AD 715363

TECHNICAL REPORT
71-14-ES

SURFACE MATERIALS AND TERRAIN FEATURES OF YUMA PROVING GROUND
(Laguna, Ariz-Calif, Quadrangle)

by
John A. Millett
and
H. Frank Barnett

October 1970

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Earth Sciences Laboratory
ES-59

60

This document has been approved for public release and sale; its distribution is unlimited.

Citation of trade names in this report does not constitute an official indorsement or approval of the use of such items.

Destroy this report when no longer needed. Do not return it to the originator.

This document nas been approved
for public release and sale; its
distribution is unlimited.

AD______________

TECHNICAL REPORT
71-14-ES

SURFACE MATERIALS AND TERRAIN FEATURES OF YUMA PROVING GROUND
(Laguna, Ariz-Calif, Quadrangle)

by

John A. Millett
and
H. Frank Barnett
Military Applications Division

October 1970

Series:
ES-59

Earth Sciences Laboratory
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

FOREWORD

In January 1970 the Test and Evaluation Directorate, Yuma Proving Ground, asked the Earth Sciences Laboratory, US Army Natick Laboratories, to map the surface materials of the Laguna (Ariz-Calif) quadrangle. The mapping, with representative slope-and-relief values of terrain units, was to provide Yuma Proving Ground with a means for determining availability and suitability of mobility test areas, and for correlating its terrain with that of other world deserts.

Yuma Proving Ground needed basic ground-truth data gathered and presented in a form useful to engineers. Yuma Proving Ground and Natick Laboratories decided in conference that this form should be a description, both graphical and numerical, of distinctive surficial associations of materials (sands, gravels, bedrock) and their topographic expressions (dissected, undissected).

The description, furthermore, should be an initial step leading to specific quantitative determinations of vehicle-terrain interrelationships and to development of desert terrain analogs.

The data of this report constitute an inventory of landforms in the Laguna quadrangle of Yuma Proving Ground and an initial demonstration of an approach to quantitative terrain description for mobility.

We gratefully acknowledge the enthusiastic cooperation and support given by Mr. John Rezin, Mr. Wahner Brooks, and Captain Kevin Pickles, Test Methodology and Instrumentation Office, Yuma Proving Ground. Lt. Peter Finké, US Army Natick Laboratories, assisted in the field and in initial compilation of data.

CONTENTS

	Page
Abstract	vi
Objectives	1
Results	1
Approach	2
Methods	3
General Geologic and Topographic Features	3
Mapping Units	7
Quantitative Description of Mapping Units	16
Discussion and Recommendations	37
APPENDIX Field Measurement Data	38 - 46

LIST OF ILLUSTRATIONS

		Page
Plate 1	Surface Materials and Terrain Features of Yuma Proving Ground	in pocket
Figure		
1.	Area covered by the study	2
2.	Generalized cross-section	3
3.	Dissected gravelly deposits	4
4.	Sandy hills	5
5.	Intermountain area	6
6.	Recent wash, topographic map pattern	8
7.	Recent wash, airphoto pattern	8
8.	Pavement, topographic map pattern	9
9.	Pavement, airphoto pattern	9
10.	Gravelly undissected piedmont, topographic map pattern	10
11.	Gravelly undissected piedmont, airphoto pattern	10
12.	Gravelly dissected piedmont, topographic map pattern	11
13.	Gravelly dissected piedmont, airphoto pattern	11
14.	Sandy plain, topographic map pattern	12
15.	Sandy plain, airphoto pattern	12
16.	Sandy hills, topographic map pattern	13
17.	Sandy hills, airphoto pattern	13
18.	Linear stabilized dunes, topographic map pattern	14

LIST OF ILLUSTRATIONS (continued)

Figure		Page
19.	Linear stabilized dunes, airphoto pattern	14
20.	Bedrock, topographic map pattern	15
21.	Bedrock, airphoto pattern	15
22.	Sketch map of location of walked traverses	17
23 through 31	Cumulative percent frequency of slopes, Traverses 1 - 9	19 - 27
32 through 40	Cumulative percent frequency of relief Traverses 1 - 9	28 - 36

ABSTRACT

Distribution and slope gradients of surficial materials in the Laguna (Arizona-California) 1:62,500-scale quadrangle were mapped in the field for engineering evaluation of vehicle testing suitability and for comparison of Yuma Proving Ground terrain with that of other world deserts.

Occurrences and topographic expressions of seven alluvial and six bedrock mapping units are shown as an overprint on the topographic map. Cumulative frequency curves of slope and relief describe these factors of alluvial terrain quantitatively. Actual field measurements of 30,000 feet of traverse are included to permit interpretation for specific materiel evaluations.

SURFACE MATERIALS AND TERRAIN FEATURES
OF YUMA PROVING GROUND
(Laguna, Ariz-Calif, Quadrangle)

Objective

The objective of this study is to describe the natural surficial features of Yuma Proving Ground in the Laguna quadrangle, by field mapping and by field measurements of slope and relief.

The following considerations are embodied in the conception, compilation, and presentation of the study:

Accurate maps and data of features of the Proving Ground facilitate evaluation and use of the Army's hot-dry desert test area for military systems.

Quantitative terrain data are applicable to the design and evaluation of terrain-dependent military systems for desert use.

Testing at Yuma Proving Ground is meaningful to the over-all Army materiel program insofar as the terrain there can be correlated with that of other deserts. It is important, therefore, that the data be quantitatively comparable to those known or inferred elsewhere.

Results

The surficial features within the boundaries of Yuma Proving Ground in the Laguna quadrangle, divided into seven units of alluvial lowlands and six of bedrock mountains, are mapped at a scale of 1:62,500 (Plate 1, in pocket).

For six alluvial mapping units, cumulative frequency curves and the mean values of slope and relief are derived from ground traverse data.

All of the Proving Ground was not mapped during the month of field work. Enough data were gathered, however, to demonstrate the feasibility and appropriateness of the approach. It is possible from the information included in this report to choose areas suitable for tests requiring given ranges of slope, relief, and materials.

Approach

The approach is tailored to requirements of the Yuma Proving Ground test mission. Fundamental engineering aspects of terrain--surficial materials and their topographic expressions--are the primary targets chosen for qualitative and quantitative description.

The map indicates what materials are in the study area without taking into account the possibility of differing origins. Geologic and geomorphic relationships were considered in the initial identification of terrain units, but were not used to subdivide the final units beyond the materials-topographic expression targets established by the approach. Well dissected sand areas, therefore, are mapped as sandy hills irrespective of whether they are developed at the edge of a dune field or from sand underlying gravelly piedmonts.

The area covered by this study is limited to that portion of the Proving Ground contained on the US Geological Survey, Laguna, Arizona-California, quadrangle map, scale 1:62,500, contour interval 40 feet, dated 1955. The location of the study area in relation to the rest of Yuma Proving Ground is shown in Figure 1.

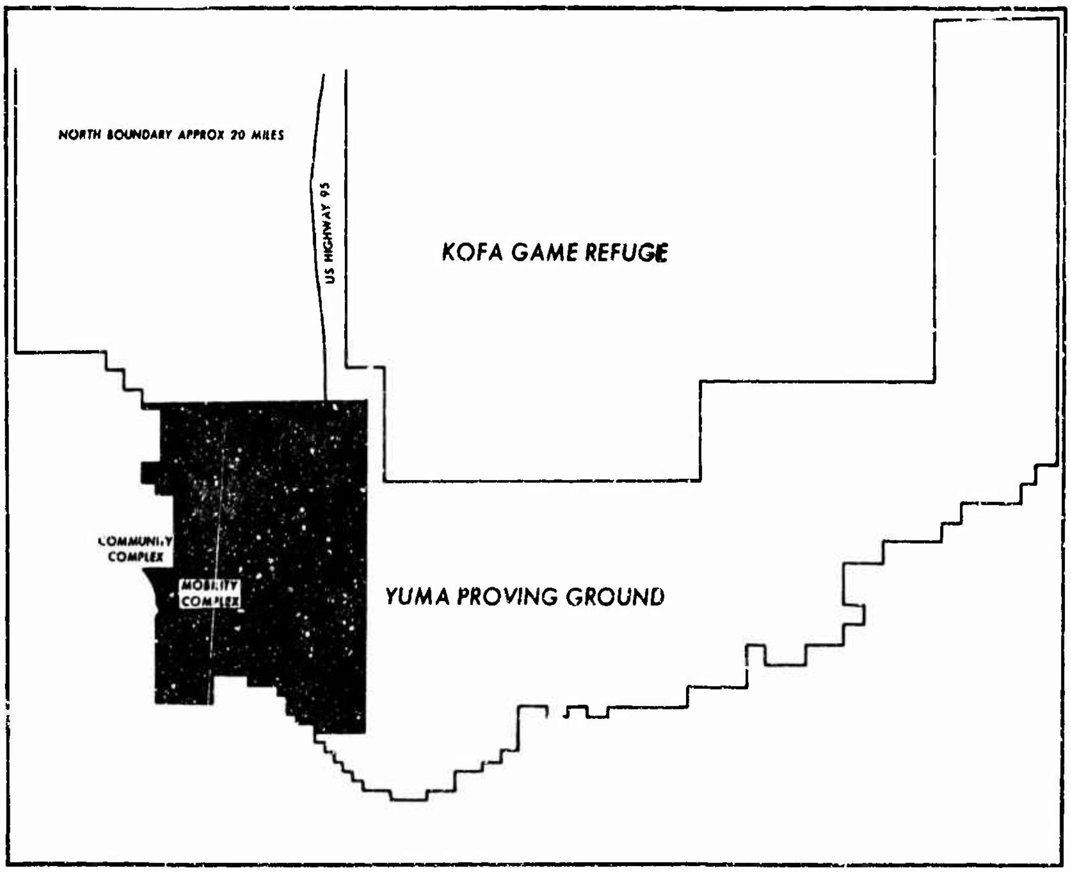


Figure 1 Shaded portion is area covered in this study.

Methods

All the data of this report were collected in the field, in the following ways:

Reconnaissance geology conducted on foot, from four-wheel-drive vehicle, and from aircraft. Geologic maps of the Arizona Bureau of Mines expedited mapping of the bedrock mountains.

Slope traverses conducted on foot, using the Abney level, an optical rangefinder accurate to within two percent, and a steel measuring tape. Nine traverses totalling approximately 30,000 feet were made in the alluvial mapping units.

Airphoto interpretation to identify nature and distribution of distinctive surficial associations. The photos were at an approximate scale of 1:13,000.

Interpretation of topographic maps at a scale of 1:2400 and a contour interval of four feet (derived from the above airphotos). Topographic map sheets of the USGS at a scale of 1:24,000 were also available for three-fourths of the study area.

Soil sampling at a few locations. Samples were analyzed by the Chemical Section, Analysis and Certification Branch, Yuma Proving Ground (data not included in this report).

General Geologic and Topographic Features

Yuma Proving Ground is in the Sonoran Desert of the Basin and Range Province in southwestern Arizona. The area consists of mountains made up of the eroded remnants of bedrock fault blocks separated by basins filled with varied sediments derived principally from these mountains. Figure 2 is a generalized cross-section showing the relationships of the mountains and basin-filling alluvium. Nearest the mountains, the gravels commonly are undissected; toward the center of the basins, both the gravels and underlying sands are dissected.

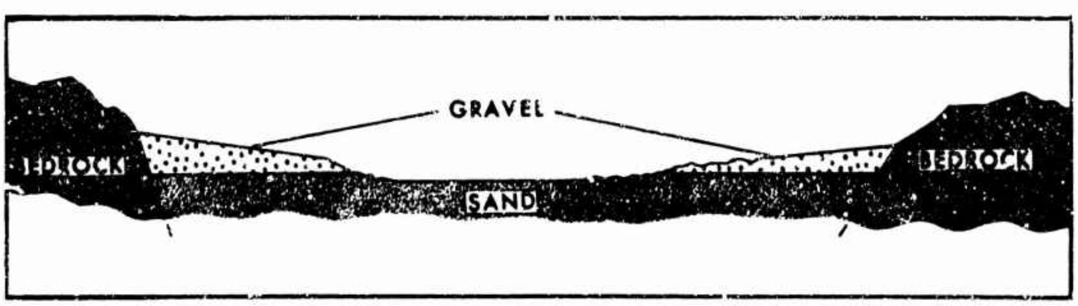


Figure 2 Generalized cross-section showing the relationship of bedrock and alluvium in the Laguna quadrangle of Yuma Proving Ground.

Areas adjacent to the bedrock mountains are generally gravelly, underlain in many places by sandy material of varying thickness. Figure 3 shows the gravelly dissected piedmont deposits in the northwest Muggins Mountains area.

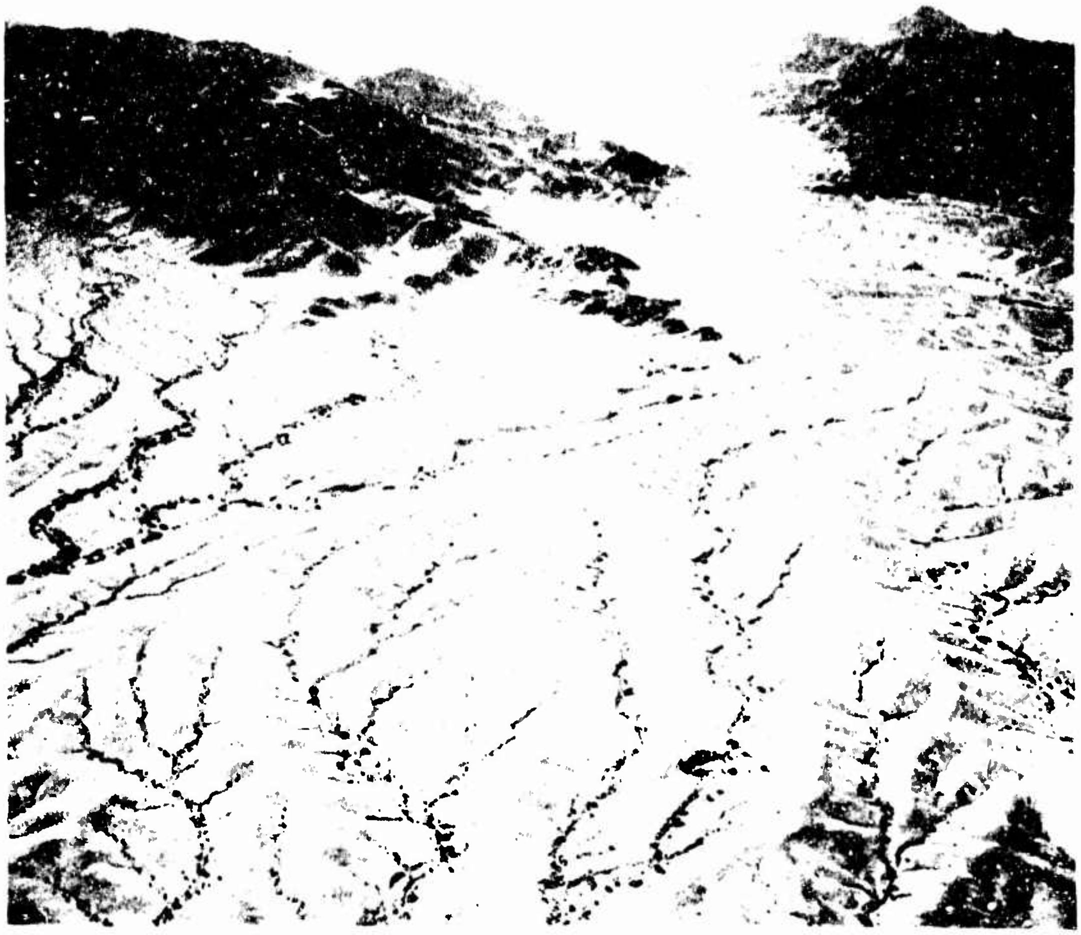


Figure 3 Dissected gravelly deposits north of Vinegarroon Wash (cinetheodolite station "C" at left center).

Figure 4 shows sandy h: ls (foreground) and gravelly undissected piedmont deposits abutting the bedrock mountains northwest of Vinegarroon Wash. Sandy hills are capped by a thin layer of gravels in much of this area.

Figure 4 Sandy hills northwest of Vinegarroon Wash (KofA ammunition bunkers at right center).

An intermountain part of the study area is shown in Figure 5. Sandy plains (foreground) are bordered by the Castle Dome pavement/wash complex (background).

Figure 5 Intermountain area (Castle Dome visible on right skyline).

Mapping Units

The following mapping units have been delineated in the Yuma Proving Ground area covered by the Laguna quadrangle:

- Recent Wash
- Pavement of Pavement/Wash Complex
- Gravelly Undissected Piedmont
- Gravelly Dissected Piedmont
- Sandy Plain
- Sandy Hills
- Linear Stabilized Dunes
- Bedrock Mountains (six subunits)

Table 1 lists the areal extents of the mapping units.

Table 1. Areal Extents of Mapping Units

Unit	Percent	Square Miles
Recent Wash	22.5	39.6
Pavement of Pavement/Wash Complex	15.6	27.4
Gravelly Undissected Piedmont	8.6	15.1
Gravelly Dissected Piedmont	12.7	22.3
Sandy Plain	8.4	14.8
Sandy Hills	6.3	11.0
Linear Stabilized Dunes	3.5	6.1
Bedrock Mountains	22.4	39.5
		175.8

On the following pages are brief descriptions of the units, and representative paired topographic map and airphoto patterns of one-square-mile areas. The map and airphoto insets are useful as keys to identify similar terrain units throughout the Proving Ground and in other desert areas.

RECENT WASH

Recent wash deposits consisting of clay to boulder-sized material deposited in active wash areas are found throughout the quadrangle.

Figure 6 Topographic map pattern for recent wash mapping unit. Unshaded portion shows part of Vinegarron Wash.

Figure 7 Airphoto pattern for recent wash mapping unit. The light area shows a part of Vinegarroon Wash.

GRAVEL PAVEMENTS IN PAVEMENT/WASH COMPLEX

These pavements as a mapping unit appear only in the Castle Dome Plain-South Middle Mountains area. They consist of well varnished, predominantly volcanic materials. Surface material is generally one quarter inch to two inches in size with occasional cobbles and boulders. Subsurface (1-2 inches) material is silty to fine sandy with considerable quantities of clay. The pavements are almost totally undissected and are nearly flat or slightly rounded with a few washes or gullies running across their surfaces.

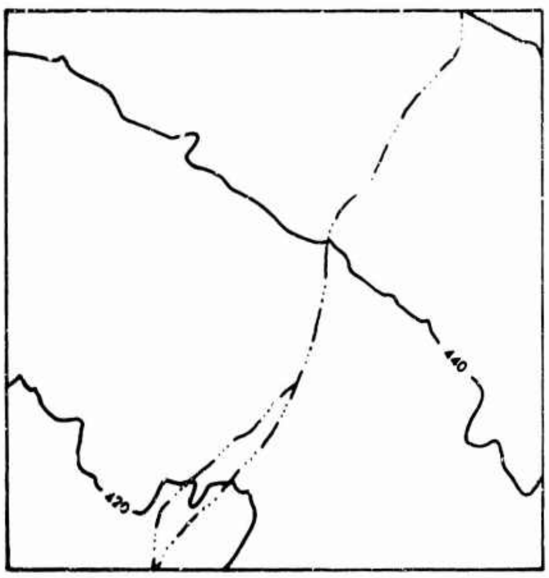


Figure 8 Topographic map pattern for gravel pavement in pavement/wash complex. (Because washes are braided, this unit is shown as part of a complex of recent washes, gullies, and gravel pavements.)

Figure 9 Airphoto pattern for gravel pavement in pavement/wash complex (dark areas).

GRAVELLY UNDISSECTED PIEDMONT

This mapping unit is in the Muggins and Laguna Mountains and in the area between the Middle Mountains and the Colorado River. The materials are coarse, unsorted gravels, in many areas underlain by varying thicknesses of sandy material. They are generally flat with a few small washes or gullies crossing them. The gravel is from three to as many as twenty feet thick, depending on the proximity to a mountain front.

Figure 10 Topographic map pattern for gravelly undissected piedmont mapping unit (shaded areas).

Figure 11 Airphoto pattern for gravelly undissected piedmont mapping unit (dark areas).

GRAVELLY DISSECTED PIEDMONT

Gravelly dissected piedmont areas are in the Muggins, Middle, and Laguna Mountains and in the area between the Middle Mountains and the Colorado River. This unit is closely related to the above unit and the materials are similar, with sand underlying the gravel in many areas. In contrast to the undissected unit, this unit is deeply dissected by numerous gullies and washes.

Figure 12 Airphoto pattern for gravelly dissected piedmont.

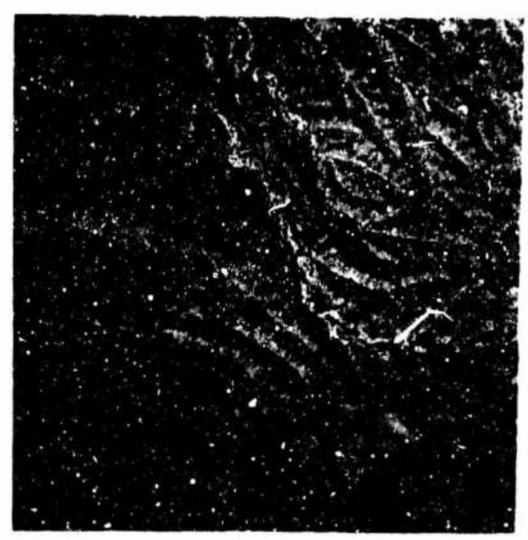


Figure 13 Airphoto pattern for gravelly dissected piedmont.

SANDY PLAIN

Throughout much of the intermountain area are flat expanses of sandy material. These flat areas, with few noticeable washes or gullies have been mapped as sandy plain, although in some places the sand forms a gently domed topographic high.

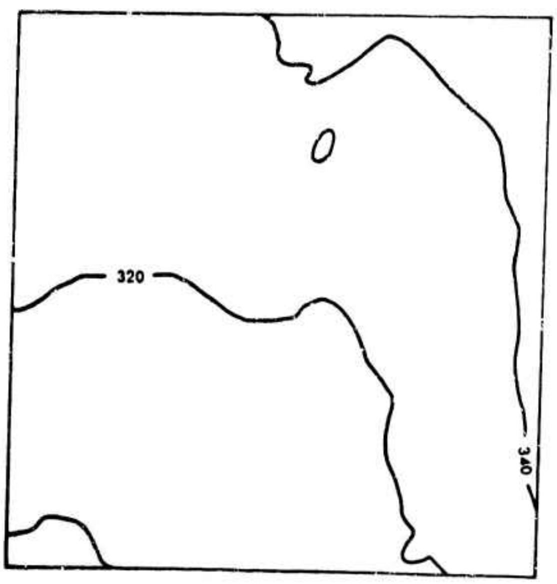


Figure 14 Topographic map pattern for sandy plain mapping unit.

Figure 15 Airphoto pattern for sandy plain mapping unit.

SANDY HILLS

Scattered throughout much of the quadrangle, with the exception of the Castle Dome Plain, sandy, well dissected areas have developed as a fringe on sandy plains, gravelly dissected piedmonts, and stabilized dunes. Regardless of origin, these similar areas, consisting of fine to coarse sands with some cemented layers and concretions, are mapped as sandy hills.

Figure 16 Topographic map pattern for sandy hills mapping unit (unshaded areas).

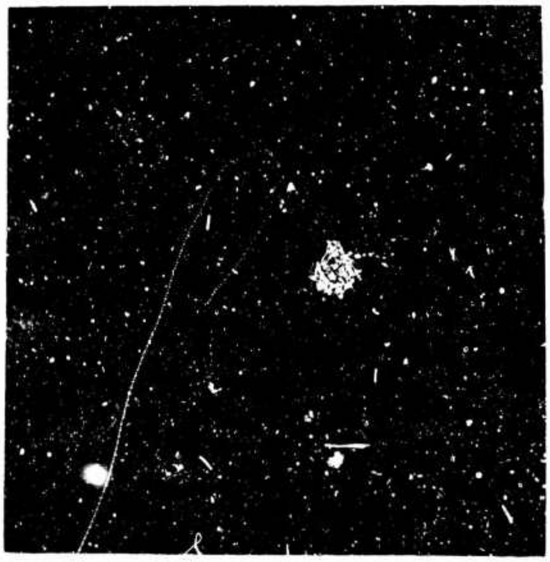
Figure 17 Airphoto pattern for sandy hills mapping unit (textured area in right half of photo).

LINEAR STABILIZED DUNES

In the intermountain basin, sandy material has been reworked into linear dune features stabilized almost completely by vegetation. These dunes, as well as the flat sandy areas between them, are mapped as one unit.

Figure 18 Topographic map pattern for linear stabilized dunes.

Figure 19 Airphoto pattern for linear stabilized dunes.



BEDROCK

Mountainous areas and numerous small hills in the basin are made up of gneiss, schist, granitic porphyry, volcanics, limestone, and sandstone and shale. These areas are easily identified and mapped by their severe dissection, high relief and lack of unconsolidated surface material. Due to the high relief and difficulty of access, only reconnaissance geology was done in the bedrock areas; testing in these areas would be limited and a lack of information is not critical to this report.

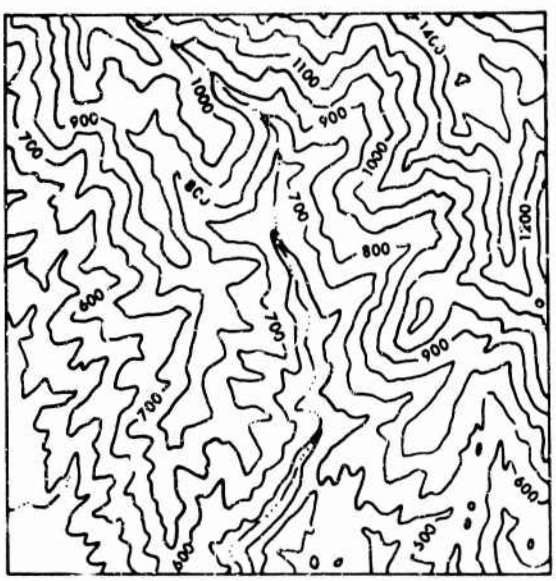
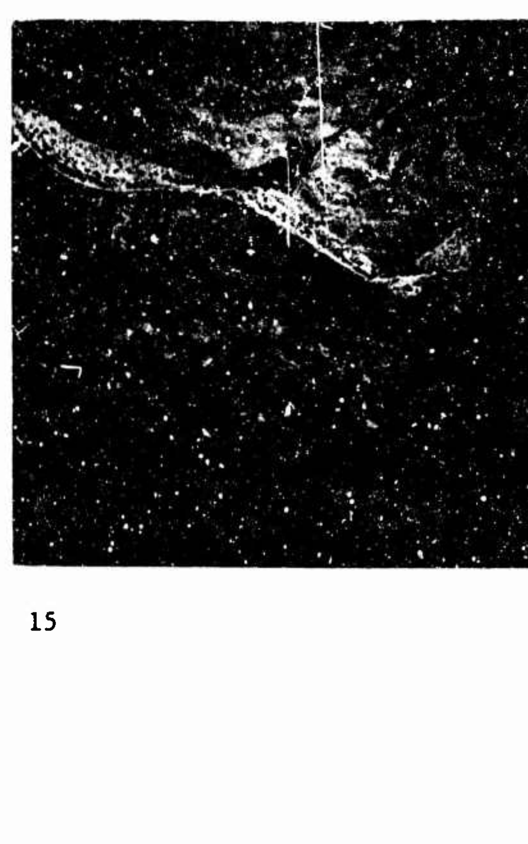


Figure 20 Topographic map pattern for bedrock mapping unit (contour interval is 100 feet).

Figure 21 Airphoto pattern for bedrock mapping unit (lower half of photo).



Quantitative Description of Mapping Units

The quantitative field data in this section augment the qualitative descriptions of the preceding pages. Because the study was intended to gather and present descriptive terrain data, only cumulative percent frequencies and mean values of slope and relief have been derived; the actual field measurements of slope inclination and length are appended (Appendix A).

The cumulative percent frequency of slopes expresses the aggregate length (in feet) of a given inclination (by degrees) as a percentage of total traverse length. Half-degree values in some traverses should be taken only as indications that the inclination is between two full degrees; the Abney level cannot be read, hand-held, to half degrees.

The cumulative percent frequency of relief expresses the aggregate vertical heights of rises (in feet), measured from the top of each rise to both adjacent lows, as a percentage of the total relief along the traverse.

The locations of walked traverses are on the sketch map of Figure 22. The exact locations, on maps of larger scales, are available at US Army Natick Laboratories. Table 2 lists mean slope and relief values for each traverse. There follow nine cumulative percent frequency curves of slope and nine of relief. There is no traverse for the sandy plain unit.

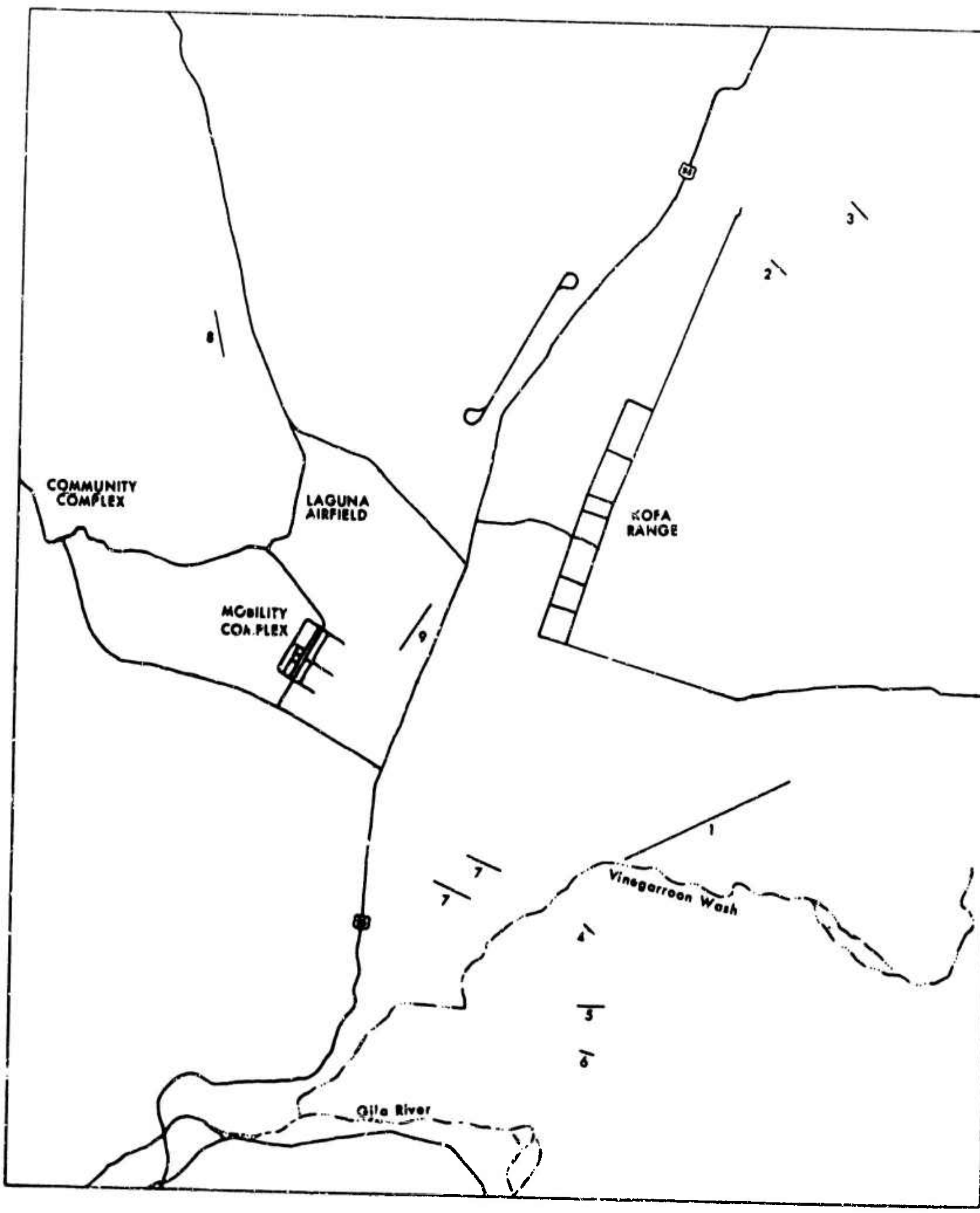


Figure 22 Sketch map of area mapped, with locations of walked traverses (numbered 1 - 9; traverse 7 is in two parts).

Table 2. Mean Slope and Relief for Mapping Units (based on walked traverses)

Traverse	Mapping Unit	Mean Slope (^{o})	Mean Relief (ft)
1	Gravelly Dissected Piedmont	9.7	18.4
2	Wash (in Pavement/Wash Complex)	1.6	1.3
3	Pavement of Pavement/Wash Complex	1.1	0.9
4	Gravelly Undissected Piedmont	1.3	1.0
5	Gravelly Dissected Piedmont	10.3	14.1
6	Sandy Hills (south of Vinegarroon Wash)	6.9	5.8
7	Sandy Hills (northwest of Vinegarroon Wash)	6.9	6.4
8	Sandy Hills (northwest of Laguna Airfield)	3.0	6.4
9	Linear Stabilized Dunes	1.4	2.2

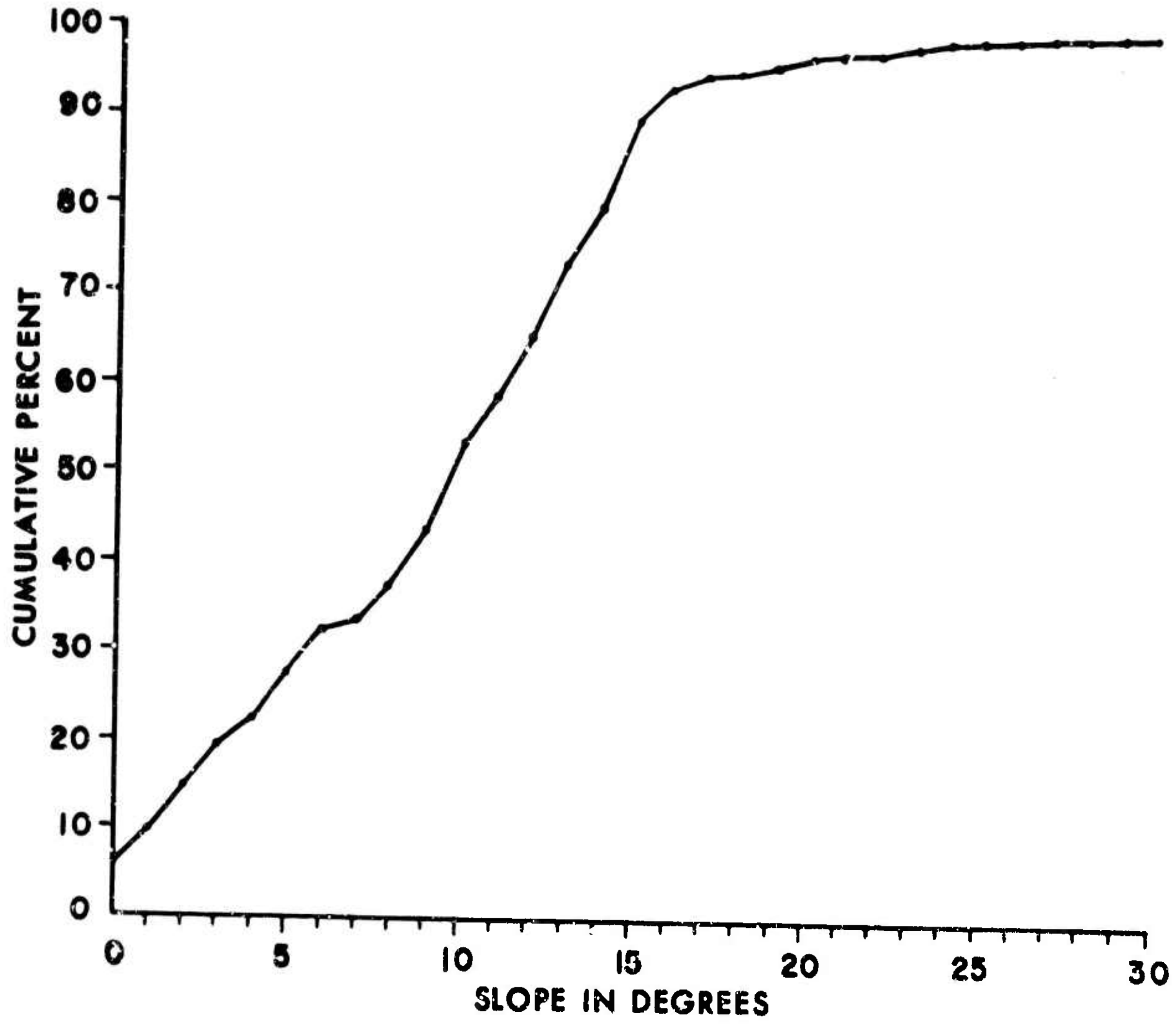


Figure 23 Cumulative percent frequency of slopes, Traverse 1 (Gravelly Dissected Piedmont).

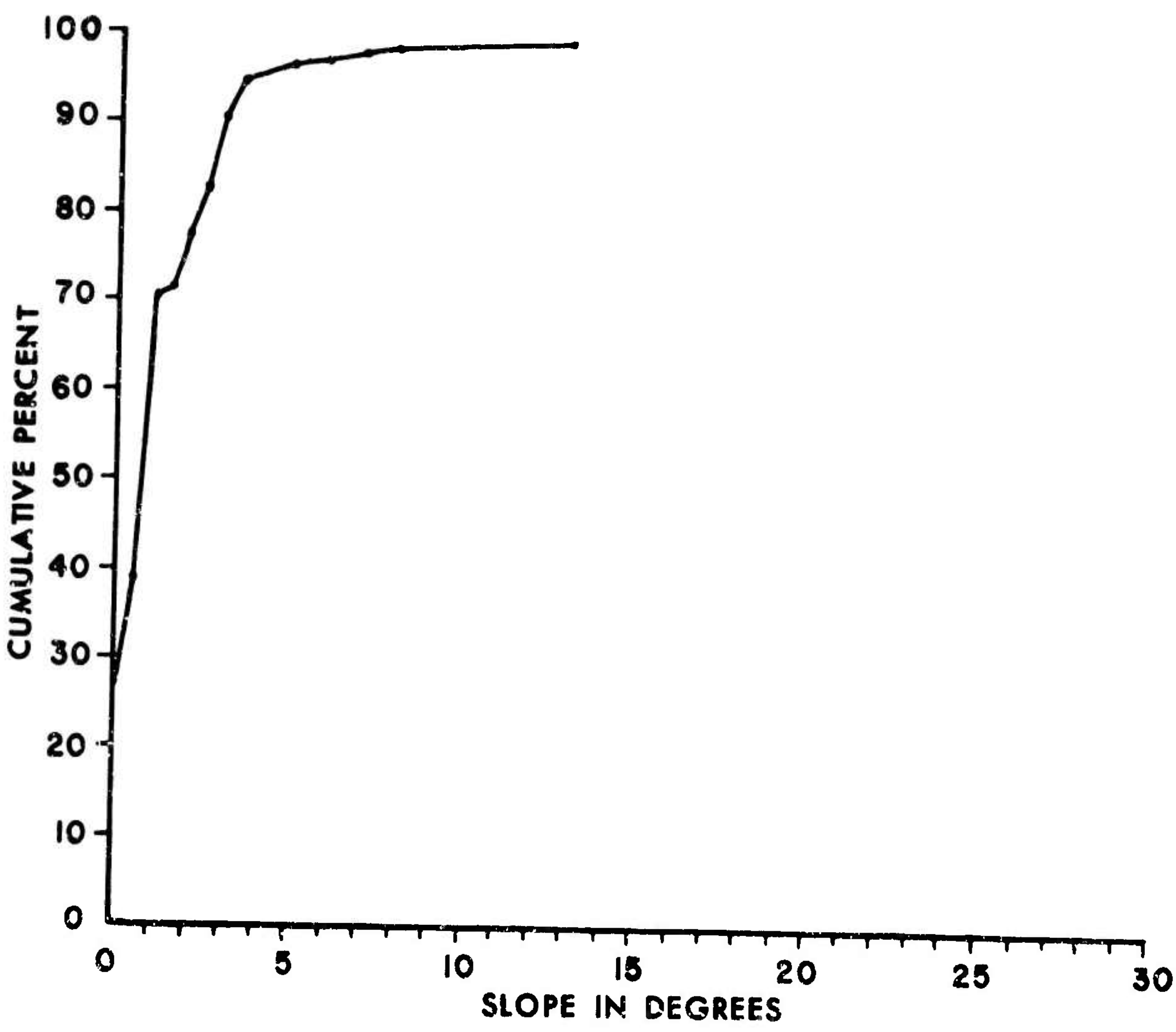


Figure 24 Cumulative percent frequency of slopes, Traverse 2 (Wash in Pavement/Wash Complex).

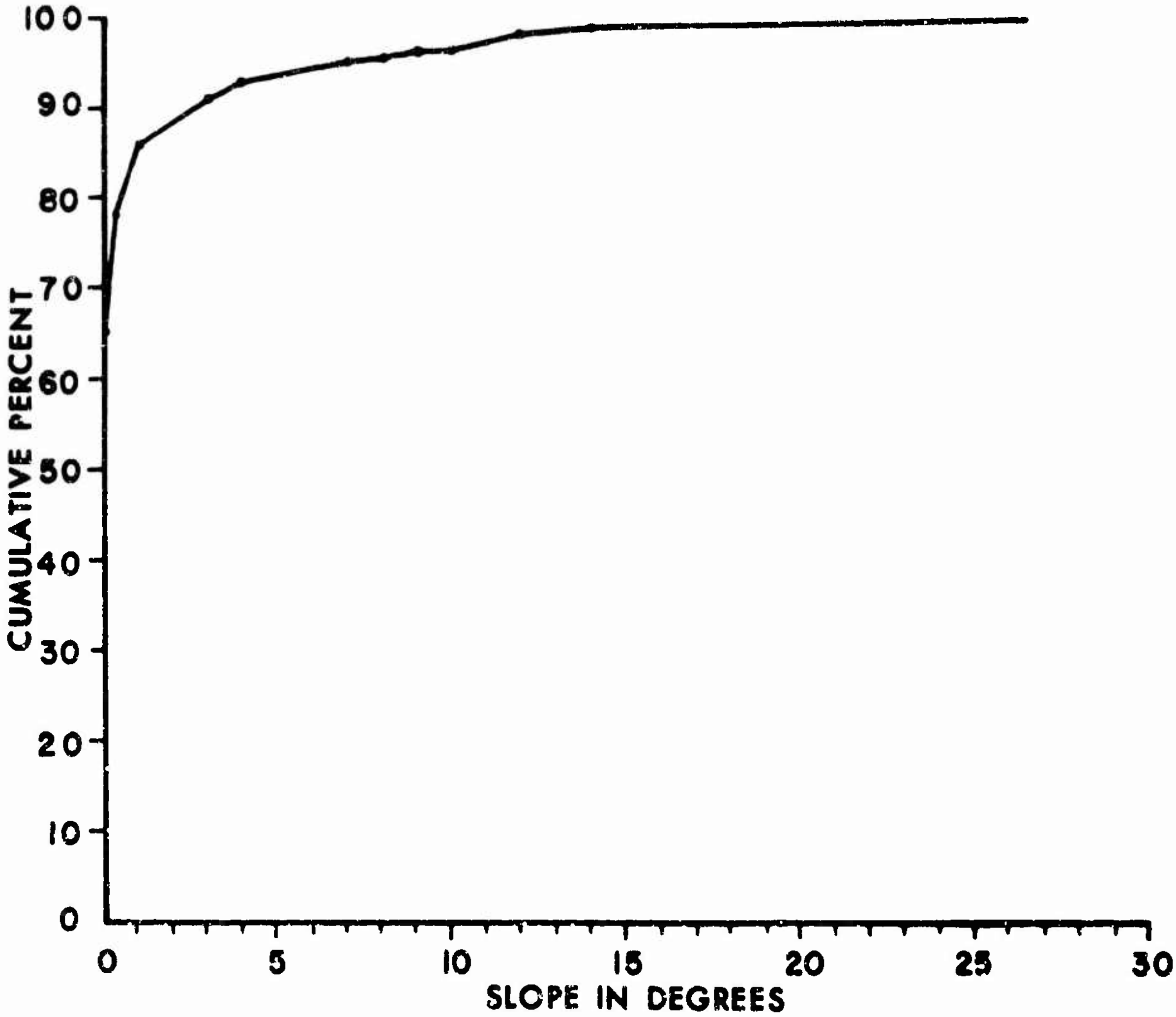


Figure 25 Cumulative percent frequency of slopes, Traverse 3 (Pavement of Pavement/Wash Complex).

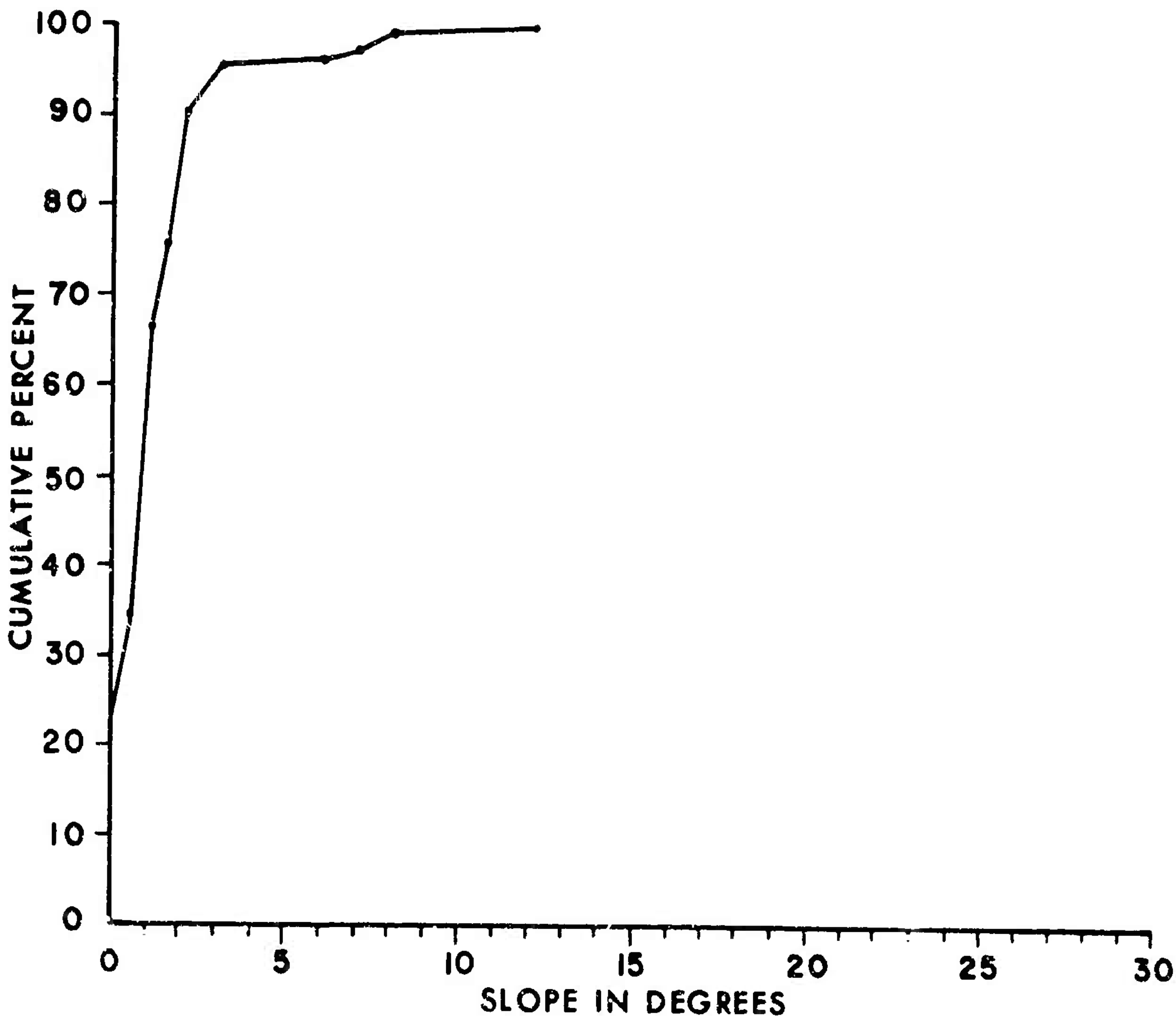


Figure 26 Cumulative percent frequency of slopes, Traverse 4 (Gravelly Undissected Piedmont).

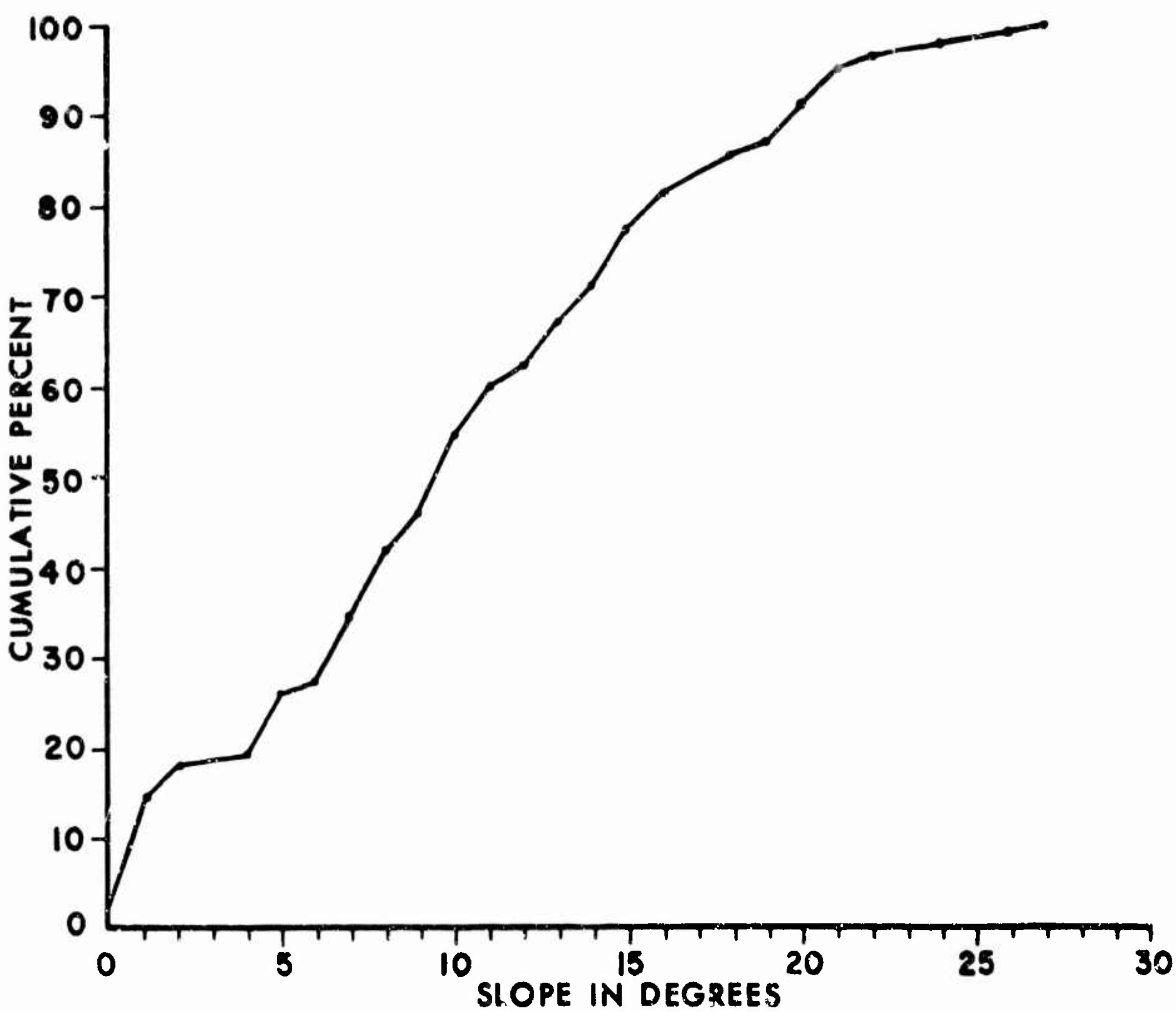


Figure 27 Cumulative percent frequency of slopes, Traverse 5 (Gravelly Dissected Piedmont).

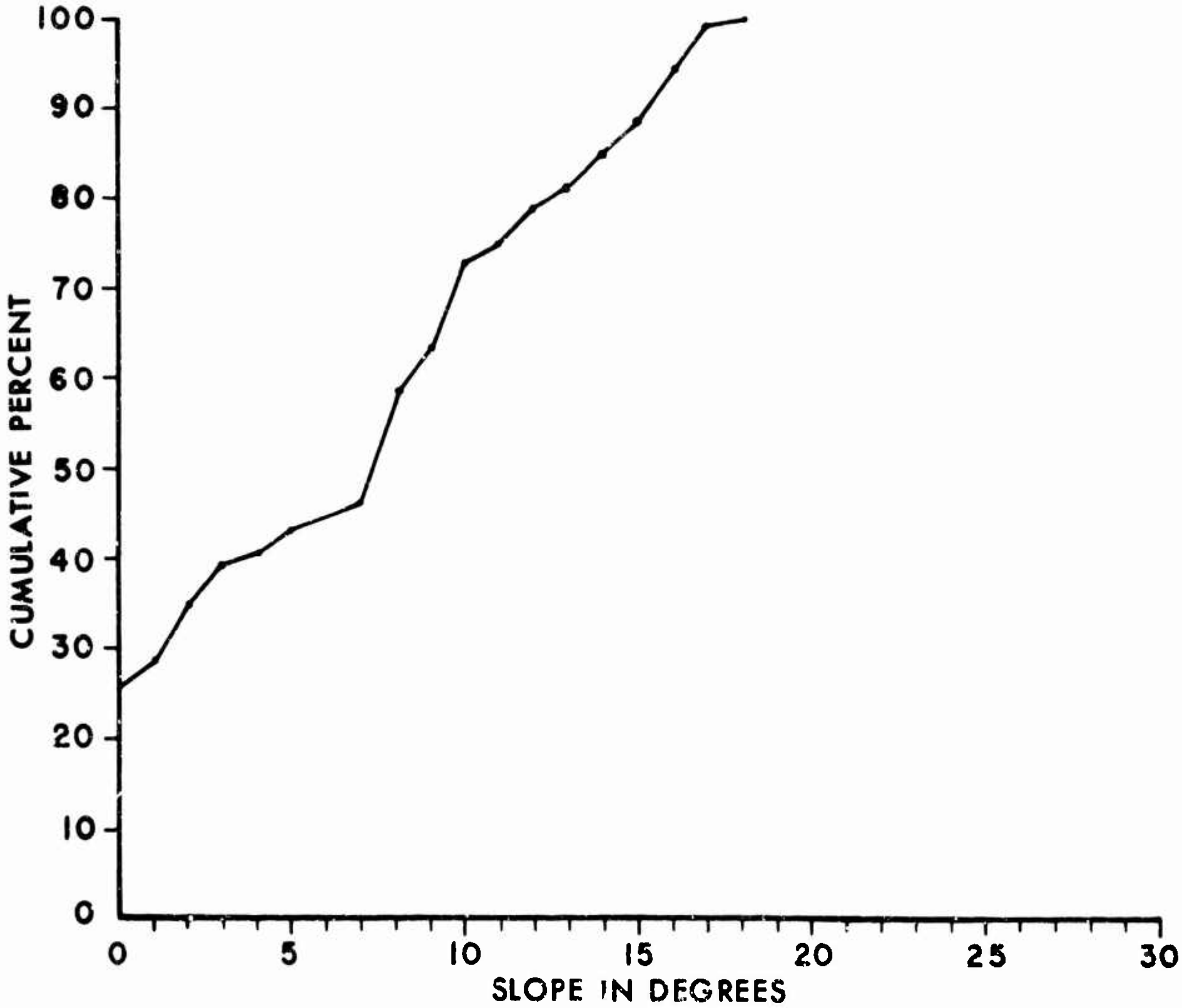


Figure 28 Cumulative percent frequency of slopes, Traverse 6 (Sandy Hills south of Vinegarroon Wash).

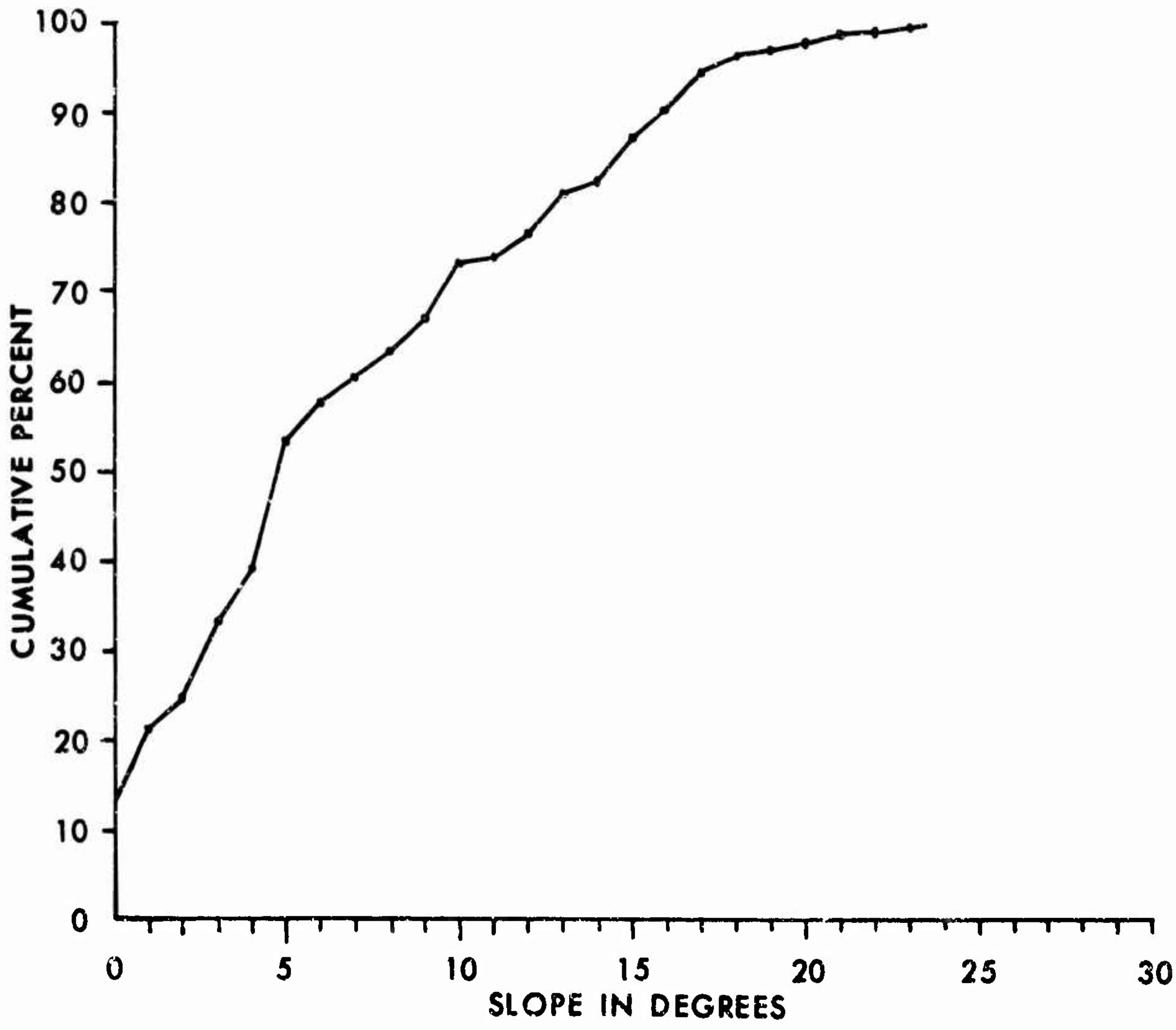


Figure 29 Cumulative percent frequency of slopes, Traverse 7 (Sandy Hills northwest of Vinegarroon Wash).

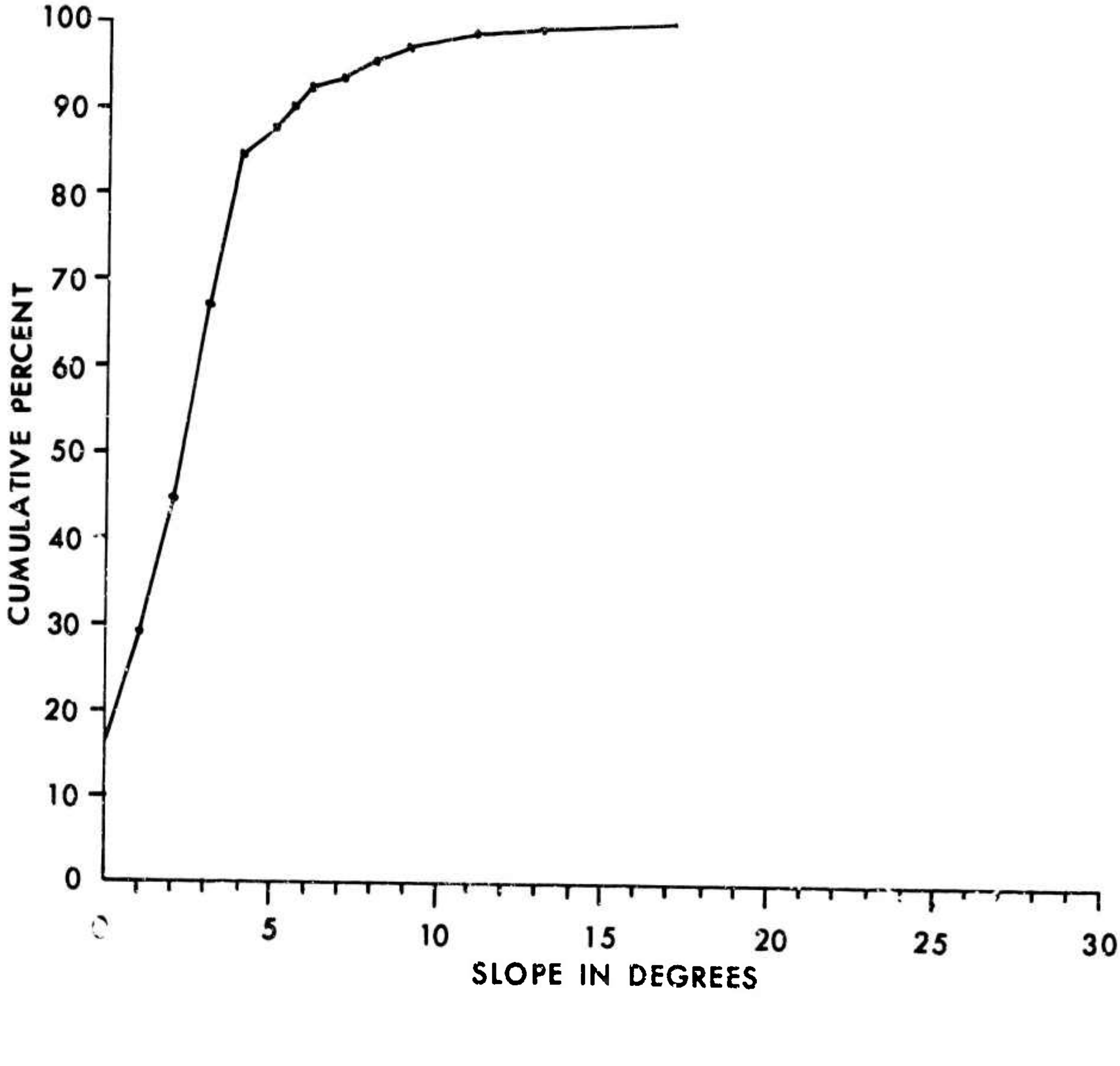


Figure 30 Cumulative percent frequency of slopes, Traverse 8 (Sandy Hills northwest of Laguna Airfield).

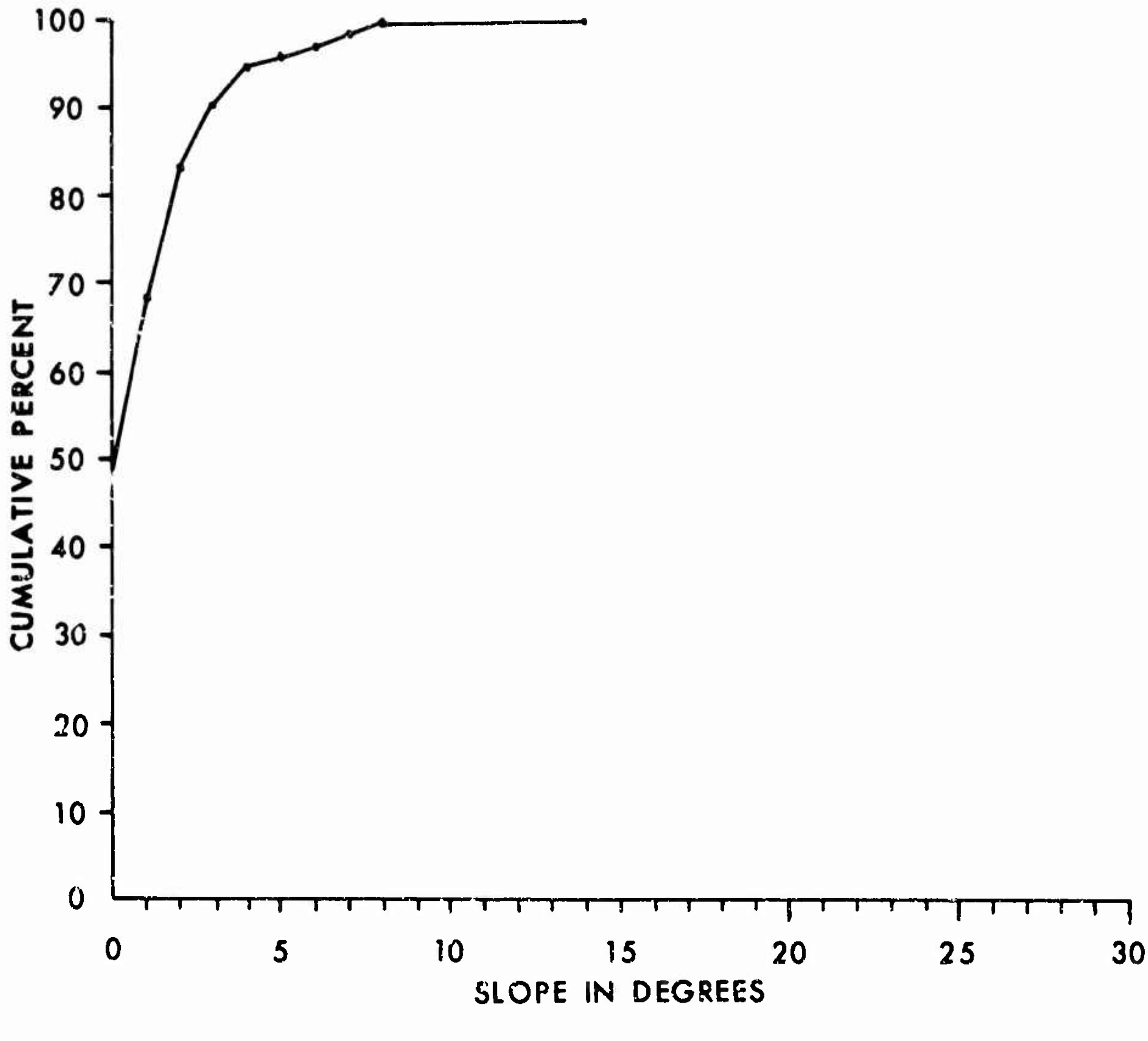


Figure 31 Cumulative percent frequency of slopes, Traverse 9 (Linear Stabilized Dunes).

Figure 32 Cumulative percent frequency of relief, Traverse 1 (Gravelly Dissected Piedmont).

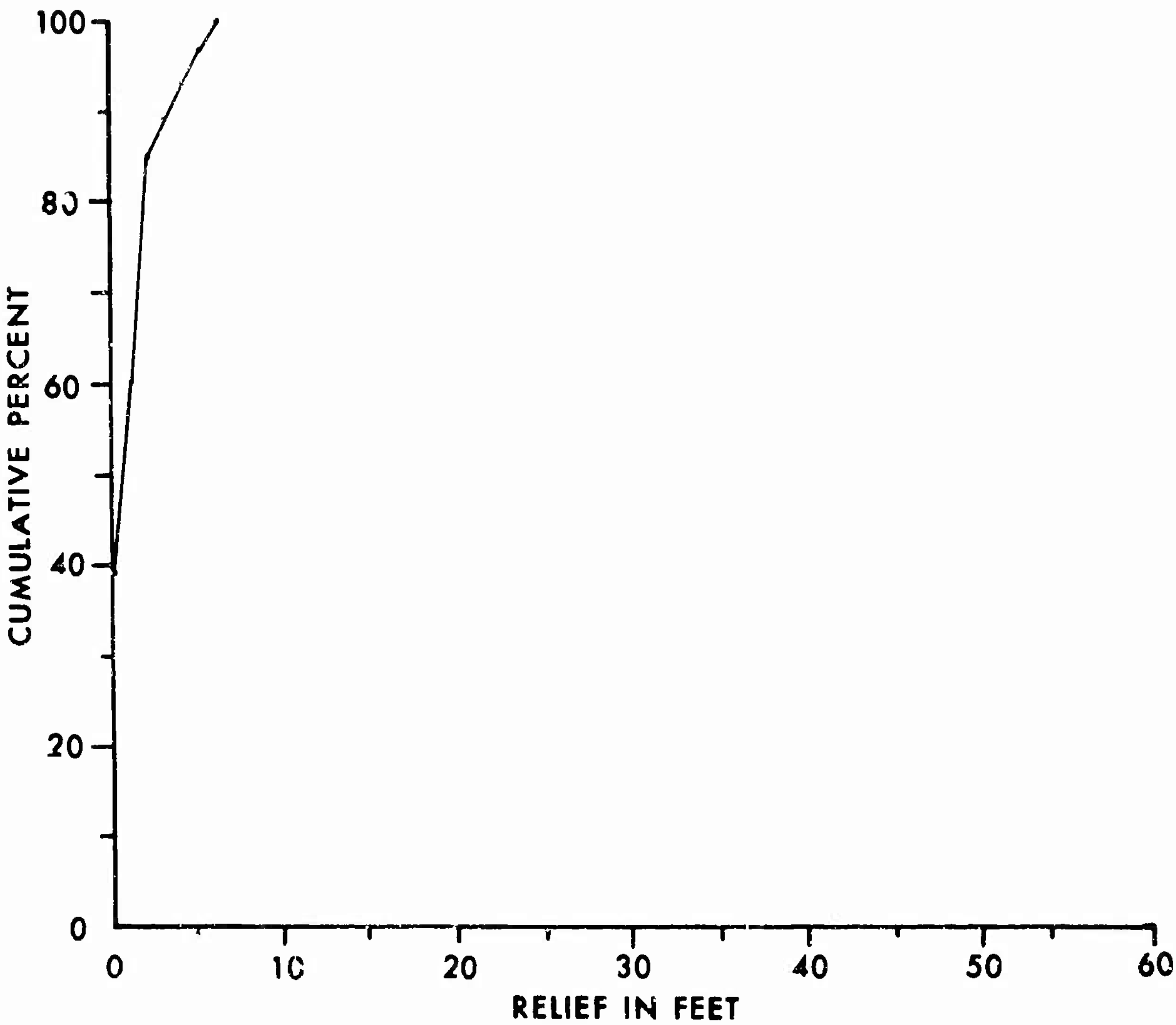


Figure 33 Cumulative percent frequency of relief, Traverse 2 (Wash in Pavement/Wash Complex).

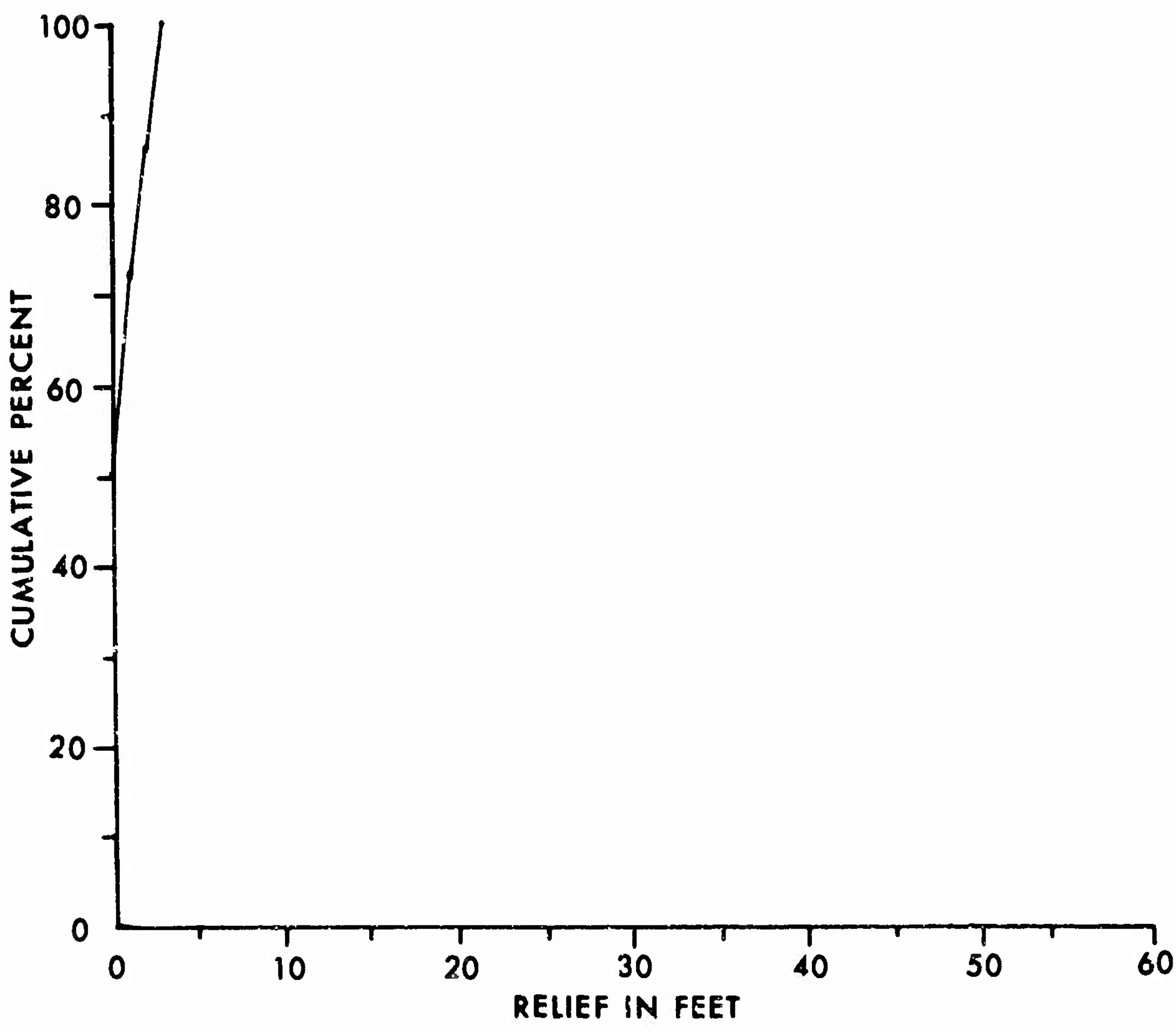


Figure 34 Cumulative percent frequency of relief, Traverse 3 (Pavement of Pavement/Wash Complex).

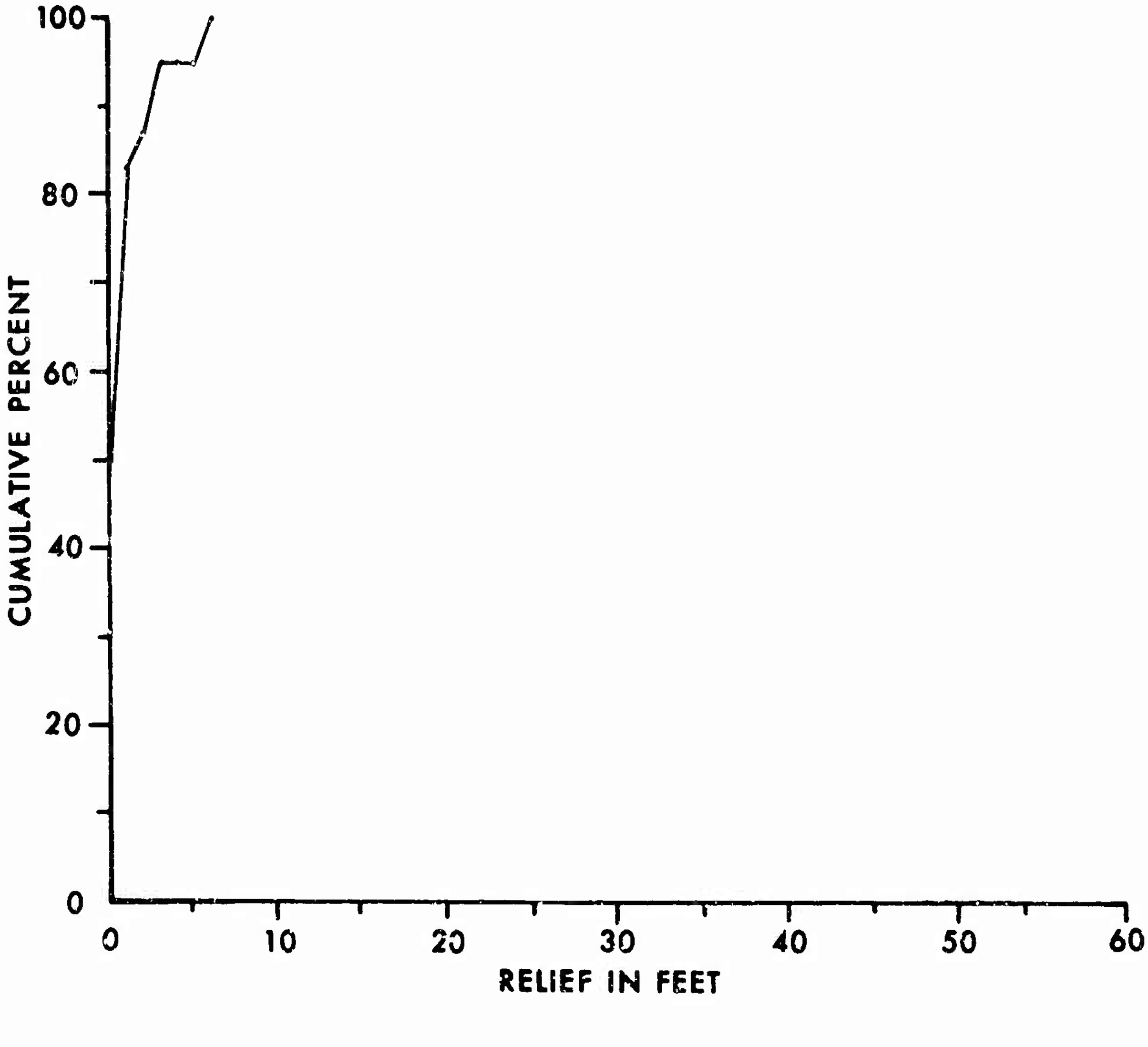


Figure 35 Cumulative percent frequency of relief, Traverse 4 (Gravelly Undissected Piedmont).

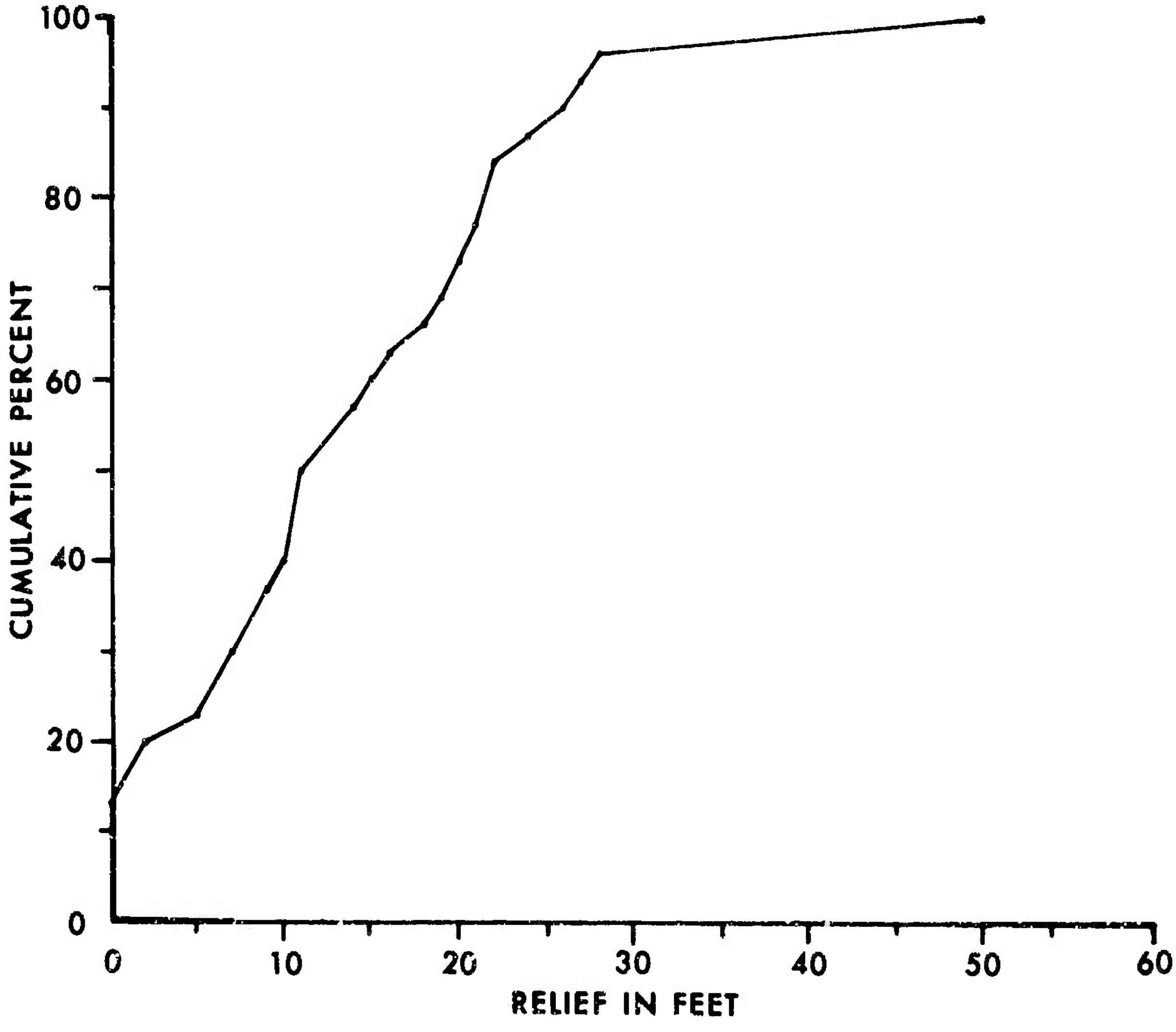


Figure 36 Cumulative percent frequency of relief, Traverse 5 (Gravelly Dissected Piedmont).

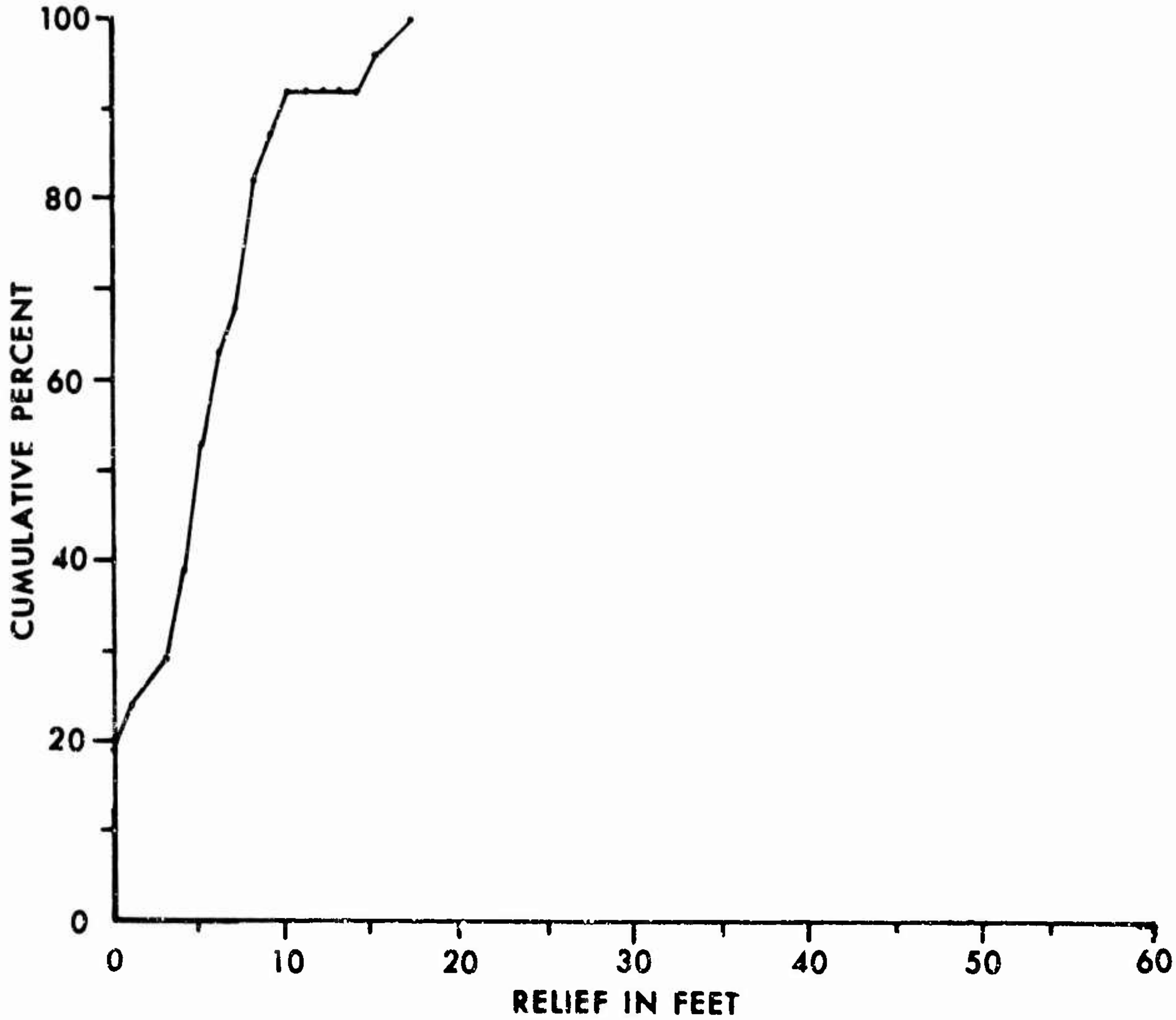


Figure 37 Cumulative percent frequency of relief, Traverse 6 (Sandy Hills south of Vinegarroon Wash).

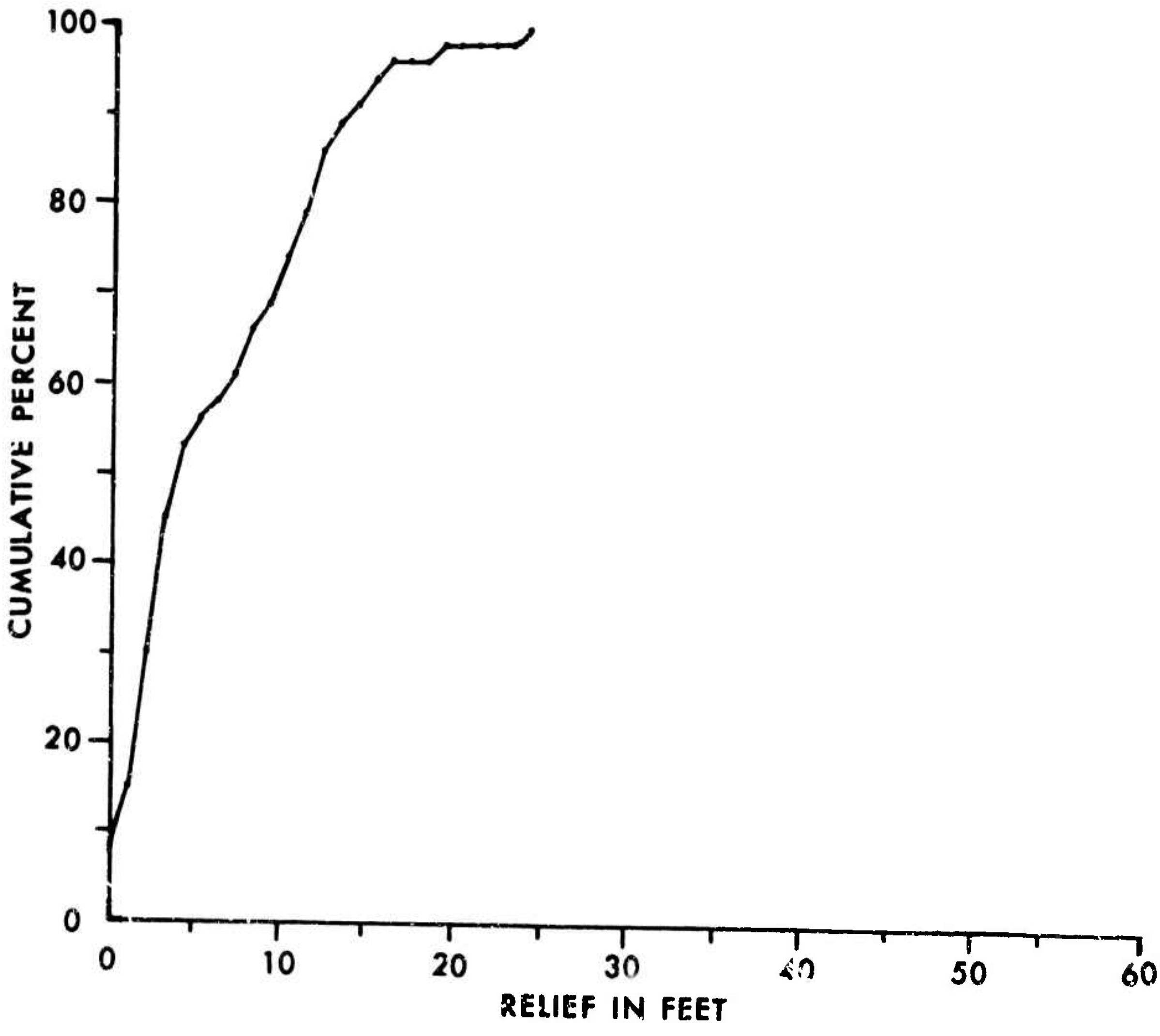


Figure 38 Cumulative percent frequency of relief, Traverse 7 (Sandy Hills northwest of Vinegarroon Wash).

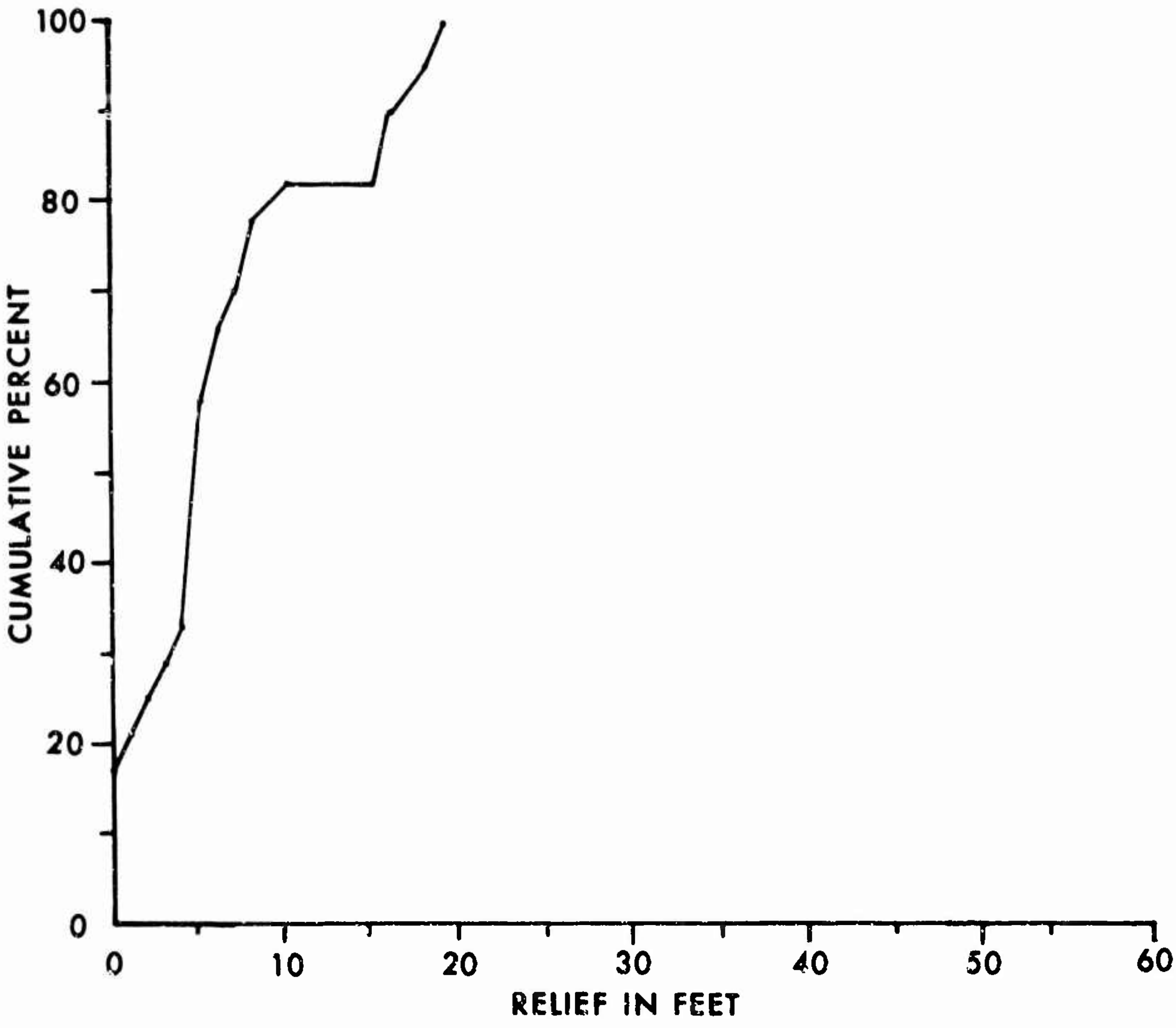


Figure 39 Cumulative percent frequency of relief, Traverse 8 (Sandy Hills northwest of Laguna Airfield).

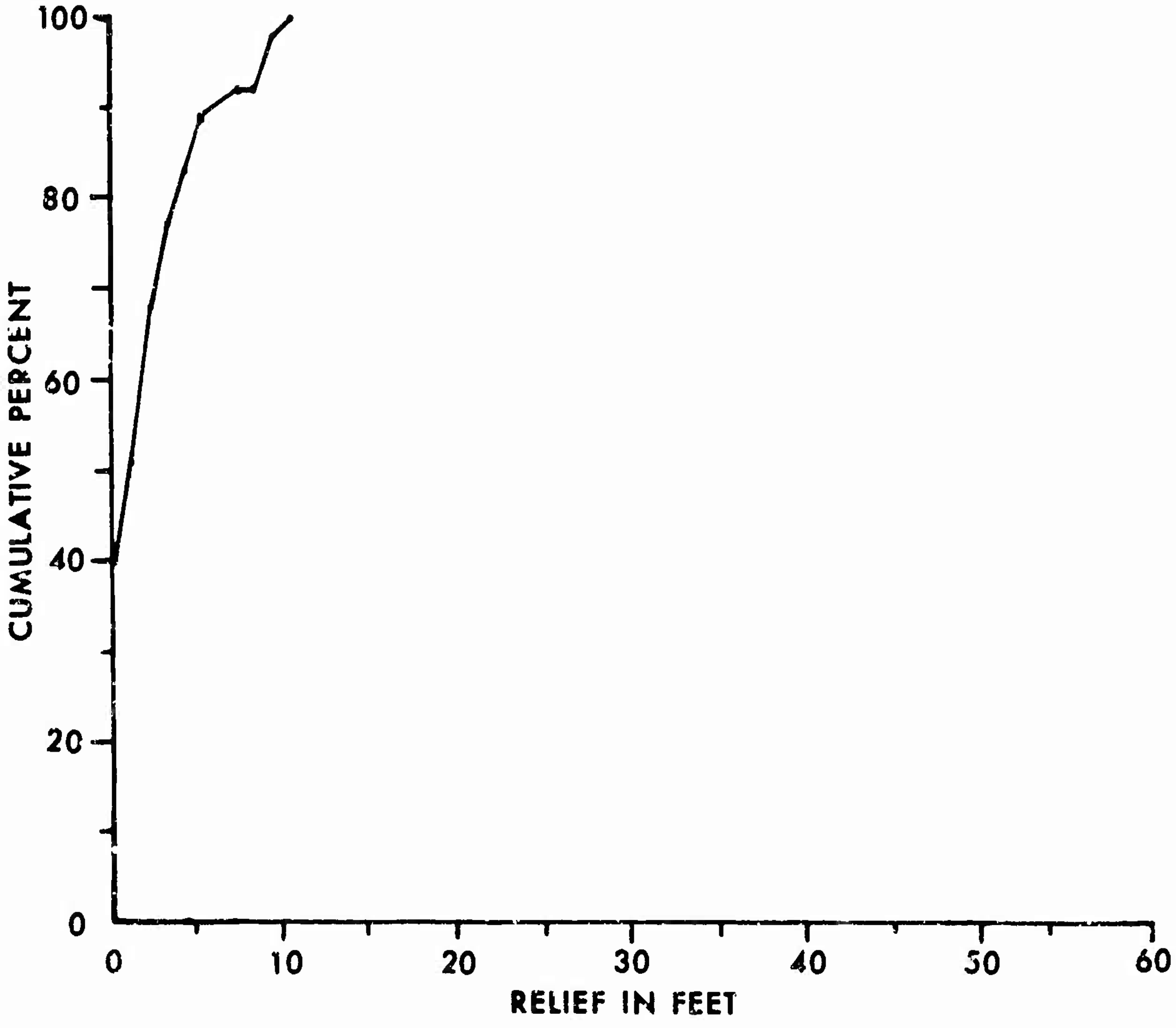


Figure 40 Cumulative percent frequency of relief, Traverse 9 (Linear Stabilized Dunes).

Discussion and Recommendations

The data of this report are an initial contribution to the mobility description of deserts envisioned in the following over-all approach:

1. Field identification and mapping of distinctive surficial associations of materials.

2. Field measurement of slope and relief within associations.

3. Sampling of unconsolidated materials, and size and composition analyses.

4. Empirical field tests relating slopes and material compositions to trafficability, by using some kind of "calibrated wheel".

5. Evaluation of field measurements, sample data, and empirical test data in combination as a statement of mobility suitability, and as a basis for comparison of world desert terrains.

The first two steps of the approach are the subject of this report. We recommend that the last three steps be carried out in the Laguna quadrangle of Yuma Proving Ground, as a capsule evaluation of the feasibility and usefulness of the approach.

The Laguna quadrangle, however, does not include all the desert landforms in the Proving Ground. Other areas should be reconnoitered to identify additional landforms for mapping and measuring.

The Proving Ground, in turn, does not include all the landforms of world deserts. Other deserts in the U. S. and overseas must eventually be investigated. Slope and relief data collected for any area should be incorporated into the Waterways Experiment Station (Corps of Engineers) system for defining world desert terrain analogs, or into a successor system.

Basic ground-truth data collection must be correlated concurrently with empirical evaluations of the effect of the topographic factors upon movement of a vehicle system. The mention of a "calibrated wheel" introduces a concept which might be implemented by measurements of deceleration caused by slopes and obstacles, wheel-to-ground torque values, travel time and distance. Classifying terrain empirically for the engineer, tactician, or vehicle commander might be adequate for the military design or operation; classifying terrain as suggested by this study would then be used to estimate movement capability in inaccessible or denied areas.

APPENDIX
FIELD MEASUREMENT DATA

Traverse 1 Gravelly Dissected Piedmont

(Segment lengths (ft) listed vertically)

Slope in Degrees

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
120	115	130	57	21	98	23	34	60	100	116	105	32	100	102	120
94	34	25	49	32	14	110	21	26	115	170	23	27	57	210	135
18	19	38	40	85	31	25	36	35	170	39	74	47	85	120	14
25	24	38	25	24	32	20	15	74	33	31	28	62	60	15	27
11	18	23	32	26	24	85	23	41	50	75	89	29	72	95	96
57	49	35	48	70	110	32	18	12	35	42	29	41	90	95	95
31	26	28	34	80	180	21		44	46	75	44	48	66	95	68
19	31	26	28		29	53		54	24	44	23	25	46	15	85
25	24	54	52		56	36		23	33	90	66	58	86	62	94
31	18	38	33		44	59		43	19	23	76	44	100	64	70
24	60	34	40		30	44		22	27	97	58	24	62		78
12	26	25	32		54	34		31	52	70		62	41		19
22	24	27	30			30		16	90	35		80	75		64
80	37	19	93			84		23	47	36		36	56		20
14		20	44							28		78			56
12		39	62							40		27			39
33										66		41			78
46										24		52			70
25										28		46			
83										78		20			
										48		32			
										32		42			
										30					

(continued)

16	17	18	19	20	21	22	23	24	25	26	27	29	30
150	19	15	16	17	17	19	11	14	12	15	29	15	13
120	27	16	14	12	12	20	18	14		18	15		
35	21	18	15	15	17	15	10	16		12	10		
15	17	30		26	27		15	12		16	14		
11	62	10		34									
28	19			12									
15	10												
90	19												
41													
74													

FIELD MEASUREMENT DATA

Traverse 2 Wash in Pavement/Wash Complex

(Segment lengths (ft) listed vertically)

Slope in Degrees

0	1/2	1	1-1/2	2	2-1/2	3	3-1/2	5	6	7	8	13	90
37	30	54	15	43	76	31	20	27	8	14	14	13	1
8	35	40		10		23	40						2
23	55	34		30		36							
50	30	50				26							
55	20	50											
29		30											
40		30											
30		30											
[illegible]		24											
25		40											
30		45											
35		35											

FIELD MEASUREMENT DATA

Traverse 3 Pavement in Pavement/Wash Complex

(Segment lengths (ft) listed vertically)

Slope in Degrees

0	1/2	1	3	4	7	8	9	10	12	14	15	36	90
45	95	70	22	16	14	3	8	2	13	10	7	4	1
8	100	44	65		10				14				1
16					6								1
19					3								2
51					5								
51													
49													
40													
68													
24													
40													
41													
12													
56													
65													
68													
10													
79													
10													
45													
6													
47													
16													
100													

FIELD MEASUREMENT DATA

Traverse 4 Gravelly Undissected Piedmont

(Segment lengths (ft) listed vertically)

Slope in Degrees

0	1/2	1	1-1/2	2	3	6	7	8	12
25	32	25	13	17	19	4	8	19	7
4	28	25	30	20	10		7		
16	13	25	13	15	12				
17	14	20	24	15	20				
21	21	20		30					
10	9	24		16					
24	15	16		24					
29		14		16					
18		16							
11		22							
21		18							
40		22							
		12							
		13							
		18							
		16							
		10							
		45							

FIELD MEASUREMENT DATA

Traverse 5 Gravvelly Dissected Piedmond

(Segment lengths (ft) listed vertically)

Slope in Degrees

0	1	2	4	5	6	7	8	9	10	11	12
18	69	33	28	12	23	56	37	30	110	54	18
10	23	48		85		61	46	21	50	26	33
20	12			36		48	68	16	40	38	
10	27			27		15	22				
7	40										
10	51										
	24										
	26										

(continued)

13	14	15	16	18	19	20	21	22	24	26	27
69	18	51	18	18	12	30	10	28	28	22	8
21	47	70	14	33	19	76	36		15	13	
32	39	22	39	25			35				
			25	18							

FIELD MEASUREMENT DATA

Traverse 6 Sandy Hills

(Segment lengths (ft) listed vertically)

Slope in Degrees

0	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	18
120	14	40	22	16	12	12	14	10	15	22	40	24	18	32	14	31	8
12	11	24	19		16	37	41	15	52				17		48	18	
38							19	16	8								
45							31	10	19								
27																	
18																	

FIELD MEASUREMENT DATA

Traverse 7 Sandy Hills

(Segment lengths (ft) listed vertically)

Slope in Degrees

0	1	2	3	4	5	6	7	8	9	10	11
30	27	26	22	23	[illegible]	20	43	25	30	48	24
84	10	21	46	25	10	21	20	24	26	15	
30	33	19	65	26	26	30	18	22	25	23	
33	64	28	25	34	81	28		24	21	19	
95	116		29	31	22	23				72	
10	17		20	39	15					24	
51	18		13		24						
42			45		65						
			19		50						
					51						
					34						
					31						

(continued)

12	13	14	15	16	17	18	19	20	21	22	23
17	52	9	58	43	42	31	15	22	26	10	19
19	51	28	22	30	15	22	23				
37	35		23	10	43						
			60		33						

FIELD MEASUREMENT DATA

Traverse 8 Sandy Hills

(Segment lengths (ft) listed vertically)

Slope in Degrees

0	1	2	3	4	5	6	7	8	9	11	13	17
108	105	100	100	74	51	63	47	58	40	43	19	19
100	64	140	52	38	60	58						
54	96	52	32	54								
60	51	48	33	92								
71	52	47	23	108								
72		64	68	65								
			89	74								
			60									
			94									
			96									

Traverse 9 Linear Stabilized Dunes

0	1	2	3	4	5	6	7	8	14
80	124	52	47	72	32	34	46	35	28
94	115	35	45	42					
73	44	85	33	40					
93	61	46	20						
88	60	92	89						
110	66	76							
115	60	95							
139	99								
125	40								
120									
115									
127									
119									
92									
56									
56									

FIELD MEASUREMENT DATA

Percent Frequency of Slope, by Traverse
(As percentage of total traverse lengths)

Slope (°)	Traverse 1	2	3	4	5	6	7	8	9
0	5.9	27.4	65.2	22.1	3.2	25.9	12.2	16.0	48.3
1/2		11.6	13.2	12.4					
1	3.8	31.6	7.7	33.8	11.6	2.5	9.3	12.7	20.2
1 1/2		1.0		7.5					
2	4.5	5.7		14.3	3.4	6.8	3.0	15.6	14.5
2 1/2		5.2							
3	5.3	7.9	5.9	5.7		4.1	9.2	22.4	7.1
3 1/2		4.1	1.1						
4	2.6				1.2	1.6	5.8	17.4	4.7
5	5.4	1.8			6.8	2.8	14.2	3.8	1.0
6	5.0	.6		.4	1.0		4.0	4.2	1.0
7	1.1	1.0	2.6	1.4	7.7	4.9	2.6	1.6	1.4
8	3.8		.2	1.8	7.4	10.4	3.1	2.0	1.1
9	6.4		.5		4.0	5.1	3.3	1.4	
10	9.9		.1		8.5	9.4	6.5		
11	4.7				5.0	2.2	.8	1.5	
12	7.3		1.8	.7	2.2	4.0	2.4		
13	7.6	.9			5.2	2.4	4.5	.7	
14	6.6		.7		4.4	3.5	1.2		.8
15	9.3		.5		6.1	3.2	5.3		
16	4.4				4.1	6.2	2.7		
17	1.5					4.9	4.3	.7	
18	.7				4.0	.8	1.7		
19	.3				1.3		1.2		
20	.9				4.5		.7		
21	.6				3.4		.8		
22	.4				1.2		.3		
23	.4						.6		
24	.4				1.8				
25	.1								
26	.5				1.5				
27	.5				.3				
28									
29	.1								
30	.1								
36			.3						
90		.2	.3						

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

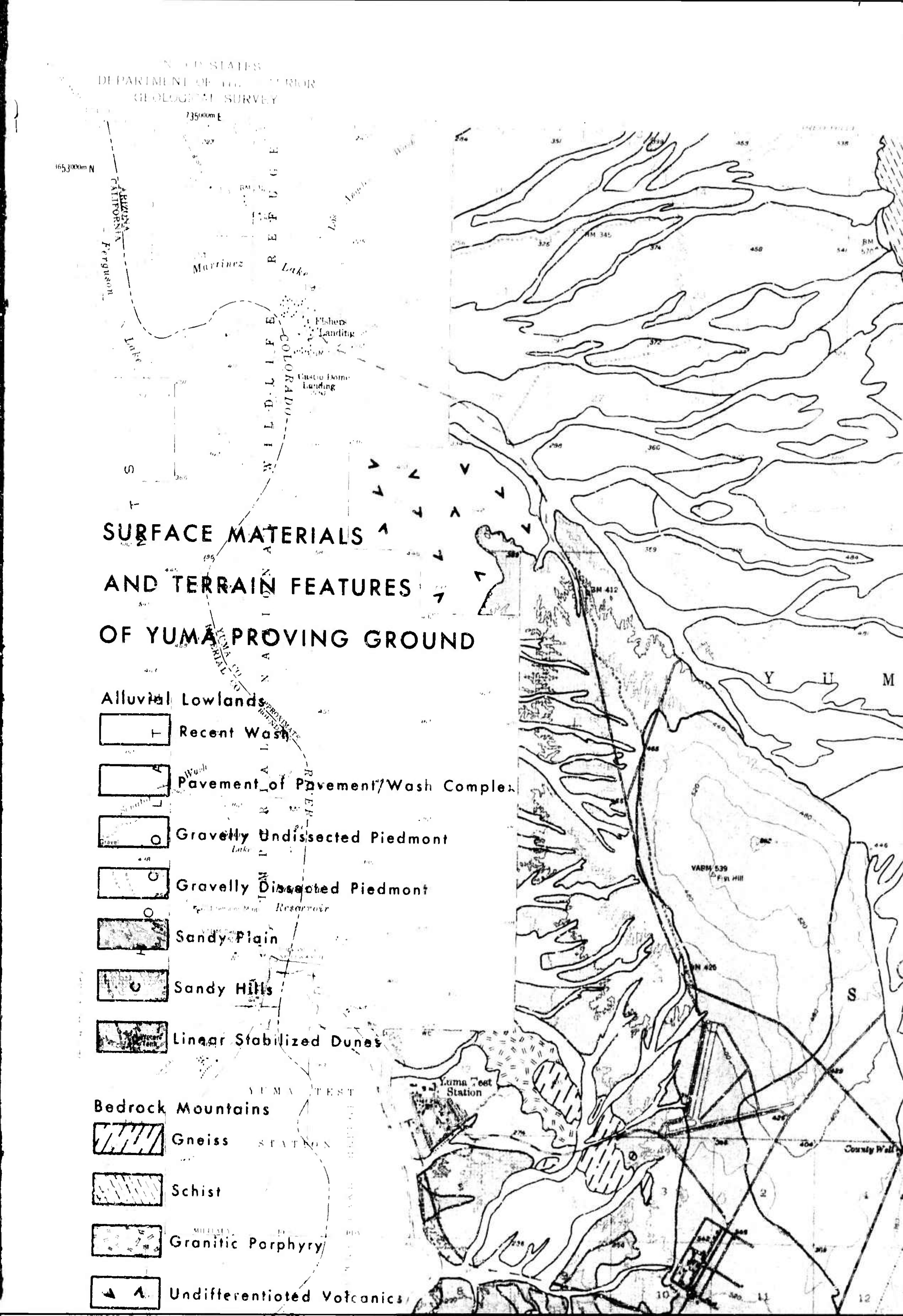
1. ORIGINATING ACTIVITY (Corporate author) U.S. Army Natick Laboratories Natick, Massachusetts 01760	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP
3. REPORT TITLE SURFACE MATERIALS AND TERRAIN FEATURES OF YUMA PROVING GROUND (Laguna, Ariz-Calif, Quadrangle)	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)	
5. AUTHOR(S) (First name, middle initial, last name) John A. Millett and H. Frank Barnett	
6. REPORT DATE October 1970	7a. TOTAL NO. OF PAGES 46 pages and map 7b. NO. OF REFS 0
8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 71-14-ES 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ES-59
10. DISTRIBUTION STATEMENT This document has been approved for public release and sale; its distribution is unlimited.	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Yuma Proving Ground Yuma, Arizona 85364

13. ABSTRACT

Distribution and slope gradients of surficial materials in the Laguna (Ariz-Calif) 1:62,500-scale quadrangle were mapped in the field for engineering evaluation of vehicle testing suitability and for comparison of Yuma Proving Ground terrain with that of other world deserts.

Occurrence and topographic expressions of seven alluvial and six bedrock mapping units are shown as an overprint on the topographic map. Cumulative frequency curves of slope and relief describe these factors of alluvial terrain quantitatively. Actual field measurements of 30,000 feet of traverse are included to permit interpretation for specific materiel evaluations.

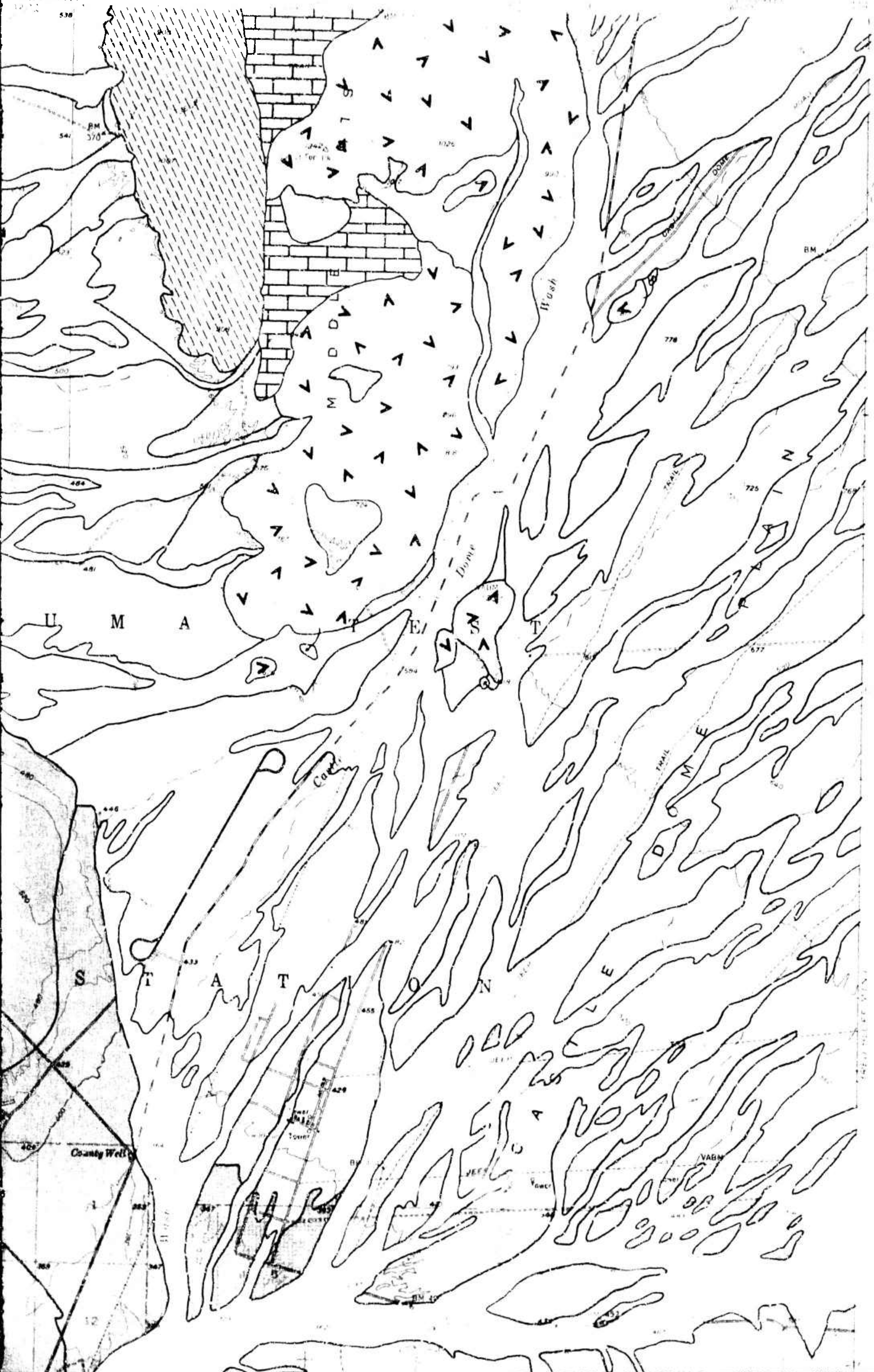
14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Topographic Features	8					
Landforms	8					
Position (Location)	8		8			
Frequency	8		8			
Slopes	8		9			
Gradients	8		9			
Surface Properties	8					
Surfaces	9					
Alluvium	9					
Terrain	9					
Yuma Proving Ground	9					
Ground Vehicles	4		4			
Engineering	4		4			
Deserts	4					
Analogs	4					
Maps	0					

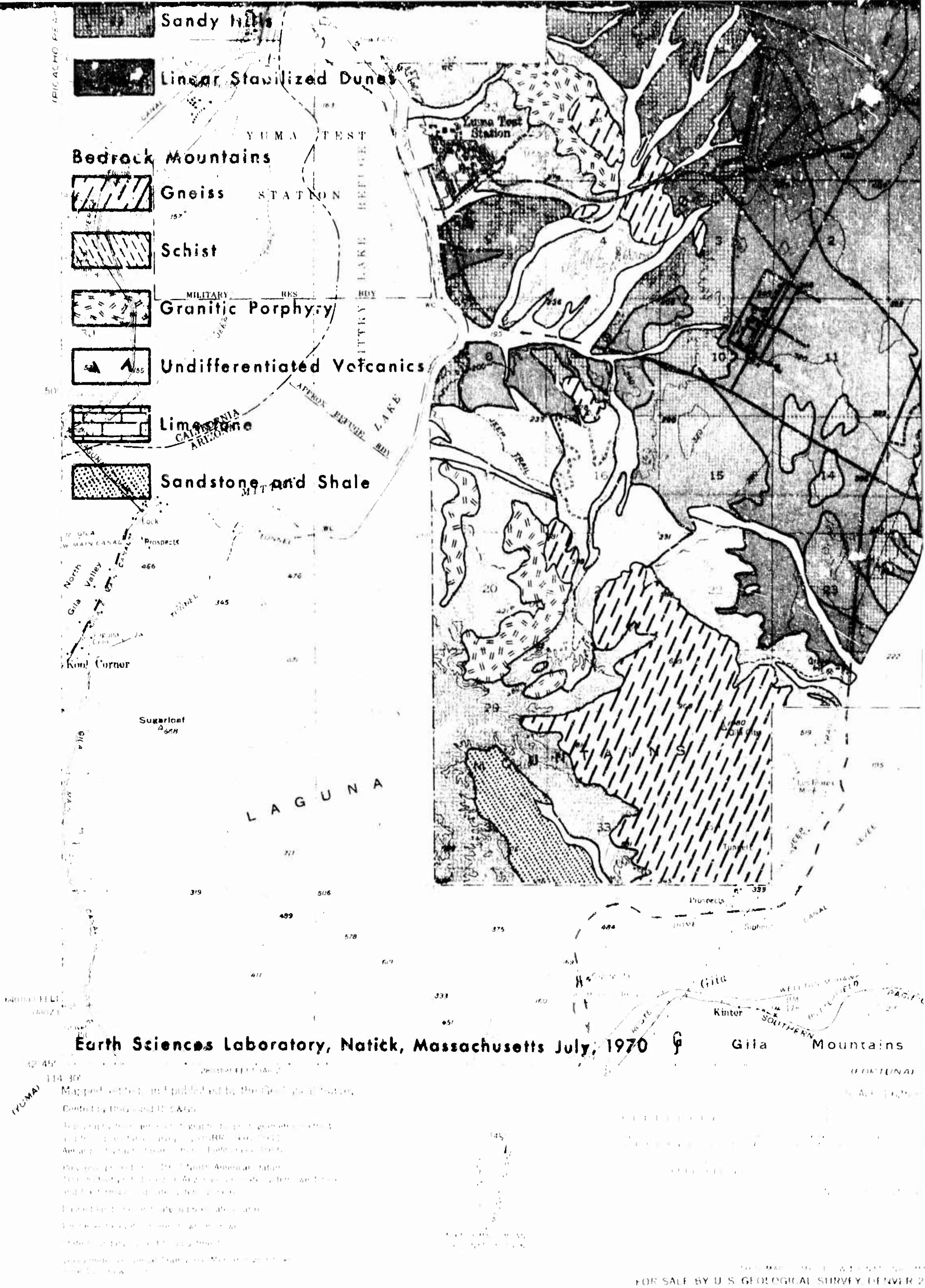


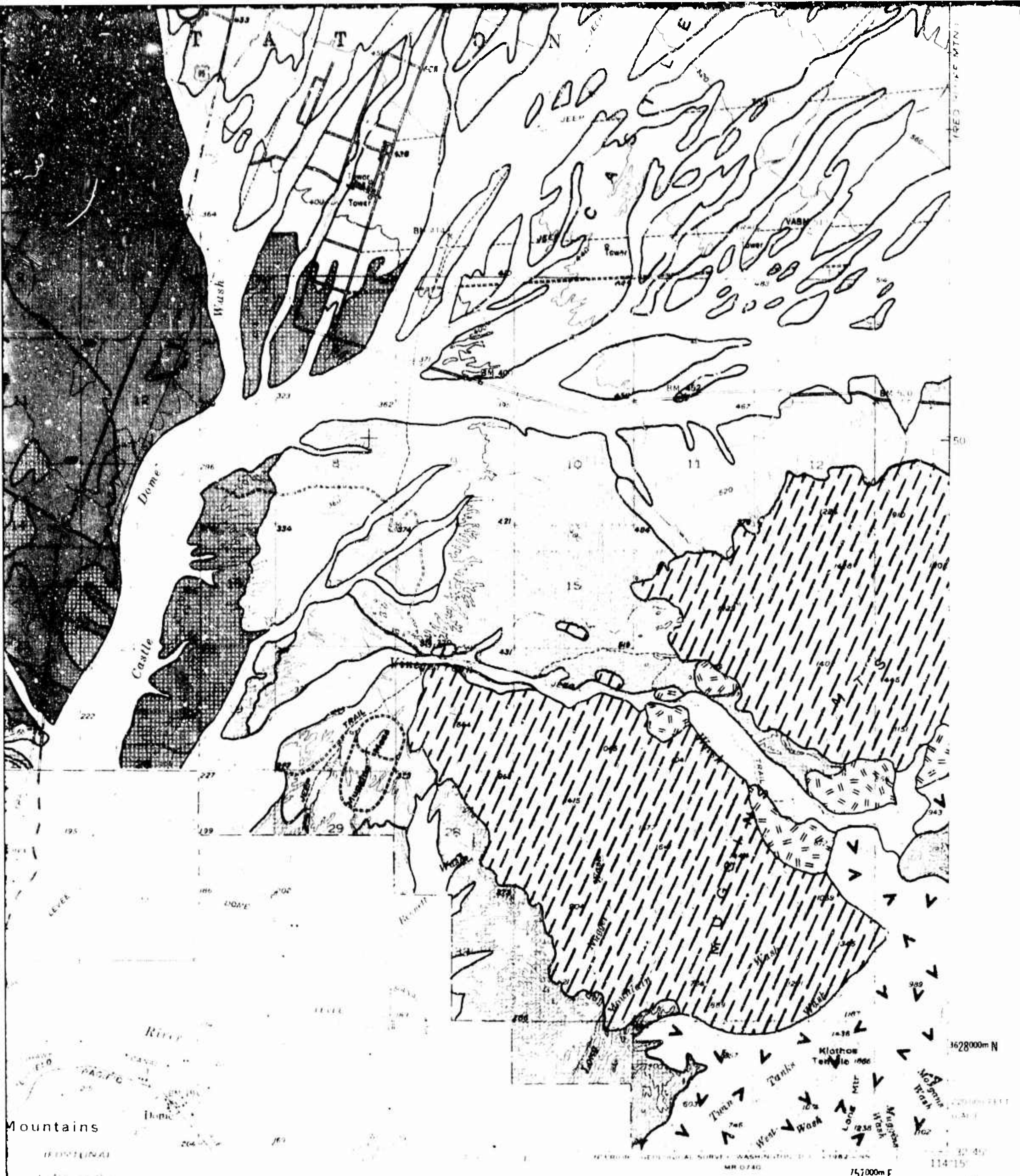
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SURFACE MATERIALS
AND TERRAIN FEATURES
OF YUMA PROVING GROUND
Alluvial Lowlands
Recent Wash
Pavement of Pavement/Wash Complex
Gravelly Undissected Piedmont
Gravelly Dissected Piedmont
Sandy Plain
Sandy Hills
Linear Stabilized Dunes
Bedrock Mountains
Gneiss
Schist
Granitic Porphyry
Undifferentiated Volcanics
ARIZONA
CALIFORNIA
Martinez
Lake
Fishers Landing
Castle Dome Landing
COLORADO
Yuma Test Station
Fort Hill
County Well

2

LAGUNA QUADRANGLE
ARIZONA - CALIFORNIA
MINUTE SERIES (TOPOGRAPHIC)




Sandy hills
Linear Stabilized Dunes
Bedrock Mountains
Gneiss
Schist
Granitic Porphyry
Undifferentiated Volcanics
Limestone
Sandstone and Shale
YUMA TEST STATION
Yuma Test Station
MILITARY RES BDY
LAGUNA
Sugarloaf
Kool Corner
North Gila Valley
Gila
Kinter
Earth Sciences Laboratory, Natick, Massachusetts July, 1970
Gila Mountains



ROAD CLASSIFICATION

Medium-duty Light-duty

Unimproved dirt

U.S. Route

This area is also partly covered by 1:24 000 scale maps of the Imperial Reservoir, Laguna Dam and Dome 7.5 minute quadrangles, surveyed 1955

LAGUNA, ARIZ.—CALIF.

SURVEY, DENVER 25, COLORADO OR WASHINGTON 25, D.C.