitude on the alluvial aprons. Vehicles crossing the aprons should avoid tracking because one or two passes is sufficient to loosen the surface considerably and expose the silty materials just beneath the layer of "pavement." The normally clear air of the desert makes it possible to see dust from a moving vehicle for a considerable distance. Because the dark varnished particles are turned over or mashed down into the light colored soil matrix the tracks of vehicles are retained for a long period of time. They are easily seen and followed on the ground, by aerial observation, or by study of airphotos of the area. The dust stirred up by a moving vehicle is shown in Figure 51. Figures 52 and 53 show how well the wheel tracks show up on desert pavement, even after six months time.

The dark varnish tone on the desert pavement precludes the use of most of the apron for the laying of mine fields. It is impossible to disturb the surface without leaving a mark. This is not true in the light-toned burrow mounds or in the washes, but vehicles are likely to avoid the burrow mounds. Washes can be mined with no difficulties.



Fig. 51. A dense cloud of dust is stirred up by a vehicle after ten passes over the desert pavement at Loc. 355.7 - 76.4. The appearance of these tracks after six months elapsed time is shown in Figure 53.



Fig. 52. The smooth surface of the desert pavement. The tracks at the right side of the photo have just been made. The faint tracks were made six months previously.



Fig. 53. Ten passes across the desert pavement leave tracks like this after six months.

## **TERRACES**

A terrace is a bench that is situated between a flood plain or stream and an upland. The Yuma Test Station Headquarters, Research and Development Area, and the Laguna Airport of the Test Station are located on a large terrace.

### **Distribution**

Three per cent of the Yuma Test Station area consists of terraces. They are found along the Gila River and along the southern part of the Colorado. The upper part of the Colorado has a narrow, restricted valley where terraces are not usually formed.

The largest terraces are the ones in the vicinity of the Research and Development Area (Figures 9 and 54) and one in the southeast corner of the mapped area on the south side of the Gila River. On the north side of the Gila, in the vicinity of Growler, a series of terraces has been fairly well dissected by washes that cross the large alluvial apron to the north.

### **Topography**

Terraces are fairly level. As can be noted on the aerial view, Figure 42, there are not so many washes crossing the terrace in the lower left corner as there are on the adjacent alluvial apron. The terrace at the southeast corner of the mapped area on Plate ~~II~~<sup>I</sup> has very little dissection.

### **Geology and Composition**

The terraces are believed to be associated with deposition from the Colorado and Gila Rivers when they were much larger and contained much more water than today. Just east of the Headquarters Area some of the major washes from the alluvial aprons have reduced the terrace surface considerably. The eroded surfaces expose beds of silt and fine



Fig. 54. Aerial view of terrace in vicinity of the Research and Development Area. This view is looking northwest with the Headquarters Area and Imperial Dam in the background.



sand. Some present a "painted desert" appearance since shades of red, yellow, tan, brown, and white occur. It is not certain whether these beds are of marine origin. However, topographically, they are situated above the flood plain of the Colorado and below the alluvial fans and aprons associated with the mountains of the area.

#### Surface Characteristics

Loose sandy materials mantle much of the terrace formations. This was observed along S.R. 95 in the vicinity of the Research and Development Area and on the terrace at the southeast corner of Plate <sup>I</sup> II. The surface of these sand plains is slightly undulating, and conditions seem to be favorable for the development of dunes. It was considered that the stage has not yet been reached where the surface can be classified as dune topography.

#### Vegetation

The vegetation on terraces is not appreciably different from that of the lower half of the alluvial apron next above the terrace. This is discussed in the section on alluvial aprons. Ocotillo is more prevalent on terraces. Palo verde and ironwood are found along the poorly developed washes. Creosote bush and bur sage are also common on the terraces.

A bur sage-creosote bush-ocotillo community on a terrace was studied in detail on the ground at Loc. 364.3 - 74.4. The density of bur sage is 425 crowns per acre. Creosote bush has a density of 72.3  $\pm$  5.0, a per cent error of 6.9. Ocotillo numbers 30.5  $\pm$  3.4 individuals per acre; the per cent error is 11. Small clumps of dry grass occurred in the density of 87 per acre.

### Military Significance

Terraces are ordinarily level enough to be easily traversed. Within Test Station Area, they are of such limited extent that they are not important as routes for cross-country travel. The loose sand that mantles several of the large terraces may cause some minor difficulties. The terraces make good sites for the location of military bases. They are not dissected as much as alluvial aprons, and the problem of runoff and sheet flooding is not so great.

### FLOOD PLAINS

Southern Yuma County, which is one of the driest and hottest desert in the United States, is more fortunate than other areas of less severe climatic extremes. The Colorado River, which is the greatest river in the Southwest, flows along the western border. Besides being the source of water supply for the Test Station and the city of Yuma, the Colorado furnishes great amounts of water for irrigation purposes, not only for the vicinity of Yuma but also for the great Imperial Valley in California. Much of the flood plain of the Colorado has been flooded since the construction of the Laguna and Imperial Dams.

### Distribution

Flood plains are found only along the Colorado River in the southwestern part of the area and along the Gila River bed that meanders in and out of the southern limit of the mapped area. Flood plains cover about 10 per cent of the Yuma Test Station Area. A view of the Colorado flood plain, looking south over the Laguna Dam is shown in Figure 55. In Figure 56, the broad flood plain of the Gila is illustrated. Additional aerial views that include the Gila flood plain are Figures 27 and 30.

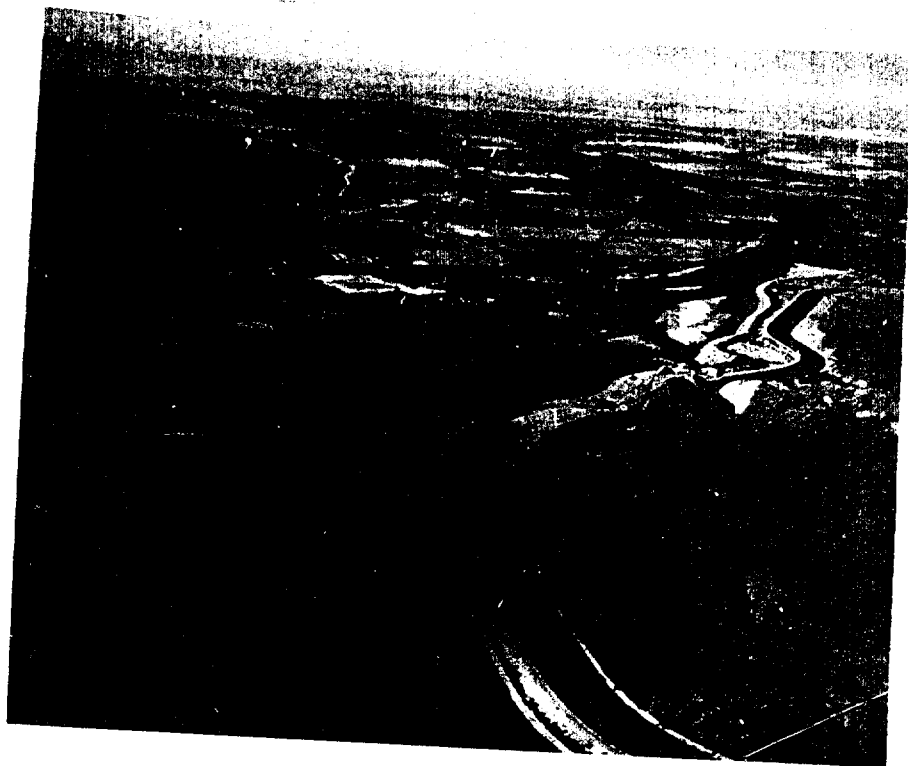


Fig. 55. Flood plain of the Colorado River, looking southward toward the Laguna Dam and irrigated fields.

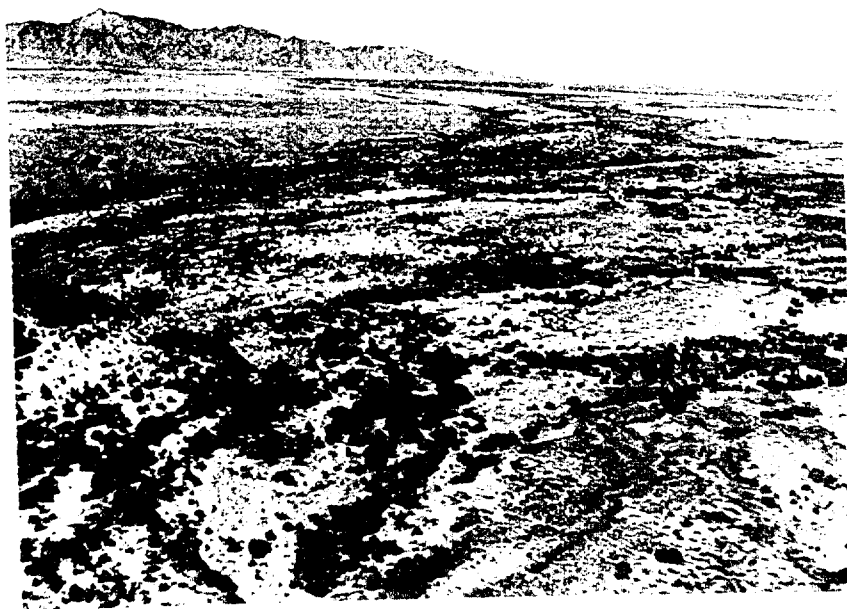


Fig. 56. Flood plain of the Gila River, looking eastward from the vicinity of Texas Hill.

Topography

The surface of the flood plains is rather level. Above the Imperial Dam the Colorado Valley is rather narrow. Because the river level has been raised by the dam, practically the entire upper valley has been flooded. This is also true of the broader flood plain between the Imperial and Laguna Dams, where the features are swamp-like. Below the Laguna Dam most of the flood plain now consists of irrigated fields. The flat plain is now well dissected by numerous irrigation canals. At some places the banks of the major canals may rise ten or fifteen feet above the adjacent plain.

Geology and Composition

The materials that make up the flood plain are recent alluvial deposits. The Colorado River formerly carried a very heavy load of sediment to deposit on its lower delta. Much of this suspended material now settles at the bottom of the lakes that have been formed above the several large dams that have been constructed along its course.

The Laguna and Imperial Dams have raised the level of the river enough that most of the flood plain is flooded above the Laguna Dam. The soil consists primarily of silts and fine sand. Where the flood plain is only slightly above the usual water level, a dry silty crust covers the moist sandy silt beneath.

Along the road between the Test Station Headquarters and the Imperial Dam, soil samples were taken on a small alkali flat on the flood plain. There were about three inches of dry alkali crust on very moist brown silt. A summary of the test data is shown below:

| <u>Depth</u> | <u>Moisture</u> | <u>L. L.</u> | <u>P. I.</u> | <u>Fines</u> |
|--------------|-----------------|--------------|--------------|--------------|
| 0-3"         | 7%              | 12%          | NP           | 97%          |
| 3-9"         | 31%             | 24%          | NP           | 93%          |

There was no vegetation where the alkali covered the surface.

The dry Gila River bed and adjacent flood plain are shown in Figure 27. The channel is marked by the vegetative growth across the photo. Immediately to the left of the inselberg in the foreground, the flood plain consists of a fine silty sand. Observations at a number of sites in various parts of the flood plains showed that the soil is predominantly silts and fine sands. In the dry bed of the Gila near the east edge of the map, a sample was taken from a depth of 1 to 8 inches, and the tests showed the following results: moisture content 4%, L. L. 38, P. I. 27, and 98% of the material passing the #200 sieve.

Practically all of the flood plain below the Laguna Dam has been irrigated. Actually, as described by Sykes (20), this is a part of the Colorado delta, but it has the same features as flood plains. Additional irrigated areas are found along the Gila River. Silts and fine sands are the predominant soils. Further discussion of the features of irrigated areas is presented at the end of this chapter.

#### Vegetation

The map of Arizona natural vegetation (16) separates the flood plain site along the lower Gila River into "irrigated land" and "mesquite and saltbush bottoms." Since the Colorado flood plain in the latitude of the Test Station has been largely covered by impoundment, and the rough land of the Chocolate (Arizona) and Trigo Mountains adjoins this reservoir, the vegetation of the Colorado flood plain need be considered only below Imperial Dam.

The flood plain alluvium supports vegetation of several stages, correlated with the period of time since deposition of the substrata, or since the last drastic disturbance of the surface and vegetation. The relation between the average position of the water table and the soil surface is the most obvious basis for the arrangement of these communities. Starting with the deepest standing water that permits plants with submerged roots but stems emerging above water, the habitat of the great bulrush is found. This plant occurs in marshes and in shallow water along river banks. It was seen in backwaters below Imperial Dam. In slightly more shallow standing water is the cat-tail, a very common marsh species. The ground in this community is more likely to be dry for a part of the year due to normal seasonal fluctuation of water-level. The next drier stage is represented by the common reed (Figure 57) and arrowweed, occurring in shallow water or on soil saturated at or near the surface.

Another condition occurs on river alluvium that ordinarily has no standing water except possibly in the deeper depressions. The water table, however, is close enough to the surface to allow the rise from it of capillary moisture. When this evaporates at the surface, it leaves a deposit or surface efflorescence of white alkali. Practically no plants grow here except picklebush (Figure 58) which is generally dominant, and some salt-cedar and saltgrass. Much of the ground is completely bare of plant cover. Picklebush is a low leafless shrub with a green succulent stem divided into thickened fleshy sections resembling miniature pickles.



Fig. 57. Common reed on the Colorado River flood plain below Imperial Dam.



Fig. 58. Picklebush, a characteristic leafless, green shrub, on soil showing white alkali bloom.

The next drier habitat is dominated by salt-cedar, arrowweed, and saltbush. The latter (Figure 59) forms extensive and dense thickets up to 15 feet high and exclusively of this species. The leaves apparently remain on throughout the year in this region. Salt-cedar (Figure 60) is, however, the most important plant of this stage. It was brought into the United States from the Mediterranean region but has become thoroughly naturalized in recent years and has crowded out more valuable species. It is but one of the pests which illustrate the folly on introducing exotic species which, when freed of their biological controls, rapidly spread at the expense of useful native plants.

The plants mentioned thus far are all fully dependent upon the ground-water reservoir, and would not long survive if the only water available were that from local precipitation.

The final group of flood plain plants is made up of two kinds of species in relation to ground water, although they grow in mixture. Some of them, as cottonwood, mesquite, and tornillo would be generally unable to develop here without the abundant gravity water and the capillary fringe derived from the water table. (An occasional mesquite occurs in mountain washes, however.) On the other hand, scattered among them are species typical of the dry upland desert. Although these species (palo verde, ironwood, and creosote bush) are well adapted to do without any contact with the water table, in the flood plain site they take advantage of this source and grow to considerably larger size than elsewhere.





Fig. 59. Dome-like masses of the largest species of saltbush in Arizona.

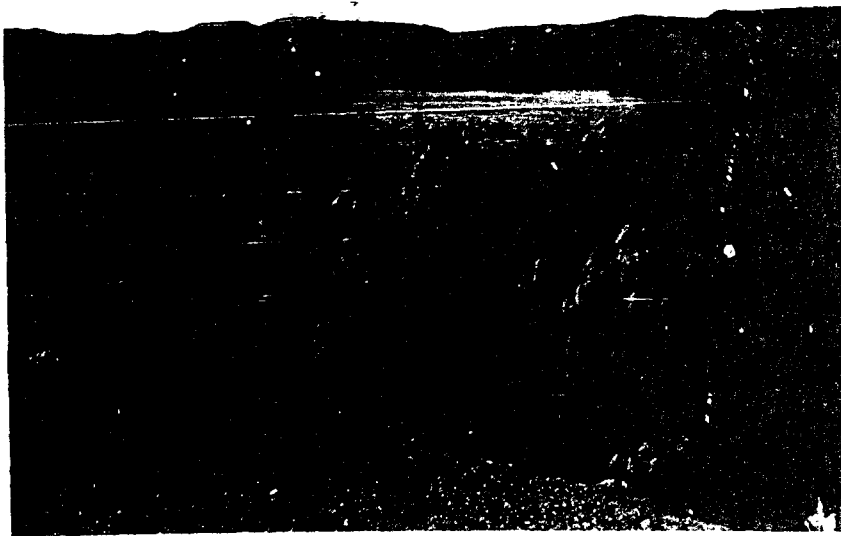


Fig. 60. Salt-cedar showing the yellowed, drooping foliage in December.

Turning next to the flood plain along the lower Gila, some of which is in agricultural use, a widespread type is practically pure mesquite occupying the domes of low stabilized dunes in a border zone paralleling the course of the river, along the outer edges of the flood plain. The mesquite as it typically develops when stabilizing dunes, is here low and shrub-like. Some leaves were present in December 1953, but were yellowed and falling. Doubtless the roots are tapping the ground water reservoir; mesquite is practically absent in the alluvial apron physiographic type at slightly higher altitudes in this area because (as a rule) it cannot do without ground water in this climate of extremely low precipitation.

#### Military Significance

Imperial Dam maintains a water level upstream that keeps almost all that portion of the flood plain under water. The narrow valley is restricted on both sides by mountains and hills. In order to traverse these flooded plains, a vehicle would need to be able to operate in several feet of water. Even access to this upper plain is difficult except just north of Castle Dome Landing.

Most of the plain between the two dams is also flooded much of the time, but the water is not as deep as it is above the Imperial Dam. Conditions are swamp-like and vegetation is dense.

Below the Laguna Dam almost all the plain is irrigated. The plain is crossed by a network of canals of various sizes, some of which are major obstacles to cross-country movement. Some of the larger canals are lined and have banks which rise ten or twelve feet above the adjacent plain so gravity flow can be maintained throughout the system.

Parts of the Gila Valley are irrigated, and these canals offer the same obstacles to movement. The rest of the Gila flood plain should present few problems in moving military vehicles.

The Colorado River is an important source of water supply, and wells in the adjacent flood plains and terraces should also furnish water. Although the Gila River is dry, underground waters draining through the unconsolidated materials probably percolate beneath the dry river bed.

#### Irrigated Areas

Large areas of land in the vicinity of Yuma are irrigated, making it an important agricultural center. Most of the irrigation projects are on the flood plains. Since irrigation is not a natural condition of the surface, irrigated areas are discussed here separately from the rest of the flood plains. Only a small portion of the irrigated land is within the Yuma Test Station Area, as shown on Plate <sup>I</sup>IV on the Colorado flood plain in the vicinity of Bard and on the Gila flood plain near McPhaul Bridge and also east of Roll.

The soil materials of these irrigated lands are similar to those in other portions of the flood plains, consisting primarily of silts and sands. These soils retain their supporting ability even while they are flooded. The cone penetrometer was used in a number of fields to check on the trafficability conditions. In a field that was still moist near Bard, the following average cone indices were obtained: 25 at surface, 145 at 3", and 270 at 6". This was in a field that had been irrigated many years, giving it a chance to become well compacted. In another field near Roll that had been leveled and



Fig. 60-A. Irrigated field in the vicinity of Bend. The All-American Canal is in the foreground, and Yuma is in the distance, which is south.

opened for irrigation the previous year, the readings were lower: 30 at surface, 50 at 3", 110 at 6", 140 at 9", 185 at 12", and 300 at 18". Where the fields had dried out, readings of 300 were obtained less than 3 inches from the surface. All these readings indicate relatively good trafficability conditions.

The network of irrigation canals is a definite barrier to cross-country movement. The main canals are too broad and too deep for most vehicles to cross. Some of them are built up, like levees, so the canal may be ten or twelve feet above the adjacent fields.

Winter vegetables, particularly lettuce, are the most important crops. Cantaloupes are the largest summer product. Cotton, dates, and citrus fruits are also cultivated.

#### PLAYAS

A playa is a level plain that occupies the lower portion of the shallow basins, or bolsons. A playa is usually dry, but after a storm, a playa lake, only a few inches deep, may cover a large area.

Playas are common in closed basins throughout the Southwest. The Colorado and Gila Rivers have extended their drainage systems through the Test Station area and provided surface drainage to the alluvial plains. Hence, true basins do not exist in the Test Station Area.

#### Distribution

The only playa or playa-like situation in the vicinity of Yuma is the one that is south of Stoval. This playa is located just outside of the southeastern corner of the mapped area; its northern tip, however, is shown on the border of Plate <sup>I</sup>~~II~~. This playa was not included when the percentages of the various land forms within the Yuma Test Station Area were computed.

### Topography

The surface of the playa is level. As shown in Figure 61, only a few clumps of vegetation are scattered across the monotonously flat plain.

### Geology and Composition

Playas occupy the lowest portion of the closed basins which result from filling-in process of erosion, removal, and deposition in basin-range areas. Materials eroded from the mountains are transported to the basins by running water.

The coarser alluvial materials have been deposited adjacent to the mountains, while the finer materials have been carried far out into the basins. Materials in the playas consist primarily of silts, with some clay and alkali deposits. As the playas dry following wet periods, cracks develop in the surface. The cracks in the silty surface of the playa south of Stoval are shown in Figure 62.

Sand that is blown across the surface by the wind tends to collect around the scattered clumps of vegetation. Ordinarily a playa is dry, but after a storm, a playa lake may be formed, covering many square miles with water only a few inches deep.

### Vegetation

The vegetation is very sparse on playas. An example is contained in Figure 61. The widely scattered shrubs are separated by barren silt surfaces.

### Military Significance

The broad, rather smooth surfaces of playas offer no obstacles to cross-country movement when dry. Dust will present a problem, however.



Fig. 61. The playa south of Stoval, looking westward with the Mohawk Mountains in the background.

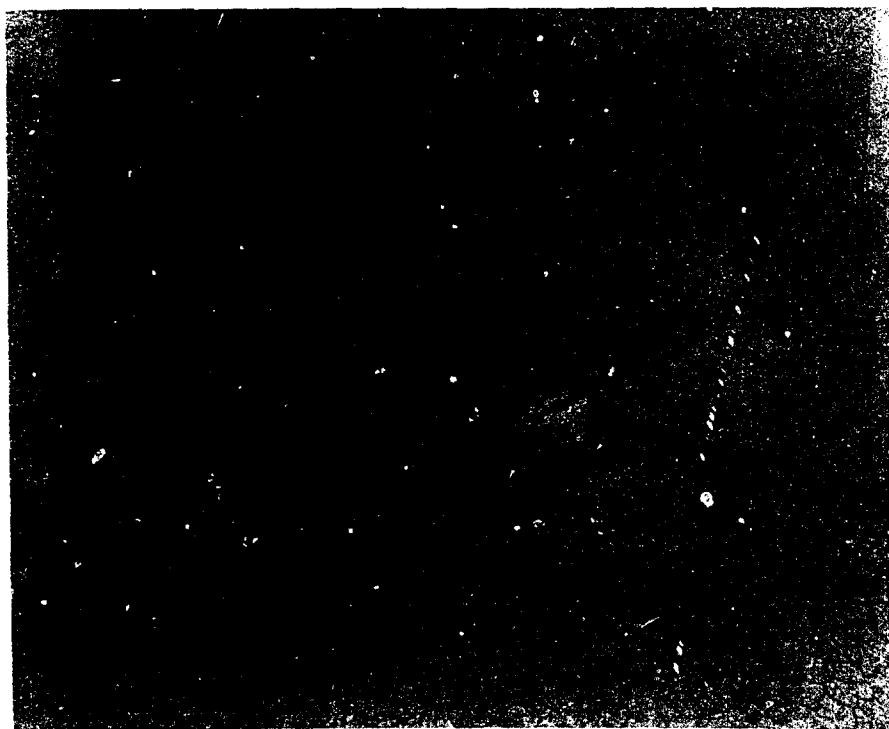


Fig. 62. Surface texture and cracks in the silty material of the playa.

The infrequent periods following rainfall when water occupies the plays may offer some problems. The shallow water should not be deep enough to impede movement, but the surface will be slippery and soft.

There are many types of playas, of which this is only one, and problems can be different or intensified, depending upon the type.

#### WASHES

Washes are such an integral part of the alluvial aprons and fans that they are most appropriately discussed in the chapter on plains in this report. Mention is also made in this section of the washes and canyons in the mountainous and hilly areas.

#### Distribution

Dry washes are found throughout every part of the area. Because they are long, narrow, and winding, their areas are difficult to compute. Besides, they are an integral part of the plains and mountains in which they are found. Therefore, when computing the percentages of the various land forms in the Test Station Area, the washes have been included with the surface forms that they traverse.

To give an indication of the extent of washes, a rough estimate has been made that approximately 12 per cent of the Yuma Test Station Area consists of dry washes, canyons, and other drainageways (about 60 per cent of the washes traverse alluvial aprons, about 25 per cent are mountain washes and canyons, and about 15 per cent are gullies in the hills). Washes in other land forms are less than 1 per cent of the area.



### Topography

The washes across the alluvial aprons are long and relatively narrow. The beds are commonly flat, but they slope gently down to the base level wash. The gradient is a little steeper near the mountains. In the lower part of the valleys where slopes are almost flat and there has been little erosion, the washes are shallow. Toward the mountains the gradients are steeper, and the washes may be five or ten feet deep. Washes converge and diverge in a braided pattern. Within the washes themselves, the surfaces are rather level. Washes and gullies dissecting the alluvial fans resemble those in the higher parts of the aprons. Large boulders are found along these upper washes.

Near the front where some of the mountain washes are broad, some of the characteristics of the washes on the fans still prevail, as that in Figure 23. Generally, however, mountain washes and canyons are winding and narrow with steep sides. Their bottoms may be rough, and "dry falls" are common.

### Geology and Composition

Dissection in the desert is more severe than it is in the humid climates. When the infrequent cloudburts occur, the runoff is large. Water velocities are high, and the erosion is severe. Channels become blocked, and new ones are made.

The erosion is most severe in the mountains where slopes are steep, flow is restricted to narrow canyons, and the velocities are high enough to move huge boulders. It is this erosion in the mountains that has moved the material that now makes up the fans and aprons.



Fig. 63. Broad wash bordered by palo verde and ironwood on the Castle Dome Plain. Coarse sands and gravels cover the channel.

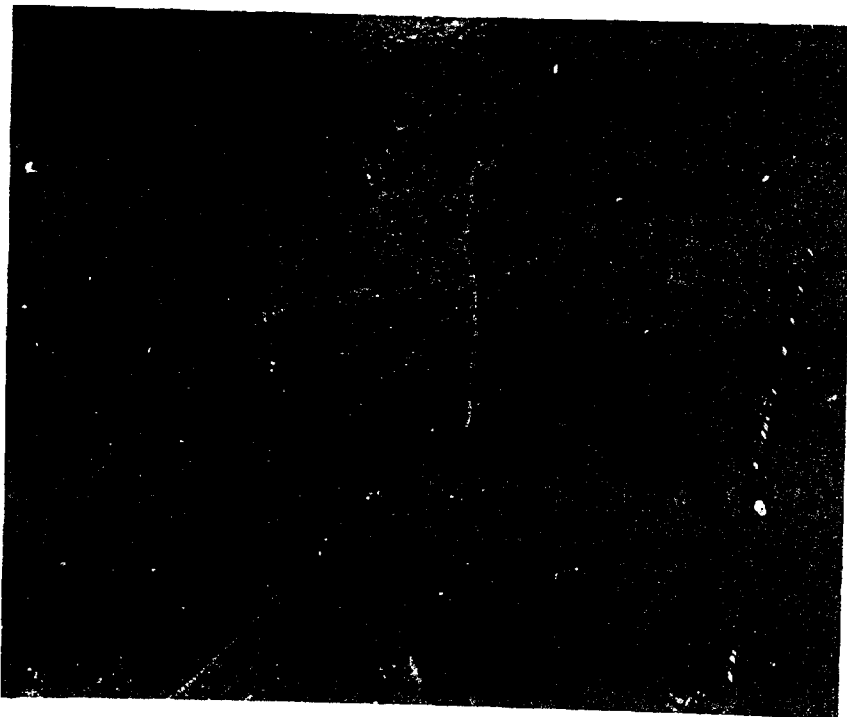


Fig. 64. Indian Wash, one of the largest in the area, is broad with steep sides.

The fans are primarily depositional forms that have been built up by the materials that have been brought down from the mountains. Considerable erosion has dissected fan surfaces as these are places where the greatest runoff is likely to be concentrated.

Washes that cross the fans and upper aprons have a considerable gradient, and deep gullies with steep sides have developed. Toward the center of the valleys the slopes are more flat, and the washes are not as deep. The washes across the aprons tend to be generally parallel, but they branch out and coalesce with adjacent washes in a braided pattern.

In the mountain canyons the bare rock channels may contain huge blocks of rock or pockets of gravels in scoured out depressions. The broader channels may be covered with coarse gravels. The material in the washes which cross the fans and aprons is loose coarse gravels, their size becoming smaller with increased distance from the mountains.

#### Surface Characteristics

In the mountains the canyons may be narrow and winding and exhibit bare rock surfaces if all the loose material has been removed. The more mature washes are broad and are mantled with gravels and boulders. The washes that cross the fans and aprons also contain very coarse materials. Finer granular materials are found along the washes farther out on the apron.

#### Vegetation

The vegetation along the washes has been discussed previously under the various land forms with which the washes are associated, since so many of the washes are an integral part of the surfaces that they dissect. Most of the vegetation described on the other land forms actually grows along washes.

It is appropriate to mention the base level washes, however, as they are broad enough to warrant further discussion. A broad storm-water drainage system between mountains is illustrated in Figure 65. The vegetation is very similar to that of the larger washes in the lower portions of alluvial aprons (Figure 50) which is to be expected since the environment is similar in general and merges imperceptibly. Table IV on Page 71 shows that base-level washes support about 10 per cent coverage by large plants, which is greater than that of any other terrain type sampled by airphoto analysis. The large crown diameters of the dominants, palo verde and ironwood, causes this increase of coverage without necessarily increasing density.

Ironwood in the low altitude washes and in the flood plain seem to be more seriously infected with the partial parasite California mistletoe; an exceptionally large mistletoe on a flood plain is shown in Figure 66. Palo verde is also attacked, but not as commonly or severely as is ironwood.

#### Military Significance

The only practical way of getting through several of the mountain ranges is to follow a route along some of the major washes. Two old roads through the Castle Dome Mountains are shown on Plate I. The roads cross low divides where broad washes extend into the heart of the mountains. These roads are in poor condition now, but they are passable by vehicles with four-wheeled drive.

The narrow winding canyons have little use in providing routes for vehicles. They usually contain huge boulders which may block the way, or "dry falls" may form an impassable barrier.



Fig. 65. Base level wash showing linear aggregation of the main vegetation.



Fig. 66. California mistletoe, a parasite infesting the crown of a large mesquite.

The washes tend to have roughly parallel courses across the fans and aprons. It is extremely difficult to move transversely across the washes where dissection has been severe. The gullies are numerous and the sides are steep. In dissected areas the best routes of travel are usually along the gullies.

Natural tanks that usually contain water are found at several locations along the gullies in the mountains. These have been caused by unequal weathering in the rock surfaces. Some of them are at the bases of "dry falls" where depressions have been scoured out. After a rain these cavities hold water for serious period of time, some of them for months.

Storms in the mountains may send dangerous rushing down the washes and catch campers unexpectedly. Therefore, it is unwise to camp overnight down in a wash.

CHAPTER VI  
MILITARY SIGNIFICANCE OF  
THE YUMA TEST STATION ENVIRONMENT

Environmental factors must be considered in planning military operations in the desert, and therefore their effects on man and material must be studied. In this chapter several important problems are discussed primarily as they are related to the conditions that are found at the Yuma Test Station, but many of these environment stresses are also found in other desert areas.

CROSS COUNTRY MOVEMENT

Military vehicles can be driven across the plains without any great difficulties. Movement is easy across the lower portions of the alluvial aprons, as the washes are very shallow and easily crossed. On some of the smooth portions of the desert pavement, a jeep can be driven almost as fast as it can along a paved road. On the alluvial fans and portions of the aprons that are adjacent to the mountains, dissection has cut gullies with steep sides, and it is necessary to locate a place to cross the washes. Travel along parallel washes (which is usually in a direction toward the mountains) will not encounter nearly as many gullies as travel at an angle.

The washes are the best routes to follow through the hills and mountains. In hilly regions it is often possible to climb the slopes of the hills in order to cross to the other side or to travel on the ridges. Movement in the mountains is very restricted. Slopes are too steep and rocky to permit travel. Two roads cross through the Castle Dome Mountains, following for the most part along washes. These

roads have not been maintained for a considerable period of time and are in very poor condition. Loose granular materials in the washes form much of the road bed. Many of the canyons are littered with huge boulders.

Considering the terrain surface in general, about 3 to 10 per cent has been shown to be covered by plants large enough to impede progress of such vehicles as jeeps and weapons carriers, at least. When attention is centered on particular habitats, however, the problem appears more serious, since in strips along wash borders larger crowned plants often coalesce into an uninterrupted mass for a considerable distance. Avoiding such matted ranks of plants, and even those individuals in more open stands, would be quite possible by selecting a circuitous route through them, but this inevitably would slow down the operation. It is believed that men traveling on foot would be slowed down more by the plant factor than by the terrain itself, whereas the reverse would be true for small vehicles because of the 2-3 foot high vertical walls of many washes.

While it might appear incredible that any desert tree could stand up to a tank, it is believed that large ironwood trees (one of which had a trunk 37 inches in diameter) could resist a tank quite effectively, since this is one of the world's hardest woods. Probably this would never become an issue because such huge trees are not common enough to be closely spaced; a tank could be readily turned to avoid such trees except possibly in the heat of battle.



## TRAFFICABILITY

During dry weather most of the soil materials are capable of supporting any military vehicle. The topography is the most important obstacle in the movement of vehicles in the vicinity of Yuma.

Materials such as loose sand require special precautions and procedures. The Sand Hills can be crossed if the tire pressure is reduced to 5 to 10 p.s.i., four-wheeled drive is used, and the route is carefully selected to avoid climbing the unstable sands along the steep slopes.

Following a heavy rain the silty soils will become soft and slippery, which may immobilize some vehicles. Moisture stabilizes the dune sand, however, and improves its trafficability.

Because of the presence of gravels and rock fragments mixed in with most of the soils, the soil penetrometer cannot be used to evaluate the soil trafficability conditions. The only places where it could be used were sites where the soil consisted of sands and silts. These include the Sand Hills, sand areas on the terraces, irrigated areas, and a few additional flood plain sites.

## AIR DROPS

From the standpoint of movement of troops by air, it might appear to the flyer unfamiliar with desert vegetation that because of the unusually wide spacing of the vegetation, it would be ideal for parachute operations. However, because of the combination of surface winds and spiny cacti in the Yuma Test Station Area, such operations would be highly impracticable in the vegetational belts above 1000 feet where

cholla grows. Although all the cacti present in the region have nasty spines, Bigelow's cholla has the worst. Its loose stem segments are readily detached and consequently more and more spines are encountered in trying to remove the first ones. They are long, slender and needlepointed, with barbs which make removal difficult and facilitate their working in more deeply. It would be difficult to imagine a worse fate than to be dragged by a parachute through even one cholla plant, let alone a stand of them.

At elevations below the lower limits of cholla, staghorn, and beavertail cacti, other thorny plants range throughout the remainder of the terrain series through the flood plain. An individual paratrooper might guide himself to a safe spot, but the success of mass jumps is dubious. The cat's-claw, lycium, sahuaro, ironwood, tornillo and others have spines of varying degrees of sharpness, size and strength; they would insure that a certain proportion of the troops would land in conditions for hospitalization unless equipped with goggles and garbed in special puncture-proof jumping suits. On a calm day or with the wind blowing parallel with the washes, many jumpers would possibly be lucky enough to land on the barren desert pavement interfluves, which are extensive in some places. However, a mass parachute landing cannot be very selective.

#### SITE SELECTION

Several important environmental factors must be considered in evaluating a site in the desert for possible military use. An airfield, for example, requires a large level area where the mountains are distant enough that they will not be a hazard to flying. The alluvial aprons or terraces would provide the best sites for this.

The concentrated runoff during the infrequent desert storms must be considered. There are not as many washes crossing the terraces as there are crossing the aprons, probably because the terraces are composed of more porous materials, and therefore a greater proportion of the water seeps into the soil rather than running off. Construction in washes is dangerous, as any wash may be suddenly flooded even though it has been dry for years. Aerial photographs and field observations show that the existing airfields in the vicinity of Yuma are located where there are not many washes. Yuma Air Force Base, as well as several inactive military fields, are located a short distance outside the Yuma Test Station Area. Terraces seem to be the preferred location for these fields.

#### ROAD CONSTRUCTION

The construction of roads across plains offers no serious difficulties. The surfaces are rather level, requiring no great amounts of cuts or fills. Granular materials are available close to the mountains although they may be scarce in the silt flats in the centers of the aprons.

The most serious problem along the highways is surface water runoff. Inadequate culverts are frequently washed out after storms. Along S.R. 95, as along many other highways in arid regions, the road dips where washes are crossed, so any water in the gullies flows over the pavement. Such a road is not conducive to driving at high speeds, but it greatly reduces the cost of construction and maintenance.

Mountains should almost always be avoided when building roads in the basin and range topography. Many of the mountains are so rugged that construction costs are extremely high. Many of the ranges cover an area small enough that the road can be routed most economically around the mountains.

## WATER SUPPLY

The only perennial source of surface water in the vicinity of Yuma is the Colorado River. Such an abundant supply of water is not available in most desert areas.

Natural rock tanks are found at several locations in the mountains. The larger tanks will hold water for several months after a rainfall. These tanks are often the only surface water supply in a large area. They may become dry when there is a long period of time between rains.

Sometimes water can be obtained by digging a few feet down in the granular materials of intermittent stream beds.

In the basin and range topography, the best source of ground water is wells that have been bored in the alluvial aprons. Much of the rainfall permeates down through the valley fill materials to the rock floor. Deep Well and Middle Well were important sources of water years ago when the mines were active. Deep Well is about 1200 feet deep.

## COVER AND CONCEALMENT

The narrow mountain canyons offer the best sites for concealment. Unless a reconnaissance plane was very nearly overhead, the aerial observer could not see anything hidden in many of the mountain canyons.

The topography of the hills offers only a small degree of concealment against aerial observation. The gullies are good routes which reveal little information to ground observation posts.

About the only topographic concealment that the plains offer is against the steep walls of the deeper washes. Much of this is insufficient for vehicles but would be adequate for a man on foot.

Desert trees bordering the washes (palo verde and ironwood) have spreading crowns, and sometimes the tree crowns coalesce. Such crowns have sufficiently dense foliage or branchlets to afford foot soldiers concealment from the air at all times of the year. The older trees have lateral branches drooping sharply, especially in the case of ironwood. A rather extreme case was furnished by one old ironwood with a trunk diameter of 36" (at one foot up). It had a complete screen of largely dead but very dense branchlets around the entire periphery of its crown, so that only by breaking branches where they are fewest could one force entry beneath the crown. Once within, there was an opening about 5 feet wide all around the trunk and the inside of the wall of vertically hanging branches. The latter were firmly anchored in the flood-deposited silt of the wash on all sides of the tree. An observer 50 feet from the tree looking for a man wearing a conspicuous black and white checked shirt (who was standing up within the tree shelter) could spot him only with difficulty even though he already knew where he was. The man under the tree, on the other hand, could see out without any difficulty.

A small vehicle, such as a jeep, could be hidden beneath many of the larger palo verde and especially ironwood. These trees would less often afford satisfactory concealment from observers on the ground. In the case of palo verde, a striking characteristic is the shedding of numerous dead branches. Often an old tree is surrounded beneath the edge of the crown by a roughly doughnut-shaped brushpile made up of its own dead and fallen branches. Some of these would usually need

to be removed in order to get a jeep or similar size equipment under its crown for concealment. For hiding men on foot, however, the dead trash would be an asset that enhances the possibility of concealing them from ground observers.

Because of the thorny nature and the dense rigid branches of many desert shrubs, they would not be very feasible hiding places for foot soldiers or for any other concealment purpose, even though the size of the dome-like clumps would seem promising. The branches reach clear to the ground. Lycium is such a shrub. Jujuba has evergreen leaves, which are large as desert leaves go and very dense. It is difficult or usually impossible to see through the clump, so that a man could hide behind it, but he could not hide under it or within its stiff branches, which are without thorns, however. Where several clumps have the crowns coalesced, a man might obtain concealment from the air by lying on the ground between such clumps. Most thornless shrubby clumped species are too sparsely branched for concealment (creosote bush) or far too small for effective concealment (bur sage), even of one man.

#### SURVIVAL

The greatest problem of man in the desert is lack of water. The natural sources of surface water and ground water in the Yuma area are mentioned in the section on water supply.

The use of barrel cactus as an emergency source of drinking water is well known. The top is cut off, and the pulpy tissue punches down to form a depression in which the bitter-tasting water collects.

The fruits of sahuaro were an important source of food for Indians of the region. The fruits of other cacti have a pulpy interior having some food value for humans, which would be edible until dried out. This is particularly true of the flat-stemmed prickly pear types which are bred as food plants in Mexico. The very small needle-like clustered spines should be very carefully removed if the entire fruits are to be eaten; otherwise they can be rubbed off sufficiently for handling, the fruit halved, and only the interior eaten.

The pods of mesquite are rich in food value and also provide some moisture when eaten.

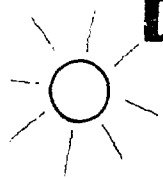
Any small variation in man's body temperature, even one or two degrees, reduces his efficiency (26). The body can obtain heat by absorption from the air, radiation by direct sunlight, absorption of reflected sunlight from the ground, contact with the ground, or by exercise. The body must get rid of the excess heat to keep its temperature normal. This is done by the evaporation of sweat from the surface of the skin.

Sweating, however, dehydrates the body at an alarming rate. Energy losses are great as the body becomes deficient in moisture. The efficiency loss by dehydration can be restored quickly by drinking water. There is no substitute for water to prevent dehydration and keep the body at normal efficiency.

Excess heat that the body gains must be balanced by the evaporation of a certain amount of sweat, and the body moisture lost by sweat must be replaced by drinking water. The only way to conserve water is to ration sweat by protecting the body against heat. This can be done by keeping the body well covered, keeping out of the sun, and doing any necessary walking at night.

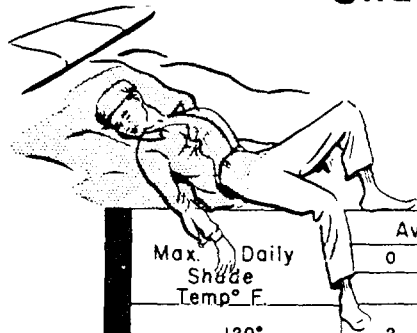
These comments on the water needs of man in the desert have been summarised from the publication "Afoot in the Desert" (26). The chart in Figure 67, obtained from the same source, shows the number of days that one can survive in the desert with limited water supplies. The data in this chart appeared originally in "Physiology of Man in the Desert" by E. F. Adolph and associates.





# DAYS of EXPECTED SURVIVAL in the DESERT

Under Two Conditions



| Max. Daily<br>Shade<br>Temp° F. | Available Water per Man, U. S. Quarts |     |     |      |      |      |
|---------------------------------|---------------------------------------|-----|-----|------|------|------|
|                                 | 0                                     | 1   | 2   | 4    | 10   | 20   |
| Days of Expected Survival       |                                       |     |     |      |      |      |
| 120°                            | 2                                     | 2   | 2   | 2.5  | 3    | 4.5  |
| 110°                            | 3                                     | 3   | 3.5 | 4    | 5    | 7    |
| 100°                            | 5                                     | 5.5 | 6   | 7    | 9.5  | 13.5 |
| 90°                             | 7                                     | 8   | 9   | 10.5 | 15   | 23   |
| 80°                             | 9                                     | 10  | 11  | 13   | 19   | 29   |
| 70°                             | 10                                    | 11  | 12  | 14   | 20.5 | 32   |
| 60°                             | 10                                    | 11  | 12  | 14   | 21   | 32   |
| 50°                             | 10                                    | 11  | 12  | 14.5 | 21   | 32   |

*No  
Walking  
at all.*



*Walking at  
night until  
exhausted  
and resting  
thereafter.*

| Max. Daily<br>Shade<br>Temp° F. | Available Water per Man, U. S. Quarts |     |     |      |      |    |
|---------------------------------|---------------------------------------|-----|-----|------|------|----|
|                                 | 0                                     | 1   | 2   | 4    | 10   | 20 |
| Days of Expected Survival       |                                       |     |     |      |      |    |
| 120°                            | 1                                     | 2   | 2   | 2.5  | 3    |    |
| 110°                            | 2                                     | 2   | 2.5 | 3    | 3.5  |    |
| 100°                            | 3                                     | 3.5 | 3.5 | 4.5  | 5.5  |    |
| 90°                             | 5                                     | 5.5 | 5.5 | 6.5  | 8    |    |
| 80°                             | 7                                     | 7.5 | 8   | 9.5  | 11.5 |    |
| 70°                             | 7.5                                   | 8   | 9   | 10.5 | 13.5 |    |
| 60°                             | 8                                     | 8.5 | 9   | 11   | 14   |    |
| 50°                             | 8                                     | 8.5 | 9   | 11   | 14   |    |

FIG. 67

## CHAPTER VII

### CONCLUSIONS AND RECOMMENDATIONS

#### EVALUATION OF THE YUMA TEST STATION

In the opinion of most of the personnel of the test teams that were interviewed, the environmental conditions at the Yuma Test Station offer conditions that are suitable for conducting most of the desert testing programs. Several of the advantages of the site of the Yuma Test Station are summarized below:

1. Plentiful water supply for adequate facilities to support desert research.
2. High summer temperatures, exceeded only by Death Valley.
3. Very low humidity.
4. Very low annual rainfall.
5. Proximity to large area of sand dunes.
6. Adequate rail, highway, and air transportation facilities available.
7. Very few cloudy days per year.
8. A wide variety of terrain conditions (slopes, soils, surfaces).
9. There are ample silty (dust) areas.

Major disadvantages of having a desert testing station at Yuma are:

1. There are no playas or enclosed basins that are common in many other southwestern deserts. There are no salt deposits.
2. Although several deserts have important rivers flowing across them, the vast majority of desert areas are far removed from a perennial stream such as the Colorado River.

3. Generally low altitude. There are no great elevation differences which would introduce climatic changes in a short distance such as occur in Death Valley.
4. There are no clay surfaces of any significant extent.

#### USE OF OTHER DESERTS

Test teams from various Branches have conducted some research in other desert areas, but it has been on a limited scale. The Ordnance Test Teams have gone from Yuma to Death Valley for several weeks during the past few summers. Equipment can be tested under several conditions there that are not available at Yuma. Climatic contrasts are more extreme and vehicles can be driven from sea level to 5,000 feet elevations in a few minutes.

The Chemical Corps has a proving ground at Dugway, Utah. It is situated on a marshy flat with a salt crust. Studies have been made in the Mojave Desert for the Quartermaster Corps by the University of Southern California and the University of California at Los Angeles.

The use of test sites in other desert areas is necessary to provide some environmental conditions which are not found at Yuma. It is doubtful if another location could be selected that would be as well situated as Yuma is for a permanent installation to provide desert testing facilities. Except for Death Valley, no other area within the United States has such extreme desert conditions. Death Valley would offer many advantages, but it does not have the adequate transportation facilities and water supply available. No area, including Yuma, has a complete range of environmental situations available. There are probably almost as many varieties of land forms at the Yuma Test Station as there are in any other desert locality.

#### SUGGESTED RESEARCH PROGRAMS

1. Use of aerial photographs for studying desert environmental features as a method of comparison. This could be done also in connection with background for every type of testing program undertaken at the station.
2. Test programs to catalog land forms on a comparative basis.
3. Test programs to catalog vegetation on a comparative basis.
4. Test programs to catalog natural materials on a comparative basis.
5. Methods of locating ground water (resistivity, seismic, airphotos) for potential field use.
6. Influence of cultivation and irrigation on local micro-climate.
7. Long range humidity study and comparison with other areas of the Southwest and the world.
8. Trafficability studies and comparison with other desert areas.
9. Influence of desert conditions on production testing.

#### AIRPHOTO MAPPING AND INTERPRETATION PROGRAM

In this study of the environmental conditions of the Yuma Test Station Area, aerial photographs were used extensively. In the field they served as a pictorial guide to select routes to reach remote sites and to map soils, rocks, and terrain in general. In the office they were used to delineate the borders between land forms and other terrain information.

Extensive use has been made of airphotos for making studies of soils, rocks, and surface features. This field work at Yuma has provided data for correlating airphoto patterns of certain desert areas with some

of the environmental conditions. Some of the surface conditions at Yuma and in other desert areas require further field observations in order to make satisfactory aerial photographic interpretations. For example, desert pavements near Yuma can be identified from airphotos and evaluated as a result of field experience; but no method has been developed for using airphotos to identify pediments when the bedrock surface is covered with alluvial materials.

Several agencies have conducted studies relating to the environmental features of deserts. As far as is known, none of these have made any particular use of airphotos. Even the study described in this report is primarily a project of mapping and describing the environmental features at the Yuma Test Station; the use of airphotos was primarily an expedient in getting this done. An additional program based on the use of airphotos for interpreting desert surface features should be of great value to the military. The airphotos were used for much of the mapping program, but the procedures were not included here as it is beyond the scope of this report.

#### Study I

It is suggested that a study be initiated to accomplish the following:

1. Develop techniques for using airphotos to identify and evaluate desert terrain features for military purposes.
2. Develop correlations between desert airphoto patterns at Yuma with those in other southwestern deserts of the United States.
3. Develop correlations between desert airphoto patterns of the United States and airphoto patterns of other world deserts.

Study II

It is suggested that a program of experimental aerial photography be initiated to accomplish the following:

1. Study the effect of scale on desert terrain information.
2. Study the effect of film type on desert terrain information.
3. Study the effect of season of photography on desert terrain information.
4. Study the effect of focal length-altitude ratio on desert terrain information.

Study III

It is suggested that a program of radar scope photography be initiated to determine limitations, reliability, and feasibility of use for desert terrain analysis.

APPENDIX

Two maps are folded in the envelope on the inside back cover of this report:

Plate I. Land form map of the Yuma Test Station Area, showing the degree of dissection and the general vegetation.

Plate II. Surface materials map of the Yuma Test Station Area, showing the soil-rock types, method of development, and degree of firmness.

SOI TEST DATA

Grain Sizes  
Per Cent Finer than  
U.S. Standard Sieve Sizes

| Sample No. | Material                | LL   | PI | MC | 3/8 | 4   | 10 | 40  | 60 | 100 | 200 | Location        |              |                  |
|------------|-------------------------|------|----|----|-----|-----|----|-----|----|-----|-----|-----------------|--------------|------------------|
| 4319       | Desert Pavement         | 0-1" | -- | -- | 56  | 36  | 13 | 4   | 3  | 2   | 1   | 364.7 - 23.7    |              |                  |
| 4320       | Desert Pavement         | 0-1" | -- | -- | 83  | 75  | 71 | 68  | 62 | 54  | 41  | 365.4 - 73.6    |              |                  |
| 4321       | Desert Pavement         | 0-1" | -- | -- | 92  | 83  | 76 | 74  | 72 | 71  | 61  | 366.7 - 74.5    |              |                  |
| 4322       | Desert Pavement         | 0-1" | -- | -- | 64  | 21  | 1  | 0   | 0  | 0   | 0   | 368.5 - 76.9    |              |                  |
| 4323       | Desert Pavement         | 0-1" | -- | -- | 26  | 3   | 0  | 0   | 0  | 0   | 0   | North Deep Well |              |                  |
| 4324       | Desert Pavement         | 0-1" | -- | -- | 18  | 3   | 0  | 0   | 0  | 0   | 0   | 368.2 - 78.0    |              |                  |
| 4325       | Desert Pavement         | 0-1" | -- | -- | 31  | 7   | 1  | 0   | 0  | 0   | 0   | 366.8 - 75.3    |              |                  |
| 4326       | Desert Pavement         | 0-1" | -- | -- | 29  | 8   | 1  | 0   | 0  | 0   | 0   | 362.8 - 78.5    |              |                  |
| 4327       | Desert Pavement         | 0-1" | -- | -- | 56  | 25  | 3  | 1   | 1  | 1   | 0   | 366.1 - 24.2    |              |                  |
| 4306       | Desert Pavement Surface | 1-8" | 46 | 23 | 2.6 | 95  | -- | 87  | 81 | 69  | 58  | 48              | 368.5 - 76.9 |                  |
| 4307       | Desert Pavement Surface | 1-6" | 20 | 2  | 1.8 | 85  | -- | 69  | 59 | 46  | 43  | 40              | 35           | North Deep Well  |
| 4308       | Desert Pavement Surface | 1-8" | 21 | 4  | 2.7 | --  | 88 | 83  | 79 | 73  | 68  | 62              | 368.2 - 78.0 |                  |
| 4328       | Desert Pavement Surface | 1-6" | -- | -- | 5.0 | --  | -- | 100 | 75 | 31  | 13  | 5               | 364.1 - 74.4 |                  |
| 4293       | Desert Pavement Surface | 1-3" | 28 | 10 | 3.3 | 92  | 86 | 83  | 80 | 77  | 76  | 73              | 62           | 366.7 - 74.5     |
| 4288       | Desert Pavement Surface | 1-6" | 15 | -- | 6.3 | 100 | -- | 97  | 93 | 77  | 70  | 61              | 46           | 364.4 - 23.9     |
| 4295       | Poor Pavement           | 1-4" | 23 | 3  | 2.0 | 91  | -- | 79  | 70 | 60  | 57  | 51              | 41           | Near Stone Cabin |
| 4299       | Desert Pavement         | 1-6" | 17 | 2  | 1.6 | --  | 91 | 82  | 77 | 64  | 62  | 60              | 56           | NW Stone Cabin   |
| 4290       | Silt Plain              | 0-8" | 28 | 6  | 9.0 | --  | -- | 100 | 99 | 97  | 96  | 94              | 89           | 365.5 - 23.3     |



Grain Sizes  
Per Cent Finer than  
U.S. Standard Sieve Sizes

| Sample No. | Material                                 | LL | PI | MC  | h   | 3/8 | 4  | 10  | 40  | 60 | Grain Sizes |     |                | Location |
|------------|------------------------------------------|----|----|-----|-----|-----|----|-----|-----|----|-------------|-----|----------------|----------|
|            |                                          |    |    |     |     |     |    |     |     |    | 100         | 200 | 400            |          |
| 4296       | Silt Plain                               | 24 | 3  | 2.8 | --  | --  | -- | --  | 100 | 99 | 96          | 93  | NW Stone Cabin |          |
| 4298       | Silt Plain                               | 22 | 3  | 1.5 | 100 | --  | 99 | 97  | 90  | 87 | 82          | 69  | NW Stone Cabin |          |
| 4292       | Sand Dunes                               | -- | -- | 0.3 | --  | --  | -- | 100 | 97  | 66 | 28          | 3   | Sand Hills     |          |
| 4294       | Sand Dunes                               | -- | -- | 0.6 | --  | --  | -- | 100 | 98  | 79 | 31          | 0   | Sand Hills     |          |
| 4282       | Sand Plain                               | -- | -- | 0.3 | --  | --  | -- | 100 | 93  | 52 | 20          | 6   | 363.9 - 74.6   |          |
| 4312       | Sand Plain (after rain)                  | -- | -- | 6.9 | --  | --  | 92 | 78  | 51  | 37 | 28          | 20  | 363.8 - 74.0   |          |
| 4313       | Sand Plain (after rain)                  | -- | -- | 0.7 | --  | 93  | 87 | 79  | 59  | 47 | 36          | 26  | 363.8 - 74.0   |          |
| 4318       | Sand Plain (after rain)                  | -- | -- | 6.1 | --  | --  | -- | 100 | 81  | 46 | 22          | 10  | 364.1 - 74.4   |          |
| 4328       | Sand Plain (after rain)                  | -- | -- | 5.0 | --  | --  | -- | 100 | 75  | 31 | 13          | 5   | 364.1 - 74.4   |          |
| 4329       | Sand from Weathered Granite in Inselberg | 19 | -- | 1.4 | --  | --  | -- | --  | 100 | 99 | 99          | 98  | 365.2 - 25.1   |          |
| 4287       | Terrace                                  | -- | -- | 1.0 | 100 | --  | 91 | 88  | 48  | 24 | 13          | 9   | 363.6 - 23.8   |          |
| 4330       | Flood Plain (Roll)                       | 39 | 13 | 4.4 | --  | --  | -- | 100 | 100 | 99 | 99          | 98  | 362.8 - 78.5   |          |

Density Measurements

A number of density measurements were made on the desert pavement surfaces of alluvial aprons. The surface layer of gravel, about one inch thick, was first removed. Tests were run at depth of 1-6 inches. The soil was gravelly silt, as indicated in the previous table under "desert pavement 1-6." An average of six tests gave an average dry density of 90.6 lbs. per cu. ft.

## DEFINITIONS

- Alluvial apron -** a series of coalescing alluvial fans that have combined to form a fairly level plain that slopes very gently away from the adjacent fans or mountains.
- Alluvial fan -** a sloping, fan-shaped mass of loose rock material deposited by a stream at the place where it emerges from an upland into a broad valley or plain (8).
- Bad lands -** an elevated arid region which is seamed and lined with innumerable deep gullies by the occasional torrential rain, the normal precipitation being insufficient to support an adequate protective covering of grass or other vegetation. (15)
- Canyon -** a steep-walled valley or gorge in a plateau or mountainous area. (8)
- Chemical agent -** a solid, liquid, or gas which through its chemical properties produces lethal, injurious, or irritant effects; a screening or colored smoke; or an incendiary agent. War gases, smokes, and incendiaries are the three main groups.
- Coverage (vegetative) -** the area in the horizontal plane of the crowns of a given species or of a group of species of similar life form. It is conveniently explained as the percent of total ground surface of an area shaded when the sun is assumed to be at the zenith.

**Crown (vegetative)** - The top of a plant that is made up of branches and leaves, as opposed to the roots or trunk. In shrubs lacking a main stem, the entire plant above ground may be considered its crown.

**Decontaminating agent** - substance used to absorb, make harmless, or destroy chemical or biological agents or to assist in removal of radioactive materials.

**Density (vegetative)** - The average number of plants per acre, usually computed from random samples restricted to a selected general type of plant community.

**Desert** - An almost barren tract of land in which the precipitation is so scanty or so spasmodic that it will not adequately support vegetation. A desert in which absolutely nothing grows, however, is uncommon; it may be extremely poor grassland or extremely poor shrub. (15)

**Desert pavement** - a relatively smooth, mosaic-like area in a desert region, consisting of pebbles closely packed together after the removal of finer material. (15)

**Desert varnish** - a surface stain or crust of manganese or iron oxide, of brown or black color and usually with a glistening luster, which characterizes many exposed rock surfaces in the desert. It coats not only ledges or rock in place but also boulders and pebbles that are scattered over the surface of the ground. (8)

**Dissection** - the work of erosion in destroying the continuity of a relatively even surface by the cutting of ravines or valleys. (8)

- Dominant (vegetative)** - The dominants of a plant community are those few species which determine to an important degree the environmental conditions for the subordinate species by shading, litter and humus accumulation, root competition, chemical antagonism, etc. The dominants are conspicuous and provide much coverage.
- Dune** - a hill or ridge of sand that has been piled up by the wind.
- Ecology** - See plant ecology.
- Habitat - (vegetative)**. The place where an individual plant or a community occurs, including all the environmental conditions within this place.
- Inselberg** - a small mountain or hill that stands above a desert plain.
- Interclave** - used in the vegetational section to designate the land surface between dry gullies or dry washes and beyond the reach of flood waters.
- Irrigation** - the artificial distribution of water on the land in order to facilitate the cultivation of crops where otherwise, owing to a deficiency of rainfall, agriculture would be impossible. (15)
- Life-form** - The general structure of the individual plant body, taking into account size, seasonal duration of leaves, texture of stems, method of overwintering, etc. Some life-forms are tree, shrub, herb, and stem succulent.
- Per cent error** - One standard error divided by the mean, times 100. If per cent error does not exceed 15, vegetational sampling is considered acceptable.

**Plant ecology (vegetative)** - That branch of botany dealing with the interrelationships of plants and their environment, and with the structure and functions of organized communities of plants.

**Playa** - a Spanish word meaning literally shore or strand; a level or nearly level area that occupies the lowest part of a completely closed basin and that is covered with water at irregular intervals, forming a temporary lake. (8)

**Standard error** - One standard error of a mean figure indicates a 66 per cent probability that the true mean of the station sampled falls within the limits indicated.

**Station (vegetative)** - An area within which sample plots are distributed for collecting quantitative data on a single general plant community type occurring in this area. The size of a station ranges up to several square miles.

**Stem-succulent plants** - those that have no leaves, but have green thickened stems which store water in pulpy tissue. The cacti are stem-succulents.

**Terrace** - a bench that is situated between a flood plain or stream and an upland.

**Vegetation** - The display which the plants of an area make collectively; the dominant, common, and conspicuous plants are those considered under vegetation, whereas the flora includes all species no matter how obscure.

Wash - A dry channel that is used for run-off whenever there is sufficient rainfall. It may be wide, narrow, deep, or shallow. Sometimes called arroyo or dry wash.

Yuma Test Station - The area within the borders of the Yuma Test Station.

Yuma Test Station Area - (or Yuma Test Area, or Test Station Area) -

The area within the limits of the area covered by the 32-sheet set of photo-maps, AMS Series W095G and W098B.

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