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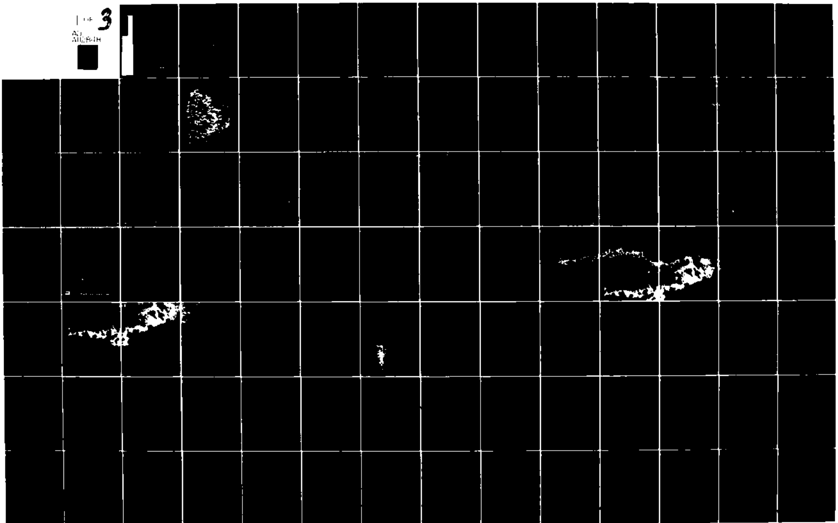

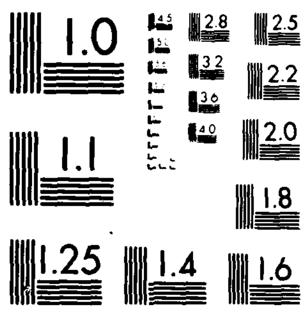

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MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

VERIFICATION STUDY
PINE VALLEY, UTAH
VOLUME I - SYNTHESIS

PREPARED FOR
BALLISTIC MISSILE OFFICE (BMO)
NORTON AIR FORCE BASE, CALIFORNIA

FUGRO NATIONAL, INC.
Consulting Engineers and Geologists

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MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

VERIFICATION STUDY - PINE VALLEY
UTAH

VOLUME I - SYNTHESIS

Prepared for:

U.S. Department of the Air Force
Ballistic Missile Office (BMO)
Norton Air Force Base, California 92409

Prepared by:

Fugro National, Inc.
3777 Long Beach Blvd.
Long Beach, California 90807

24 March 1981

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Se~~tting~~ ~~Surface~~ soils, Terrain, geology, bedrock,
water level, Seismic refraction, electrical resistivity, boring,
trench, test pit, cone penetrometer, California Bearing ratio, grain size

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents results of geotechnical studies which were conducted in Pine Valley, Utah.

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FOREWORD

This report was prepared for the U.S. Department of the Air Force, Ballistic Missile Office (BMO), in compliance with Contract No. F04704-80-C0006, CDRL Item 004A6. It contains an evaluation of the suitability of Pine Valley, Utah, for siting the MX Land Mobile Advanced ICBM system and presents the geological, geophysical, and soils engineering data upon which the evaluation is based. It is one of a series of reports covering the results of Verification studies in the Nevada-Utah region.

Verification studies, which were started in 1979, are the final phase of a site-selection process which was begun in 1977. The Verification objectives are to define sufficient area suitable for deployment of the MX system and to provide preliminary soils engineering data. Previous phases of the site-selection process were Screening, Characterization, and Ranking. In preparing this report, it has been assumed that the reader will be familiar with the previous studies.

Volume I of this report is a synthesis of the data obtained during the study. It contains discussions relative to the horizontal and vertical shelter basing modes. Volume II is a compilation of the data which may be used for independent interpretations or analyses.

VOLUME I

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF DRAWINGS

1.0 INTRODUCTION

1.1 PURPOSE AND BACKGROUND

This report presents the results of the geotechnical studies which were conducted in Pine Valley, Utah, during the summer of 1980. The work was done as part of Fugro National, Inc.'s (FNI) Verification studies which have two major objectives:

1. Verify and refine suitable area boundaries for two proposed basing modes (horizontal and vertical shelter) for the MX missile system; and
2. Provide preliminary physical and engineering characteristics of the soils.

The report contains two volumes. This volume is a synthesis of the data collected during the studies. The data obtained as a result of the field and laboratory work are compiled by activity in Volume II.

The Verification program is the final phase of a site-selection process which started in 1977. The objective of the site-selection process is to identify and rank geotechnically suitable areas which are sufficiently large for deployment of the Missile-X (MX), an advanced intercontinental ballistic missile system. The phases are called Screening, Characterization, Ranking, and Verification. Screening used existing information from literature to identify areas which appeared to be suitable for deployment of MX based on geotechnical, cultural, and environmental criteria. Potentially usable regions were identified in seven western states. Both Characterization and Verification programs use field studies as well as published information. Following Screening and Characterization, the available geotechnical data were used to rank the seven regions. The ranking, based on relative construction costs, was made for various basing modes. Characterization studies emphasized collection of information to characterize geologic units with respect to construction of the MX basing options. Verification studies also obtain information on construction properties of the geologic units, but special emphasis is given to refining the usable area boundaries that were drawn during the Screening studies. Table 1-1 summarizes the investigative techniques being employed during Verification studies.

Figure 1-1 shows the site-selection schedule and identifies the FNI technical report for each element in the process. Based on the results of Screening, Characterization, and Ranking, contiguous portions of Nevada and Utah were selected as a candidate siting region for the MX system, and Verification studies were started in 1978. As shown, the Verification Program is continuing, and field work should be completed in 1981. The areas for which reports have been issued on the Verification studies are shown in Figure 1-2. The present usable-area boundaries for the Nevada-Utah siting region are shown in Drawing 1-1. The boundaries will be adjusted as Verification studies are completed.

1.2 SCOPE OF STUDY

The field work in Pine Valley was done in 1980. Table 1-2 lists the types and number of field activities that were performed in

OBJECTIVES → VERIFICATION OF SUITABLE AREA FOF

DATA FOR EVALUATIONS → TERRAIN PARAMETERS | GEOLOGIC HAZARD | DEP

FIELD TECHNIQUES AND APPLICATIONS →

Geologic mapping

- Identification and limits of areas with slopes greater than 5% and 10% grade

Geologic mapping

- Identification of faults and lineaments

Ge

- Surface
- Depth to from top geologic
- Geomor erosion
Seismi
- Subsurfa rock lim
- Delineat layers f velocitie
- Occurre
E
- Publishe

EA FOR MX DEPLOYMENT

CHARACTERISTIC

50'/150' DEPTH TO ROCK

Geologic mapping

- Surface limits of rock
- Depth to rock from topographic and geologic interpretation
- Geomorphic expression and erosion history

Seismic refraction surveys

- Subsurface projection of rock limits
- Delineation of high velocity layers from p wave velocities (> 7000 fps)

Borings

- Occurrence of rock

Existing data

- Published literature

50'/150' DEPTH TO GROUND WATER

Geologic mapping

- Obtain water depths from wells in study area

Borings

- Occurrence of ground water

Electrical resistivity/ seismic refraction surveys

- Provide supplemental data to support presence or absence of ground water

Existing data

- Published literature

EXTENT AND CHARACTERISTICS OF SOILS

Geologic mapping

- Extent of surficial soil units
- Surficial soil types

Borings

- Identification of subsurface soil types
- In situ soil density and consistency
- Samples for laboratory testing

Trenches and test pits

- Identification of surface and subsurface soil types
- Degree of induration and cementation of soils
- In situ moisture and density of soil
- Samples for laboratory testing

Cone penetrometer tests

- In situ soil strength

Laboratory tests

- Physical properties
- Engineering properties – shear strength, compressibility
- Chemical properties

GEOPHYSICAL PROPERTIES

Seismic refraction surveys

- Compressional wave velocities
- Layering of soil

Electrical resistivity surveys

- Electrical conductivity of soils
- Layering of soil

2

ICS OF BASIN FILL

PRELIMINARY GEOTECHNICAL CONSIDERATIONS AND RECOMMENDATIONS

ROAD DESIGN DATA

<u>Trenches and test pits</u>

- Identification of soil types
- In situ soil density and moisture

<u>Cone penetrometer tests</u>

- In situ soil strength
- Thickness of low strength surficial soil

<u>Laboratory tests</u>

- Physical properties
- Compaction and CBR data
- Suitability of soils for use as road subgrade, subbase or base

<u>Existing data</u>

- Suitability of soils for use as road subgrade, subbase or base
- Behavior of compacted soils

EXCAVATABILITY AND STABILITY

<u>Borings</u>

- Subsurface soil types
- Presence of cobbles and boulders
- In situ density of subsurface soils
- Stability of vertical walls

<u>Trenches and test pits</u>

- *Subsurface soil types*
- Subsurface soil density and cementation
- Stability of vertical walls
- Presence of cobbles and boulders

<u>Laboratory tests</u>

- Physical properties
- Engineering properties

<u>Geologic mapping</u>

- Distribution of geologic units

<u>Seismic refraction surveys</u>

- Excavatability

FIELD TECHNIQUES VERIFICATION STUDIES NEVADA–UTAH

MX SITING INVESTIGATION

DEPARTMENT OF THE AIR FORCE – BMO

TABLE 1 1

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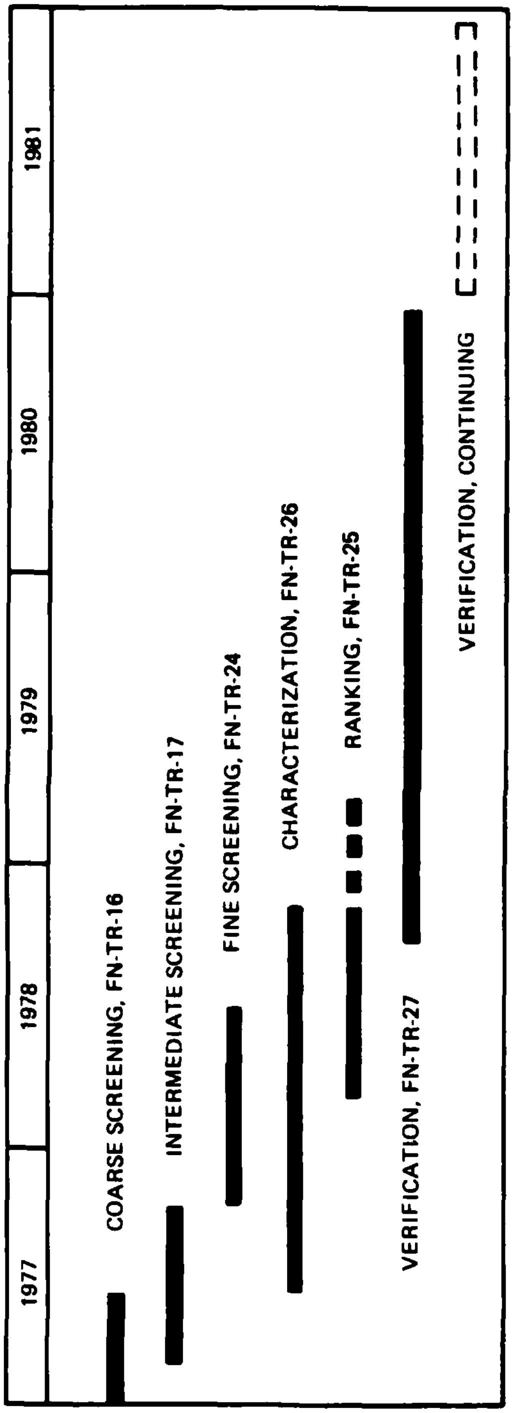
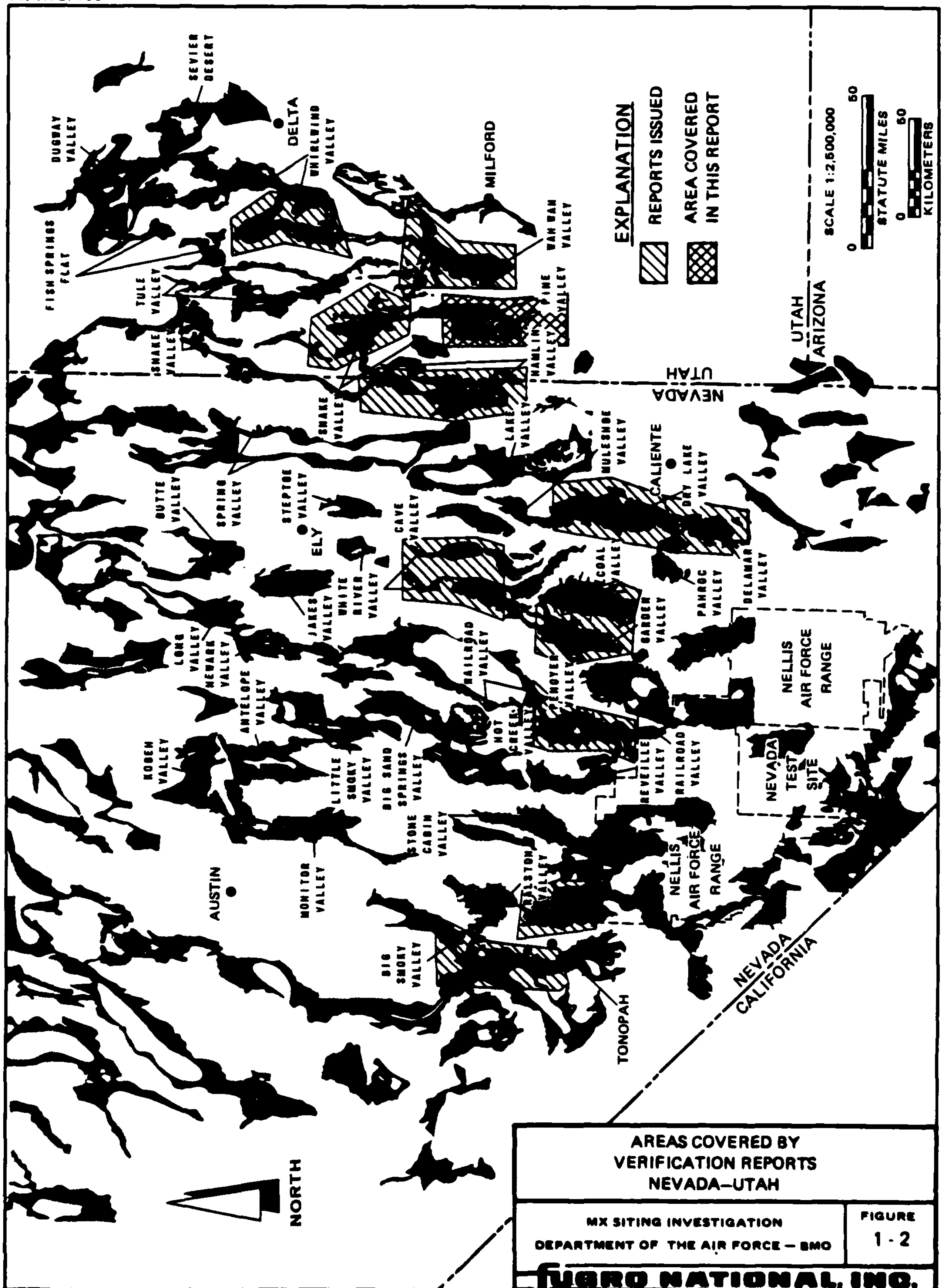


SUMMARY OF SITE
SELECTION SCHEDULE

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE — BMO	FIGURE 1-1

FUGRO NATIONAL, INC.



AREAS COVERED BY VERIFICATION REPORTS NEVADA–UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

FIGURE 1-2

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24 MAR 81

GEOLOGY AND GEOPHYSICS– FIELD ACTIVITIES

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geologic mapping stations	86
Borings (Depth to rock)	2
Shallow refraction	23
Electrical resistivity	22

ENGINEERING–FIELD ACTIVITIES

ACTIVITY	NO.	NOMINAL DEPTH - FEET (METERS)
Borings	7 1	160 (49) 100 (30)
Trenches	16 3	9-14 (3-4) 2-4 (1-1)
Test pits	25	5 (2)
Surficial soil samples	40	2-3 (0.6-1)
CPT soundings	86	0.2-75 (0.1-23)
Field CBR tests	15	1-3 (0.3-1)

ENGINEERING–LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	130
Specific gravity	9
Sieve analysis	182
Hydrometer	0
Atterberg limits	19
Consolidation	0
Unconfined compression	0
Triaxial compression	0
Direct shear	7
Compaction	24
CBR	23
Chemical analysis	12

SCOPE OF ACTIVITIES
PINE VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

TABLE 1-2

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Pine Valley. The techniques of investigation are discussed in the Appendix.

Access to public lands in Pine Valley was arranged through the Richfield and Cedar City, Utah, district offices of the Bureau of Land Management (BLM) and the Utah Division of State Lands and Forestry. At their request, all field activities were performed along existing roads or trails to minimize site disturbance. In some cases, this restriction prevents distributing activities in an optimum pattern for analysis of geotechnical conditions. Archaeological and environmental surveys were performed at each proposed activity location. Activity locations were moved from those few places where a potential environmental or archaeological disturbance was identified.

1.3 DISCUSSION OF ANALYSIS TECHNIQUES

1.3.1 Determination of Suitable Area

The number of field activities performed during this investigation established a relatively small data base for characterizing such a large area, especially in view of its complex geology and frequent soil variations. In some cases, the environmental restrictions limited the ability to achieve an optimum distribution of data points. Nevertheless, care has been taken to optimize the information that could be obtained within specified cost and time constraints of the project. The determination of suitable area is based on the exclusion criteria given in Appendix A2.0. The main attention was focused on the study of depth to rock, depth to water, terrain conditions, and near-surface soil characteristics. Maps showing the results of these studies are included in Section 3.0 and the suitable area map is included in Section 2.0.

a. Depth to rock: For a Verification study, the subsurface location of the 50- and 150-foot (15- to 46-m) depths to rock are estimated and contoured (Drawing 3-3). These contours are interpreted from published well data, geologic literature, boring logs, and geophysical data. The interpretation considers the presence or absence of range-bounding faults, bedding plane attitudes, topographic slopes, evidence of erosional features such as pediments, and the presence or absence of young volcanic rocks.

b. Depth to Water: The depth-to-water map (Drawing 3-4) is based on well data listed in Table II-2-1 (Volume II). Data compiled in Table II-2-1 came from FNI water resources program wells, well logs on file with the State of Utah Engineer's Office, and literature describing the valley hydrology. Whenever possible, the depth to water listed for a well represents the depth to the first, shallow water-bearing zone not the static water level. Static levels can be higher than first-encountered water depths since many valleys contain artesian aquifers for which the static water level is above the aquifer. The well data are plotted on a map and used to define the 50- and 150-foot (15- and 46-m) depth-to-water contours.

c. Terrain: The terrain map (Drawing 3-5) was compiled to show areas unsuitable for either vertical or horizontal shelters due to either high surface slopes or frequent deep drainage incisions (criteria are described on Appendix Table A2-1). The interpretation of terrain exclusions is based on a combination of field- and office-derived data. Field data includes the visual information obtained by visiting the areas and making measurements of typical drainage incision depths. Visits frequently result in recognition of areas with locally steep slopes (for example, the sides of large and deeply incised drainages) that are not recognizable from data available in the office. Office-determined data consists of 1) interpretation of 1:60,000-scale black and white and 1:25,000-scale color aerial photographs to determine terrain exclusions in areas lacking road access; and 2) topographic map analysis to define areas of greater than 10 percent slope.

d. Faults: The faults shown on the geologic map (Drawing 3-2) are primarily mapped from high resolution photogeologic studies and field reconnaissance. These faults are primarily Quaternary age but some late Tertiary faults may also be included. Generally, those within alluvial deposits are of Quaternary age. The faults shown within rocks in the mountain blocks or at the mountain-valley contact are of unknown age but are most likely of late Tertiary and/or Quaternary age and have been active under the present tectonic regime. Published maps show numerous other faults within the rocks of the mountain blocks and some of these also may have been active under the present tectonic regime. Since they are not within the siting areas, they have not been studied. The published maps also show numerous inferred faults buried under the alluvium along the mountain-valley contacts. These faults are commonly verified by geophysical studies. They may represent earthquake hazards but since they have no surface expression, they cannot be verified by the reconnaissance methods employed in the fault studies.

1.3.2 Determination of Basin-Fill Characteristics

In addition to the primary objective of refining suitable area boundaries, a secondary objective was to provide preliminary physical and engineering properties of the basin-fill materials. These data will be used for preliminary engineering design studies, will assist in planning future site-specific studies, and will be used by other MX participants.

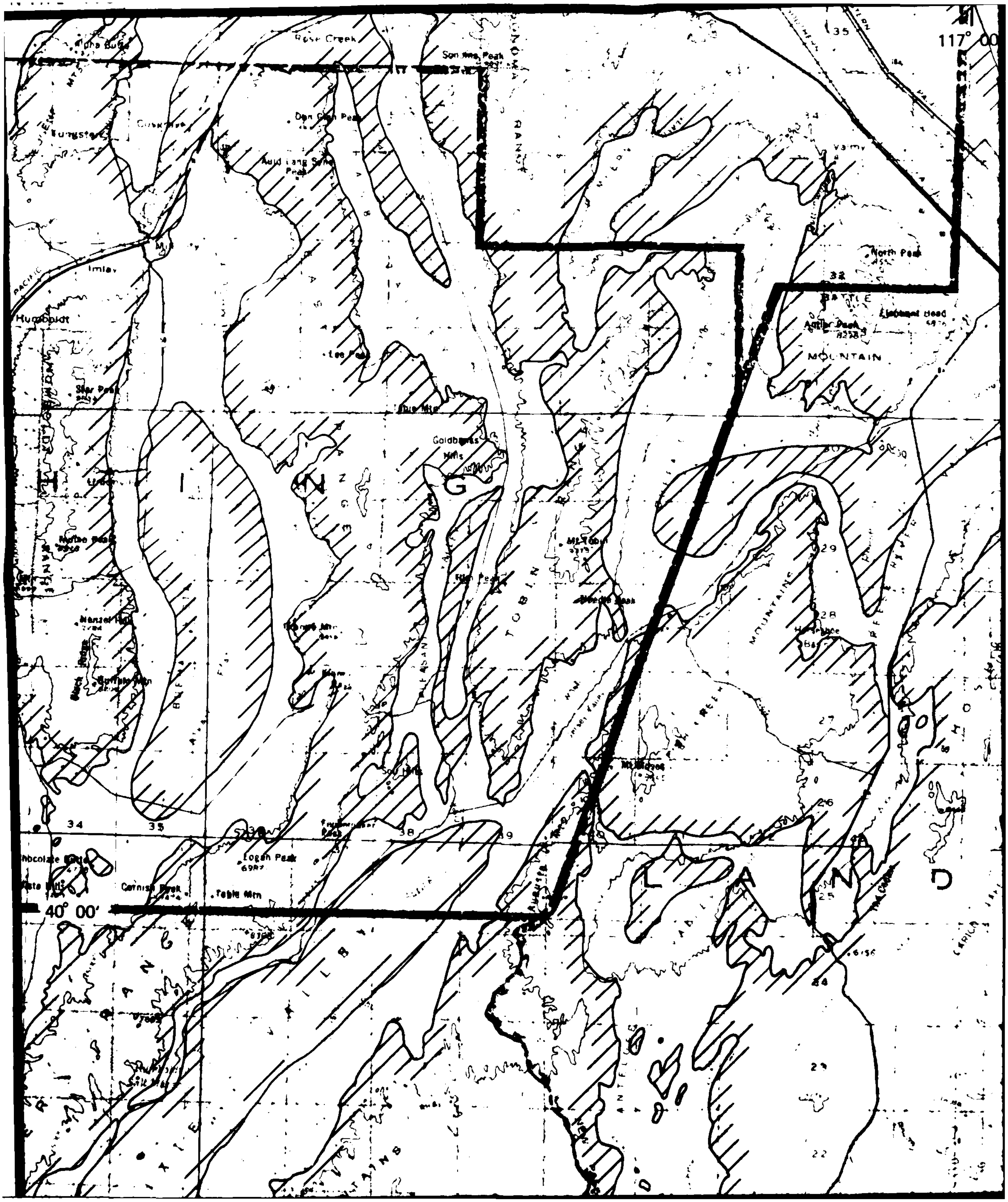
The geologic map (Drawing 3-2) showing the distribution of surficial soils is based on the interpretation of aerial photos, field mapping, and information from trenches, test pits, and surficial soil samples.

The investigations of engineering properties were designed primarily to obtain information needed for construction activities. For Verification studies, surficial-soil conditions as related to road construction, a major cost item, received particular emphasis. Emphasis was placed also on soil conditions in the upper 20 feet (6 m) to supply information to the approximate depth of excavation for the horizontal shelter basing mode.

The results of laboratory tests made on samples from borings, trenches, and test pits and data from seismic refraction lines were used to estimate physical and engineering properties of the soils to a depth of 20 feet (6 m). The data are limited since only 19 trenches, 25 test pits, eight borings, and 23 seismic lines were available. Three of 19 trenches were less than 5 feet (1.5 m) deep because they encountered hard cementation and/or cobbles. There may be soil conditions in the upper 20 feet (6 m) that were not encountered by these 75 data points. The number of data points available for description of the surficial soils was increased to 201 by using 40 surface samples for laboratory tests and 86 Cone Penetrometer Test (CPT) soundings to measure in-situ properties.

The soil parameters between a depth of 20 and 160 feet (6 and 49 m) are based on data obtained from only eight borings. The spacing between borings ranged from 3 to 10 miles (5 to 16 km); therefore, the data presented may not be representative of the entire valley.

The length of the seismic refraction lines was chosen so that the velocity profile could be investigated to a depth of at least 150 feet (46 m), which is the depth of interest for the vertical shelter basing mode.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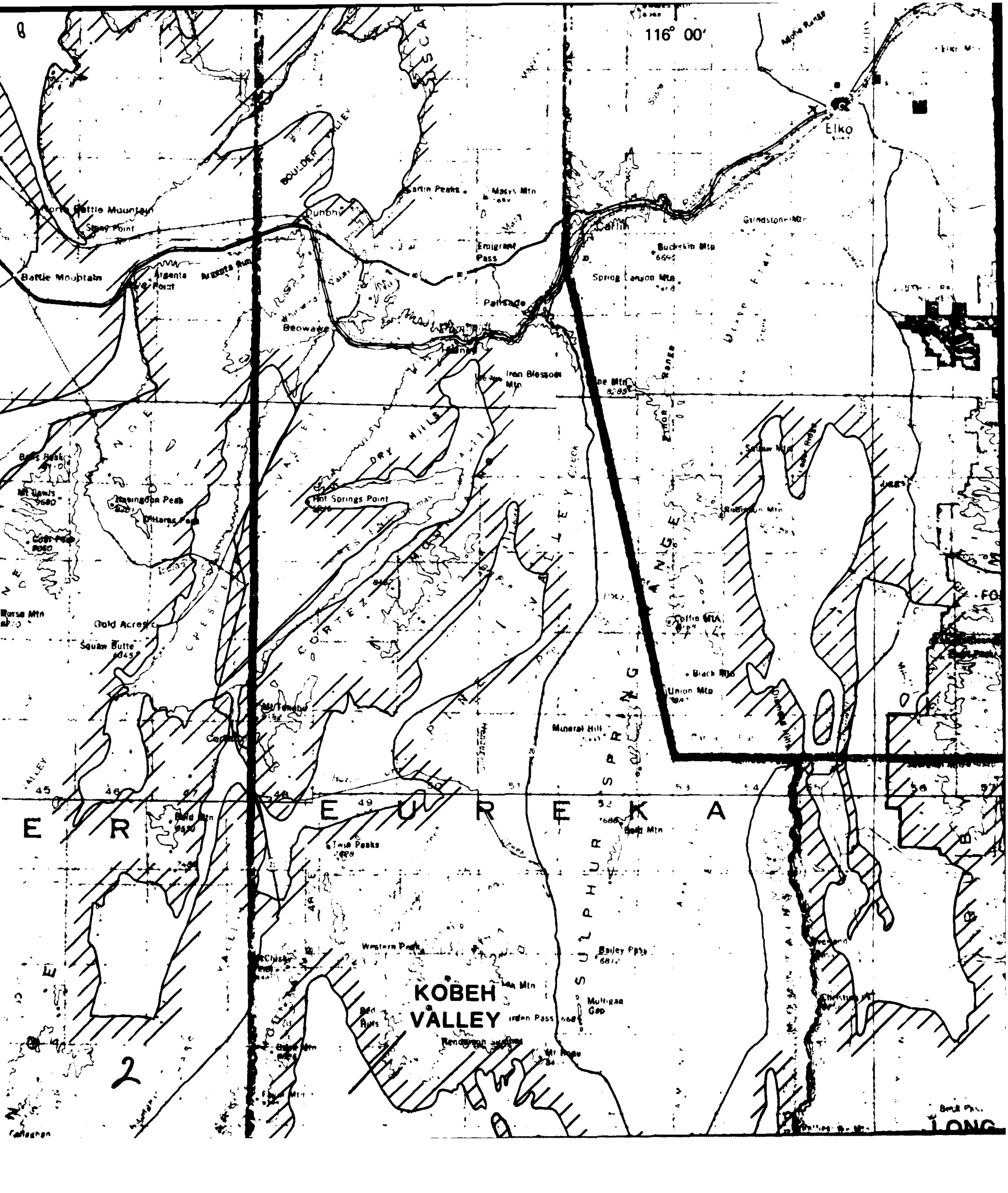
40° 00'
Rose Creek
Imlay
Humboldt
Star Peak
Don Carl Peak
Auld Lang Syne Peak
Lee Peak
Goldbanks Mills
Mt Tobin
North Peak
Antler Peak
MOUNTAIN
Logan Peak
Table Mtn
Cornish Peak



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Grindstone Mtn
Buckskin Mtn
6694
Spring Canyon Mtn
Battle Mountain
Argenta
Argenta Point
Dunphy
Emigrant Pass
Palisade
Beowawe
Iron Blossom Mtn
BOULDER VALLEY
DRY HILLS
Hot Springs Point
Bells Peak
Mt Lewis
9680
Hasington Peak
Goat Peak
8680
Horse Mtn
Gold Acres
Squaw Butte
6845
CORTEZ
Mt Tenabo
Mineral Hill
Coffin Mtn
Black Mtn
Union Mtn
Jiggs
45
46
47
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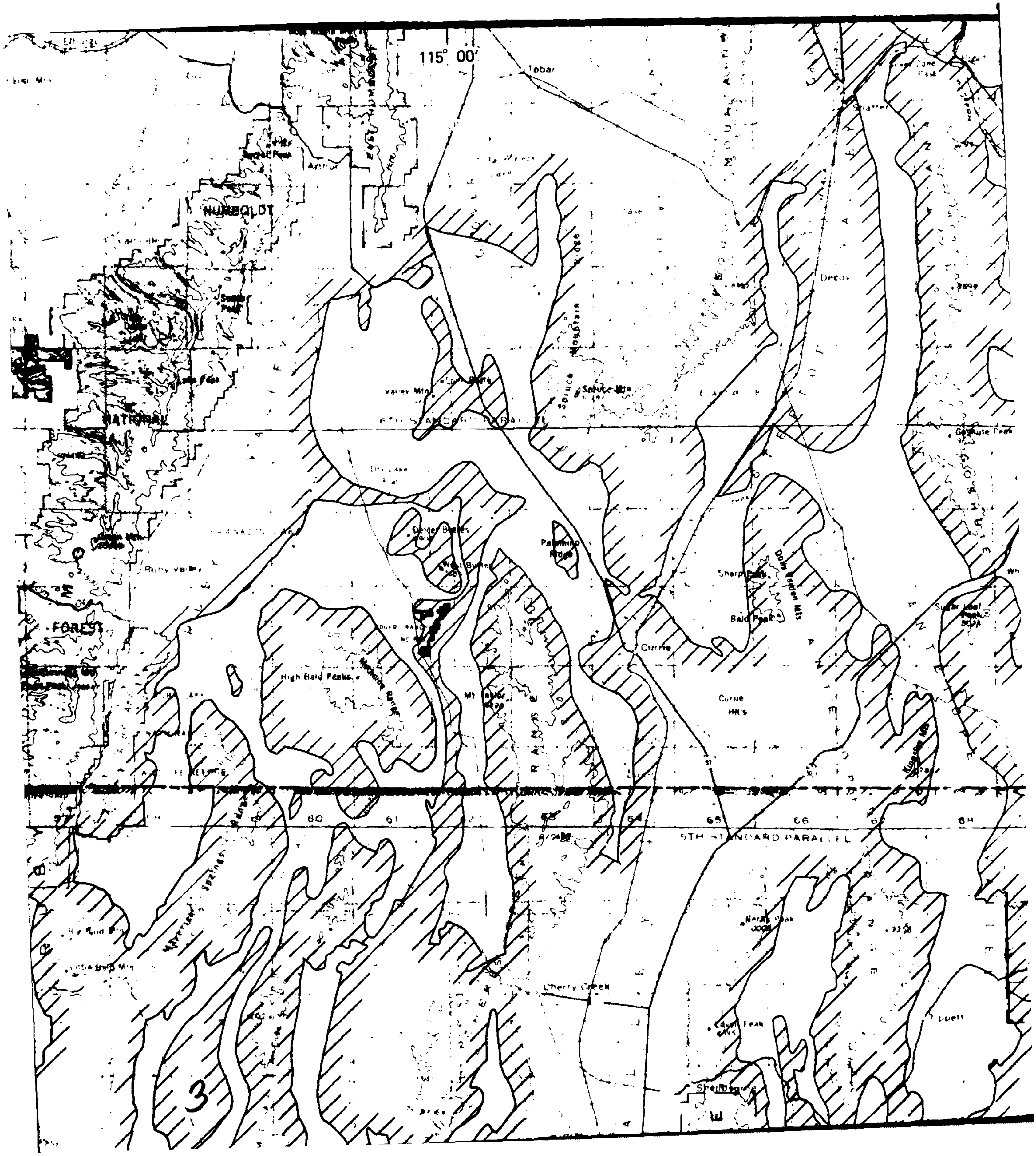

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Ruby Valley
Decoy
Valley Mtn
Spruce Mountain
6TH STANDARD PARALLEL
Palomino Ridge
Sharp Peak
Bald Peak
Dolly Varden Mts
Currie
Currie Hills
High Bald Peak
Medicine Range
Mt Taylor
5TH STANDARD PARALLEL
60
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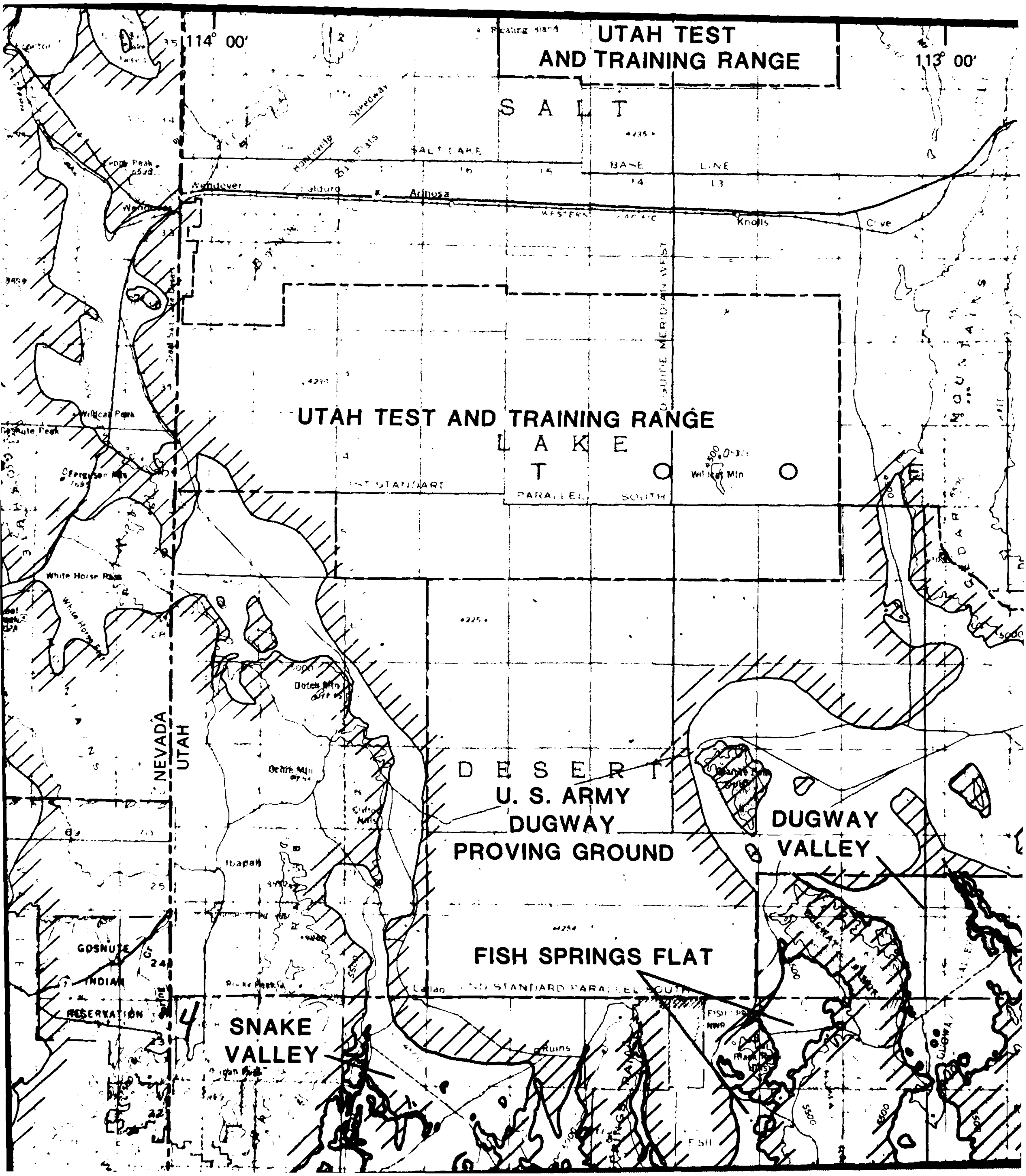
Cherry Creek
Shellbourne
3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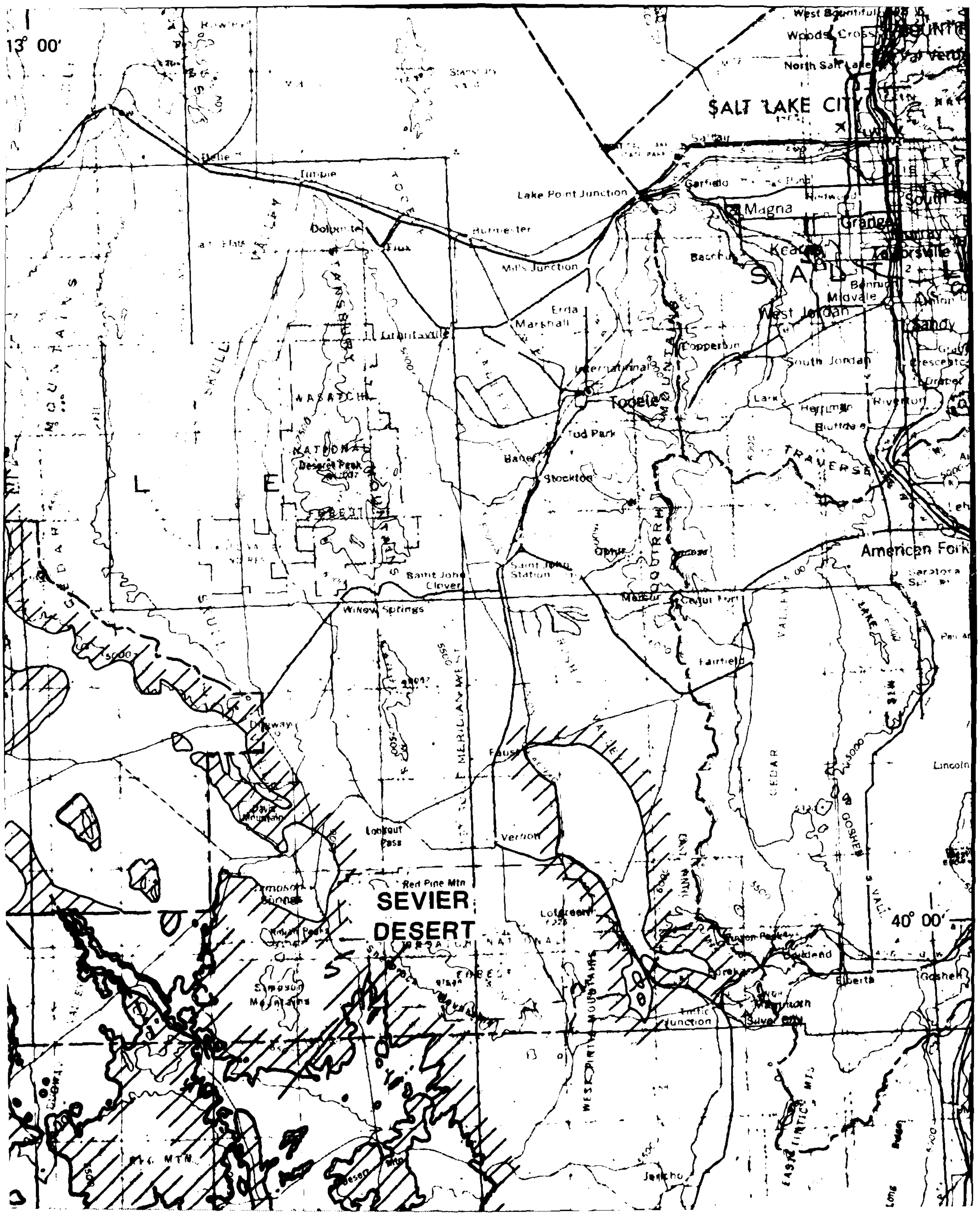
SALT LAKE
BASE LINE
Wendover
Knolls
UTAH TEST AND TRAINING RANGE
LAKE
TOOELE
Wildcat Mtn
1ST STANDARD PARALLEL SOUTH
Wildcat Peak
White Horse Pass
Dutch Mtn
Ochre Mtn
NEVADA
UTAH
DESERT
U. S. ARMY
DUGWAY
PROVING GROUND
DUGWAY
VALLEY
Ibapah
GOSHUTE
INDIAN
RESERVATION
FISH SPRINGS FLAT
2ND STANDARD PARALLEL SOUTH
SNAKE
VALLEY
Callao
Ruins
FISH



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West Bountiful
Woods Cross
North Salt Lake
SALT LAKE CITY
Lake Point Junction
Garfield
Magna
Kearns
Tooele
Grantsville
Erda
Marshall
Copperton
West Jordan
South Jordan
Midvale
Sandy
Riverton
Herriman
Bluffdale
Lark
Stockton
Tod Park
Burmester
Timpie
Dolomite
Delle
Mills Junction
International
Ophir
Mercur
Cedar Fort
Fairfield
American Fork
Saratoga Springs
Saint John Station
Clover
Willow Springs
Dugway
Faust
Vernon
Lookout Pass
Red Pine Mtn
SEVIER DESERT
Lofgreen
Simpson Mountains
Simpson Springs
Eureka
Mammoth
Silver City
Jericho
Elberta
Goshen
Lincoln
40° 00'
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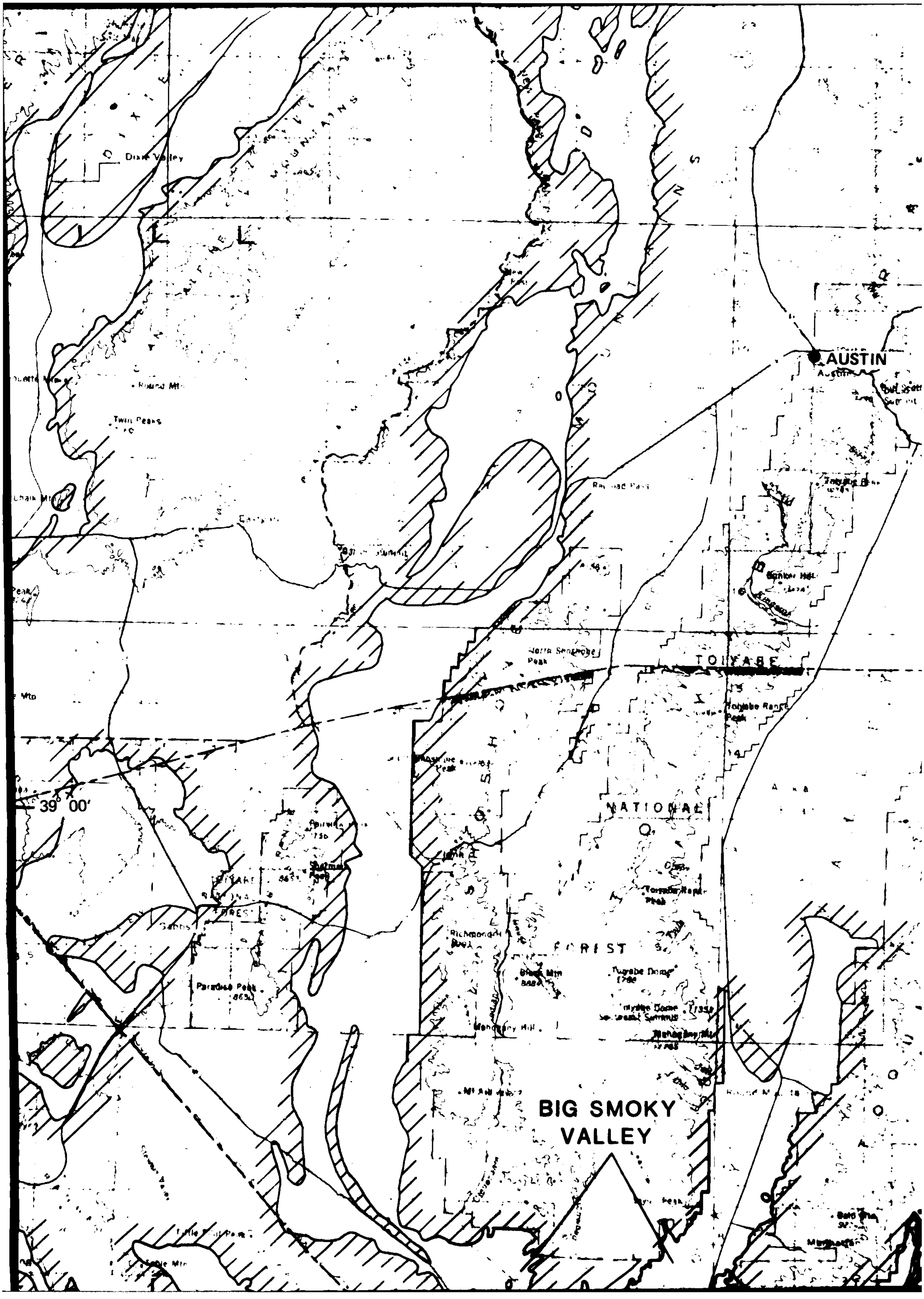
Deseret Peak
OQUIRRH MOUNTAINS
CEDAR VALLEY
TRAVERSE
WEST TINTIC MOUNTAINS
EAST TINTIC MTS
SALT


AUSTIN
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Twin Peaks
Chalk Mtn
Railroad Pass
North Shoshone Peak
TOIYABE
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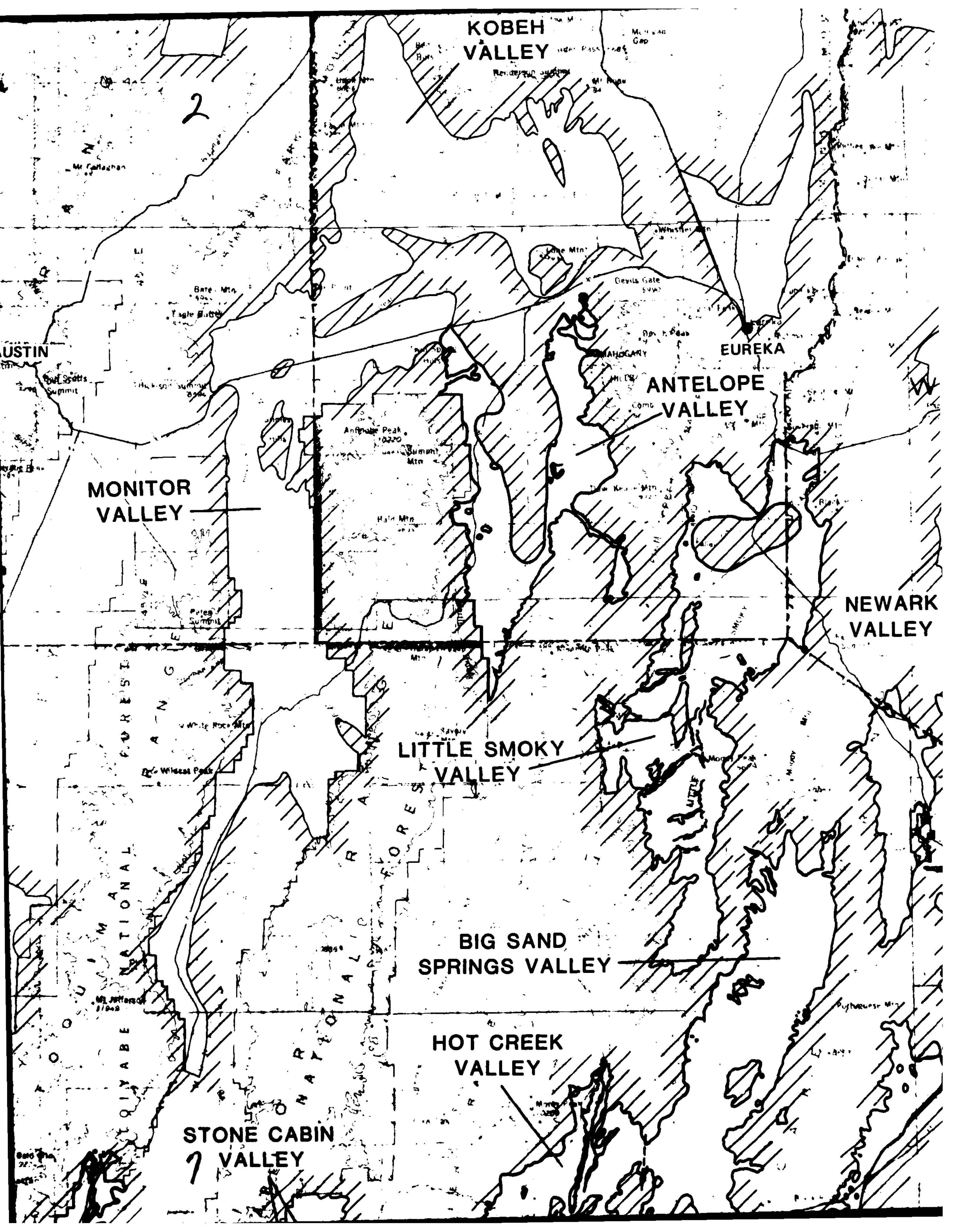
Richmond Peak
Black Mtn
Toiyabe Dome
Mahogany Hill
BIG SMOKY
VALLEY


KOBEH VALLEY
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BIG SAND SPRINGS VALLEY
HOT CREEK VALLEY
STONE CABIN VALLEY
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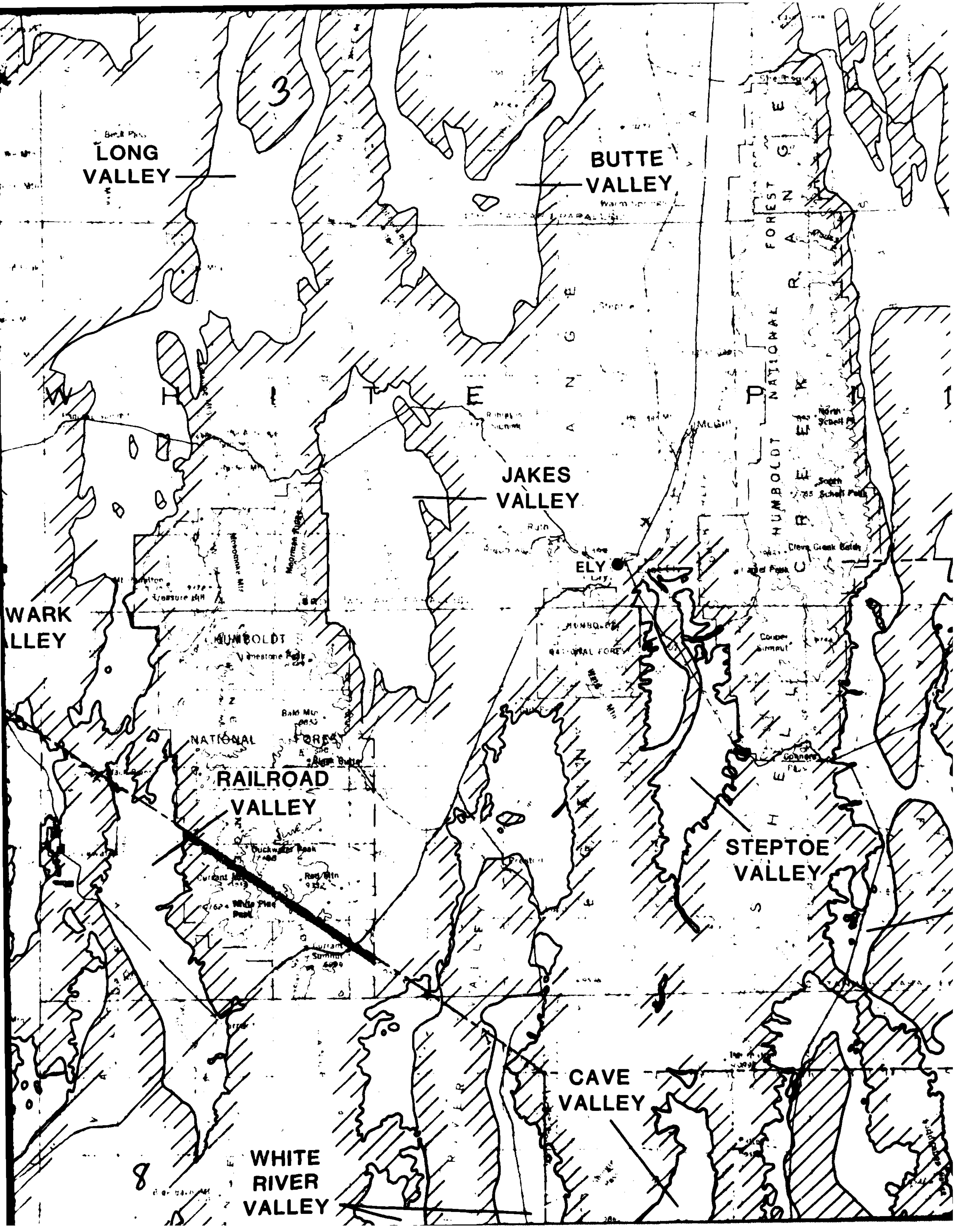

3
LONG VALLEY
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W H I T E P I N E
JAKES VALLEY
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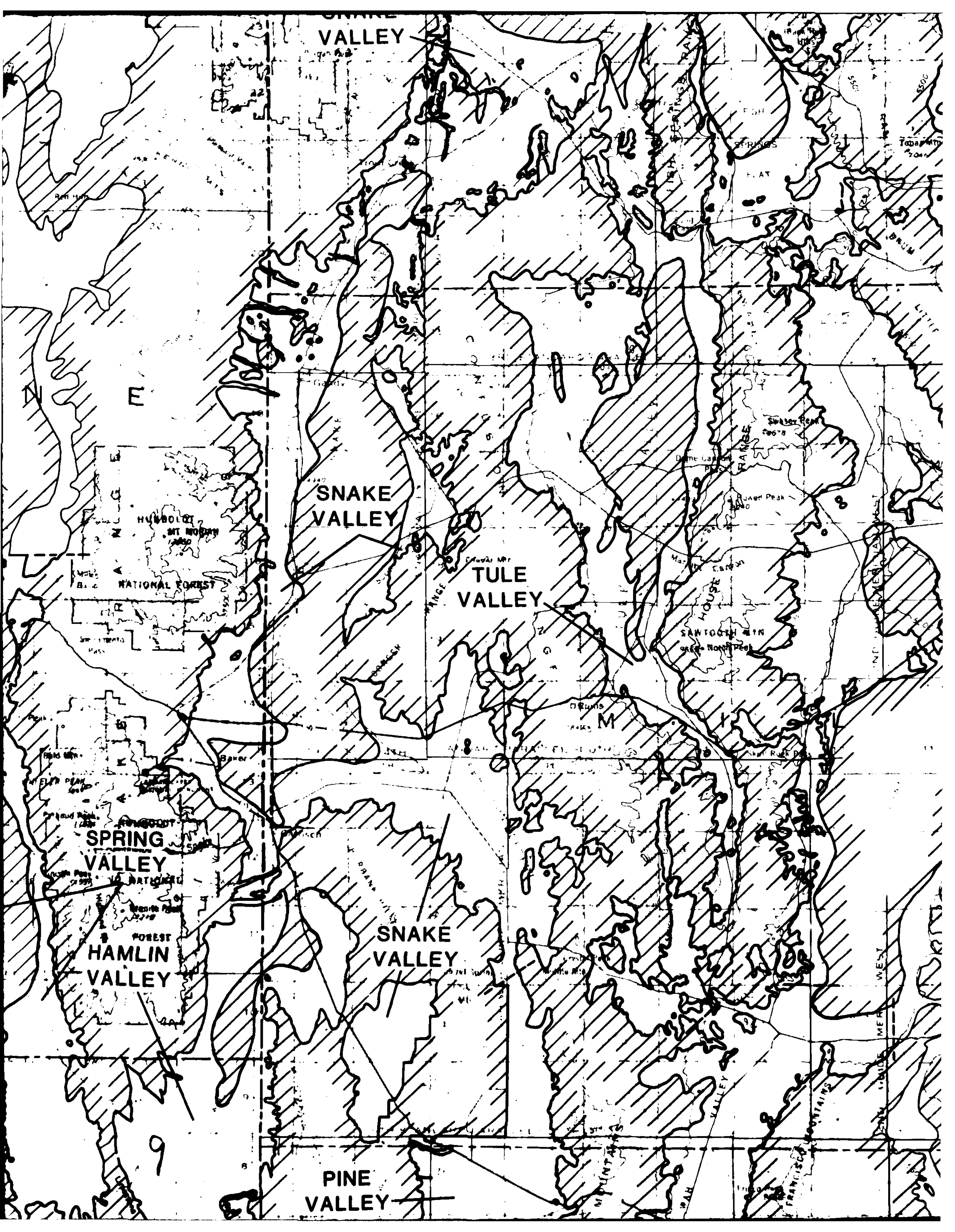
LLEY
HUMBOLDT NATIONAL FOREST
RAILROAD VALLEY
STEPTOE VALLEY
CAVE VALLEY
WHITE RIVER VALLEY
8



VALLEY
SNAKE VALLEY
TULE VALLEY
SPRING VALLEY
HAMLIN VALLEY
SNAKE VALLEY
PINE VALLEY
HUMBOLDT
NATIONAL FOREST
SAWTOOTH MTN
Swasey Peak
Baker
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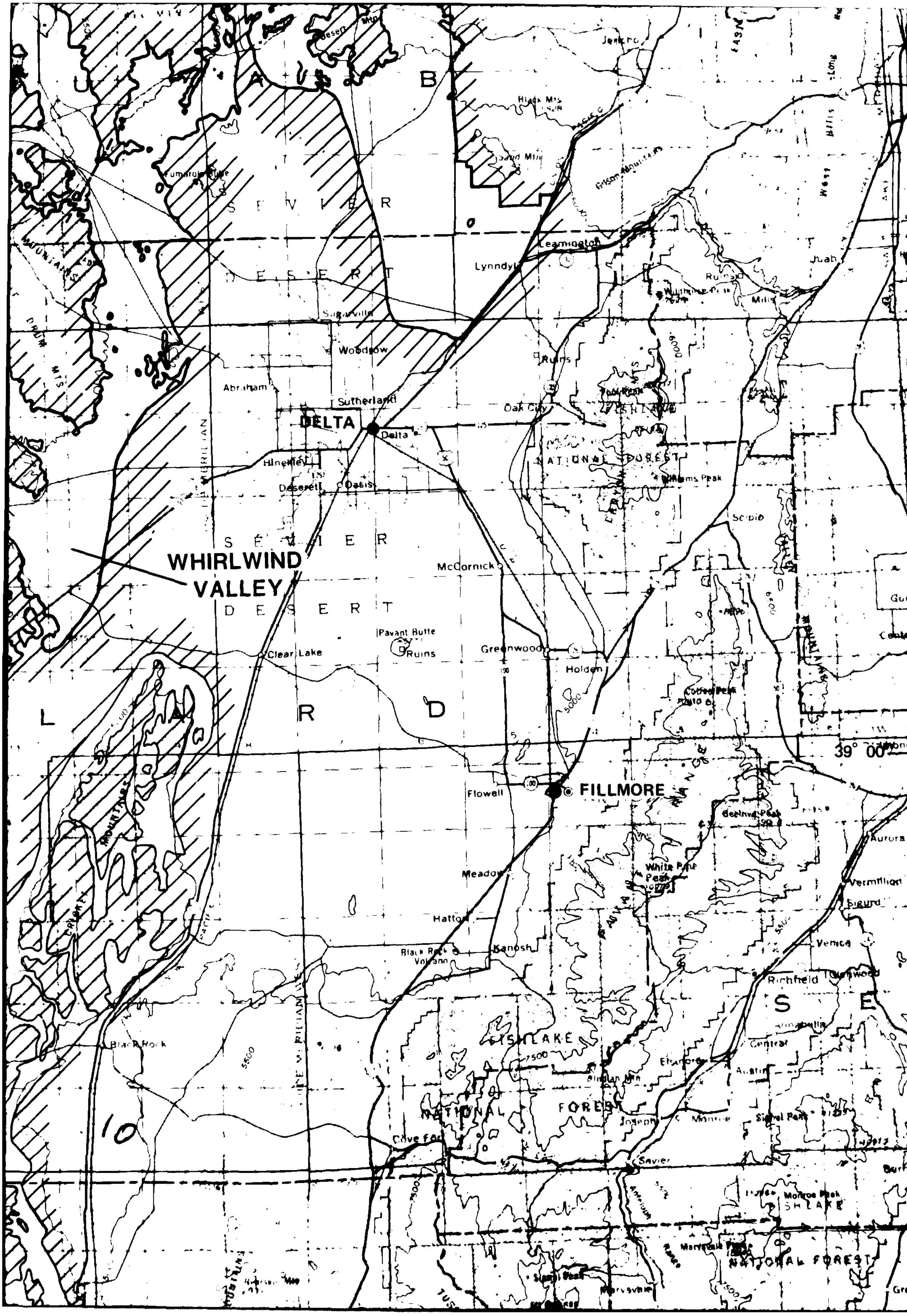

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Hinckley
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McCornick
Greenwood
Holden
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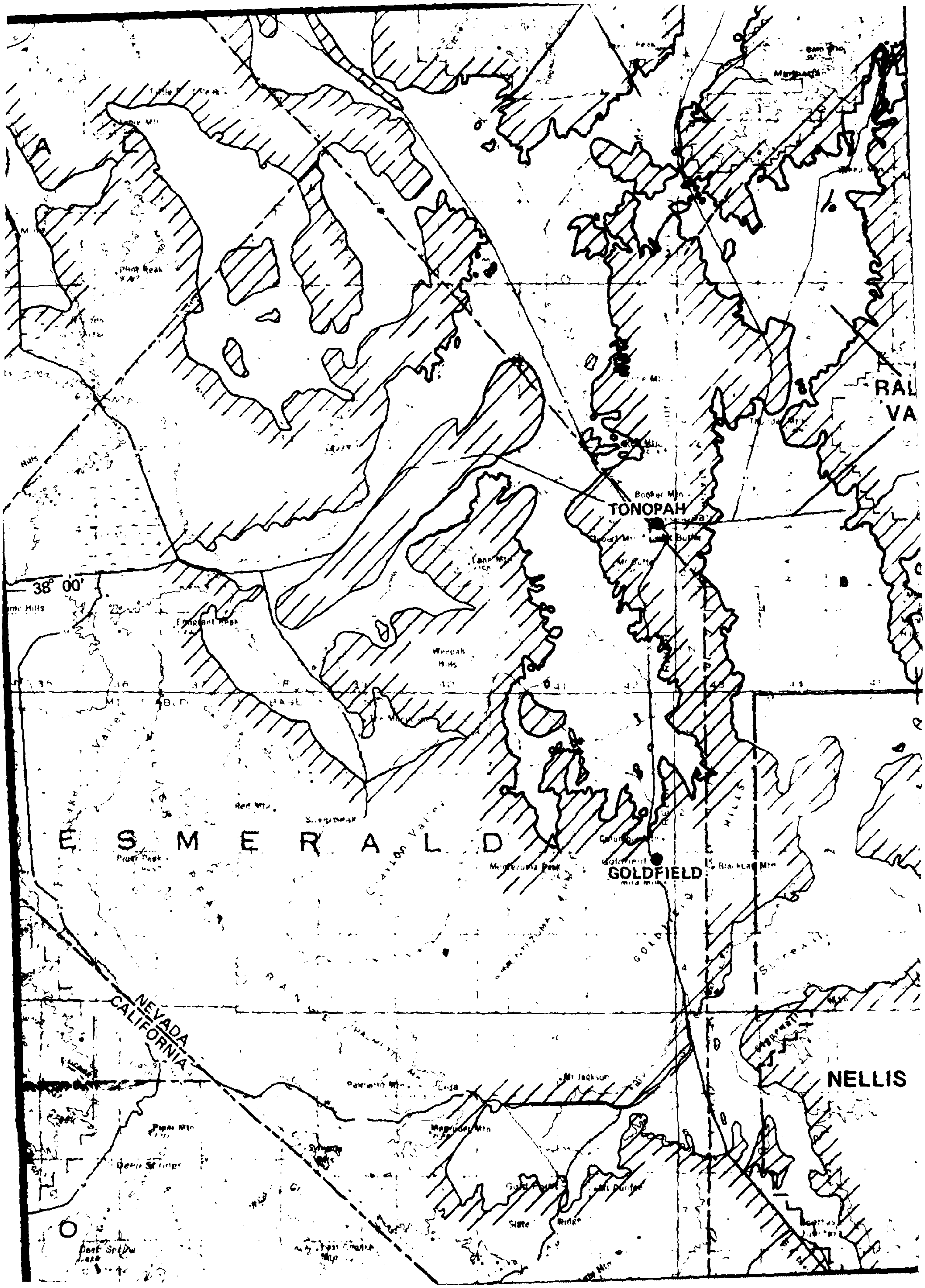
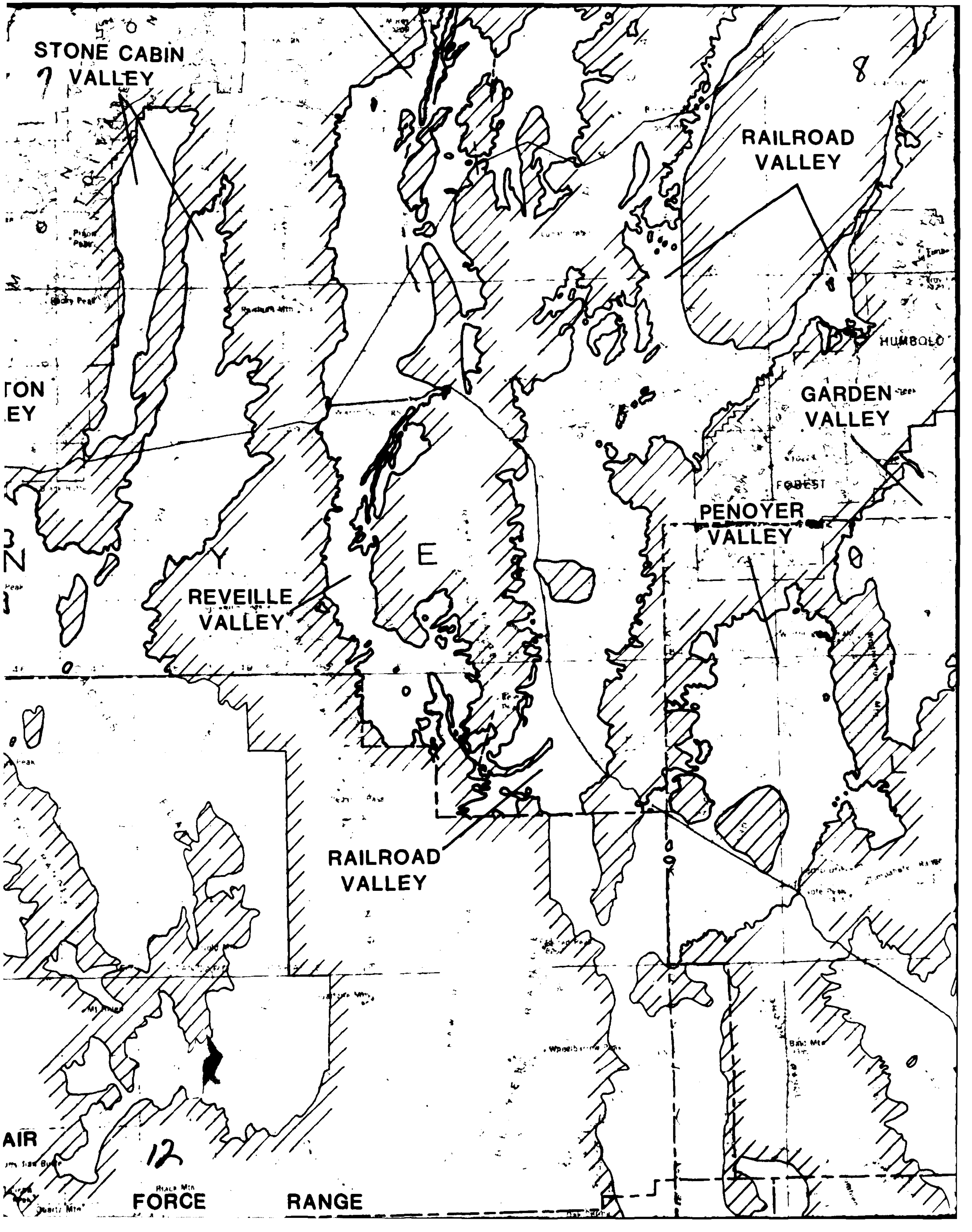
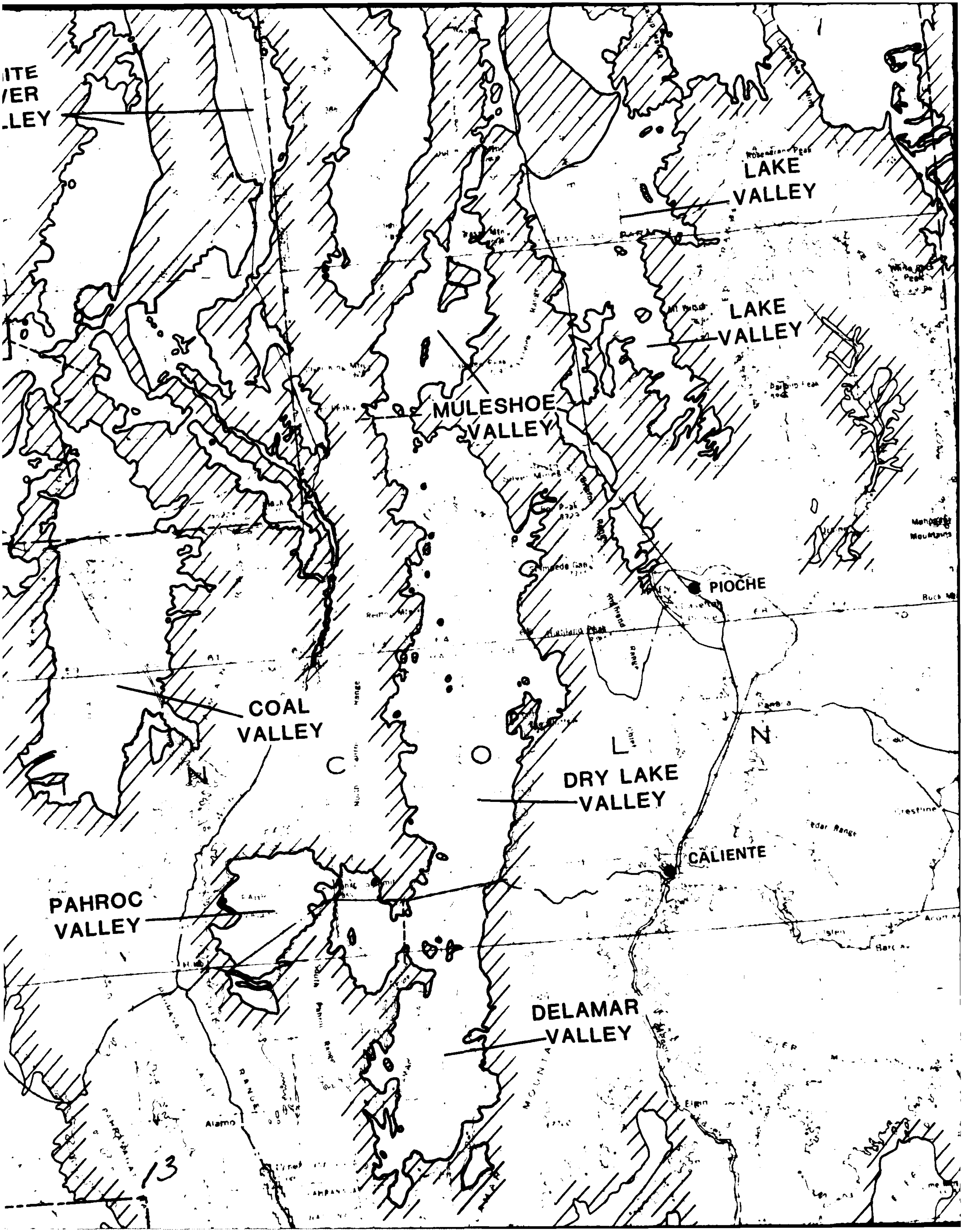
Pavant Butte
Ruins
Flowell
Meadow
Hatton
Kanosh
Black Rock
Volcano
Black Rock
Scipio
Juab
Mills
NATIONAL FOREST
Williams Peak
FISHLAKE
NATIONAL
FOREST
Cove Fort
Sevier
Joseph
Monroe
Elsinore
Richfield
Glenwood
Venice
Sigurd
Vermillion
Aurora
Central
Annabella
White Pine
Peak
Monroe Peak
NATIONAL FOREST
Marysvale
S E
39° 00'
10



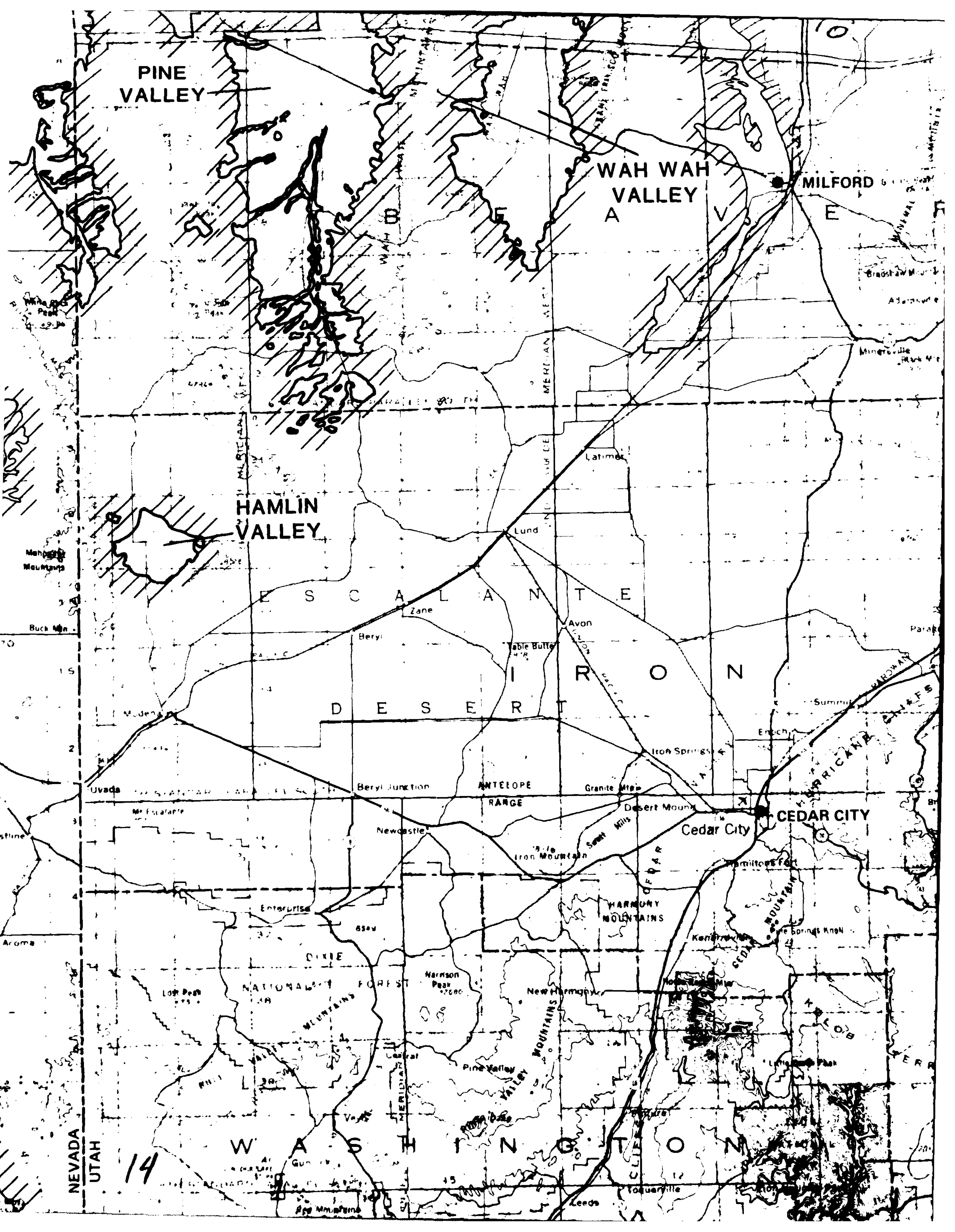
TONOPAH
GOLDFIELD
NELLIS
E S M E R A L D
38° 00'
NEVADA
CALIFORNIA
Weepah Hills
Booker Mtn
Lone Mtn
Emigrant Peak
Red Mtn
Montezuma Peak
Blackcap Mtn
Mt Jackson
Palmetto Mtn
Magruder Mtn
Gold Point
Slate Ridge
Piper Peak
Deep Springs
Hills
RA
VA

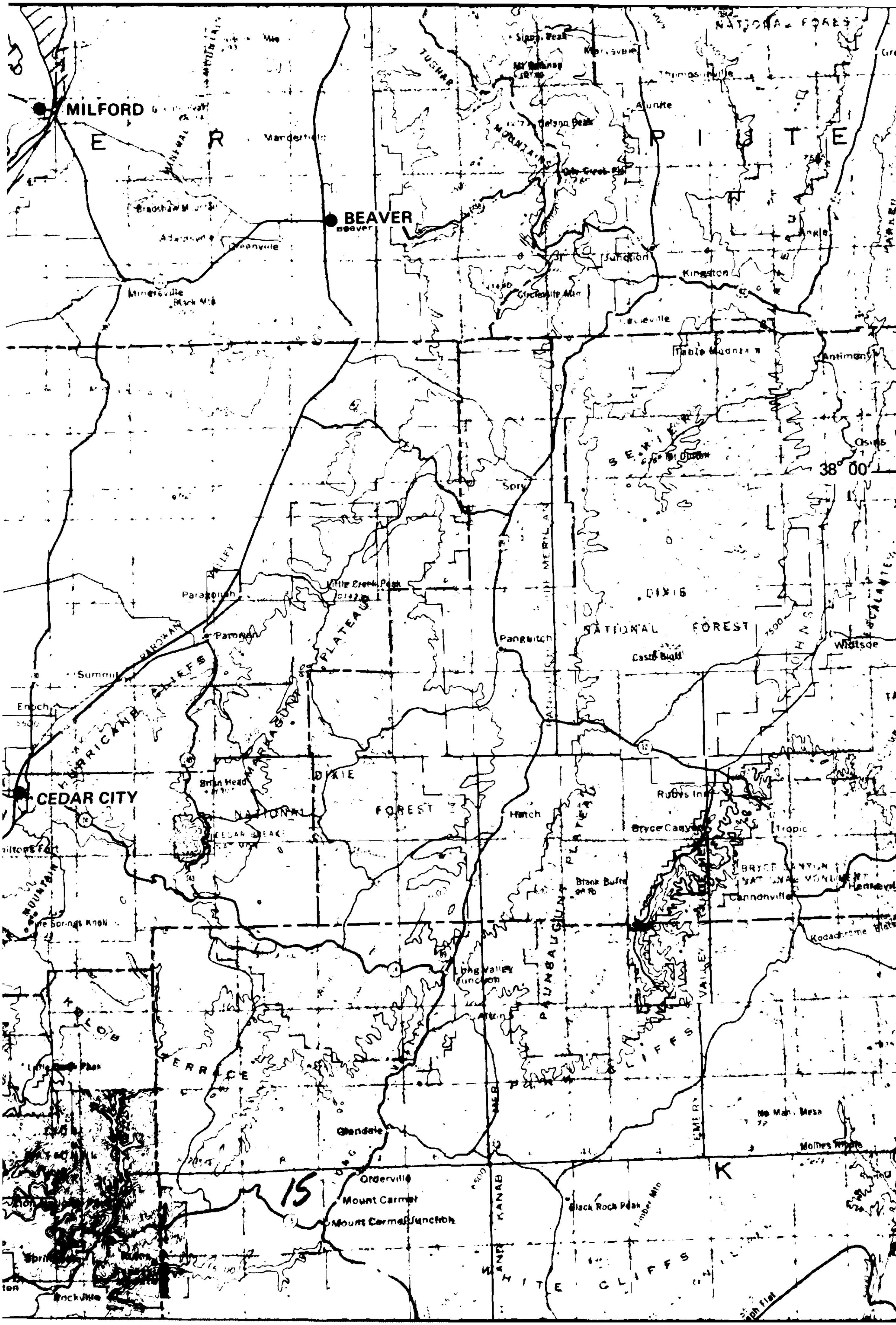


STONE CABIN
7 VALLEY
8
RAILROAD
VALLEY
HUMBOLD
TON
EY
GARDEN
VALLEY
FOREST
PENOYER
VALLEY
Y
E
REVEILLE
VALLEY
RAILROAD
VALLEY
AIR
12
FORCE
RANGE

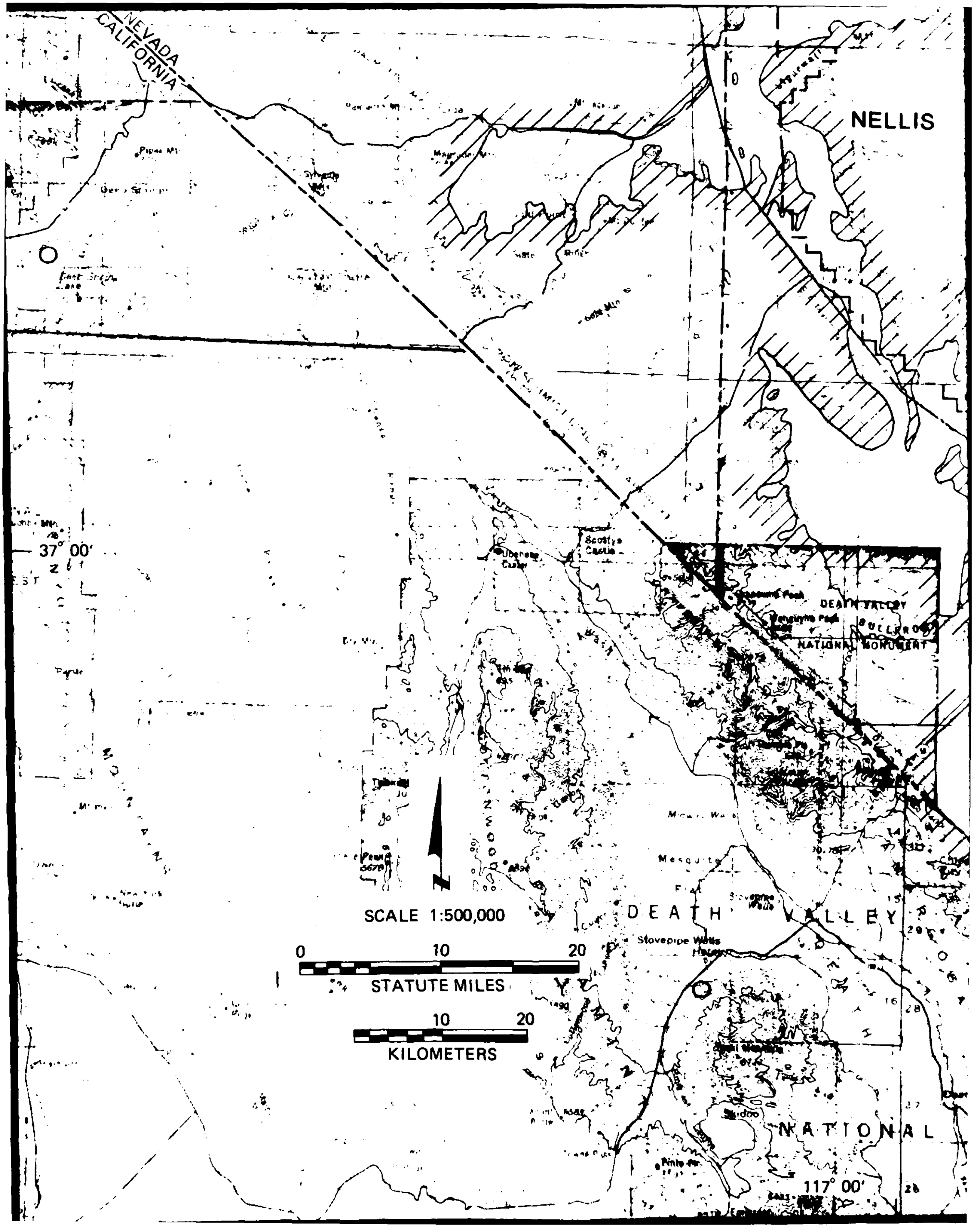


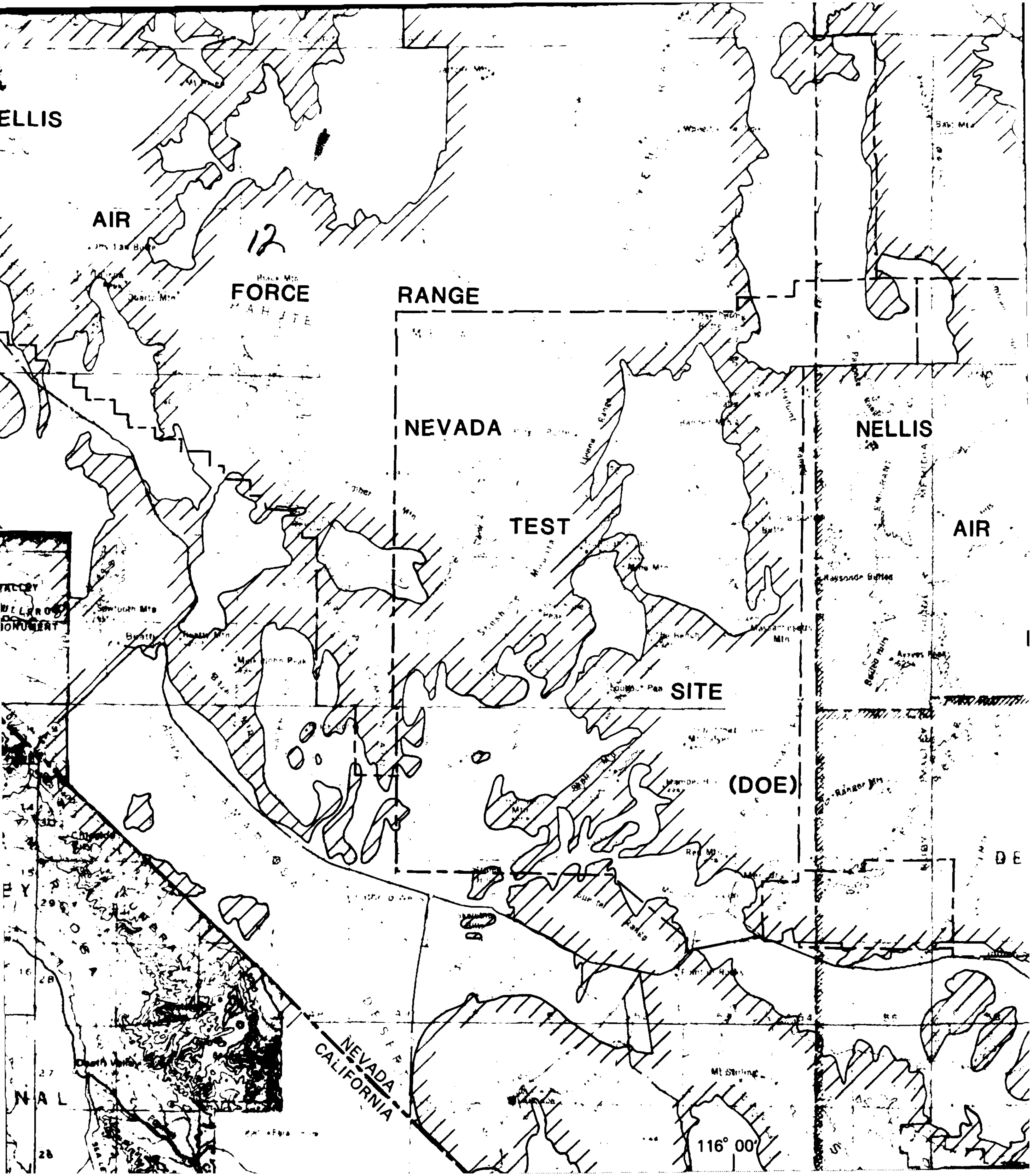
ITE
VER
LLEY
LAKE
VALLEY
LAKE
VALLEY
MULESHOE
VALLEY
PIOCHE
COAL
VALLEY
DRY LAKE
VALLEY
CALIENTE
PAHROC
VALLEY
DELAMAR
VALLEY

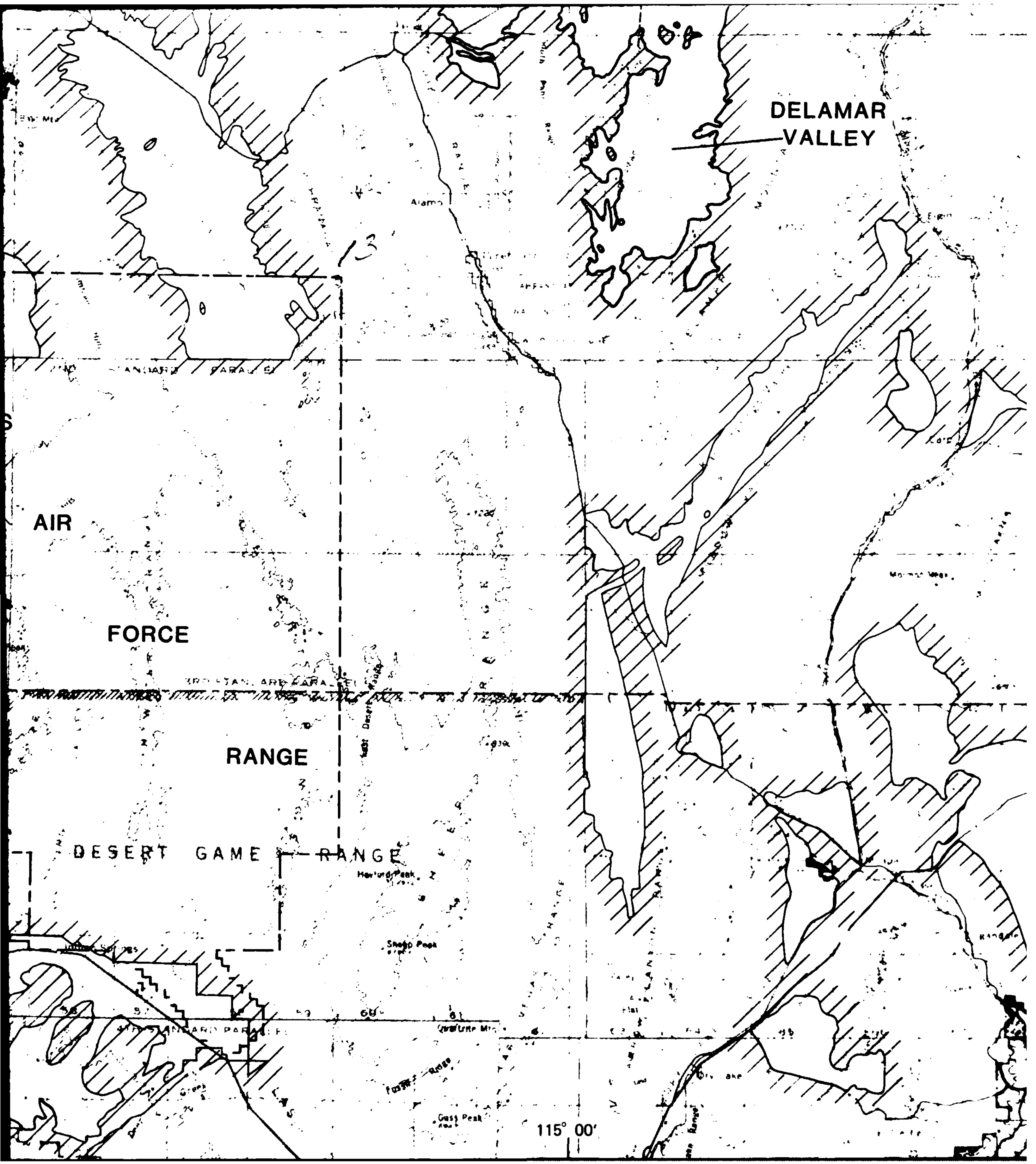

PINE
VALLEY
WAH WAH
VALLEY
MILFORD
HAMLIN
VALLEY
E S C A L A N T E
I R O N
D E S E R T
CEDAR CITY
Cedar City
Lund
Zane
Beryl
Avon
Table Butte
Modena
Iron Springs
Uvada
Beryl Junction
ANTELOPE
RANGE
Granite Mtn
Desert Mount
Newcastle
Iron Mountain
Latimer
Minersville
Summit
Enoch
Hamiltons Fort
Kanarraville
HARMONY
MOUNTAINS
Enterprise
DIXIE
NATIONAL FOREST
Harrison
Peak
New Harmony
Pine Valley
Central
Veyo
Gunlock
Leeds
Toquerville
W A S H I N G T O N
HURRICANE CLIFFS
NEVADA
UTAH
Buck Mtn
Aroma
14

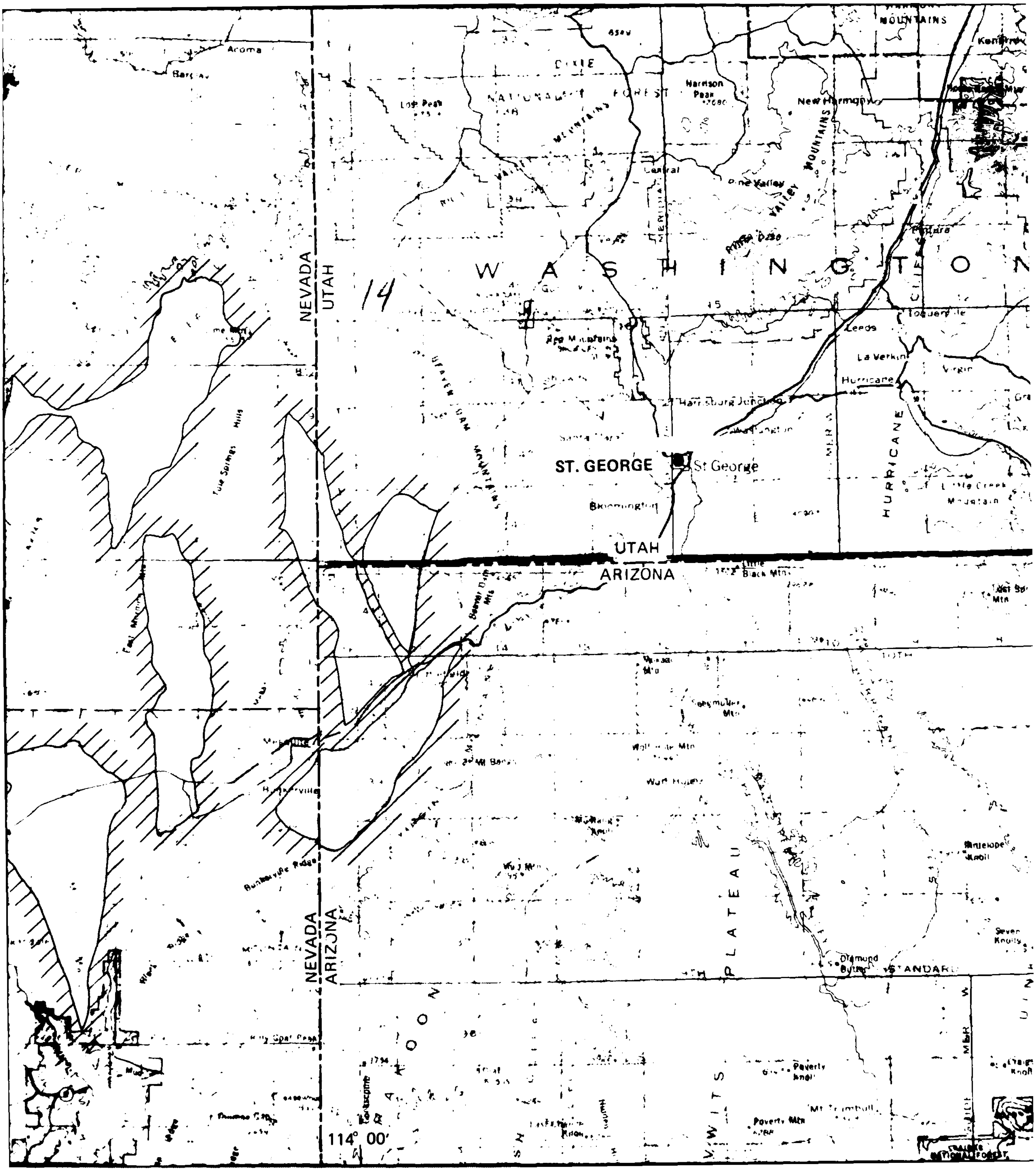


MILFORD
BEAVER
CEDAR CITY
Minersville
Adamsville
Greenville
Kingston
Junction
Circleville
Antimony
Osiris
38° 00'
Table Mountain
Paragonah
Parowan
Summit
Enoch
Little Creek Peak
Brian Head
Panguitch
Hatch
Rubys Inn
Bryce Canyon
Tropic
Cannonville
Widtsoe
Casto Bluff
DIXIE NATIONAL FOREST
PLATEAU
FOREST
Long Valley Junction
Alton
Glendale
Orderville
Mount Carmel
Mount Carmel Junction
Black Rock Peak
No Man Mesa
Mollies Nipple
KANAB
15

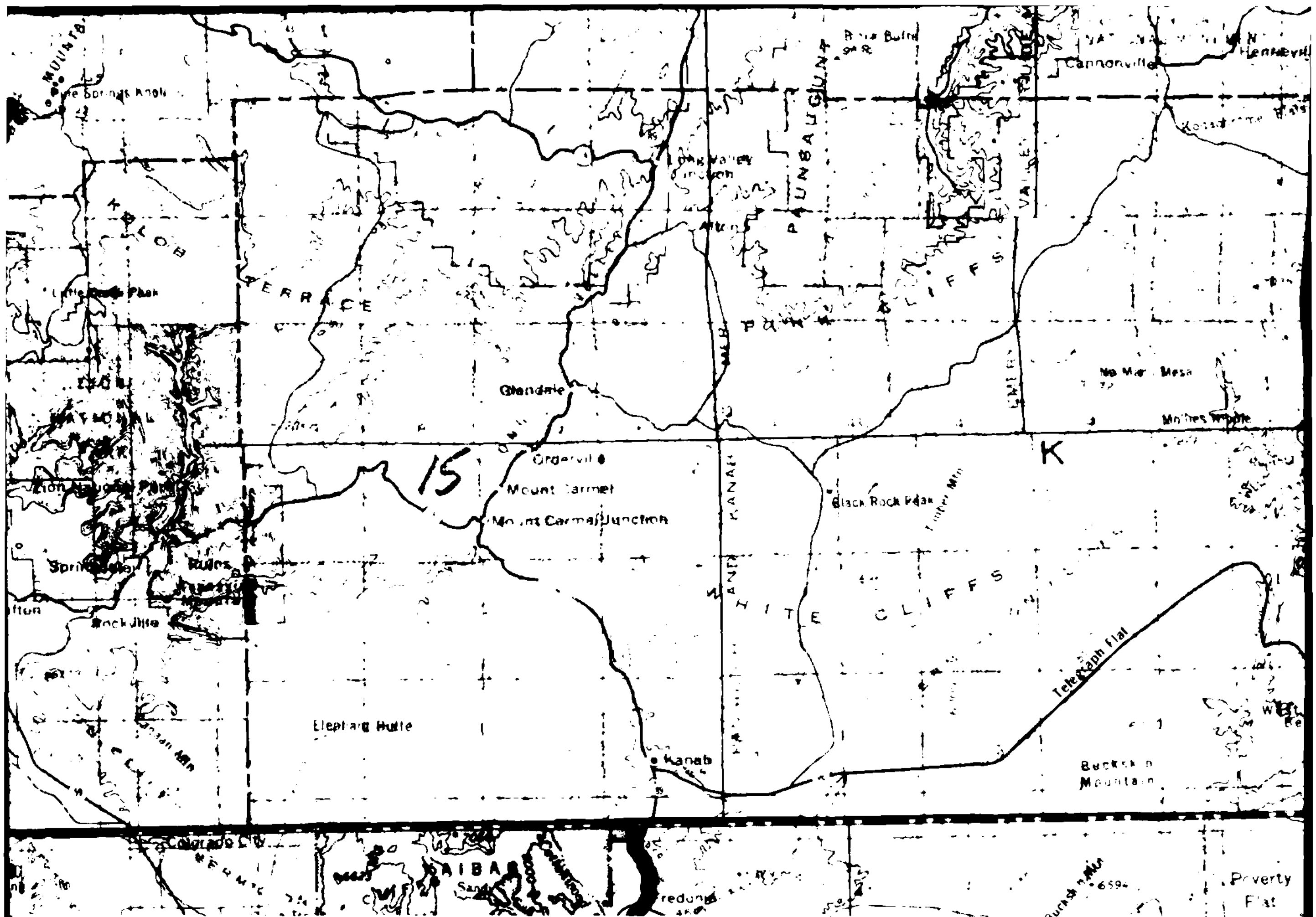

NEVADA
CALIFORNIA
NELLIS
37° 00'
Scottys Castle
DEATH VALLEY
NATIONAL MONUMENT
Mesquite
Stovepipe Wells
DEATH VALLEY
NATIONAL
117° 00'
SCALE 1:500,000
0
10
20
STATUTE MILES
10
20
KILOMETERS


12
ELLIS
AIR
FORCE
RANGE
NEVADA
TEST
SITE
(DOE)
NELLIS
AIR
NEVADA
CALIFORNIA
116° 00'


DELAMAR
VALLEY
Alamo
AIR
FORCE
RANGE
DESERT GAME RANGE
Hayford Peak
Sheep Peak
Gass Peak
115° 00'



Aroma
DIXIE
NATIONAL FOREST
Harrison Peak
New Harmony
MOUNTAINS
Lost Peak
Central
Pine Valley
VALLEY
MOUNTAINS
NEVADA
UTAH
14
W A S H I N G T O N
Leeds
La Verkin
Virgin
Hurricane
Harrisburg Junction
ST. GEORGE
St George
Bloomington
HURRICANE
Little Creek
Mountain
UTAH
ARIZONA
Little Black Mtn
Seegmuller Mtn
Wolf Hole
Bunkerville
Bunkerville Ridge
Antelope Knoll
NEVADA
ARIZONA
PLATEAU
Seven Knolls
Diamond Butte
STANDARD
Poverty Knoll
Mt Trumbull
Poverty Mtn
114° 00′



EXPLANATION

SUITABLE AREA FOR HORIZONTAL SHELTER BASED ON VERIFICATION STUDIES FY 78, FY 79 AND FY 80

SUITABLE AREA FOR HORIZONTAL SHELTER BASED ON SCREENING STUDIES. LOCALLY MODIFIED BY PRIOR VERIFICATION STUDIES

1 25 OCT 1979
2 27 FEB 1980
3 20 JUN 1980
4 26 NOV 1980
5 ______
6 ______
7 ______

113° 00'

GEOTECHNICALLY SUITABLE AREAS NEVADA-UTAH

MX SITING INVESTIGATION

DEPARTMENT OF THE AIR FORCE – BMO

DRAWING 1-1

FUGRO NATIONAL, INC.

2.0 RESULTS AND CONCLUSIONS

2.1 SUITABLE AREA

The results of the suitable area interpretation for Pine Valley are listed in Table 2-1 and shown in map form in Drawing 2-1. The exclusion criteria used to make this interpretation are discussed in Appendix A2.0.

The total area of basin-fill materials in Pine Valley, outside the boundaries of the Desert Experimental Range, is 407 square miles (mi^2) (1054 square kilometers [km^2]). Thirty-two percent of this area is excluded for the horizontal shelter basing mode, leaving a suitable area of 278 mi^2 (720 km^2). For the vertical shelter basing mode, 37 percent of the total area is excluded, leaving a suitable area of 256 mi^2 (663 km^2).

2.2 BASIN-FILL CHARACTERISTICS

This section contains brief descriptions of the soils in Pine Valley. More detailed information is presented in Sections 3.3 and 3.4.

2.2.1 Surficial Soils

Coarse-grained granular soils are the predominant surficial soils, covering approximately 90 to 95 percent of the area. They consist of sandy gravels and gravelly, silty and/or clayey sands. Generally sandy gravels and gravelly sands occur sporadically along the mountain fronts.

Down slope from the valley margins, the surficial soils grade to silty and/or clayey sands. The sands and gravels are generally

FN-TR-27-PI-I

VERIFICATION VALLEY	STATE	AREA MI² (KM²)		
		BEGINNING AREA*	SUITABLE AREA	
			HORIZONTAL	VERTICAL
PINE	UTAH	407 (1054)	278 (720)	256 (663)

EXCLUSIONS	AREA MI² (KM²)	PERCENT REDUCTION**
< 50 FEET (15m) TO ROCK	51 (132)	13
< 150 FEET (46m) TO ROCK	84 (218)	21
< 50 FEET (15m) TO WATER	1 (3)	< 1
< 150 FEET (46m) TO WATER	2 (5)	< 1
TERRAIN	78 (202)	19

*BEGINNING AREA COMPOSED OF BASIN-FILL MATERIALS EXCLUDING ALL ROCK OUTCROPS. ALL LARGE SQUARE MILE AREAS ARE ROUNDED OFF TO NEAREST ONE SQUARE MILE INCREMENT. METRIC CONVERSIONS ARE ROUNDED OFF TO NEAREST ONE SQUARE KILOMETER INCREMENT.

**PERCENT REDUCTIONS, BASED ON BEGINNING AREAS, ARE ROUNDED OFF TO NEAREST WHOLE PERCENT.

ESTIMATED SUITABLE AREA
PINE VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

TABLE 2-1

FUGRO NATIONAL, INC.

poorly graded and have various degrees of calcium-carbonate cementation.

Fine-grained soils cover from five to 10 percent of the area. They consist of sandy silts, silts, sandy clays, and silty clays. In this northern sloping valley, the fine-grained soils settle mainly in the active playa in the north-central portion of the valley and in the south central part at the mouth of the Pine Valley Wash. Their plasticity ranges from slightly plastic to medium plastic.

2.2.2 Subsurface Soils

Soils in the subsurface are also predominantly coarse-grained consisting of sandy gravels, gravelly sands, sands, silty sands, and clayey sands. Gravels and gravelly sands commonly occur along the mountain fronts and grade to finer soils toward the valley axis. The coarse-grained soils are generally dense to very dense below 10 to 15 feet (3.0 to 4.6 m). They are usually well-graded along the Pine Valley Wash. They contain coarse to fine sand and/or gravel, exhibit low compressibilities, and possess moderate to high shear strengths. Variation in the areal extent of playas in the geologic past has resulted in local interfingering of coarse- and fine-grained deposits in the subsurface near active playa margins. This occurs in the north-central portion of the valley which still maintains an active playa. Fine-grained soils (silts and clays) probably occur in about five to 10 percent of the subsurface and are generally restricted to these buried lacustrine deposits in the north-central portion of the valley. The fine-grained soils are nonplastic to medium plastic with low to moderate compressibilities and shear strengths. Variable calcium-carbonate cementation exists in all the subsurface soils.

2.3 CONSTRUCTION CONSIDERATIONS

Geotechnical factors and conditions pertaining to construction of the MX system in suitable areas of Pine Valley are discussed in this section. Both the horizontal shelter and vertical shelter basing modes are considered.

2.3.1 Grading

Mean surficial slopes in the suitable area are approximately three percent. Surface gradients exceed five percent in about eight percent of the suitable area. These steeper gradients occur mainly along the mountain front on the eastern side of the valley. Therefore, preconstruction grading will be minimal for most of the valley. More extensive grading will be necessary near the mountain fronts where surface slopes range from five to nine percent.

Detailed layout studies show that, with 5200 feet (1585 m) between shelters, five clusters can be placed in Pine Valley. The maximum grade at any shelter location in this layout would be between five and nine percent.

2.3.2 Roads

The predominant coarse-grained surficial soils will generally provide good subgrade support for roads where they are in a dense state. However, most of these soils are not dense near the surface and, therefore exhibit low strength to an average depth of 3 feet (0.9 m). The subgrade supporting properties of these low-strength, coarse-grained soils are inadequate but can be improved by mechanical compaction. Compaction to moderate depths of 3 to 4 feet (0.9 to 1.2 m) appears to be necessary in a majority of the suitable area. Compaction to greater depth may be required in approximately 25 percent of the granular soil area. Based on results of laboratory CBR tests, compacted granular soils will provide good to very good support for roads.

Fine-grained surficial soils, which have an areal extent of five to 10 percent of the suitable area, exhibit low strength to an average depth of 3.5 feet (1.1 m), with a maximum depth of about 6 feet (1.8 m). Supporting qualities of these soils are inadequate for direct support of the base or subbase course of the road system. Results of laboratory CBR tests indicate that mechanical compaction will not adequately strengthen these fine-grained soils for use as a subgrade, but a select granular subbase layer over the compacted fine-grained surficial soils will give the required support.

Well-graded gravelly sands and sandy gravels with less than 25 percent fines (passing a No. 200 sieve) can be used for road subbase and base courses. These soils are present both in the surface and subsurface; however, their extent is not known.

Drainage incision depths appear to be generally less than 6 feet (1.8 m) within 70 to 80 percent of the suitable area. Therefore, the overall cost of drainage structures for roads will be moderate. However, to make maximum use of the potentially suitable areas, it may be necessary to cross a few significant drainages at relatively high cost. For example, there are several major washes in the western and southwestern portion of Pine Valley that have incision depths greater than 100 feet (30 m). These washes have walls with slopes in excess of 10 percent and hence are excluded from the suitable area. Also, small parcels of suitable area in the southern portion of the valley are isolated by drainages incised more than 25 feet (7.6 m). If these areas are used for shelters, the cost of the necessary drainage structures for the cluster roads will be high.

2.3.3 Excavatability and Stability

The soils in the construction zone are generally dense to very dense and possess various degrees of calcium-carbonate cementation. Fine-grained soils are estimated to occur in less than 10 percent of the subsurface.

Horizontal Shelter: Excavation for the horizontal shelter can be done using conventional equipment such as scrapers, backhoes, and dozers. Excavation will be easy in approximately 30 to 40 percent of the area; however, excavation will be moderately difficult to difficult in the remaining area due to cobbles, boulders, and strong calcium carbonate-cementation in the subsurface. Difficult excavation is generally limited to the areas adjacent to the mountain fronts and the southern portion of the valley. The soils investigation indicates that excavations for construction of shelters should be cut back to slopes ranging from 3/4:1 to 1 1/2:1 (horizontal:vertical) for stability. Variations in density and shear strength, which depend on soil composition and the degree of cementation, cause the wide variation in slope angle. Because of low-strength surficial soil, the top 2 to 5 feet (0.6 to 1.5 m) in all excavations will generally have to be cut back to 2:1 slope or flatter.

Vertical Shelter: Relatively low compressional wave velocities in the upper 120 feet (36 m) indicate that large diameter auger drills could be used for vertical shelter excavation. Most excavations will be in granular soils with only intermittent cemented or cohesive soil intervals. Therefore, the vertical walls of these excavations will probably require the use of slurry or other stabilizing techniques.

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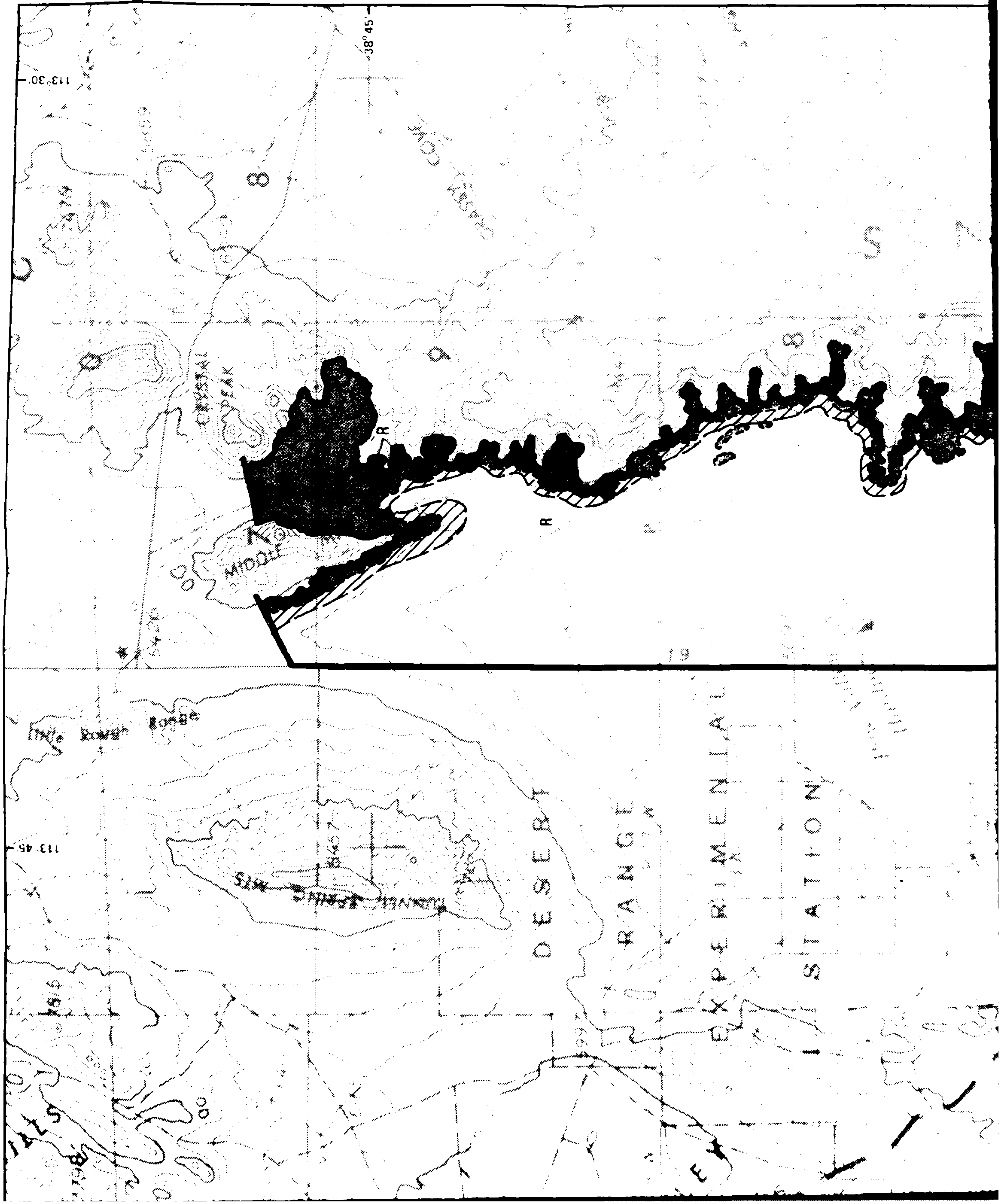
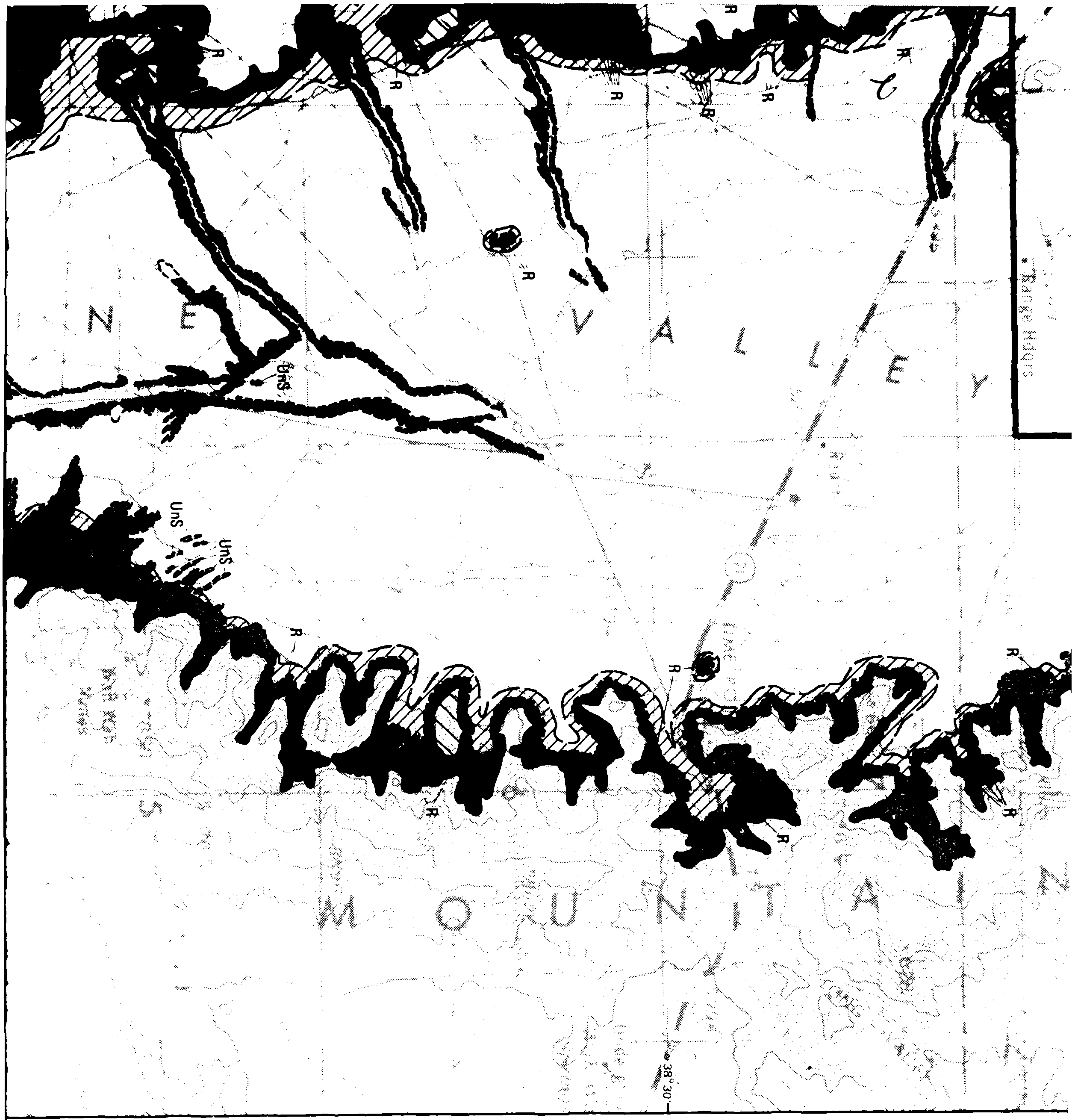
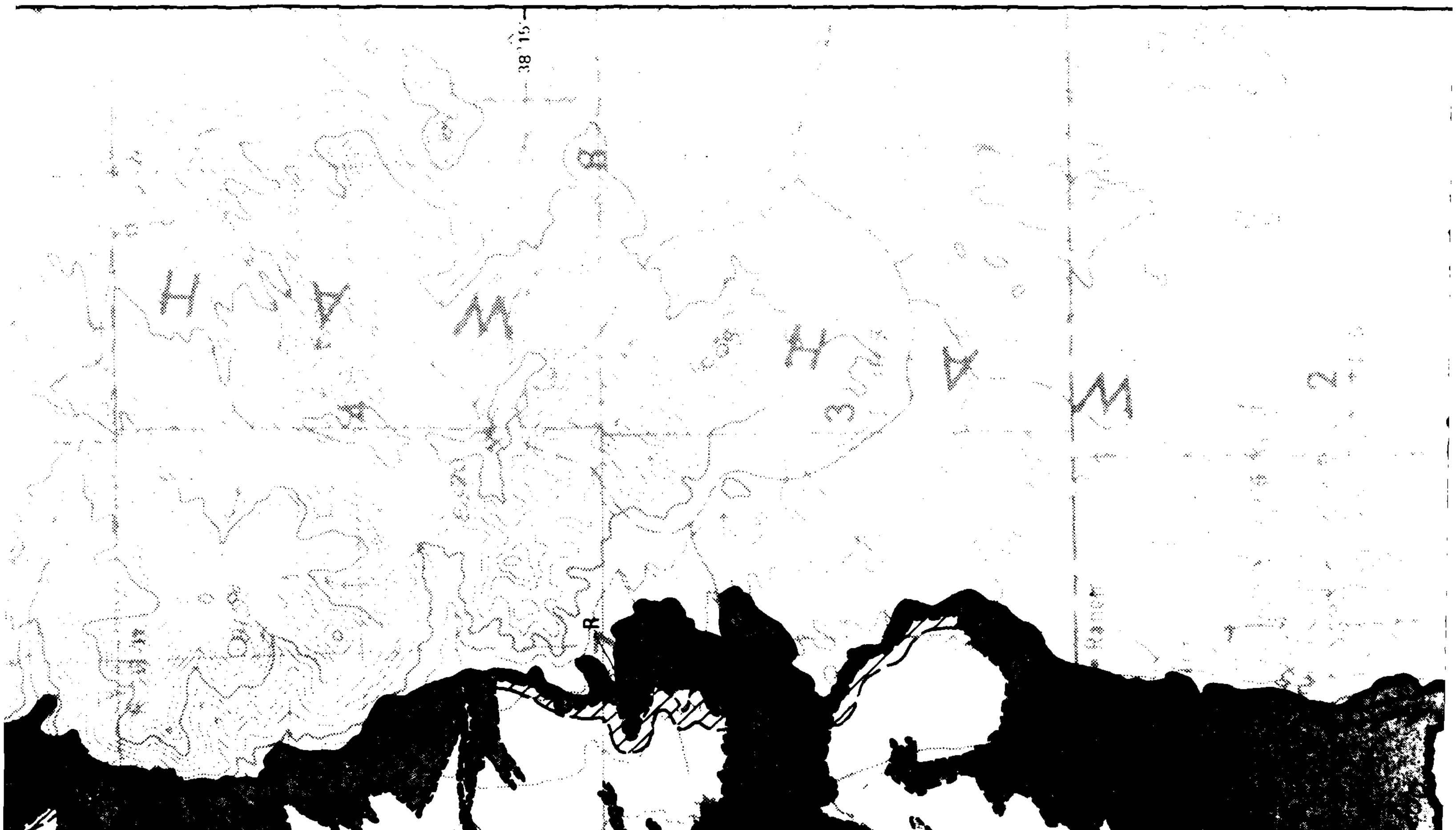
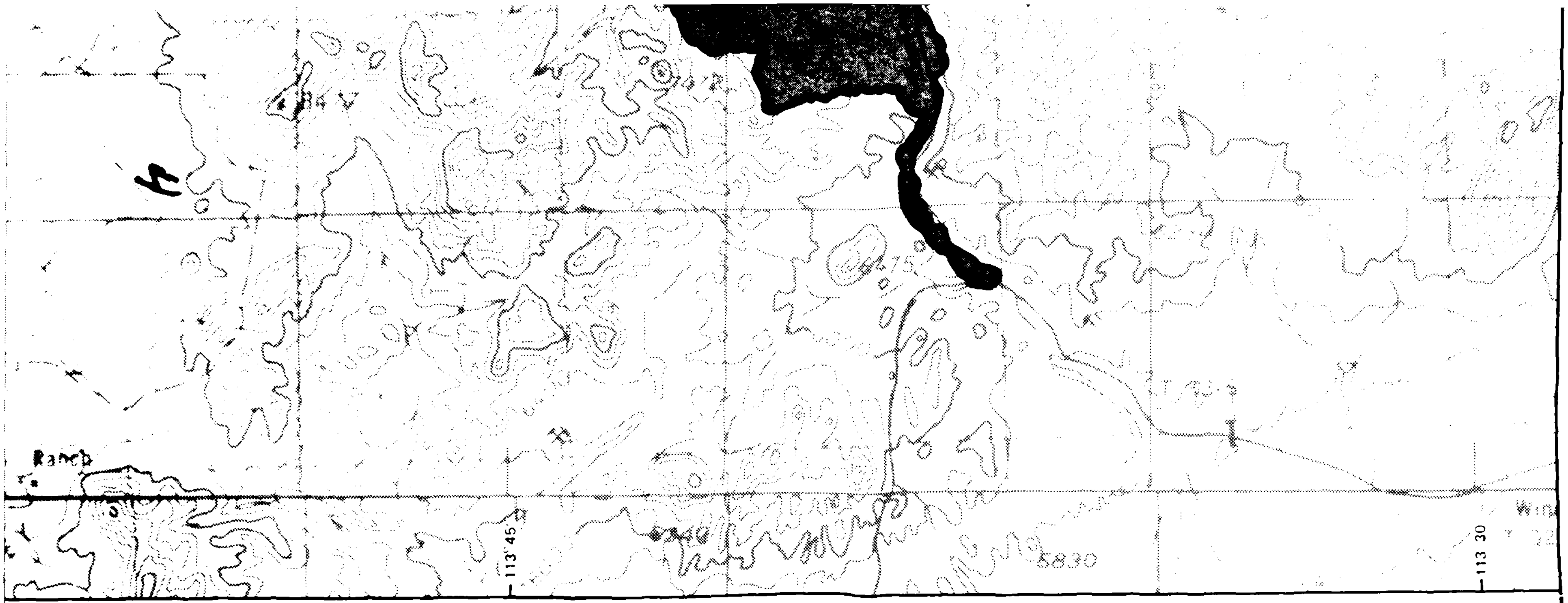

38°45'
113°30'
CRYSTAL
PEAK
MIDDLE
Little Rough Range
113°45'
DESERT
RANGE
EXPERIMENTAL
STATION



NE VALLEY
MOUNTAIN
Range Hdqrs
38°30'
R
UnS





EXPLANATION

Area suitable for horizontal and vertical shelter basing modes. Depth to rock and water greater than 150 feet (46m).

Area suitable for horizontal shelter but, not suitable for vertical shelter. Depth to rock greater than 50 feet (15m) and less than 150 feet (46m).

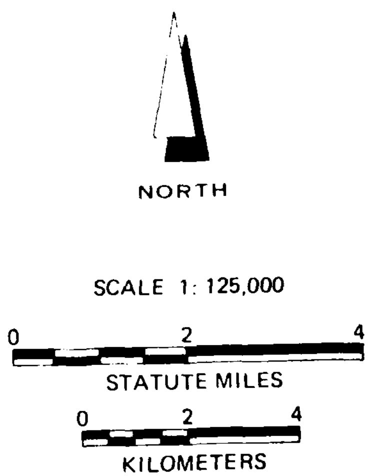
Area unsuitable for both horizontal and vertical shelter basing modes as determined from application of depth to rock and water, topography/terrain, and cultural exclusions.

UnS Area unsuitable for both horizontal and vertical shelter, too small for shading.

Areas of isolated exposed rock.

R Areas of isolated exposed rock too small for shading.

Contact between rock and basin fill.



EXPLANATION

Area suitable for horizontal and vertical shelter basing modes. Depth to rock and water greater than 150 feet (46m).

Area suitable for horizontal shelter but, not suitable for vertical shelter. Depth to rock greater than 50 feet (15m) and less than 150 feet (46m).

Area unsuitable for both horizontal and vertical shelter basing modes as determined from application of depth to rock and water, topography/terrain, and cultural exclusions.

UnS Area un[illegible]uitable for both horizontal and vertical shelter, too small for shading.

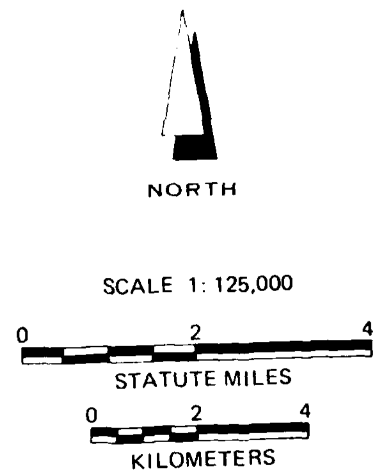
Areas of isolated exposed rock.

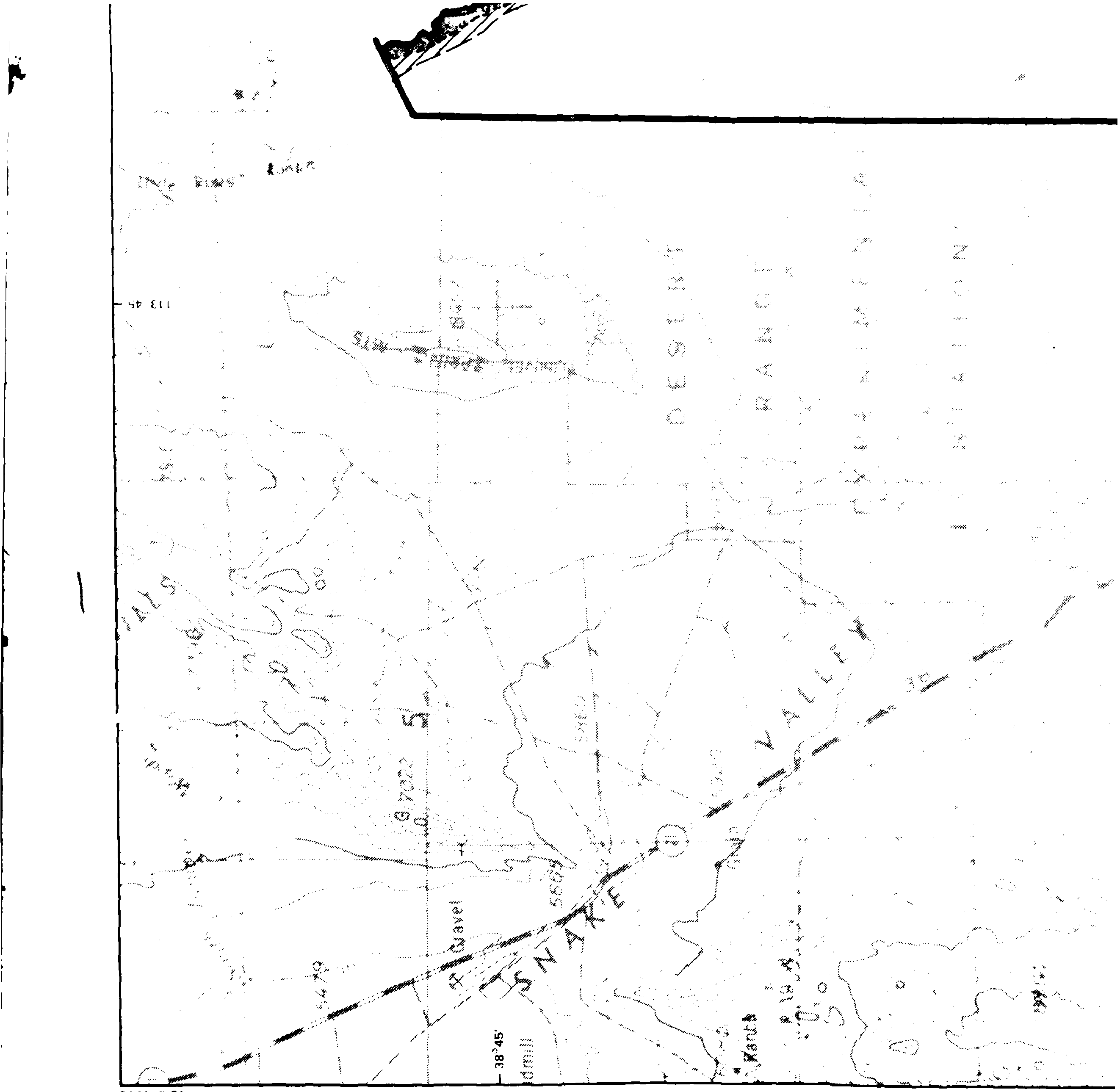
R Areas of isolated exposed rock too small for shading.

Contact betw[illegible]ock and basin fill.

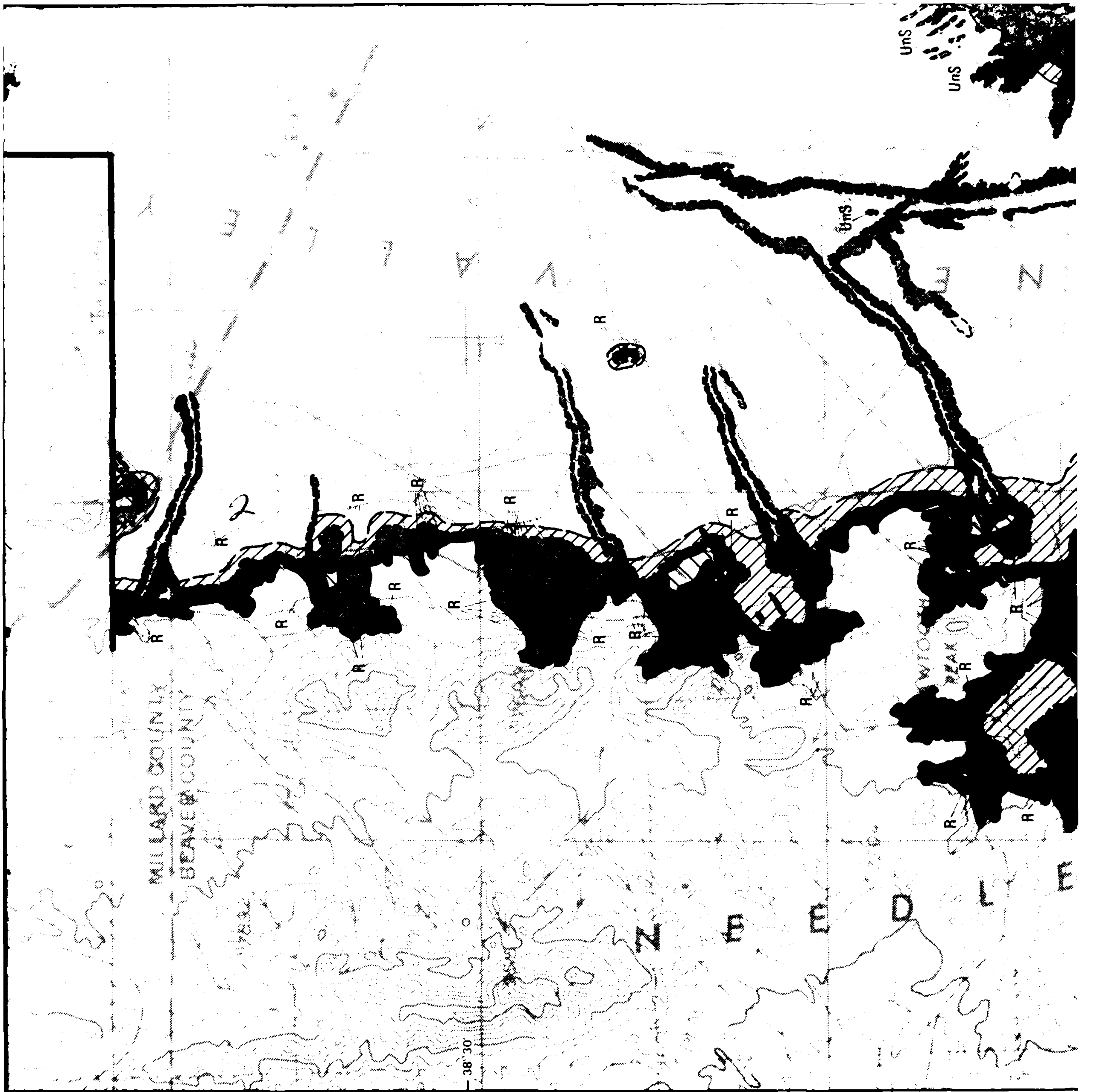
Valley borders (north and west).

5

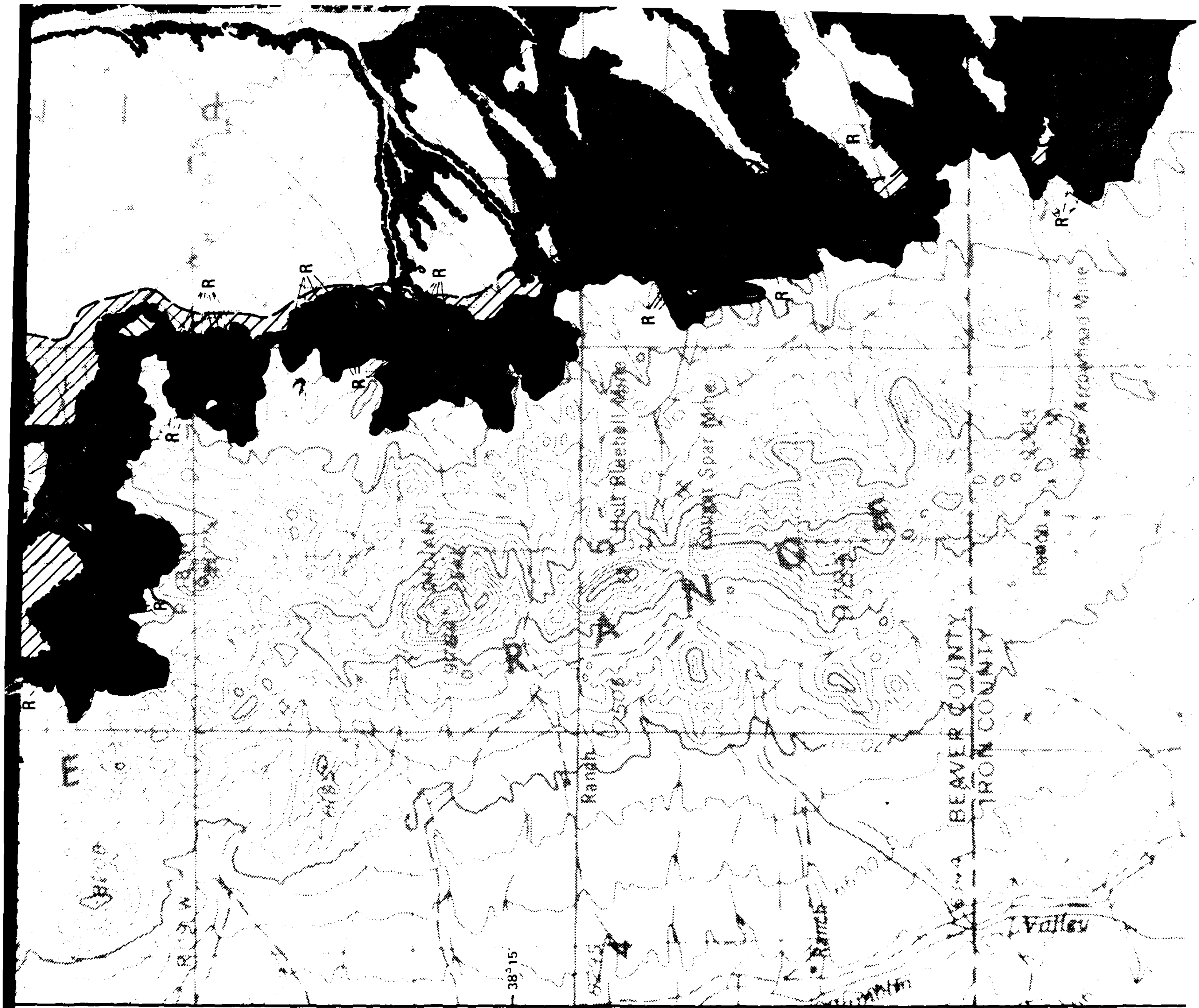




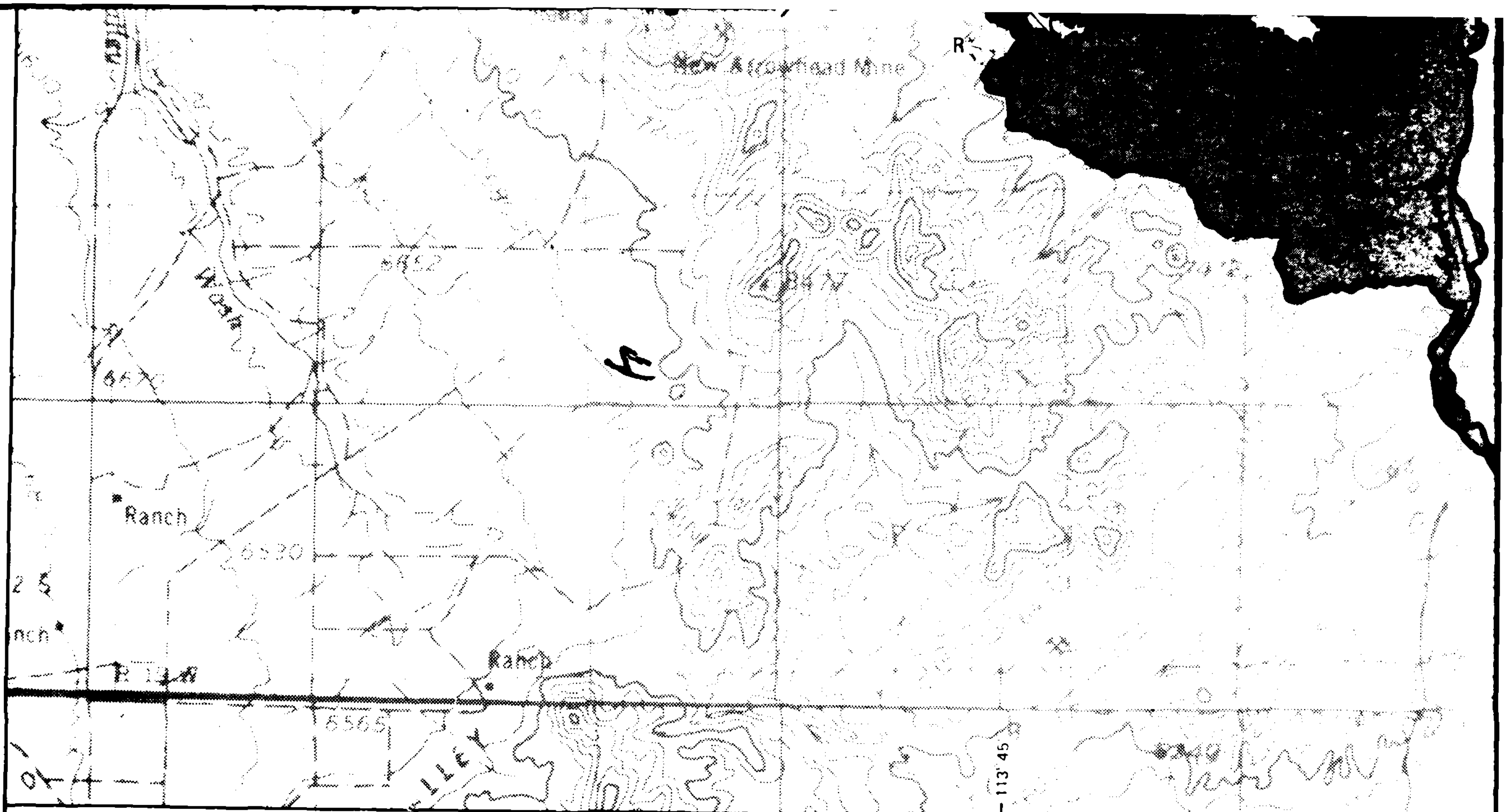
24 MAR 81



7


BEAVER COUNTY
IRON COUNTY
Valley
Ranch
Ranch
38°15'
R
A
N
G
E
Cobalt Spar Mine
Half Bluebell Mine

8'



4

EXPLANATION

Area suitable for horizontal and vertical shelter basing modes. Depth to rock and water greater than 150 feet (46m).

Area suitable for horizontal shelter but, not suitable for vertical shelter. Depth to rock greater than 50 feet (15m) and less than 150 feet (46m).

Area unsuitable for both horizontal and vertical shelter basing modes as determined from applicati of depth to rock and water, topography/terrain, and cultural exclusions.

UnS Area unsuitable for both horizontal and vertical shelter, too small for shading.

Areas of isolated exposed rock

SUI
FOR HORIZONTA
PINE

MX SITING IN
DEPARTMENT OF TH

FUGRO N

	Area suitable for horizontal and vertical shelter basing modes. Depth to rock and water greater than 150 feet (46m).
	Area suitable for horizontal shelter but, not suitable for vertical shelter. Depth to rock greater than 50 feet (15m) and less than 150 feet (46m).
	Area unsuitable for both horizontal and vertical shelter basing modes as determined from applicatio[n] of depth to rock and water, topography/terrain, and cultural exclusions.
UnS	Area unsuitable for both horizontal and vertical shelter, too small for shading.
	Areas of isolated exposed rock.
R	Areas of isolated exposed rock too small for shading.
	Contact between rock and basin fill.
	Valley borders (north and west).

5

SUITABLE AREA
FOR HORIZONTAL AND VERTICAL SHELTERS
PINE VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

DRAWING
2-1

FUGRO NATIONAL, INC.

10

3.0 GEOTECHNICAL SUMMARY

3.1 GEOGRAPHIC SETTING

Pine Valley is located in western Beaver and Millard counties, Utah (Figure 3-1). The valley is bounded on the west by the Tunnel Spring Mountains and The Needles, and on the west and south by the Indian Peak Range. It is bounded on the east by the Wah Wah Mountains and on the north by Snake Valley. State Highway 21 runs diagonally northwest-southeast across the north-central part of the valley. A network of graded roads and four-wheel drive trails provides access to the rest of the area. The valley is primarily undeveloped desert rangeland, with scattered corrals and water tanks. The Desert Experimental Range, operated by the University of Utah Research Institute is located in the northwest part of the valley. Milford, the nearest town, is 36 miles (58 km) to the east on State Highway 21.

3.2 GEOLOGIC SETTING

3.2.1 Rock Types

Pine Valley is a north-south trending alluvial basin. The Wah Wah Mountains to the east consist principally of Paleozoic limestones, dolomites, and quartzites with minor amounts of younger volcanic rocks. In the southern part of the mountains, the volcanic rocks predominate. The mountains to the west of the valley consist almost exclusively of Tertiary volcanic dacite and ash-flow tuff.

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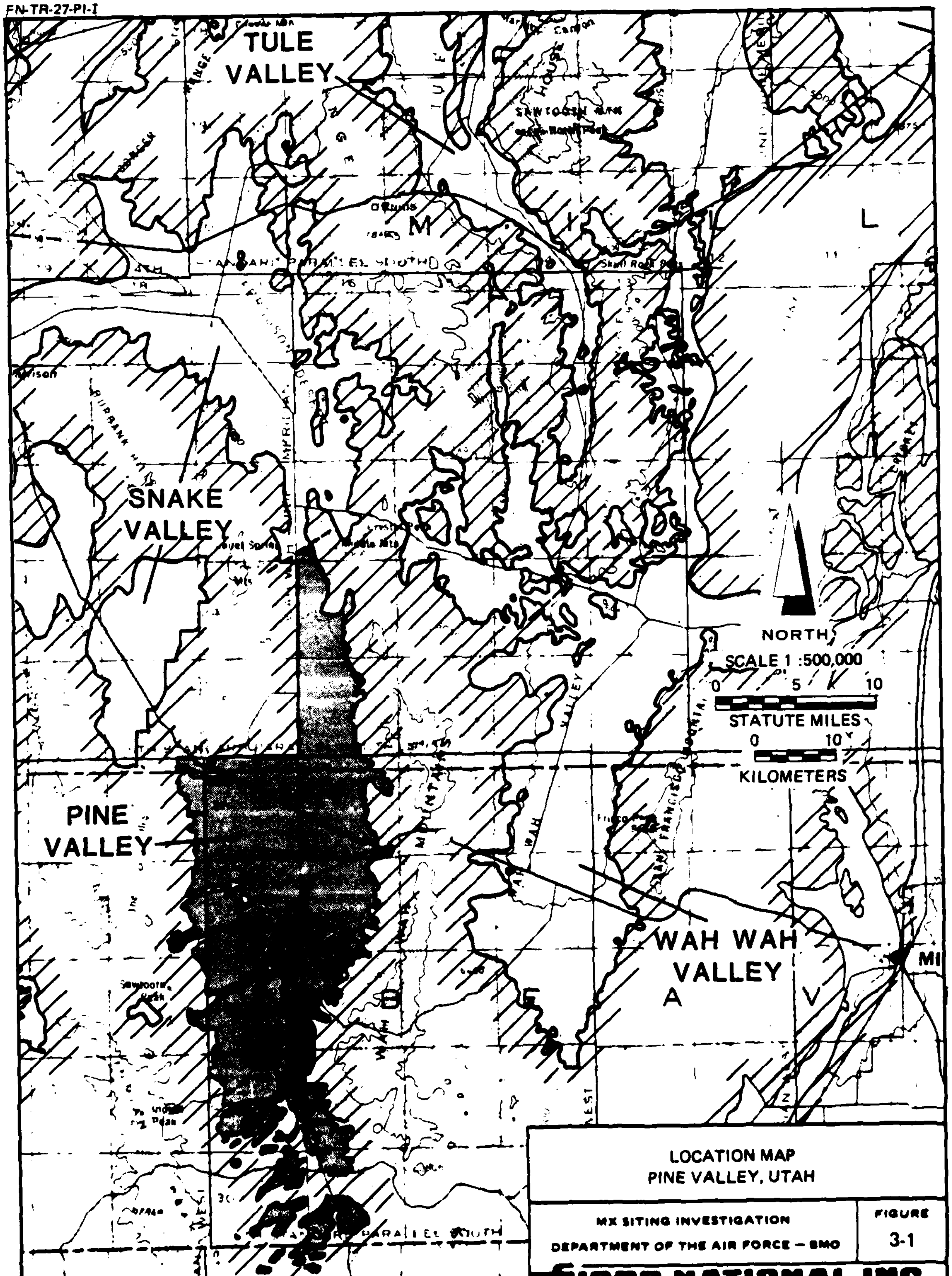

LOCATION MAP
PINE VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

FIGURE 3-1

FUGRO NATIONAL, INC.

24 MAR 81

3.2.2 Structure

The geologic structure of Pine Valley is typical of the Great Basin tectonic province. It resulted from late Tertiary-Quaternary block faulting due to tensional stresses directed east-west or northwest-southeast. Fault structures in the Great Basin are tilted horst and graben structures with the valleys occupying the down-tilted or the down-dropped blocks and the mountains representing the upturned or uplifted blocks. Major faults bounding these blocks generally trend north-south and are usually located near the margins of the valleys. In some cases, however, faults are oriented in other directions. A few faults have been found near the valley axes.

Pine Valley overlies the down-to-the-east tilted portion of a block that includes The Needles and the Indian Peak Range along the valley's western margin (Drawing 3-2). A few minor faults cut the Quaternary alluvium of the valley, but the major range-bounding faults do not displace surficial geologic units. Faults within the valley and in the bordering ranges trend north and are normal faults typical of the Great Basin Province.

Linear gravity anomalies (FNI, 1981a) indicate a major range-bounding fault system beneath the alluvium on the eastern side of Pine Valley. This system roughly parallels the western edge of the Wah Wah Mountains and projects to the surface at the approximate location of a fault inferred by Hintze (1963). Our geologic studies did not reveal any surface expression of this fault, and thus, it is probably older than late Quaternary. The fault parallels geomorphically conspicuous, north-trending faults within the Wah Wah Mountains. Together, these faults probably form the eastern boundary of the Pine Mountains tilt block and are responsible for most of the vertical displacement between the Pine Valley block and the Wah Wah Mountains block.

Faults of Quaternary age occur in two small areas of Pine Valley: 1) near the center of the valley within a group of tectonic lineaments; and 2) at the southern end of the valley in older-intermediate fan material (A5i). In both areas, the faults are expressed primarily as vegetation lineaments having little or no topographic relief. Faults in the central part of the valley cut intermediate-age alluvial fans and are of late Quaternary age. The fault in the south may be of early Quaternary age because it cuts older intermediate fan deposits but this cannot be documented with certainty. This fault is directly aligned with bedrock faults of unknown age in the Indian Peak Range at the southern end of the valley. Gravity data do not indicate any major faults in this area.

There are numerous faults within the Indian Peak Range and The Needles along the western side of the valley. Most of these faults appear to have small displacements. Their orientations are relatively random. The most conspicuous faults, presumed to be the youngest, are shown in Drawing 3-2 and strike north-northwest along or near the edge of the mountain block. The age of last movement on these faults could not be determined because they displace only Paleozoic and Tertiary rocks and are not overlain by young stratigraphic units. Their geomorphic expression, trend, and sense of normal displacement, however, suggest that they have been active under the present tectonic regime. Gravity data (FNI, 1981a) suggest that the bedrock of the Indian Peak Range forms a relatively continuous, gently eastward dipping pediment under the alluvium. Farther north, near the junction with The Needles, the gravity data indicate two short, intersecting faults with large subsurface displacements, but there is no evidence on the surface of any late Quaternary movement.

3.2.3 Surficial Geologic Units

Geologic data stops and engineering field activities were used to verify the aerial photographic interpretation of surficial geologic units. Their locations are shown in Drawing 3-1.

Alluvial fans of intermediate relative age (A5i) are the predominant surficial geologic unit within the valley (Drawing 3-2). They range from sandy gravels near the mountain fronts to sandy silts near the center of the valley. The valley axis is occupied by young fluvial sediments. Playa deposits, covering only a small percentage of the valley surface, are found in the north-central part of the valley.

Surficial geologic units mapped in Pine Valley (Drawing 3-2) consist of the following:

- o Older Alluvial Fan Deposits (A5o) - These sediments form one of the least extensive units in the valley, occupying less than five percent of the total area. The fans consist of sandy gravels and gravelly sands and occur adjacent to the mountain fronts. The topographically higher portions of these fans are underlain by shallow rock. Cementation is generally moderate; caliche development is usually Stage III but can be as low as Stage I.

- o Intermediate Alluvial Fan Deposits (A5i) - These Pleistocene-age fans occupy 75 to 80 percent of the total valley area. They form a narrow band along the mountain front in the northeast part of the valley, widening toward the south to become the predominant unit on either side of the valley axis. The topographically higher portions are generally underlain by shallow rock. The unit consists of sandy gravels and gravelly sands whose cementation varies from none to strong. Caliche development is also highly variable, ranging from none to Stage IV.

- o Younger Alluvial Fan Deposits (A5y) - These Holocene sediments occupy three to eight percent of the total valley area. They occur in bands along the axial drainage. The unit consists primarily of silty sands; a few small fans are composed of sandy gravels or of fine-grained sediments. Cementation is none to weak; caliche development varies from none to Stage III.

- o Fluvial and Associated Flood-plain Deposits (A1) - These sediments are also of Holocene age and cover three to eight percent of the total valley area. They occur along most of the valley axis and in the channels of major tributary streams. Near the mountain front, the sediments are composed of sandy gravels, which grade toward the valley axis into gravelly and silty sands. Near the playa, the channel sediments are silts and clays. There is generally no caliche development nor cementation.

- o Lacustrine Deposits (A4, A4o) - A4 represents Holocene playas and A4o designates Quaternary lacustrine sediments. These two units together cover approximately five to 10 percent of Pine Valley. They occupy a topographically low basin at the northern end of the valley. The A4 unit is almost exclusively composed of silty clays deposited in playas; a few small A4 deposits consist of silty and clayey sands. The A4o unit is composed of sediments ranging from fines to sandy gravels. There is generally no cementation nor caliche development.

- o Aeolian Deposits (A3s, A3d) - These Holocene-age units consist of wind-blown sand deposited in sheets (designated "s") and dunes (designated "d"). They occupy less than five per-cent of the total area and occur exclusively in the region north-east of the playa. They are composed of clean sand containing no gravel. No cementation nor caliche development is present.

3.3 SURFACE SOILS

Surficial soils of Pine Valley are predominantly coarse-grained. They range from gravels with little fines to sands with some fines. Fine-grained soils (silts and clays) have a limited areal distribution confined generally to the mouth of the Pine Valley Wash and north-central portion of the valley. Soils from the predominant surficial geologic units can be combined into the following three categories based on their physical and engineering characteristics:

1. Sandy gravels and gravelly sands (geologic units A4os and A5is); and
2. Silty sands and clayey sands (geologic units A4os and A5is);
3. Silts and clays (geologic units A4os and A5yf).

3.3.1 Characteristics

A summary of the characteristics of surficial soils, based on field and laboratory test results, is presented in Table 3-1. In addition to the physical properties, the table includes road design data, consisting of laboratory compaction and CBR test results, thickness of low-strength surficial soils, and a qualitative assessment of their suitability for road use. Gradation ranges for the three categories of surficial soils are shown in Figure 3-2. The surficial soils in the top 2 feet (0.6 m) have sporadic, weak calcium-carbonate cementation.

Sandy gravels and gravelly sands have an approximate areal distribution of 20 to 40 percent. Gravelly soils commonly occur in the intermediate-age fans along the valley flanks and in the

SOIL DESCRIPTION		Sandy Gravels and Gravelly Sands		Silty Sands and C
USCS SYMBOLS		GW, GP, GM, SW, SP, SM		SM, SC
PREDOMINANT SURFICIAL GEOLOGIC UNITS		A4os A5is		A4os, A5is
ESTIMATED AREAL EXTENT %		20 - 40		60 - 80
PHYSICAL PROPERTIES				
COBBLES 3 – 12 inches (8 – 30 cm) %		0 - 10		0 - 10
GRAVEL %		17 - 58	[20]	0 - 26
SAND %		33 - 71	[20]	33 - 87
SILT AND CLAY %		4 - 21	[20]	13 - 47
LIQUID LIMIT		NDA		31 - 42
PLASTICITY INDEX		NDA		NP - 18
ROAD DESIGN DATA				
MAXIMUM DRY DENSITY pcf (kg/m3)		121.4 - 142.5 (1945 - 2283)	[5]	115.1 - 128.8 (1844 - 2063)
OPTIMUM MOISTURE CONTENT %		6.0 - 13.0	[5]	9.0 15.0
CBR AT 90% RELATIVE COMPACTION %		6 - 27	[5]	4 - 27
SUITABILITY AS ROAD SUBGRADE (1)		good to very good		fair to good
SUITABILITY AS ROAD SUBBASE OR BASE (1)		fair to good		poor to fair
THICKNESS OF LOW STRENGTH SURFICIAL SOIL (2)	RANGE ft (m)	0.1 - 10.0 (0.0 - 3.0)	[20]	0.4 - 11.0 (0.1 - 3.4)
	AVERAGE ft (m)	1.9 (0.6)	[20]	3.4 (1.0)

(1) Suitability is a subjective rating explained in Section A5.0 of the Appendix.

(2) Low strength surficial soil is defined as soil which will perform poorly as a road subgrade at its present consistency; see Table 3.2 for details.

NOTES: • [ ] -

• NDA - No

Silty Sands and Clayey Sands		Sandy Silts, Silts, Sandy Clays, and Silty Clays		
SM, SC		ML, CL		
A4os, A5is		A4os, A5yf		
60 - 80		5 - 10		
0 - 10		0		
0 - 26	[54]	0 - 4	[6]	
33 - 87	[54]	7 - 39	[6]	
13 - 47	[54]	60 - 93	[6]	
31 - 42	[4]	28 - 42	[6]	
NP - 18	[5]	7 - 21	[6]	
115.1 - 128.8 (1844 - 2063)	[14]	105.5 - 115.0 (1690 - 1842)	[4]	
9.0 - 15.0	[14]	15.3 - 19.6	[4]	
4 - 27	[14]	2 - 5	[4]	
fair to good		poor		
poor to fair		not suitable		
0.4 - 11.0 (0.1 - 3.4)	[57]	1.9 - 6.1 (0.6 - 1.9)	[3]	
3.4 (1.0)	[57]	3.5 (1.1)	[3]	

S:
- [ ] - Number of tests performed
- NDA - No data available (insufficient data or tests not performed)

2

CHARACTERISTICS OF SURFICIAL SOILS
PINE VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 3 1

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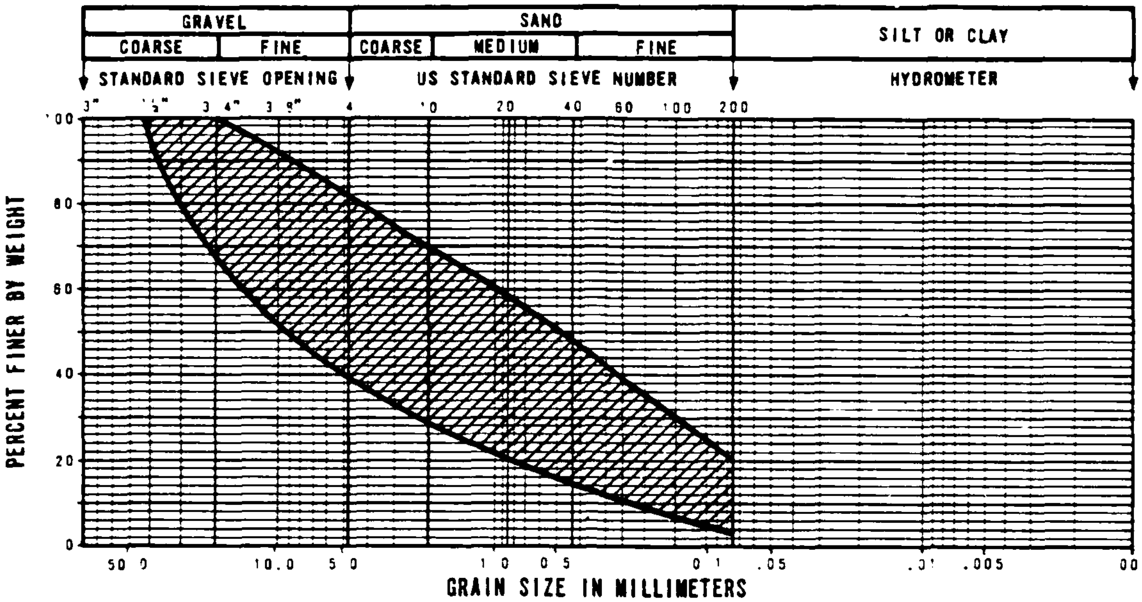
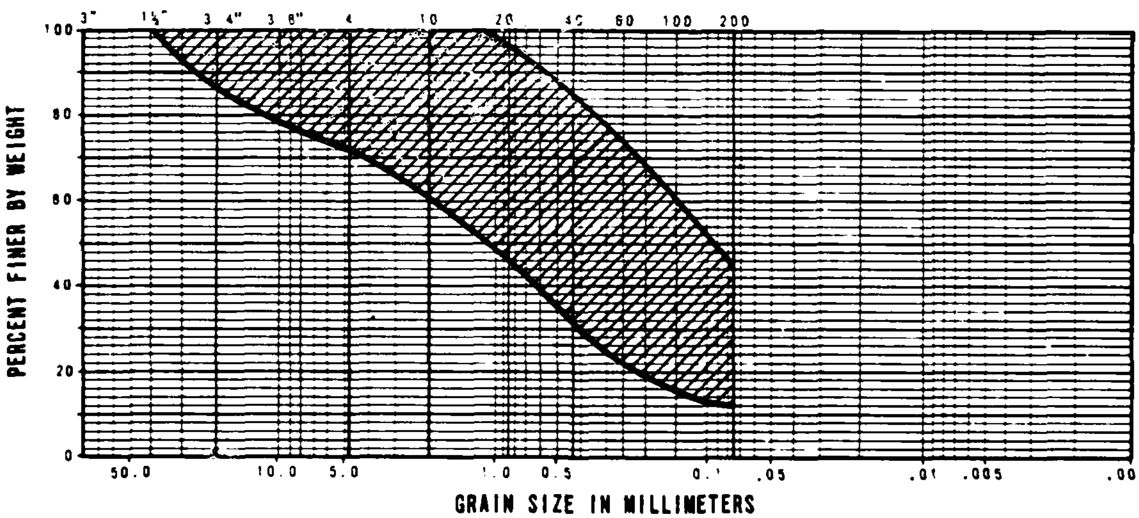
AFV-19



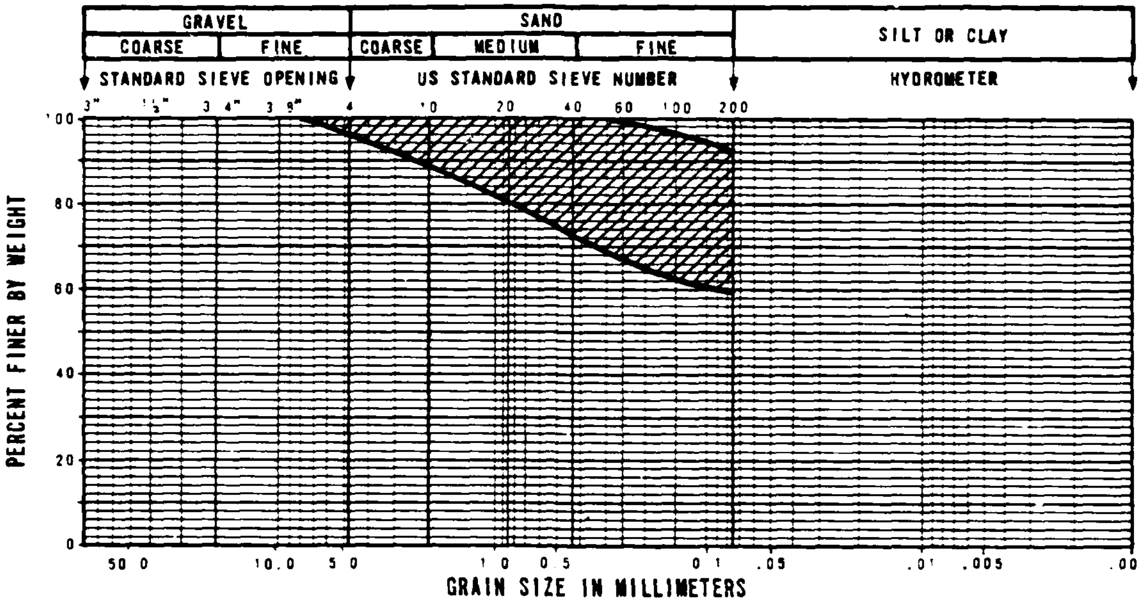
SOIL DESCRIPTION: Sandy Gravels and Gravelly Sands from 0 to 2 feet (0 to 0.6m)



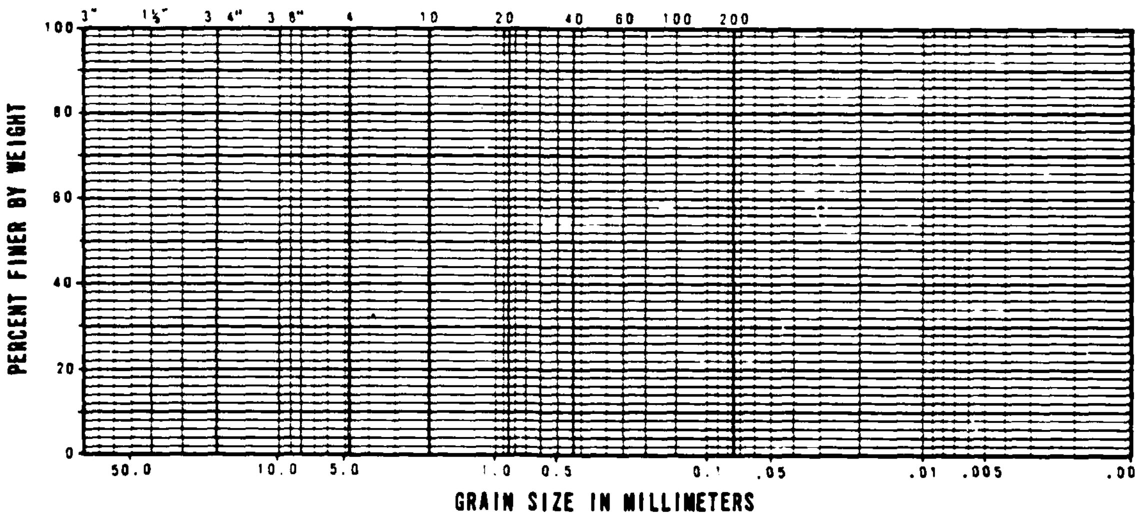
SOIL DESCRIPTION: Silty Sands and Clayey Sands from 0 to 2 feet (0 to 0.6m)

RANGE OF GRADATION OF SURFICIAL SOILS PINE VALLEY, UTAH	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	FIGURE 3-2 1 OF 2

FUGRO NATIONAL, INC.



SOIL DESCRIPTION: Sandy Silts, Silts, Sandy Clays and Silty Clays from 0 to 2 feet (0 to 0.6m)



RANGE OF GRADATION OF SURFICIAL SOILS PINE VALLEY, UTAH	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	FIGURE 3-2 2 OF 2

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young alluvial fans associated with small tributary stream channels. The sands generally extend to the mountains. Their gravel content increases toward the mountains, with local grading into gravels. This is especially noticeable along the Wah Wah Mountains at the eastern valley edge. Gravelly sands and sandy gravels have a wide range of particle sizes and contain traces to some fines. Cobbles and boulders to 12 inches (30 cm) and even larger in diameter are occasionally encountered at or near the ground surface in these gravelly deposits. The percentage of cobbles and boulders increases in the southern portion of the valley.

Silty sands and clayey sands are the predominant surficial soils, covering approximately 60 to 80 percent of the area. They are widely distributed, being the major component in all areas except the alluvial fans very near mountain fronts, alluvial fan deposits associated with small stream channels, and the lacustrine and active playa deposits in the north-central part of the valley. The sands are coarse to fine and are poorly graded. They contain some fines and their plasticity ranges from nonplastic to medium plastic. The fines content is highest near the playa and decreases toward the basin margin. Gravel content increases toward the mountain fronts.

Silts and clays cover approximately five to 10 percent of the valley. They consist of sandy silts, silts, sandy clays, and silty clays. They occur predominantly as active playa deposits in the north-central portion of the valley. These soils contain traces to some sand. Their plasticity ranges from slightly plastic to medium plastic.

3.3.2 Low-Strength Surficial Soil

Based on the CPT results and soil classification, the thickness of low-strength surficial soil at each CPT location was estimated and is presented in Table 3-2.

Summaries of the range and mean thickness of the low-strength surficial soil for the three soil categories are included in Table 3-1. Sandy gravels and gravelly sands exhibit low strength to depths ranging from 0.1 to 10.0 feet (0.0 to 3.0 m), with an average of 1.9 feet (0.6 m). Silty and clayey sands exhibit low strengths to depths ranging from 0.4 to 11.0 feet (0.1 to 3.4 m), with an average of 3.4 feet (1.0 m). The variation in the thickness of low-strength granular soils is due to fluctuations in the in-situ density and calcium-carbonate cementation. Silts and clays exhibit low strength to depths ranging from 1.9 to 6.1 feet (0.6 to 1.9 m), with an average of 3.5 feet (1.1 m). Changes in the thickness of low-strength, fine-grained soils are associated with variations in the in-situ density, the amount of fine sand present, and calcium-carbonate cementation.

3.4 SUBSURFACE SOILS

Subsurface soils are predominantly coarse-grained (granular) except in the playa area in the north-central portion of the valley where fine-grained soils predominate. The coarse-grained soils consist of sandy gravels, gravelly sands, sands,

CONE PENETROMETER TEST NUMBER (1)	THICKNESS OF LOW STRENGTH SURFICIAL SOIL,(2)		SOIL TYPE (3)
	FEET	METERS	
C-1	2.6	0.8	GM
C-2	0.1	0.0	GP-GM
C-3	0.4	0.1	SM
C-4	0.9	0.3	SM
C-5	0.6	0.2	NDA
C-6	1.0	0.3	GP-GM
C-7	0.9	0.3	GW-GM
C-8	3.5	1.1	SM/GM
C-9	6.4	2.0	SM
C-10	0.9	0.3	SM
C-11	1.8	0.5	SM
C-12	4.8	1.5	SM
C-13	10.0	3.0	SP
C-14	6.5	2.0	SC
C-15	5.2	1.6	SM/SP
C-16	0.1	0.0	GM
C-17	0.4	0.1	GM
C-18	0.3	0.1	NDA
C-19	2.7	0.8	NDA
C-20	11.0	3.4	SM
C-21	3.0	0.9	SM
C-22	1.3	0.4	SM
C-23	4.4	1.3	SM/SW-SM
C-24	2.2	0.7	SM
C-25	5.1	1.6	SM
C-26	4.0	1.2	SM
C-27	•	•	SC
C-28	0.5	0.2	GW-GM

CONE PENETROMETER TEST NUMBER (1)	THICKNESS OF LOW STRENG SURFICIAL SOIL,(2)	
	FEET	METERS
C-29	•	•
C-30	1.0	0.3
C-31	1.1	0.3
C-32	4.9	1.5
C-33	3.0	0.9
C-34	3.8	1.2
C-35	1.5	0.5
C-36	2.0	0.6
C-37	2.3	0.7
C-38	6.1	1.9
C-39	2.5	0.8
C-40	3.6	1.1
C-41	1.3	0.4
C-42	1.0	0.3
C-43	0.5	0.2
C-44	0.8	0.2
C-45	1.2	0.4
C-46	3.3	1.0
C-47	2.4	0.7
C-48	5.2	1.6
C-49	2.0	0.6
C-50	6.3	1.9
C-51	4.1	1.2
C-52	3.2	1.0
C-53	1.5	0.5
C-54	4.4	1.3
C-55	7.0	2.1
C-56	3.3	1.0

(1) For Cone Penetrometer Test locations see Drawing Activity Location Map.

(2) Thickness corresponds to depth below ground surface. Low strength surficial soil is defined as soil which will perform poorly as a road subgrade at its present consistency. Low strength is based on Cone Penetrometer Test results using the following criteria:

Coarse grained soils: $q_c < 120$ tsf (117 kg/cm^2)
Fine grained soils: $q_c < 80$ tsf (78 kg/cm^2)

where q_c is cone resistance.

(3) Soil type is based on Unified Soil Classification System; see Section A5.0 in the Appendix for explanation

NOTES: • For fine g
strength s
of the soi

• SM/GM – in

• NDA – No d

• • Insuf

NESS OF LOW STRENGTH SURFICIAL SOIL,(2) ET	METERS	SOIL TYPE (3)
•	•	GM
1.0	0.3	SM
1.1	0.3	SW-SM
.9	1.5	SM
3.0	0.9	SM
3.8	1.2	SM
1.5	0.5	SM
2.0	0.6	SM
2.3	0.7	SM
6.1	1.9	CL
2.5	0.8	SM
3.6	1.1	SM
1.3	0.4	SM
1.0	0.3	SM
0.5	0.2	SM
0.8	0.2	SM
1.2	0.4	SM
3.3	1.0	SM
2.4	0.7	SM
5.2	1.6	SM/SW-SM
2.0	0.6	SM
6.3	1.9	SM
4.1	1.2	SM
3.2	1.0	SM/SP-SM
1.5	0.5	SM
4.4	1.3	SM/SW-SM
7.0	2.1	SM/SP-SM
3.3	1.0	SM

CONE PENETROMETER TEST NUMBER(1)	THICKNESS OF LOW STRENGTH SURFICIAL SOIL,(2)		SOIL TYPE (3)
	FEET	METERS	
C-57	4.0	1.2	SM
C-58	0.7	0.2	SP
C-59	2.0	0.6	SM
C-60	4.4	1.3	SM
C-61	•	•	SM
C-62	5.0	1.5	SP-SM/SP
C-63	5.4	1.6	SM
C-64	3.1	0.9	SM/GW
C-65	1.5	0.5	SM
C-66	3.1	0.9	SM/SP
C-67	1.2	0.4	SM
C-68	3.0	0.9	SM/SW
C-69	1.5	0.5	SM
C-70	4.5	1.4	SM
C-71	3.6	1.1	SM
C-72	3.2	1.0	SM
C-73	4.2	1.3	SM
C-74	4.2	1.3	SM
C-75	1.9	0.6	ML
C-76	2.6	0.8	CL
C-77	6.1	1.9	SM
C-78	3.2	1.0	SM/SW-SM
C-79	3.0	0.9	SM
C-80	1.1	0.3	SM
C-81	2.3	0.7	SM
C-82	1.0	0.3	GW-GM
C-83	1.8	0.5	GM
C-84	1.0	0.3	GM

TES:
- For fine grained soils (ML, CL, MH and CH), thickness of low strength surficial soil will vary depending on moisture content of the soil at time of testing.
- SM/GM - indicates SM underlain by GM
- NDA - No data available
- • Insufficient data

2

THICKNESS OF LOW STRENGTH SURFICIAL SOIL
PINE VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 3-2
1 OF 2

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AFV-21

CONE PENETROMETER TEST NUMBER (1)	THICKNESS OF LOW STRENGTH SURFICIAL SOIL,(2)		SOIL TYPE (3)
	FEET	METERS	
C-85	3.4	1.0	SM/SP-SM
C-86	4.0	1.2	SM

(1) For Cone Penetrometer Test locations see Drawing 3-1 Activity Location Map.

(2) Thickness corresponds to depth below ground surface. Low strength surficial soil is defined as soil which will perform poorly as a road subgrade at its present consistency. Low strength is based on Cone Penetrometer Test results using the following criteria:

Coarse grained soils: $q_c < 120$ tsf (117 kg/cm²)
Fine grained soils: $q_c < 80$ tsf (78 kg/cm²)

where q_c is cone resistance.

(3) Soil type is based on Unified Soil Classification System; see Section A5.0 in the Appendix for explanation

CONE PENETROMETER TEST NUMBER (1)	THICKNESS OF LOW STRENGTH SURFICIAL SOIL,(2)	
	FEET	METERS

NOTES: • For fine grai
strength sur
of the soil

• SM/GM – indi

• NDA – No dat

• * – Insuffici

...ESS OF LOW STRENGTH ...URFICIAL SOIL,(2)		SOIL TYPE (3)
...ET	METERS	

CONE PENETROMETER TEST NUMBER(1)	THICKNESS OF LOW STRENGTH SURFICIAL SOIL,(2)		SOIL TYPE (3)
	FEET	METERS	

...ES:
- For fine grained soils (ML, CL, MH and CH), thickness of low strength surficial soil will vary depending on moisture content of the soil at time of testing.
- SM/GM - indicates SM underlain by GM
- NDA - No data available
- * Insufficient data

2

THICKNESS OF LOW STRENGTH SURFICIAL SOIL PINE VALLEY, UTAH	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	TABLE 3-2 2 OF 2

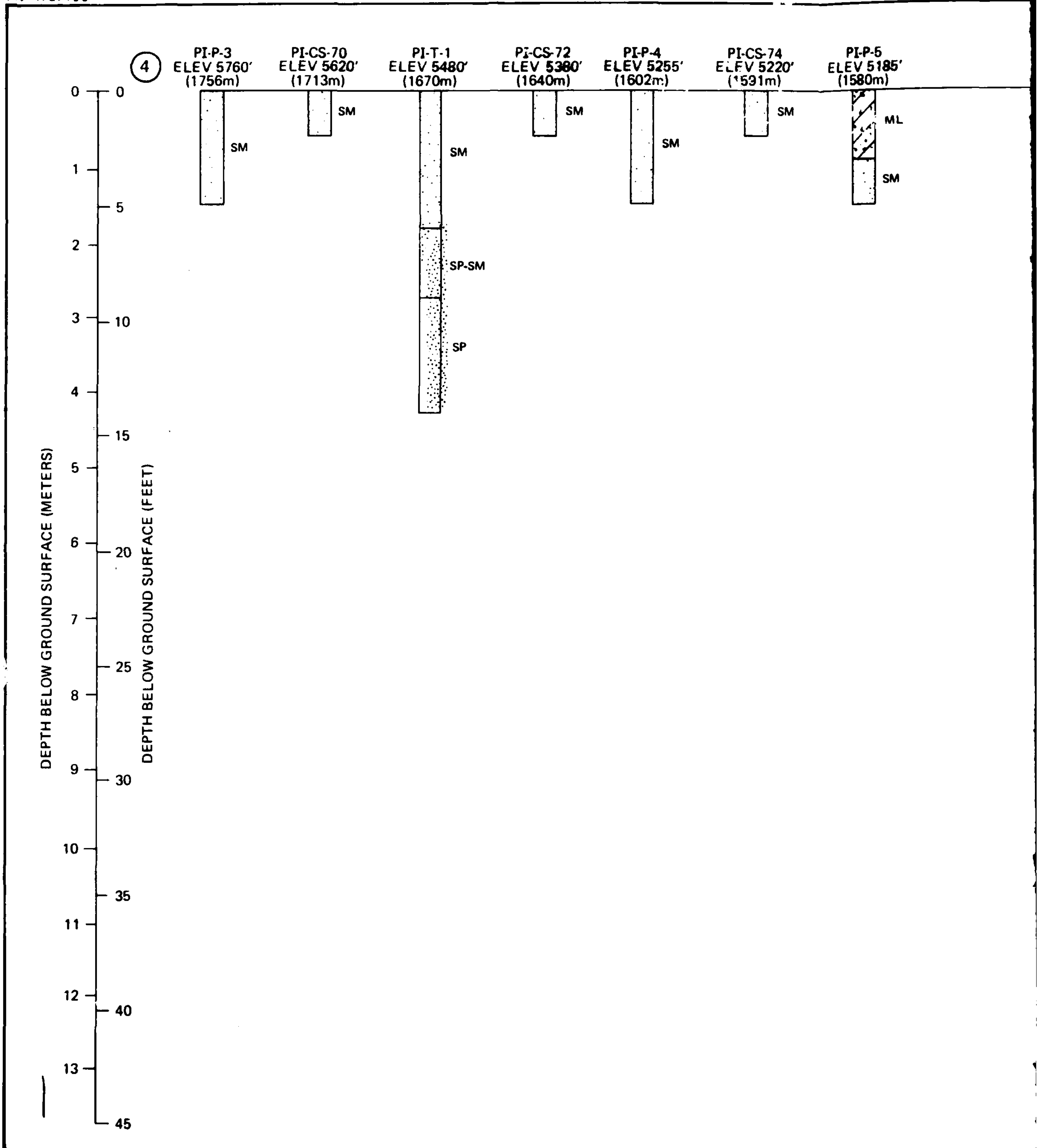
FUGRO NATIONAL, INC.

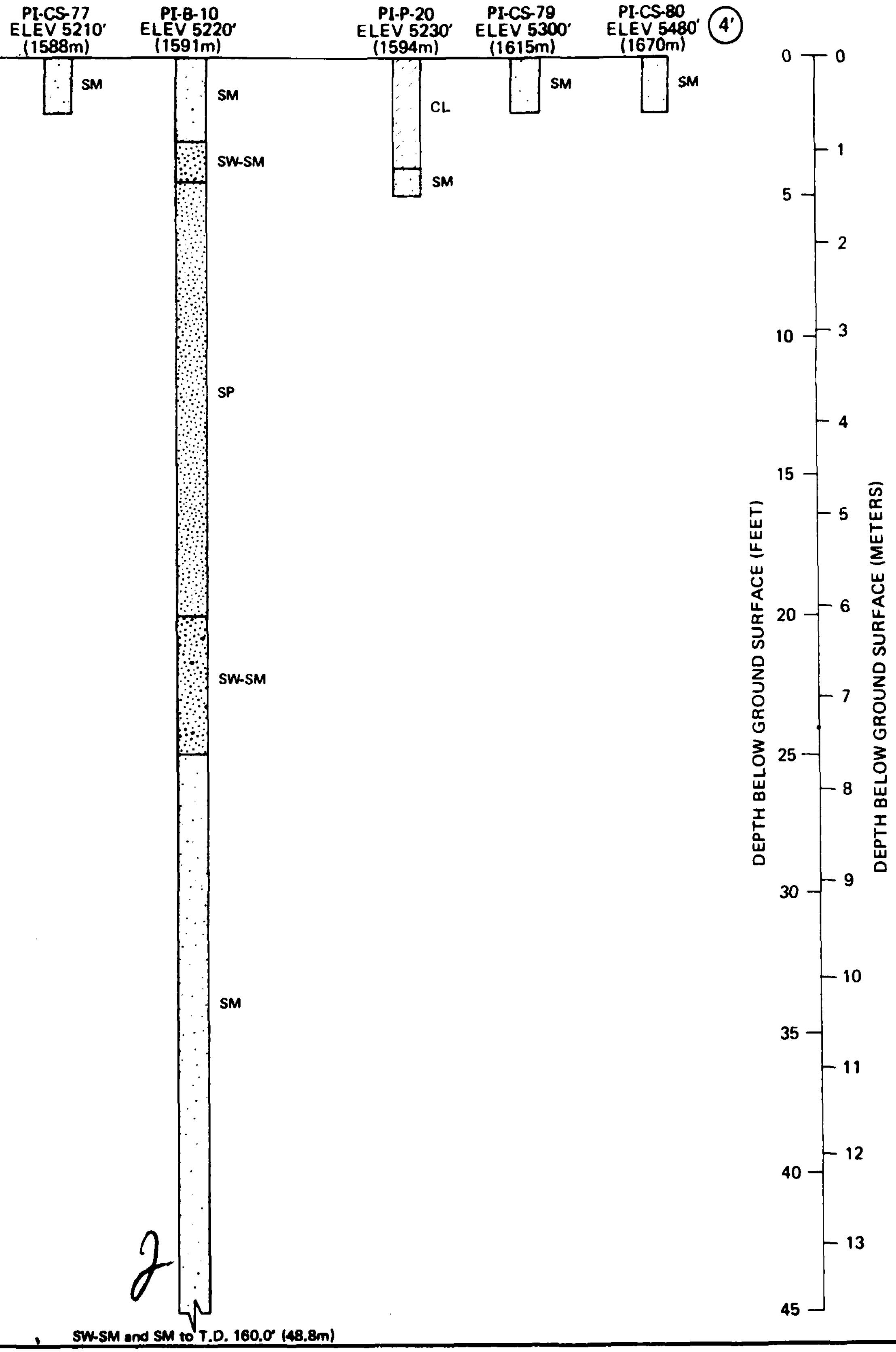
AFV-21

silty sands, and clayey sands. Subsurface soils within the playa area of the valley are predominantly fine-grained. These fine-grained soils consist of sandy silts and sandy clays, with plasticity ranging from nonplastic to medium plastic. At the playa margin these fine-grained soils interfinger with the coarse-grained soils. Fine-grained soils are estimated to compose five to 10 percent of the subsurface deposits within the suitable area boundaries. The composition of subsurface soils with depth, as determined from borings, trenches, test pits, and surficial soil samples is illustrated in the soil profiles presented in Figures 3-3 through 3-6.

Results of seismic and electrical surveys are summarized in Table 3-3. The characteristics of subsurface soils, determined from field and laboratory tests, are presented in Table 3-4. Ranges of gradation of the subsurface soils are shown in Figure 3-7. Coarse-grained subsurface soils are poorly to well-graded, contain coarse to fine sands and gravels, and are dense to very dense below 10 to 15 feet (3.6 to 4.6 m). Variable cementation occurs sporadically, but well-developed, continuous cementation was not encountered. These soils exhibit low compressibilities and moderate to high shear strengths.

Fine-grained soils (silts and clays) range in consistency from firm to stiff and exhibit low to moderate compressibilities and shear strengths. Soil plasticity ranges from nonplastic to medium plastic depending in part on the amount of fine sand present. Calcium-carbonate cementation is usually from none to moderate, depending on the age of the deposit.


4
PI-P-3
ELEV 5760'
(1756m)
PI-CS-70
ELEV 5620'
(1713m)
PI-T-1
ELEV 5480'
(1670m)
PI-CS-72
ELEV 5380'
(1640m)
PI-P-4
ELEV 5255'
(1602m)
PI-CS-74
ELEV 5220'
(1591m)
PI-P-5
ELEV 5185'
(1580m)
SM
SP-SM
SP
ML
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0
5
10
15
20
25
30
35
40
45



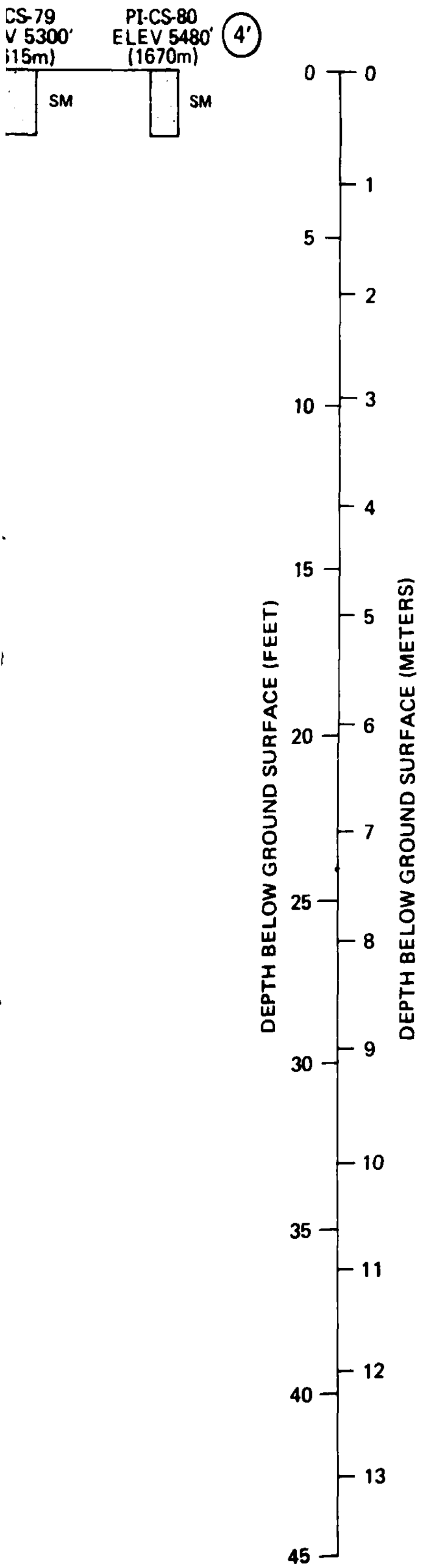
B - Boring
T - Trench
P - Test Pit
CS - Surficial so

NOTES:

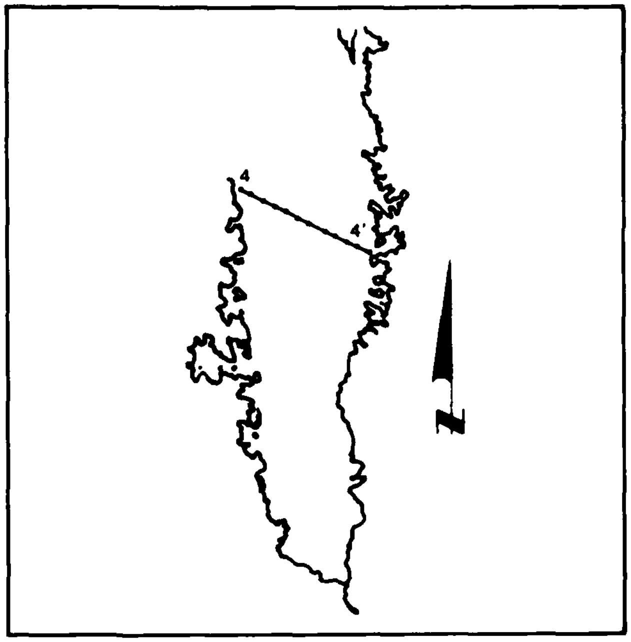
1. Ground surfa
2. T. D. = Total
3. Soil types sh
   Classification

STATUTE MI

KILOMETER



LOCATION MAP



EXPLANATION

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at Cone Penetrometer Test location.

NOTES:

1. Ground surface elevations shown at activity locations are approximate.
2. T. D. = Total Depth.
3. Soil types shown adjacent to soil column are based on the Unified Soil Classification System (USCS) and are explained in the Appendix.

HORIZONTAL SCALE

STATUTE MILES 0 1 2

KILOMETERS 0 1 2 3

3 SOIL PROFILE 4–4'
PINE VALLEY, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	FIGURE 3-3

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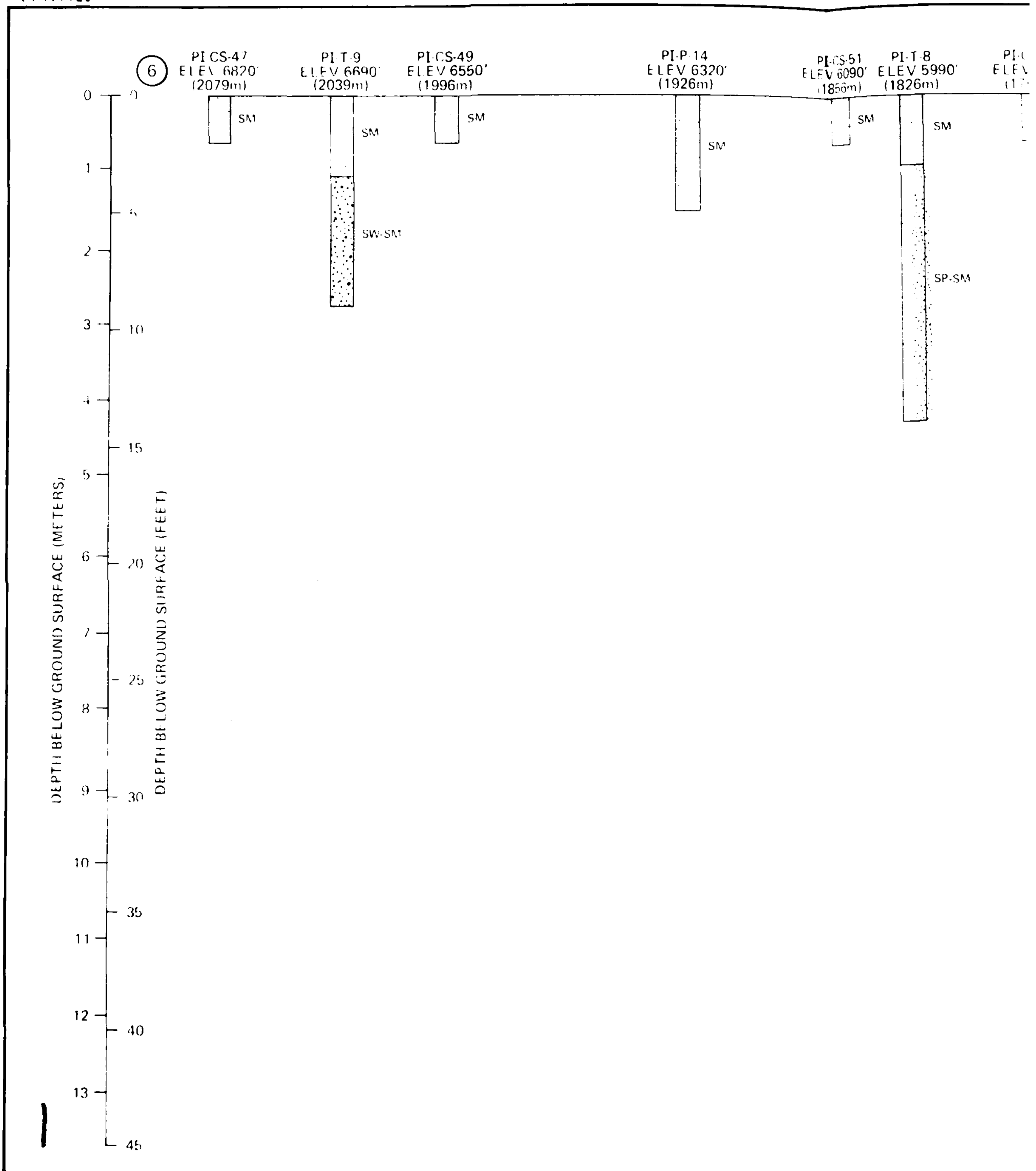
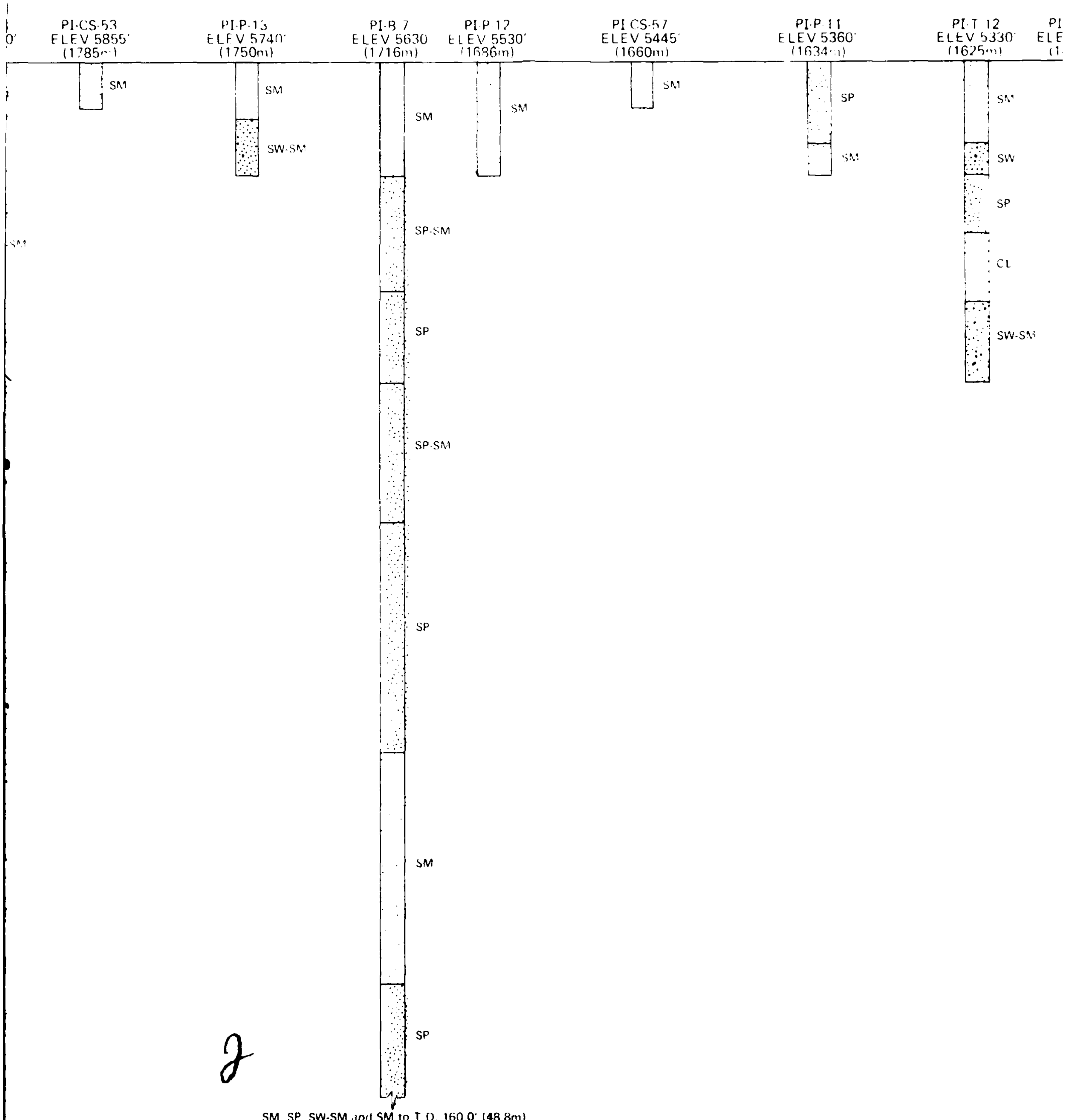
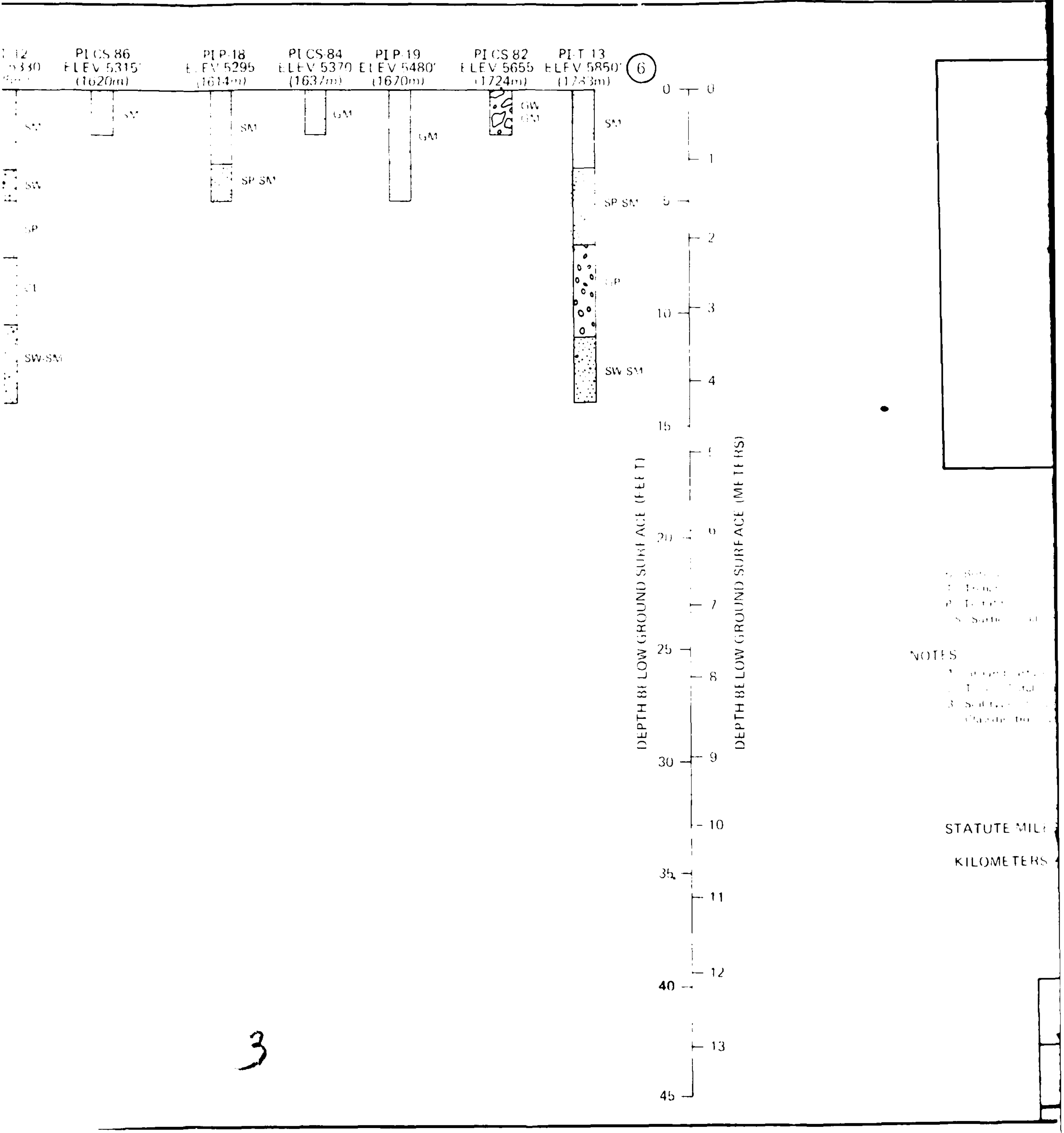
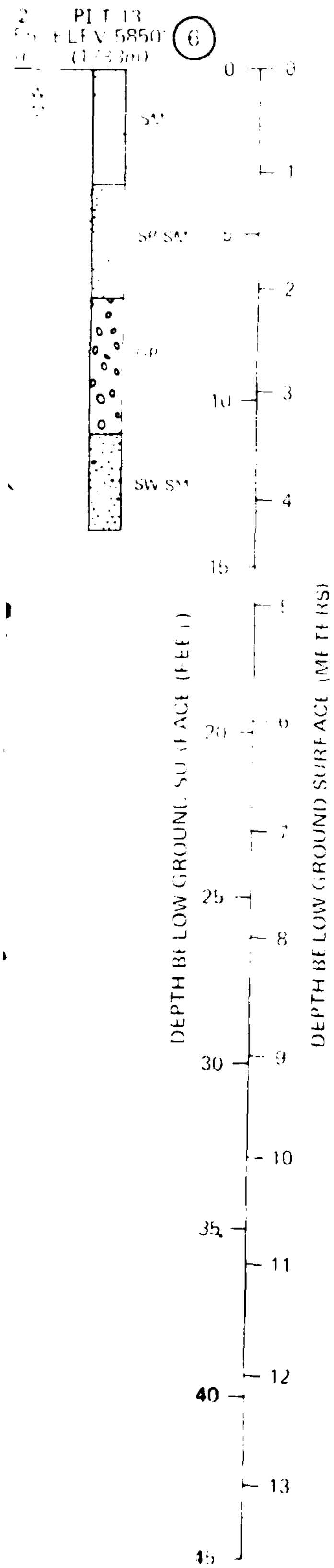
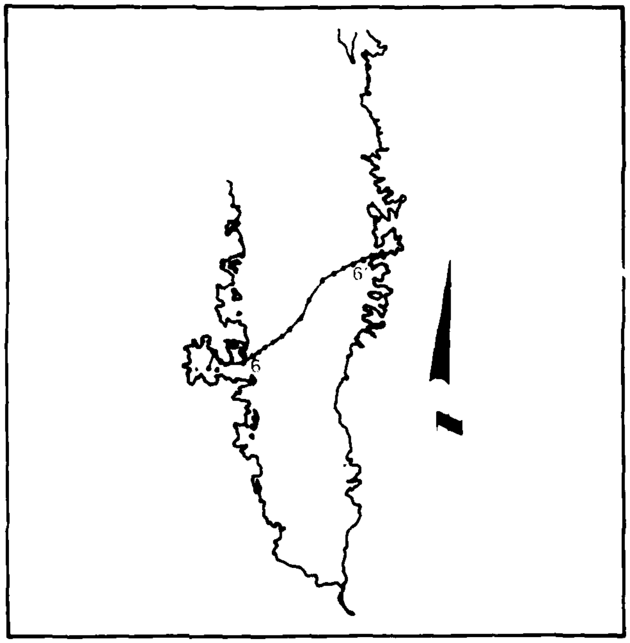

6
PI-CS-47
ELEV 6820'
(2079m)
SM
PI-T-9
ELEV 6690'
(2039m)
SM
SW-SM
PI-CS-49
ELEV 6550'
(1996m)
SM
PI-P-14
ELEV 6320'
(1926m)
SM
PI-CS-51
ELEV 6090'
(1856m)
SM
PI-T-8
ELEV 5990'
(1826m)
SM
SP-SM
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0
5
10
15
20
25
30
35
40
45


PI-CS-53
ELEV 5855'
SM
PI-P-13
ELEV 5740'
(1750m)
SM
SW-SM
PI-B-7
ELEV 5630
(1716m)
SM
SP-SM
SP
SP-SM
SP
SM
SP
SM, SP, SW-SM and SM to T.D. 160.0' (48.8m)
PI-P-12
ELEV 5530'
SM
PI-CS-57
ELEV 5445'
(1660m)
SM
PI-P-11
ELEV 5360'
SP
SM
PI-T-12
ELEV 5330'
(1625m)
SW
SP
CL
SW-SM
2


PI CS 86
ELEV 5315'
(1620m)
PI P-18
ELEV 5295
(1614m)
PI CS-84
ELEV 5370
(1637m)
PI P-19
ELEV 5480'
(1670m)
PI CS 82
ELEV 5655
(1724m)
PI-T 13
ELEV 5850'
(1783m)
6
SM
SP SM
GM
GW
GM
SW
SP
SW-SM
GP
SW SM
DEPTH BELOW GROUND SURFACE (FEET)
DEPTH BELOW GROUND SURFACE (METERS)
NOTES
STATUTE MILE
KILOMETERS
3



LOCATION MAP



EXPLANATION

B Boring
T Trench
P Test Pit
CS Surface Soil sample or Cone Penetrometer Test location

NOTES

1 Ground surface elevations at activity locations are approximate
2 T.D. Total Depth
3 Soil types shown adjacent to soil column are based on the Unified Soil Classification System (USCS) and are explained in the Appendix

HORIZONTAL SCALE

STATUTE MILES 0 1 2

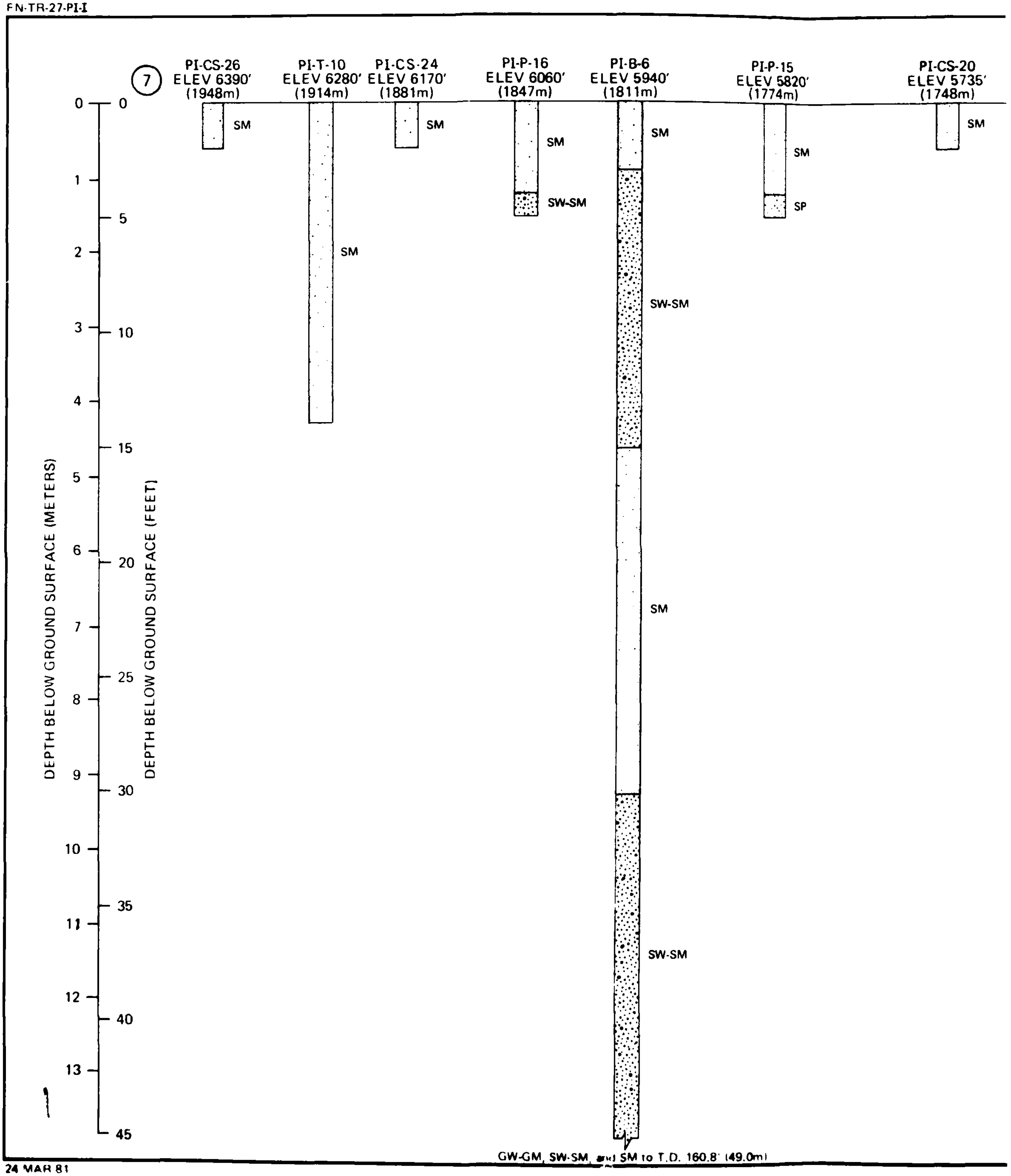
KILOMETERS 0 1 2 3

SOIL PROFILE 6-6'
PINE VALLEY, UTAH 4

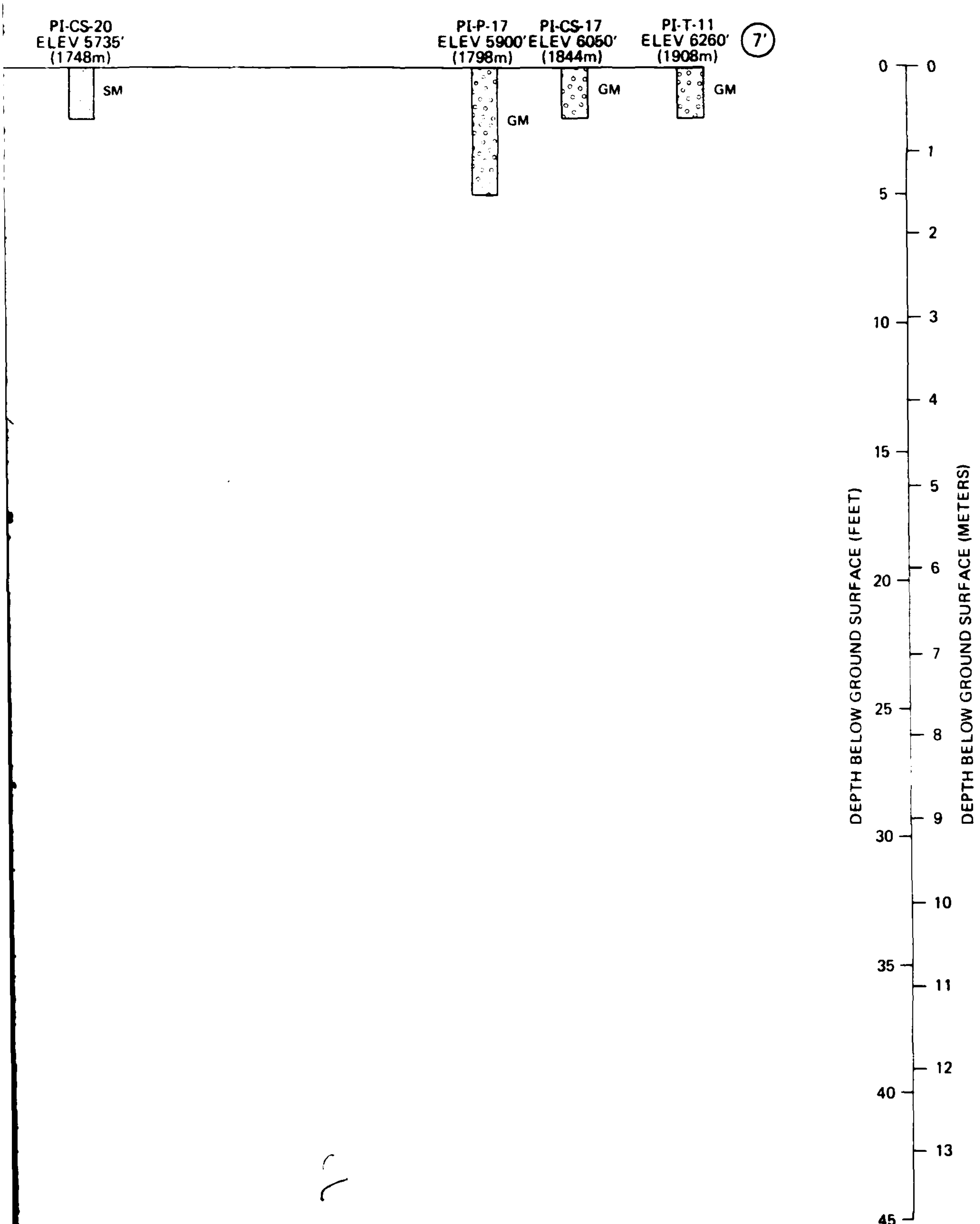
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

FIGURE 34

FUGRO NATIONAL, INC.



7
PI-CS-26
ELEV 6390'
(1948m)
PI-T-10
ELEV 6280'
(1914m)
PI-CS-24
ELEV 6170'
(1881m)
PI-P-16
ELEV 6060'
(1847m)
PI-B-6
ELEV 5940'
(1811m)
PI-P-15
ELEV 5820'
(1774m)
PI-CS-20
ELEV 5735'
(1748m)
SM
SW-SM
SP
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0
5
10
15
20
25
30
35
40
45
GW-GM, SW-SM, and SM to T.D. 160.8' (49.0m)

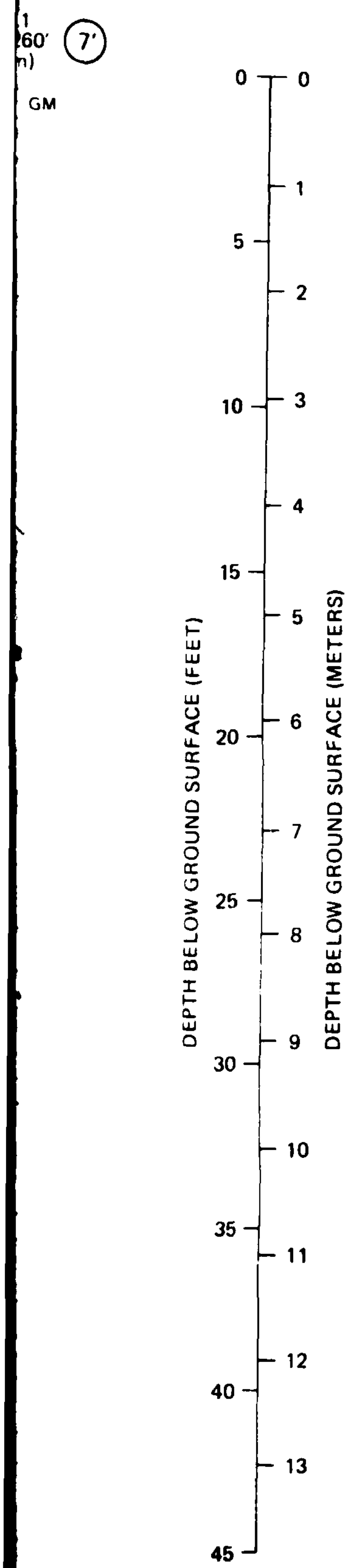


B -
T -
P -
CS

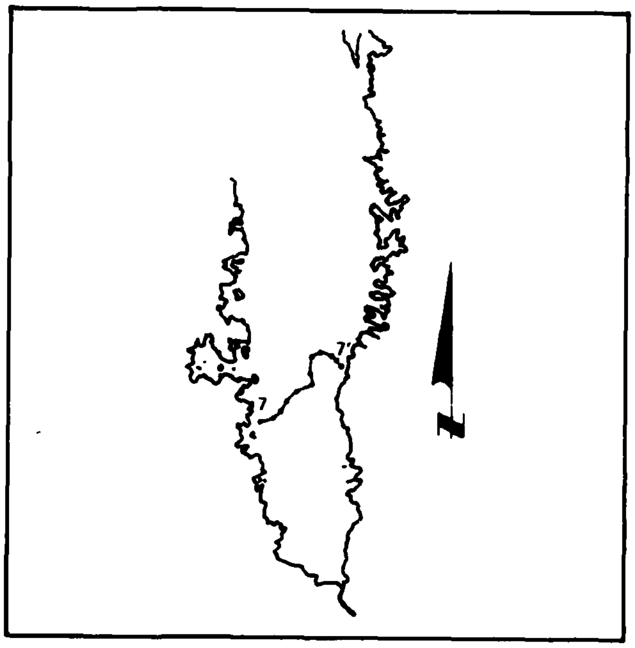
NOTES
1
2
3

ST

KI



LOCATION MAP



EXPLANATION

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at Cone Penetrometer Test location.

NOTES:

1. Ground surface elevations shown at activity locations are approximate.
2. T. D. = Total Depth.
3. Soil types shown adjacent to soil column are based on the Unified Soil Classification System (USCS) and are explained in the Appendix.

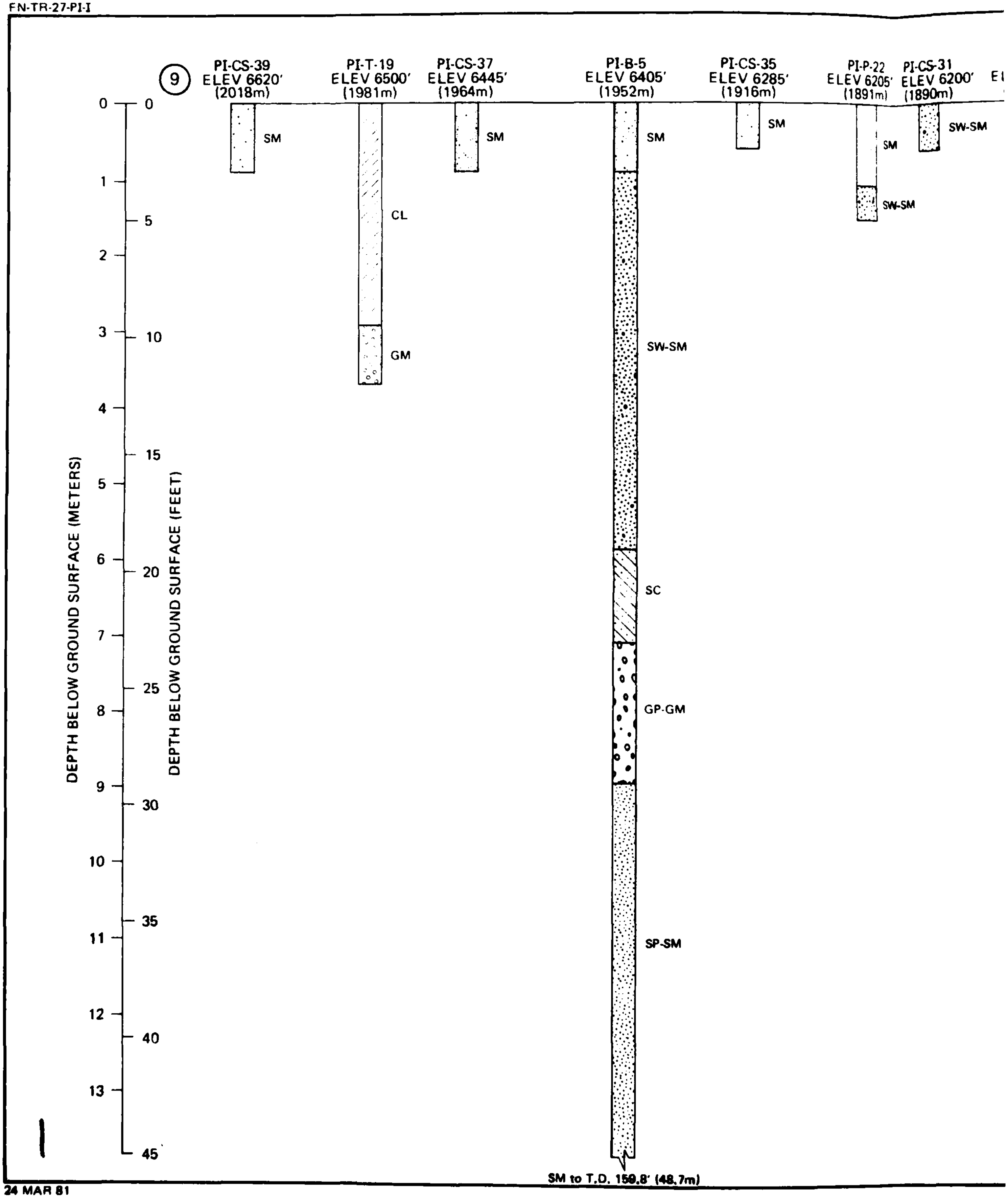
HORIZONTAL SCALE

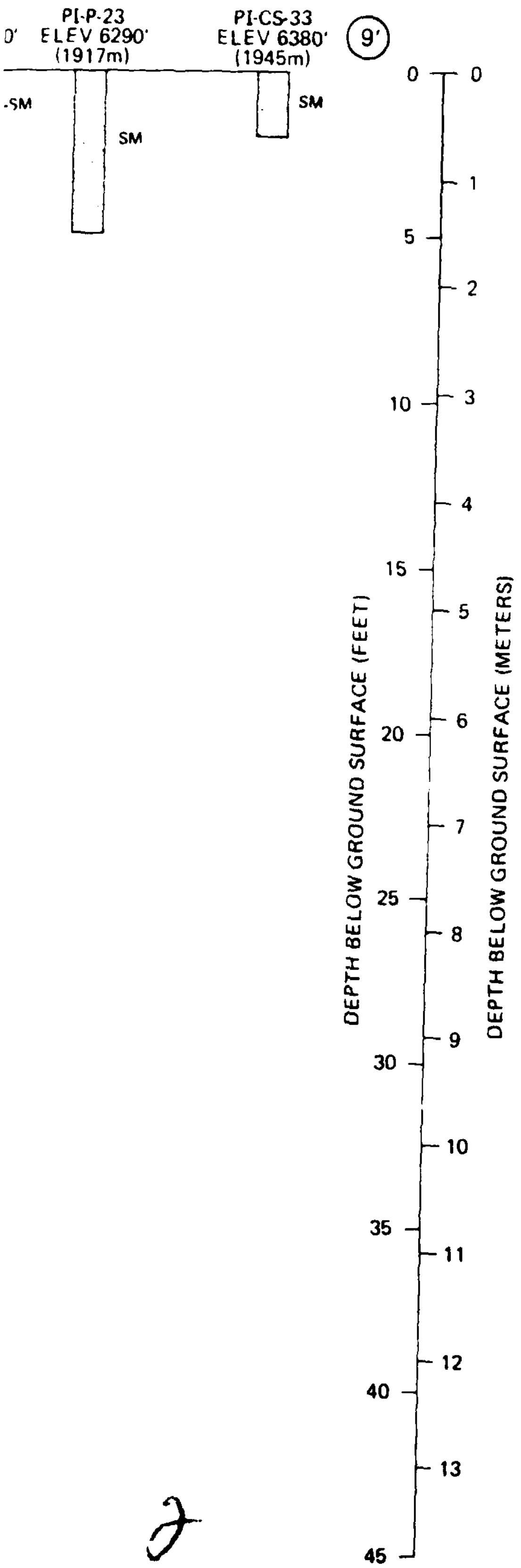
STATUTE MILES 0 1 2

KILOMETERS 0 1 2 3

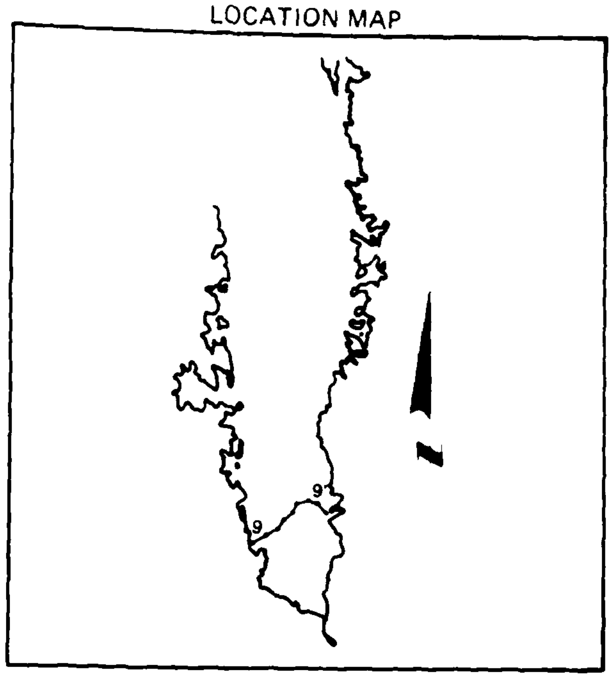
3 SOIL PROFILE 7–7' PINE VALLEY, UTAH	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	FIGURE 3-5

FUGRO NATIONAL, INC.


9
PI-CS-39 ELEV 6620' (2018m)
PI-T-19 ELEV 6500' (1981m)
PI-CS-37 ELEV 6445' (1964m)
PI-B-5 ELEV 6405' (1952m)
PI-CS-35 ELEV 6285' (1916m)
PI-P-22 ELEV 6205' (1891m)
PI-CS-31 ELEV 6200' (1890m)
SM
CL
GM
SW-SM
SC
GP-GM
SP-SM
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0
5
10
15
20
25
30
35
40
45
SM to T.D. 159.8' (48.7m)



LOCATION MAP



EXPLANATION

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at Cone Penetrometer Test location.

NOTES:

1. Ground surface elevations shown at activity locations are approximate.
2. T. D. = Total Depth.
3. Soil types shown adjacent to soil column are based on the Unified Soil Classification System (USCS) and are explained in the Appendix.

HORIZONTAL SCALE

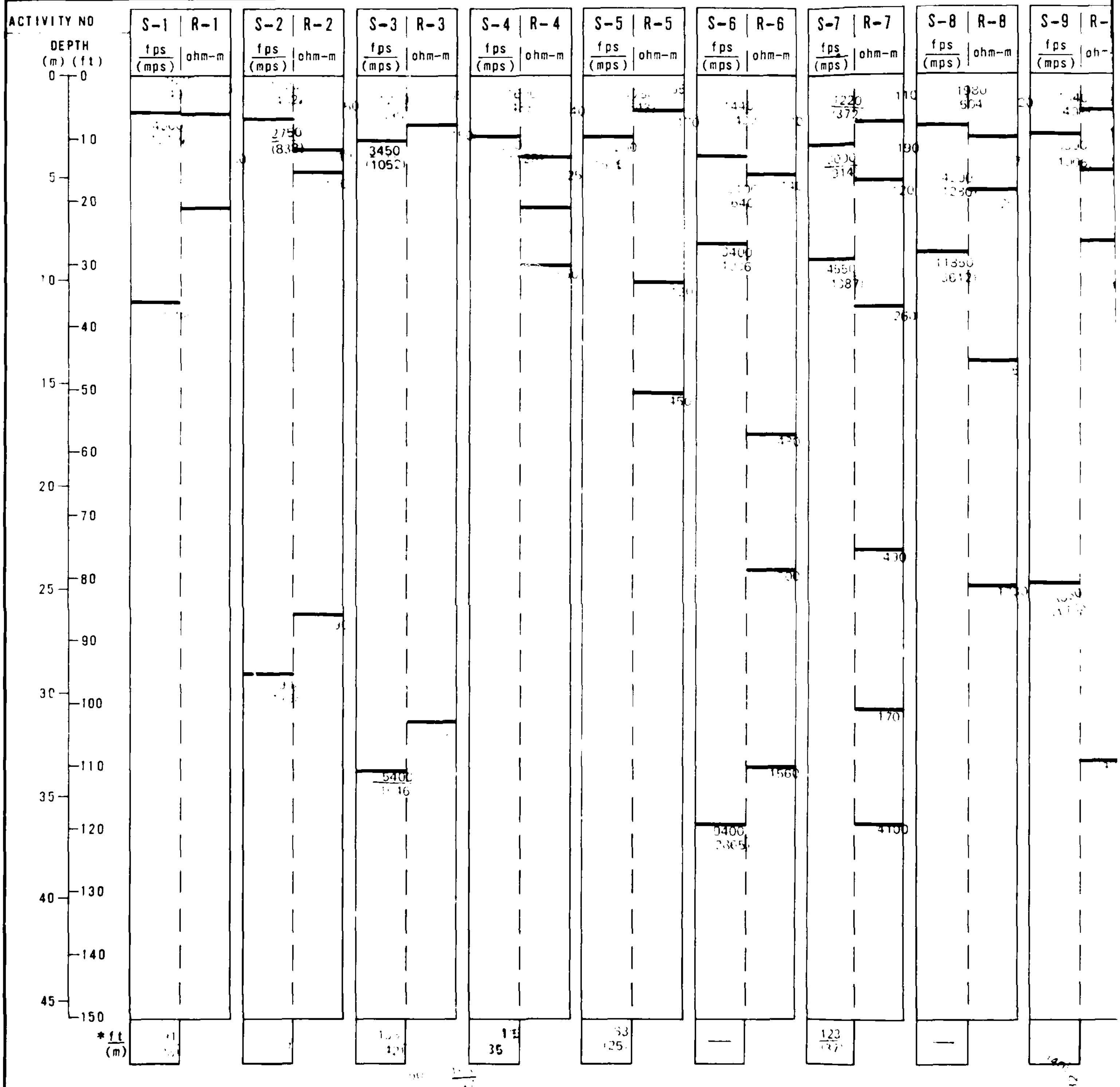
STATUTE MILES 0 1 2

KILOMETERS 0 1 2 3

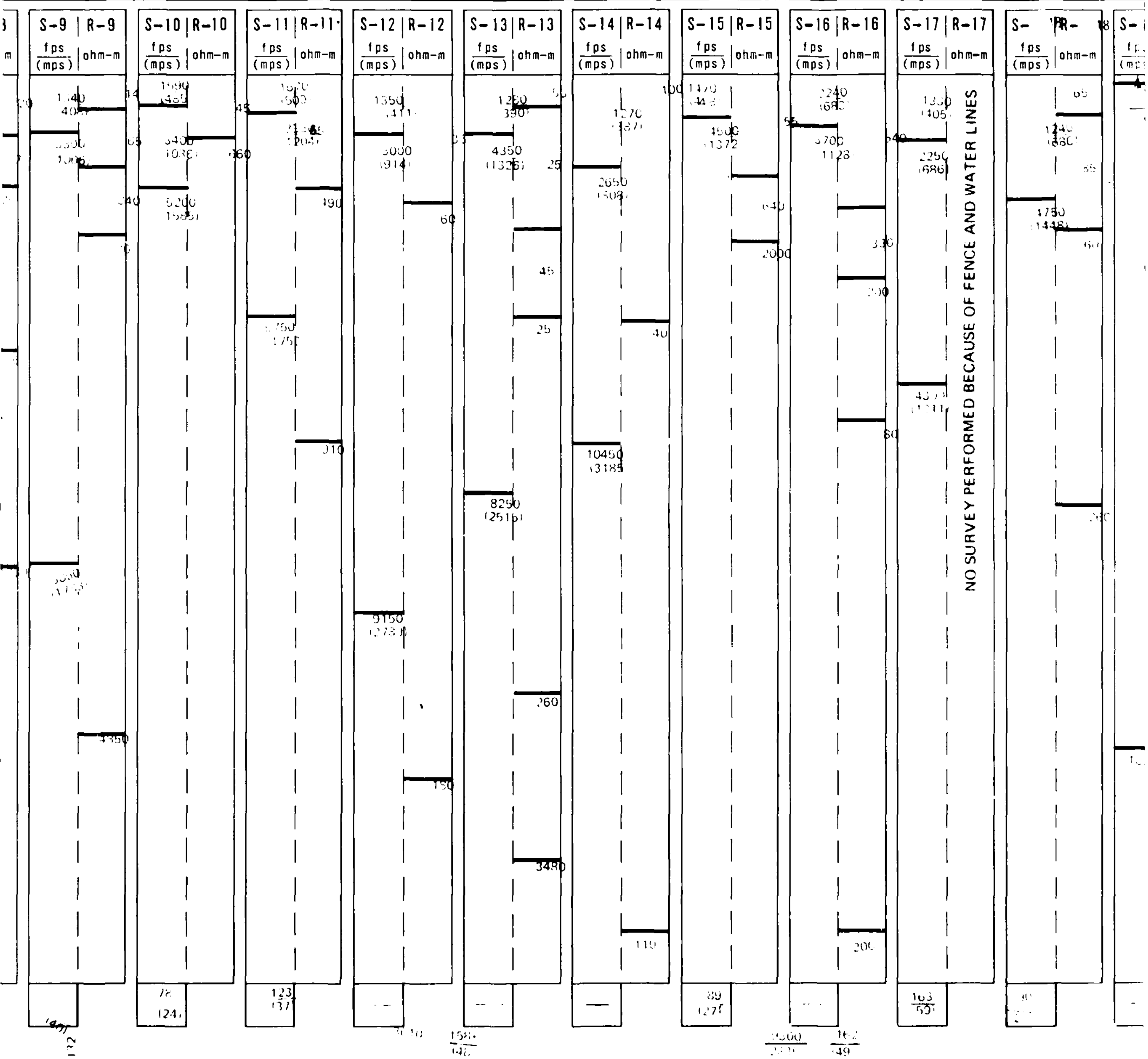
SOIL PROFILE 9–9'
PINE VALLEY, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	FIGURE 3-6

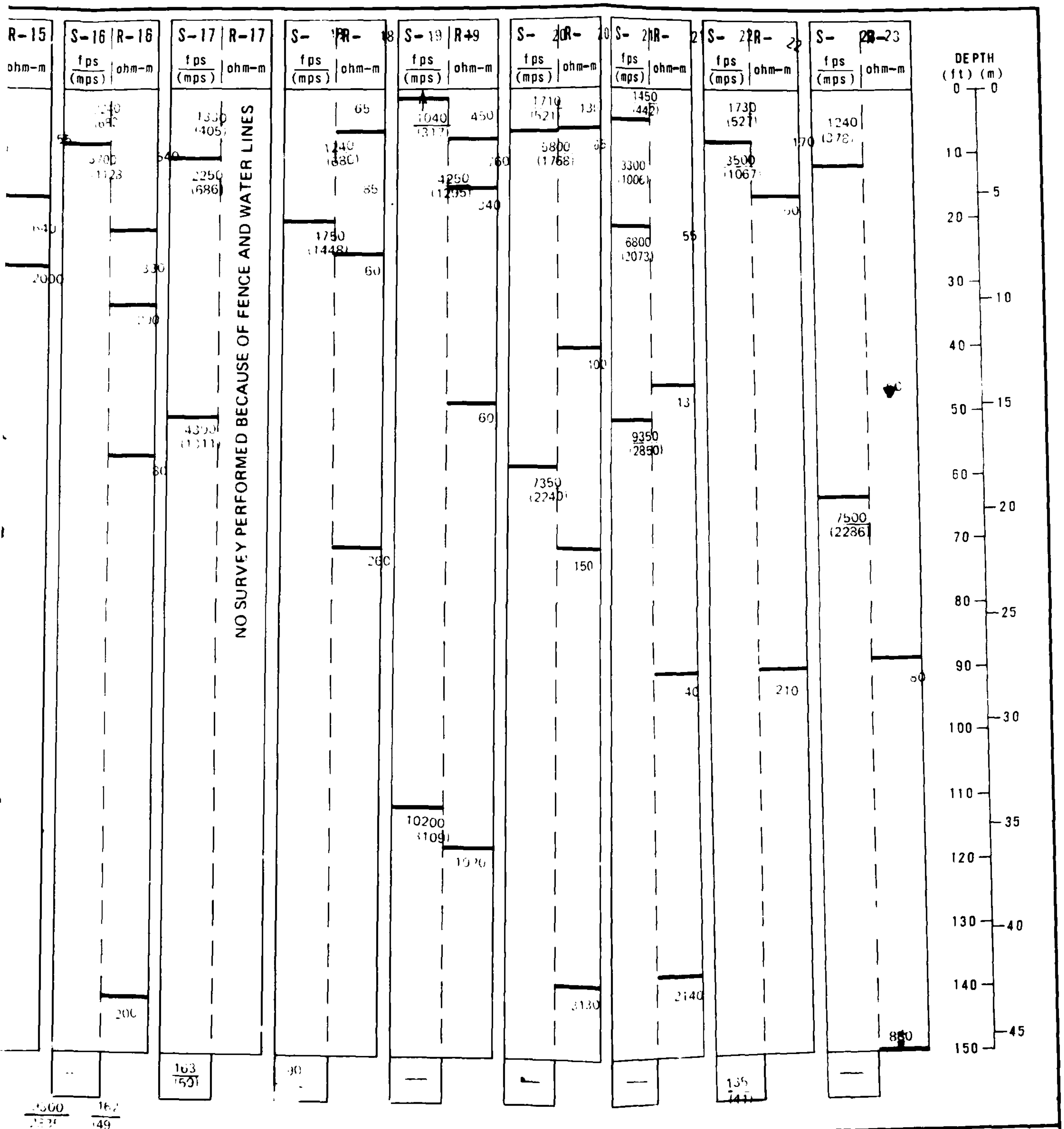
FUGRO NATIONAL, INC.



* Approximate depth above which there is no indication of material with a velocity as great as 7000 fps (2134 mps) See Appendix A for an explanation of how this exclusion depth is calculated when the observed velocities are all less then 7000 fps (2134 mps).



S-9 | R-9
S-10 | R-10
S-11 | R-11
S-12 | R-12
S-13 | R-13
S-14 | R-14
S-15 | R-15
S-16 | R-16
S-17 | R-17
fps (mps) | ohm-m
NO SURVEY PERFORMED BECAUSE OF FENCE AND WATER LINES
4350 (1326)
8250 (2515)
10450 (3185)
2650 (808)
4750 (1448)
260
3480



SEISMIC REFRACTION AND
ELECTRICAL RESISTIVITY RESULTS
PINE VALLEY, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE BMO	TABLE 3-3

FUGRO NATIONAL, INC.

AFV-16

DEPTH RANGE	2' - 20' (0.6 - 6.0m)	
SOIL DESCRIPTION	Coarse-grained soils	Fine-grained soils
	Sandy Gravels, Gravelly Sands, Sands, Silty Sands, and Clayey Sands	Sandy Silts and Sandy Clays
USCS SYMBOLS	GW, GP, GM, SW, SP, SM, SC,	ML, CL, MH
ESTIMATED EXTENT IN SUBSURFACE %	90 - 95	5 - 10
PHYSICAL PROPERTIES		
DRY DENSITY pcf (kg/m³)	91.4 - 136.5 (1464 - 2187) [29]	90.8 (1455)
MOISTURE CONTENT %	2.6 - 24.2 [30]	15.7
DEGREE OF CEMENTATION	none to strong	none to moderate
COBBLES 3 - 12 inches (8 - 30 cm) %	0 - 30	0
GRAVEL %	0 - 81 [57]	0 - 9
SAND %	14 - 94 [57]	13 47
SILT AND CLAY %	1 - 50 [57]	53 - 87
LIQUID LIMIT	35 - 37 [2]	27 - 62
PLASTICITY INDEX	NP - 16 [3]	NP - 22
COMPRESSIONAL WAVE VELOCITY fps (mps)	1220 - 5800 (372 - 1768) [44]	NDA
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION S_u - ksf (kN/m²)	NDA	NDA
TRIAXIAL COMPRESSION c - ksf (kN/m²), ø°	NDA	NDA
DIRECT SHEAR c - ksf (kN/m²), ø°	C = 0. ø > 45* [2]	NDA

NOTES:

- Characteristics of soils between 2 and 20 feet (0.6 and 6.0 meters) are based on results of tests on samples from 8 borings, 13 trenches, and 10 test pits, and results of 23 seismic refraction surveys.
- Characteristics of soils below 20 feet (6.0 meters) are based on results of tests on samples from 8 borings and results of 23 seismic refraction surveys.

- [ ] - Number of tes
- NDA - No data availab
- * - High angle due to l

6 - 6.0m)	20' - 160' (6.0 - 49.0m)	
Fine-grained soils	Coarse-grained soils	Fine-grained soils
Sandy Silts and Sandy Clays	Sandy Gravels, Gravelly Sands, Sands, and Silty Sands	NDA
ML, CL, MH	GW, GP, SW, SP, SM,	
5 - 10	90 - 95	
90.8 (1455) [1]	94.3 - 139.7 (1519 - 2238) [93]	
15.7 [1]	3.9 - 21.7 [93]	
none to moderate	none to strong	
0	0 - 30	
0 - 9 [5]	0 - 53 [40]	
13 - 47 [5]	36 - 91 [40]	
53 - 87 [5]	4 - 36 [40]	
27 - 62 [3]	58 [1]	
NP - 22 [4]	17 [1]	
NDA	1240 - 5950 (378 - 1814) [31]	
NDA	NDA	
NDA	NDA	
NDA	C = 0, ∅ = 40 - > 45* [5]	

- [ ] - Number of tests performed.
- NDA - No data available (insufficient data or tests not performed.)

* - High angle due to large gravels and/or cementation.

2

CHARACTERISTICS OF SUBSURFACE SOILS
PINE VALLEY, UTAH

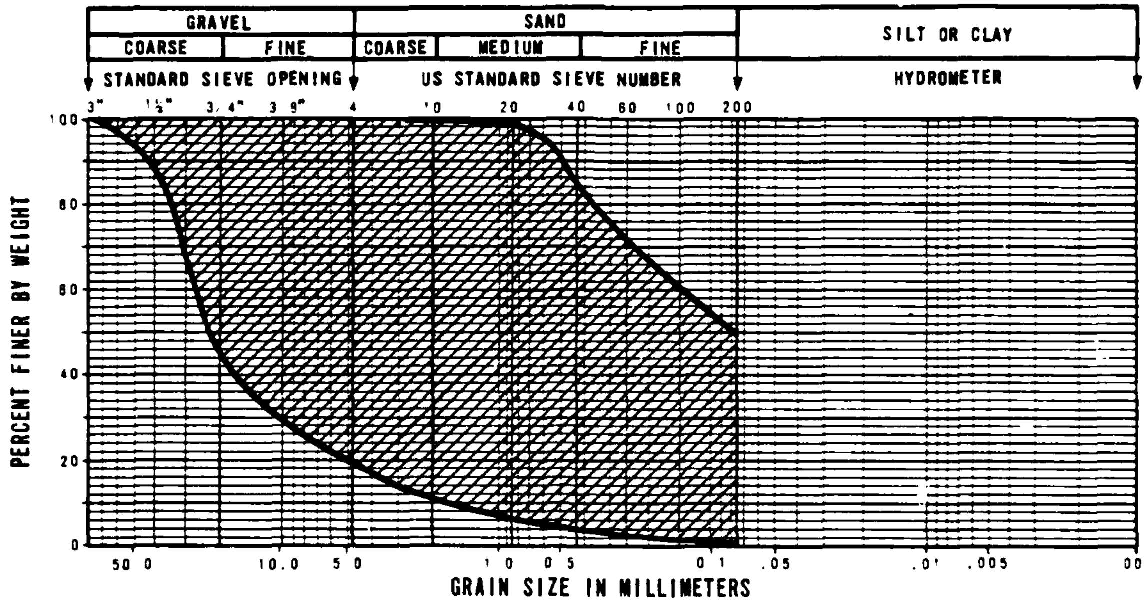
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 3-4

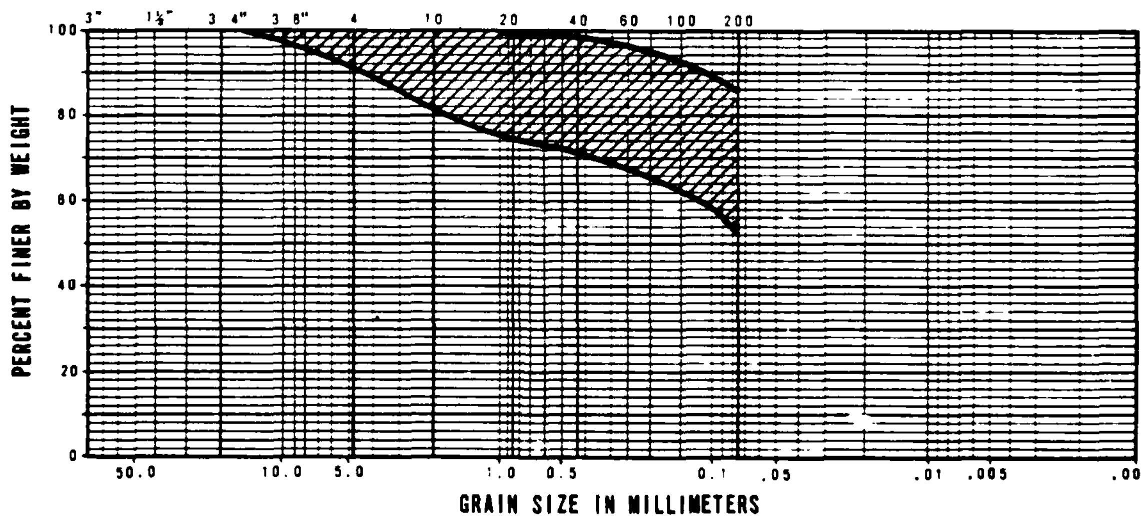
FUGRO NATIONAL, INC.

AFV-20

FN-TR-27-PI-I



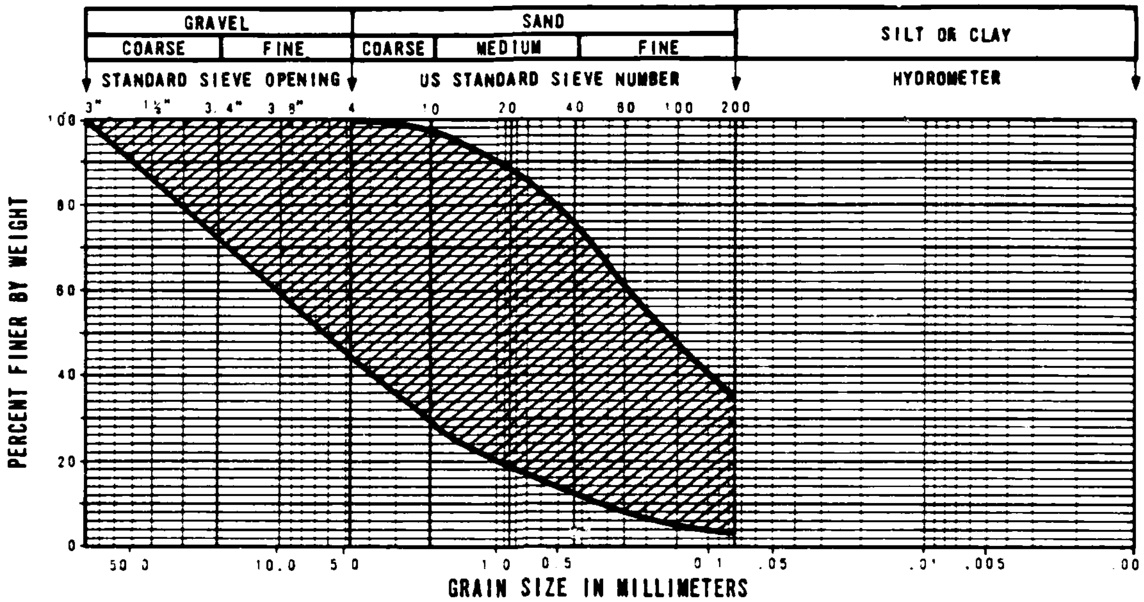
SOIL DESCRIPTION: Coarse - Grained Soils
from 2 to 20 feet (0.6 to 6.0m)



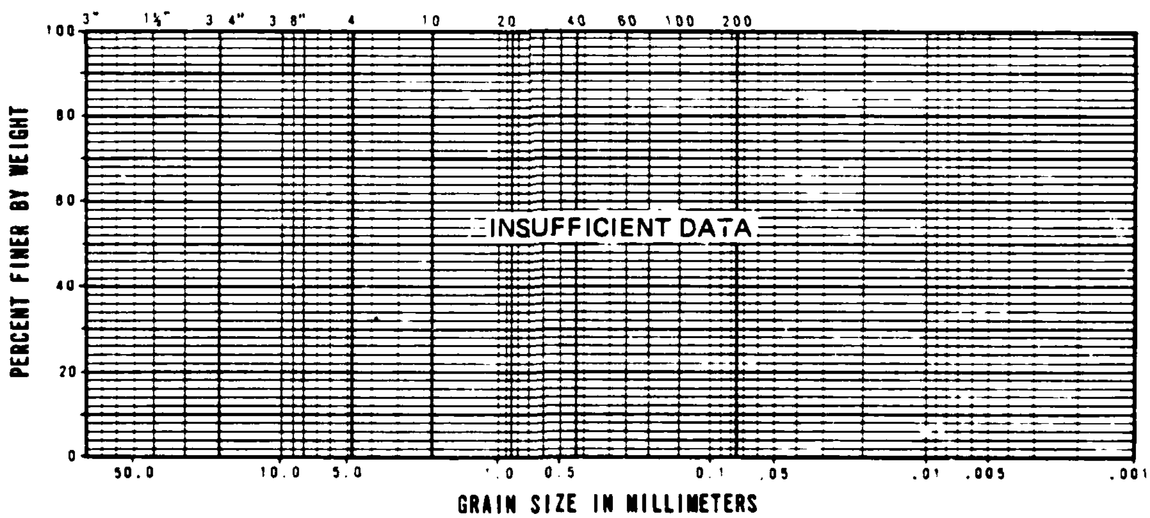
SOIL DESCRIPTION: Fine - Grained Soils
from 2 to 20 feet (0.6m to 6.0m)

RANGE OF GRADATION OF SUBSURFACE SOILS PINE VALLEY, UTAH	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	FIGURE 3-7 1 OF 2

FUGRO NATIONAL, INC.



SOIL DESCRIPTION: Coarse - Grained Soils
from 20 to 160 feet (6.0 to 49.0m)



SOIL DESCRIPTION: Fine - Grained Soils
from 20 to 160 feet (6.0 to 49.0m)

RANGE OF GRADATION OF SUBSURFACE SOILS
PINE VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE
3-7
2 OF 2

FUGRO NATIONAL, INC.

AD-A112 848 FUGRO NATIONAL INC LONG BEACH CA F/G 8/7

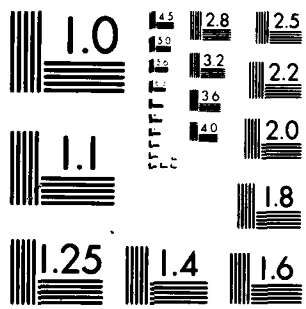
MX SITING INVESTIGATION GEOTECHNICAL EVALUATION VERIFICATION ST--ETC(U)

MAR 81 F04704-80-C-0006

UNCLASSIFIED FN-TR-27-PI-1 NL

2 OF 3

AD A112848



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

The soils in the construction zone (120 feet [37 m]) have a wide range of seismic compressional wave velocities (1220 to 5950 fps [372 to 1814 mps]), depending on their composition, consistency, cementation, and moisture content. Seismic compressional wave velocities were measured in only coarse-grained soils. Generally, velocities in fine-grained soils are found to be substantially lower than those in coarse-grained soils. Compressional wave velocities for deeper materials are also listed in Table 3-3. The soil types represented by these velocities are unknown.

Electrical conductivity measured for the soils in the upper 50 feet (15 m) ranged from 0.0009 to 0.0305 mhos per meter (average 0.0109 mhos per meter). At four of the 22 measurement locations, the measured conductivities were less than the minimum value of 0.004 mhos per meter specified in the Fine Screening criteria.

Results of chemical tests indicate that potential for sulfate attack of soils on concrete will range from "negligible" to "mild."

3.5 DEPTH TO ROCK

Drawing 3-3 shows the approximate configuration of 50- and 150-foot (15- and 46-m) depth-to-rock contours in Pine Valley. This interpretation is based on limited point data from borings, seismic refraction surveys, site-specific published data, and depths inferred from geologic and geomorphic relationships.

Contours generally parallel exposed rock in the valley. Approximately 13 percent of the basin-fill material in the valley is interpreted to be underlain by rock at depths of less than 50 feet (Table 2-1). An additional eight percent of the valley is interpreted to contain shallow rock between depths of 50 and 150 feet (15 to 46 m).

The rock-alluvium contact on the western side of the valley is highly irregular. Volcanic rocks were found cropping out as far as a mile into the valley. Consequently, the area where rock is interpreted to be shallower than 50 feet (15 m) forms a strip varying from one-quarter mile (0.4 km) to 2 miles (3.2 km) in width along the entire western margin. An outcrop of rock in the west-central part of the valley about 4 miles (6.4 km) from the mountain front is interpreted to be surrounded by a narrow belt of shallow rock.

The eastern side of the valley is characterized by a fairly regular mountain front interrupted by long, narrow reentrant canyons. These canyons contain fluvial sediments interpreted to be thin veneers over bedrock.

Subsurface data concerning depth to rock were obtained from several borings located in the valley. Nine water wells (Drawing 3-4) have been drilled by others to depths ranging from 140 to 2006 feet (43 to 611 m) without encountering rock. Boring WR-0-4 drilled by the FNI Water Resources program (FNI, 1981b) reached a depth of 1157 feet (353 m) without penetrating rock.

3.6 DEPTH TO WATER

Drawing 3-4 shows the approximate locations of all data points used to define ground-water conditions in Pine Valley. The sources of these data, in addition to FNI activities, are the Utah State Engineer's Office (1979), and Stephens (1976).

Nine existing wells in the basin-fill materials indicate that ground water exists at a depth generally greater than 300 feet (91 m). One well, W-5 (Drawing 3-4 and Volume II, Table II-2-1), on the eastern side of the valley, shows a depth to water of 50 feet (15 m); this probably indicates local perched water, a condition which may be similar in other reentrant canyons. The only 50- and 150-foot (15- and 46-m) depth-to-water contours in Drawing 3-4 are around this well.

3.7 TERRAIN

3.7.1 Terrain Exclusions

Terrain conditions are shown in Drawing 3-5. Areas designated as terrain exclusions are considered to be unsuitable based on a combination of field-derived and office-derived data which were evaluated versus the criteria in Appendix A2-1. Field derived exclusions include: 1) areas having very steep slopes, such as the sides of major drainages; and 2) areas in which incisions deeper than 10 feet (3 m) are spaced closer than 1000 feet (305 m) apart. Office-derived exclusions were primarily those areas that could be identified on topographic maps as having topographic slopes greater than 10 percent. In some places where road access was not adequate for field work, office analysis of aerial photographs was used to identify and exclude areas of rugged or adverse terrain. However, preference was given to determining such exclusions in the field. Because they require special consideration in planning construction and operations, areas where slopes exceed five percent are shown in Drawing 3-5 even though these areas are considered to be suitable.

Narrow bands of terrain exclusions are mapped on the western side of Pine Valley bordering deeply incised major tributaries to Pine Valley Wash, the main axial drainage. In the central portion of the valley, the wash itself is bordered by similar exclusions. Much of the eastern side of the valley adjacent to the mountains, and most of the valley's southern end, are excluded primarily on the incision depth-spacing criteria (field derived) modified by 10 percent slope exclusions. Ten percent slope exclusions are numerous along the western side of the valley, but the total area excluded is relatively small.

3.7.2 Incision Depths and Number of Drainages Per Mile

Information on incision depths and drainages encountered per mile within the suitable areas was obtained from field observations; the number of drainages per mile was determined based on both field observations and aerial photographic interpretation. These data were analyzed versus the prevalent surficial geologic units. The results are shown in Table 3-5. Average values of the two drainage characteristics are listed for each prevalent surficial unit with further breakdowns providing data

SURFICIAL GEOLOGIC UNIT		AVERAGE NUMBER OF DRAINAGES PER MILE			
		WESTERN SIDE OF VALLEY		EASTERN SIDE OF VALLEY	
		SURFACE SLOPE, %		SURFACE SLOPE, %	
		0-5	5-10	0-5	5-10
A5os		—	—	—	—
A5is		6.1 (2.7)	—	8.6 (2.7)	10.6 (1.8)
A5ys		5.5 (2.3)	—	—	—
A4os		2.5 *	—	2.2 (1.2)	—
A1	s	3.0*	—	—	—
	f	3.0*	—	—	—

NOTE: DRAINAGES WERE COUNTED ALONG A ONE-MILE LINE PERPENDICULAR TO THE DRAINAGE DIRECTION

SURFICIAL GEOLOGIC UNIT		AVERAGE DEPTH OF INCISIONS			
		WESTERN SIDE OF VALLEY		EASTERN SIDE OF VALLEY	
		SURFACE SLOPE, %		SURFACE SLOPE, %	
		0-5	5-10	0-5	5-10
A5os		—	8.0 ft * 2.4 m	—	—
A5is		7.2 ft (5.1 ft) 2.2 m (1.6 m)	8.6 ft (6.4 ft) 2.6 m (2.0 m)	5.8 ft (3.4 ft) 1.8 m (1.0 m)	5.1 ft (1.6 ft) 2.4 m (0.7 m)
A5ys		2.0 ft * 0.6 m	—	3.3 ft (1.3 ft) 1.0 m (0.4 m)	3.0 ft * 0.9 m
A4os		—	—	—	—
A1	s	15.1 ft (9.7 ft) 4.6 m (3.0 m)	—	12.0 ft (13.3 ft) 3.7 m (4.1 m)	—
	f	—	—	—	—

- * LIMITED DATA (6 ≤ n ≤ 10) VALUE IS MEDIAN, NO STANDARD DEVIATION
- — NO DATA OR INSUFFICIENT DATA (n < 6)
- ( ) STANDARD DEVIATION
- A5o OLD-AGE ALLUVIAL FANS
- A5i INTERMEDIATE-AGE ALLUVIAL FANS
- A5y YOUNG-AGE ALLUVIAL FANS
- A4o LACUSTRINE DEPOSITS
- A1 FLUVIAL DEPOSITS
- s SANDS
- f FINES; CLAYS, SILTS

DRAINAGES PER MILE AND DEPTH OF INCISIONS IN PREVALENT SURFICIAL GEOLOGIC UNITS PINE VALLEY, UTAH

MX SITING INVESTIGATION

DEPARTMENT OF THE AIR FORCE — BMO

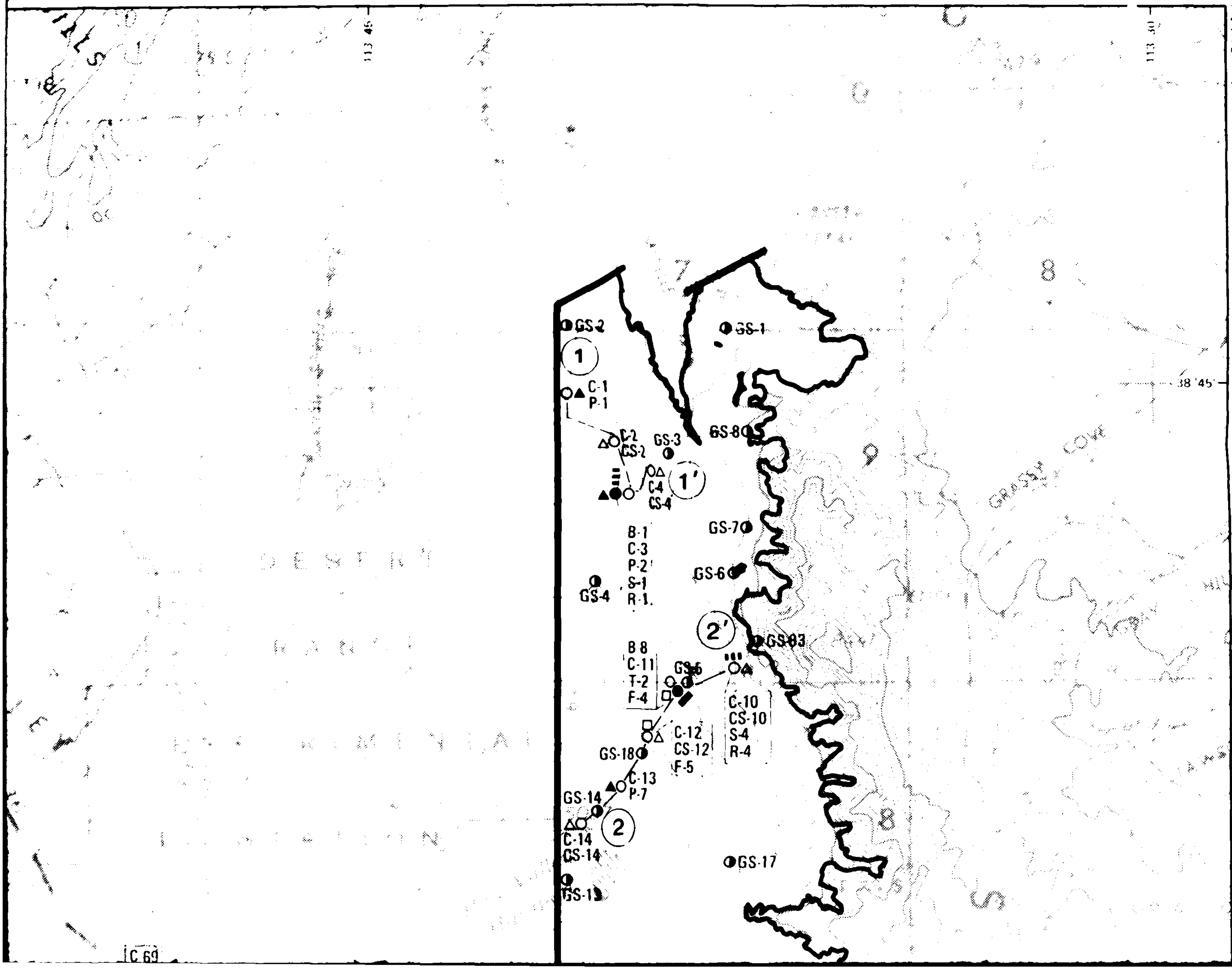
TABLE 3-5

FUGRO NATIONAL, INC.

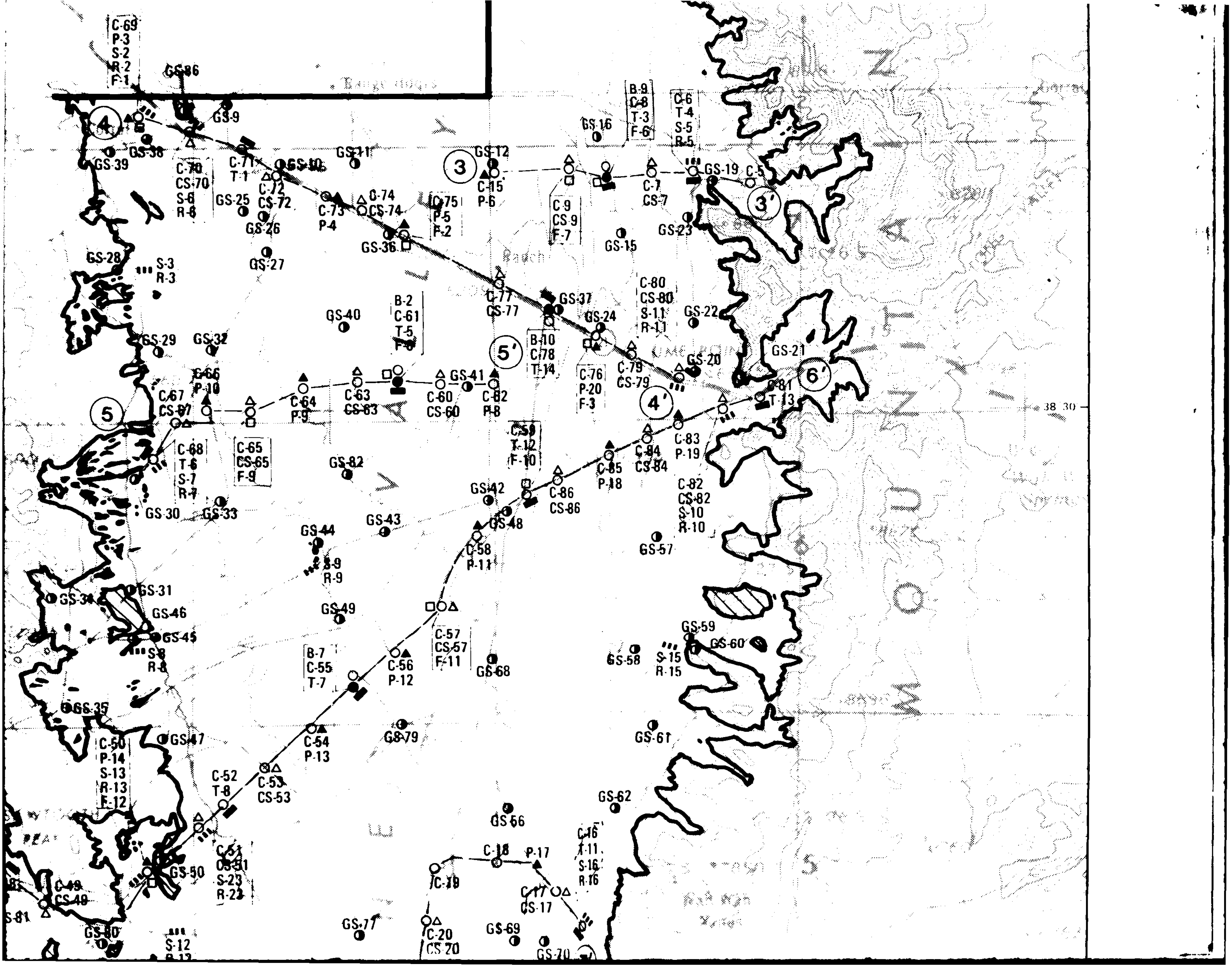
on 1) characteristics in the unit on the eastern side of the valley axial drainage versus those on the western side; and 2) characteristics of the unit where its surface slopes are between five and 10 percent versus places where its slope is less than five percent.

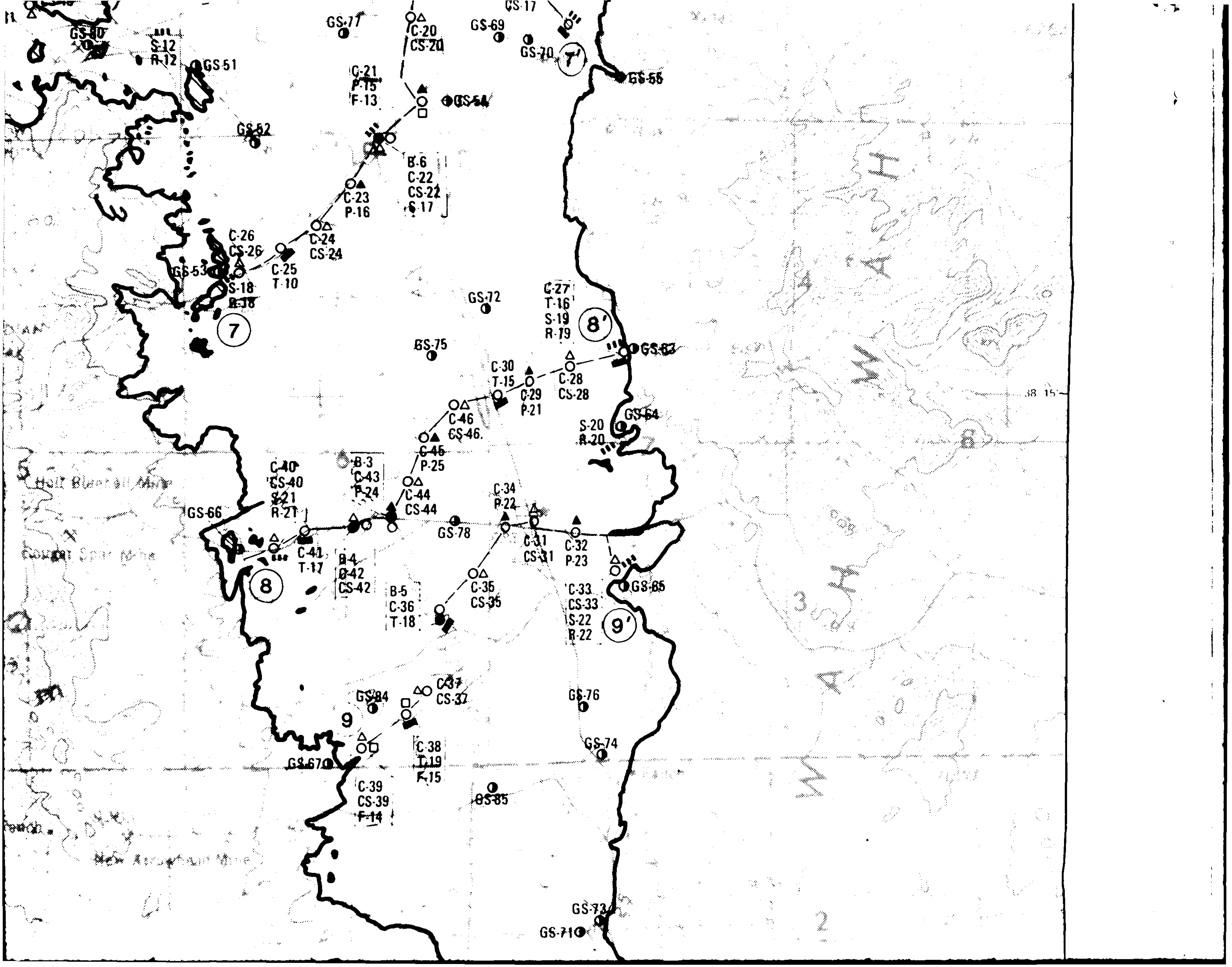
The small areal extent of some of the surficial units resulted in no data or such a limited amount that it was insufficient for analysis. The available data show that from the standpoint of drainages, the intermediate-age fan unit (A5i) will present the most concerns for deployment of the MX system. The drainages in this unit are among the deepest found and occur at a considerably higher rate per mile than those in other units. Drainages in this unit are the western side of the valley are typically deeper than on the eastern side, but they occur more frequently on the eastern side.

The only other geologic units in Pine Valley that present any potentially significant concern with regard to drainages are the fluvial deposits (A1). These deposits contain the deepest drainages, but they occur much less frequently than the drainages in the A5i deposits.

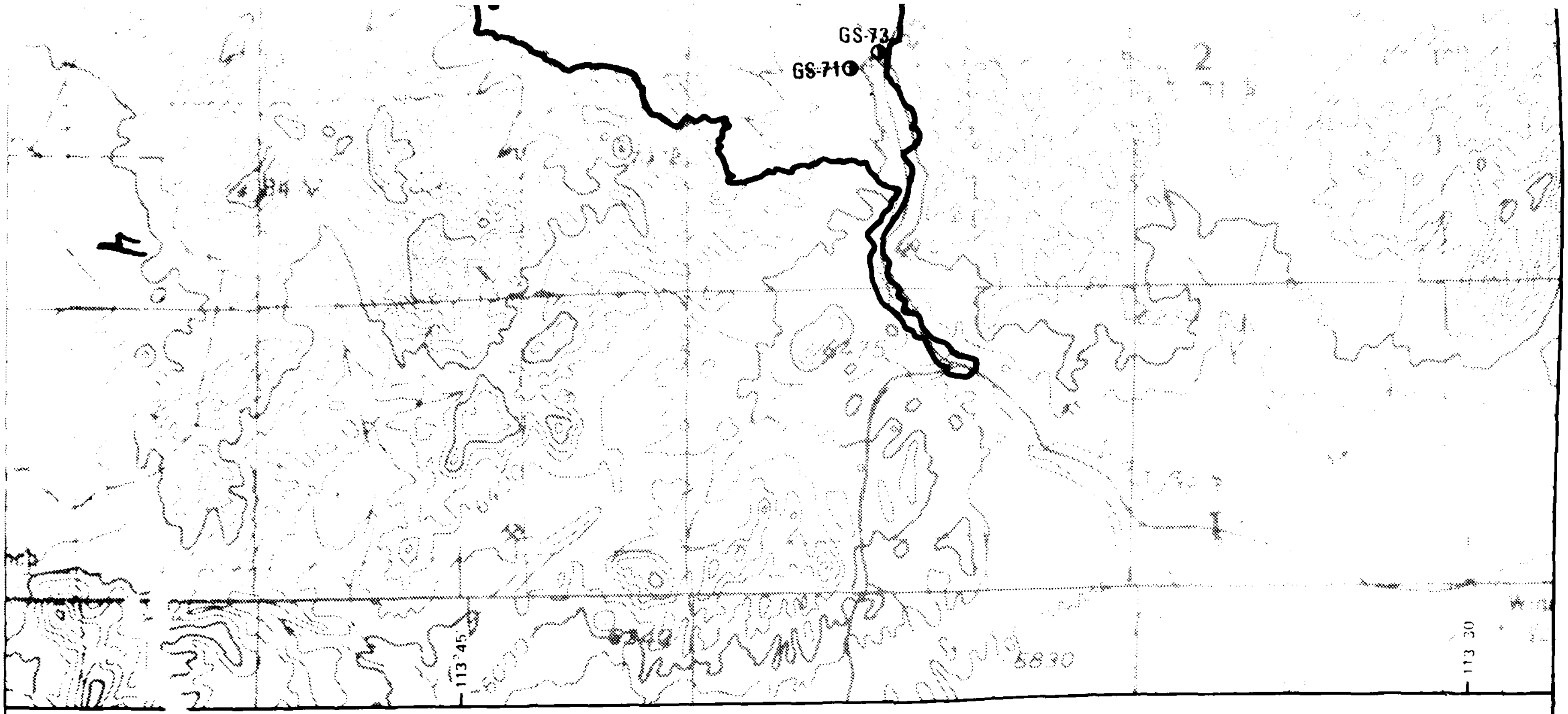


113 45
113 30
38 45
GS-2
GS-1
1
C-1
P-1
C-2
CS-2
GS-3
GS-8
C-4
CS-4
1'
GS-7
B-1
C-3
P-2
S-1
R-1
GS-4
GS-6
2'
GS-83
B-8
C-11
T-2
F-4
GS-5
C-10
CS-10
S-4
R-4
C-12
CS-12
F-5
GS-18
C-13
P-7
GS-14
2
C-14
CS-14
GS-17
GS-13
GRASSY COVE
C 69


C-69
P-3
S-2
R-2
F-1
GS-86
GS-9
4
GS-39
GS-38
C-70
CS-70
S-6
R-6
C-71
T-1
GS-25
C-72
CS-72
GS-26
GS-10
GS-11
C-73
P-4
C-74
CS-74
C-75
P-5
F-2
GS-36
GS-27
GS-28
S-3
R-3
3
GS-12
C-15
P-6
C-9
CS-9
F-7
GS-16
B-9
C-8
T-3
F-6
C-6
T-4
S-5
R-5
C-7
CS-7
GS-19
C-5
3′
GS-23
GS-15
C-77
CS-77
GS-37
C-80
CS-80
S-11
R-11
GS-22
GS-24
GS-40
B-2
C-61
T-5
F-8
5′
B-10
C-78
T-14
C-76
P-20
F-3
C-79
CS-79
GS-20
GS-21
6′
C-81
T-13
GS-29
GS-32
C-66
P-10
C-67
CS-67
5
C-64
P-9
C-63
CS-63
C-60
CS-60
GS-41
C-62
P-8
4′
C-83
P-19
38 30
C-68
T-6
S-7
R-7
C-65
CS-65
F-9
GS-82
C-59
T-12
F-10
C-84
CS-84
C-85
P-18
C-82
CS-82
S-10
R-10
GS-30
GS-33
GS-42
C-86
CS-86
GS-43
GS-44
GS-48
S-9
R-9
C-58
P-11
GS-57
GS-34
GS-31
GS-46
GS-45
S-8
R-8
GS-49
C-57
CS-57
F-11
GS-59
GS-60
B-7
C-55
T-7
C-56
P-12
GS-68
GS-58
S-15
R-15
GS-35
GS-79
GS-61
GS-47
C-50
P-14
S-13
R-13
F-12
C-54
P-13
C-52
T-8
C-53
CS-53
GS-62
GS-66
C-51
CS-51
S-23
R-23
GS-50
C-16
T-11
S-16
R-16
C-18
P-17
C-19
C-49
CS-49
S-81
C-17
CS-17
GS-80
S-12
GS-77
C-20
CS-20
GS-69
GS-70



GS-77
C-20
CS-20
GS-69
GS-17
GS-70
7'
GS-55
S-12
R-12
GS-51
C-21
P-15
F-13
GS-54
GS-52
B-6
C-22
CS-22
S-17
C-23
P-16
C-24
CS-24
C-26
CS-26
C-25
T-10
GS-53
S-18
R-18
7
GS-72
C-27
T-16
S-19
R-19
8'
GS-63
GS-75
C-30
T-15
C-29
P-21
C-28
CS-28
C-46
CS-46
GS-64
S-20
R-20
C-45
P-25
B-3
C-43
P-24
C-44
CS-44
C-40
CS-40
S-21
R-21
GS-66
C-34
P-22
GS-78
C-41
T-17
B-4
C-42
CS-42
C-31
CS-31
C-32
P-23
8
B-5
C-36
T-18
C-35
CS-35
C-33
CS-33
S-22
R-22
GS-65
9'
C-37
CS-37
GS-84
GS-76
9
C-38
T-19
F-15
GS-67
GS-74
C-39
CS-39
F-14
GS-85
GS-73
GS-71
W
A
H
3
2
38 15
Holt Bluebell Mine
Cougar Spar Mine
New Aerospace Mine



EXPLANATION

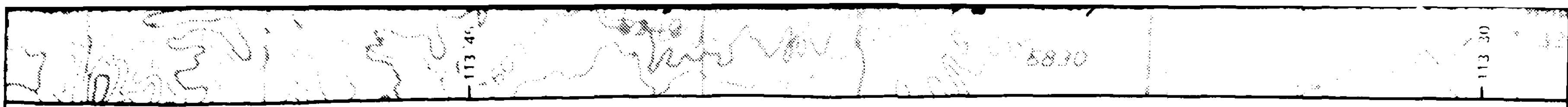
◐	GS-1	GEOLOGIC STATION
●	B-1	BORING
○	C-1	CONE PENETROMETER TEST (CPT)
△	CS-1	SURFICIAL SOIL SAMPLE
▬	T-1	TRENCH
▲	P-1	TEST PIT
•••	S-1	SEISMIC REFRACTION LINE
	R-1	ELECTRICAL RESISTIVITY SOUNDING
□	F-1	FIELD CALIFORNIA BEARING RATIO (CBR) TEST

NORTH

SCALE 1:125,000

0 2 4

STATUTE MILES



EXPLANATION

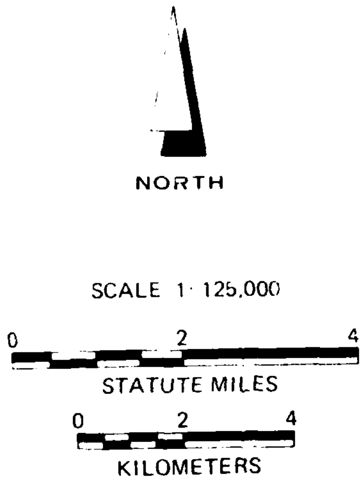
●	GS-1	GEOLOGIC STATION
●	B-1	BORING
○	C-1	CONE PENETROMETER TEST (CPT)
△	CS-1	SURFICIAL SOIL SAMPLE
▬	T-1	TRENCH
▲	P-1	TEST PIT
▪▪▪	S-1	SEISMIC REFRACTION LINE
	R-1	ELECTRICAL RESISTIVITY SOUNDING
□	F-1	FIELD CALIFORNIA BEARING RATIO (CBR) TEST
1 — — 1'		ACTIVITY LINE

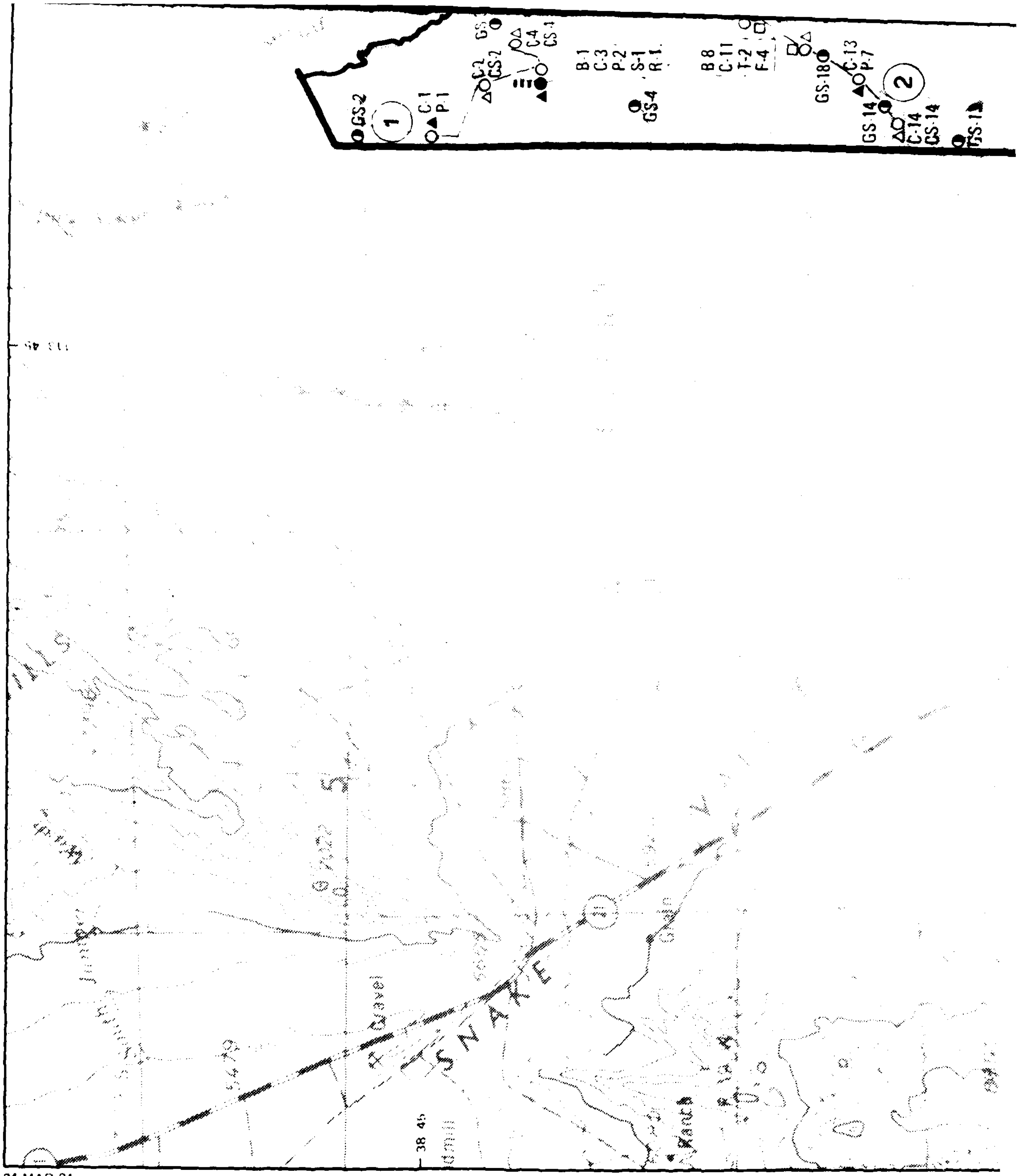
Contact between rock and basin fill.

Valley border (north and west).

Areas of isolated exposed rock.

NOTE Where multiple activities were performed at the same location, the correct location is designated by either (1) the boring symbol or (2) CPT symbol, if no boring was drilled.

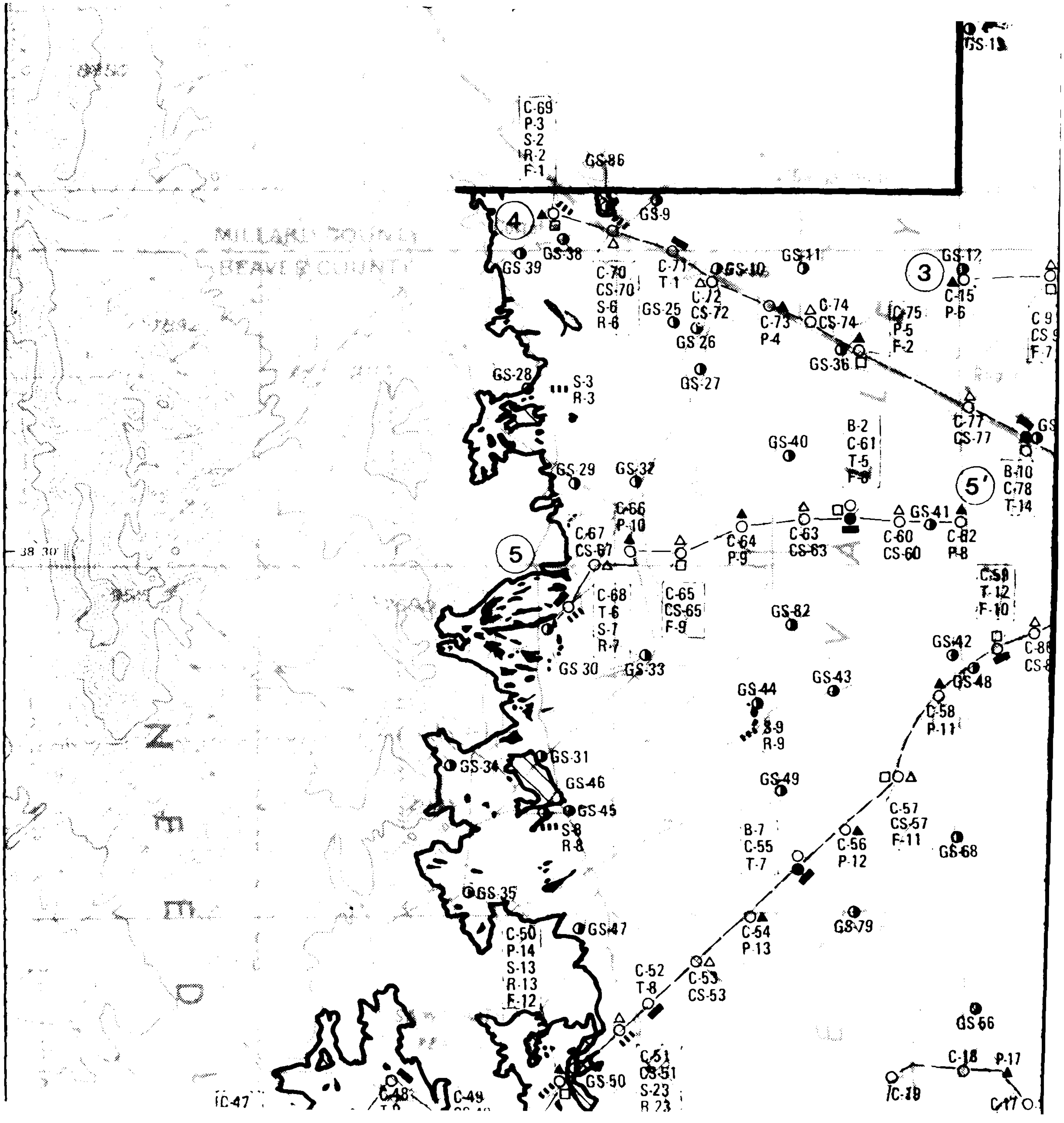



GS-2
C-1
P-1
1
C-2
GS-2
C-4
GS-1
B-1
C-3
P-2
S-1
R-1
GS-4
B-8
C-11
T-2
F-4
GS-18
C-13
P-7
2
GS-14
C-14
GS-14
SNAKE
Gravel
38 45
Ranch

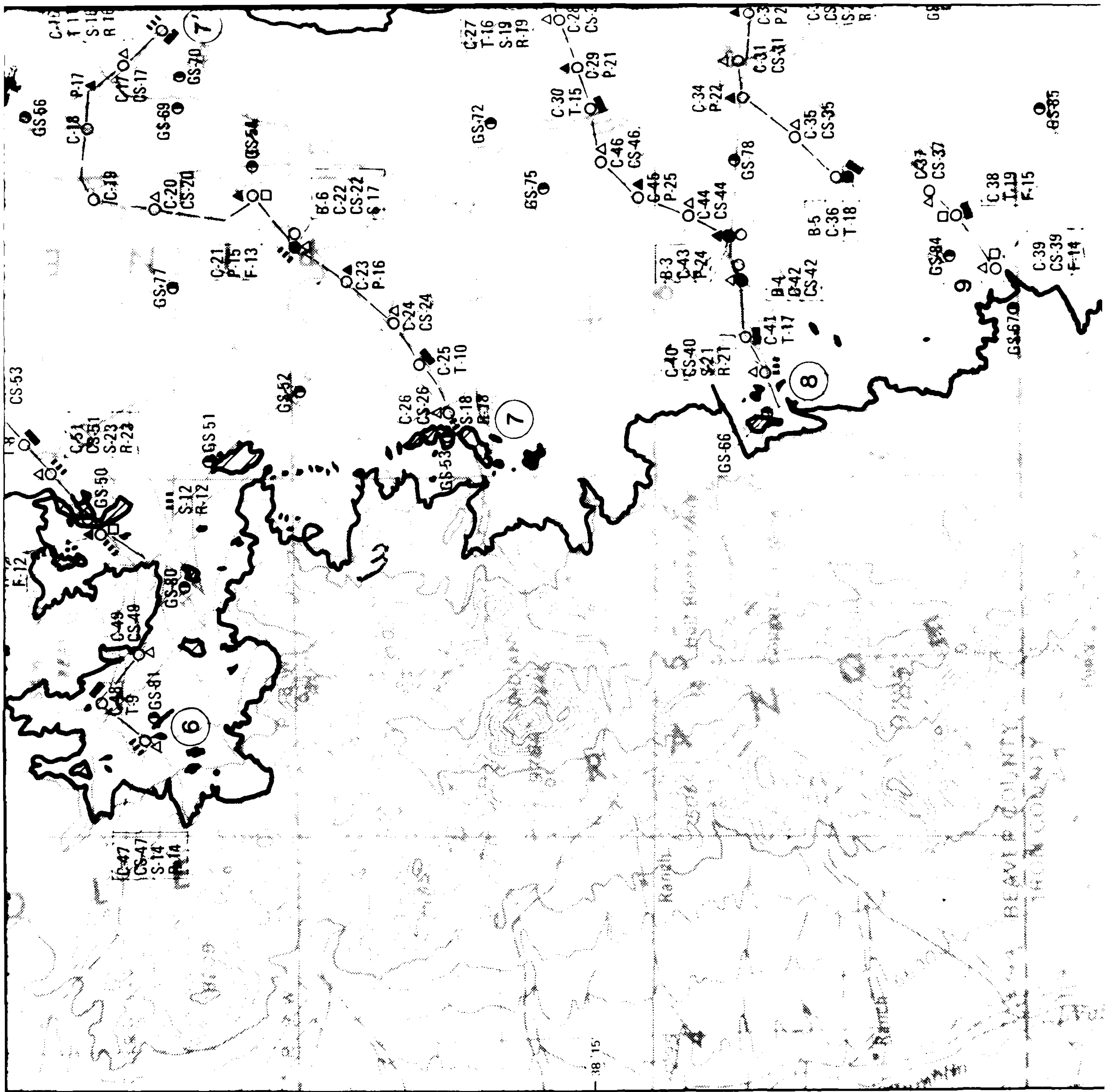
24 MAR 81

1

6

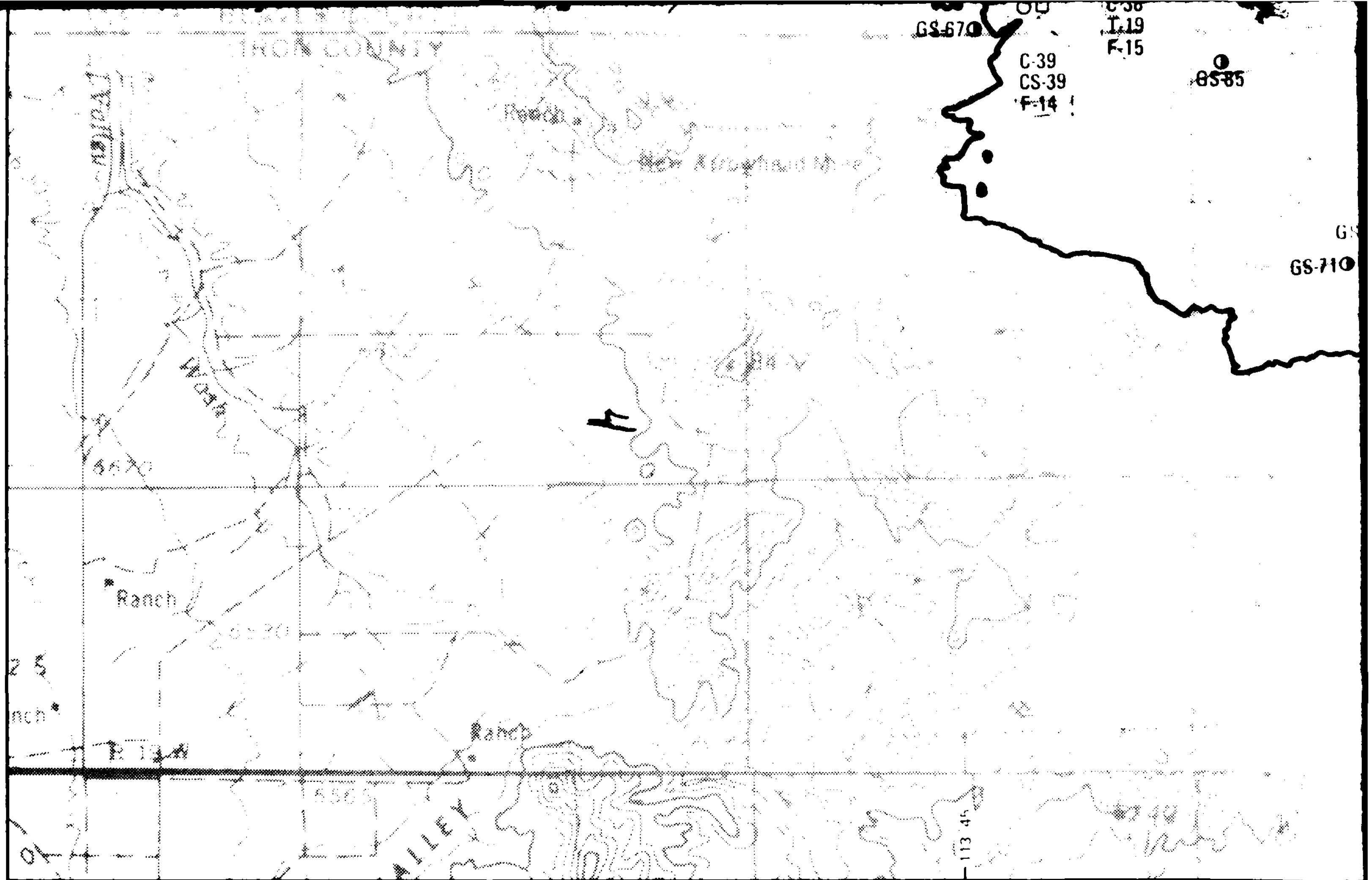

MILLARD COUNTY
BEAVER COUNTY
38°30'
N
E
E
D
3
4
5
5'
C-69
P-3
S-2
R-2
F-1
GS-86
GS-9
GS-38
GS-39
C-70
CS-70
S-6
R-6
C-71
T-1
GS-10
GS-11
GS-12
C-15
P-6
C-72
CS-72
GS-25
GS-26
GS-27
C-73
P-4
C-74
CS-74
C-75
P-5
F-2
GS-36
GS-28
S-3
R-3
C-77
CS-77
B-2
C-61
T-5
GS-40
B-10
C-78
T-14
GS-29
GS-32
C-66
P-10
C-67
CS-67
C-64
P-9
C-63
CS-63
C-60
CS-60
GS-41
C-82
P-8
C-68
T-6
S-7
R-7
C-65
CS-65
F-9
GS-82
C-59
T-12
F-10
GS-30
GS-33
GS-42
GS-48
GS-43
GS-44
S-9
R-9
C-58
P-11
GS-31
GS-34
GS-46
GS-45
S-8
R-8
GS-49
C-57
CS-57
F-11
B-7
C-55
T-7
C-56
P-12
GS-68
GS-35
GS-47
C-54
P-13
GS-79
C-50
P-14
S-13
R-13
F-12
C-52
T-8
C-53
CS-53
GS-66
C-51
CS-51
S-23
R-23
GS-50
C-18
P-17
C-19
C-17
C-47
C-48
C-49
GS-13

7



GS-66
C-18
C-19
C-20
CS-20
GS-69
GS-70
GS-77
C-21
P-15
F-13
B-6
C-22
CS-22
C-23
P-16
C-24
CS-24
C-25
T-10
C-26
CS-26
GS-52
GS-51
S-12
R-12
GS-50
GS-80
C-49
CS-49
C-48
T-9
GS-81
C-47
CS-47
S-14
C-27
T-16
S-19
R-19
GS-72
GS-75
C-29
P-21
C-30
T-15
C-46
CS-46
C-45
P-25
C-44
CS-44
B-3
C-43
P-24
C-40
CS-40
S-21
R-21
GS-66
C-41
T-17
B-4
C-42
CS-42
B-5
C-36
T-18
C-34
P-22
GS-78
C-31
CS-31
C-35
CS-35
C-37
CS-37
C-38
T-19
F-15
C-39
CS-39
F-14
GS-84
GS-85
GS-67
CS-53
S-23
R-23
6
7
8
9
38°15'
Ranch
BEAVER COUNTY
IRON COUNTY

8



EXPLANATION

◐	GS-1	GEOLOGIC STATION
●	B-1	BORING
○	C-1	CONE PENETROMETER TEST (CPT)
△	CS-1	SURFICIAL SOIL SAMPLE
▬	T-1	TRENCH
▲	P-1	TEST PIT

EXPLANATION

◑	GS-1	GEOLOGIC STATION
●	B-1	BORING
○	C-1	CONE PENETROMETER TEST (CPT)
△	CS-1	SURFICIAL SOIL SAMPLE
▬	T-1	TRENCH
▲	P-1	TEST PIT
▮▮▮	S-1	SEISMIC REFRACTION LINE
	R-1	ELECTRICAL RESISTIVITY SOUNDING
□	F-1	FIELD CALIFORNIA BEARING RATIO (CBR) TEST
1 — — 1'		ACTIVITY LINE

Contact between rock and basin fill.

Valley border (north and west).

Areas of isolated exposed rock.

NOTE Where multiple activities were performed at the same location, the correct location is designated by either (1) the boring symbol or (2) CPT symbol, if no boring was drilled.

ACTIVITY LOCATIONS
PINE VALLEY, UTAH

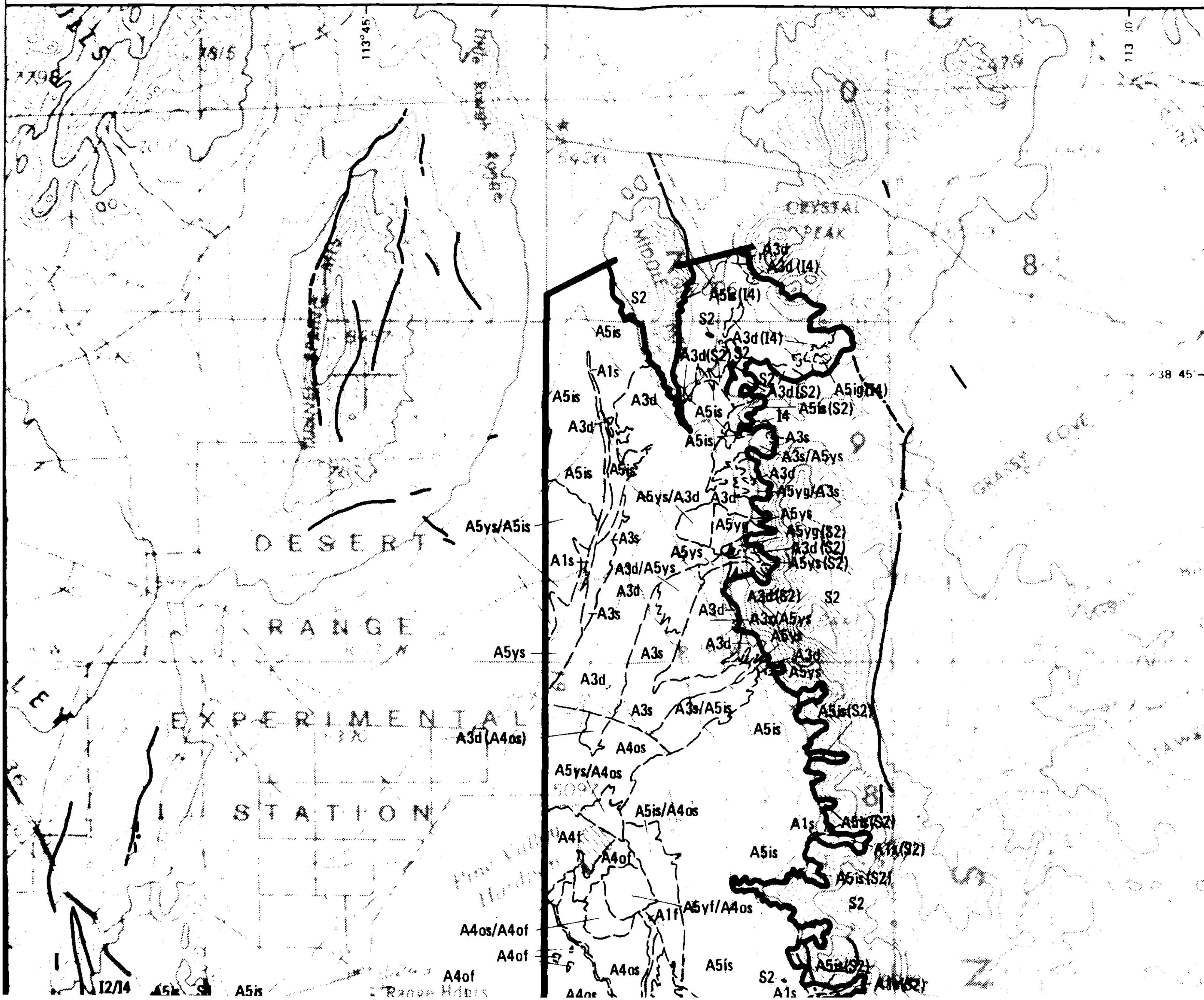
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

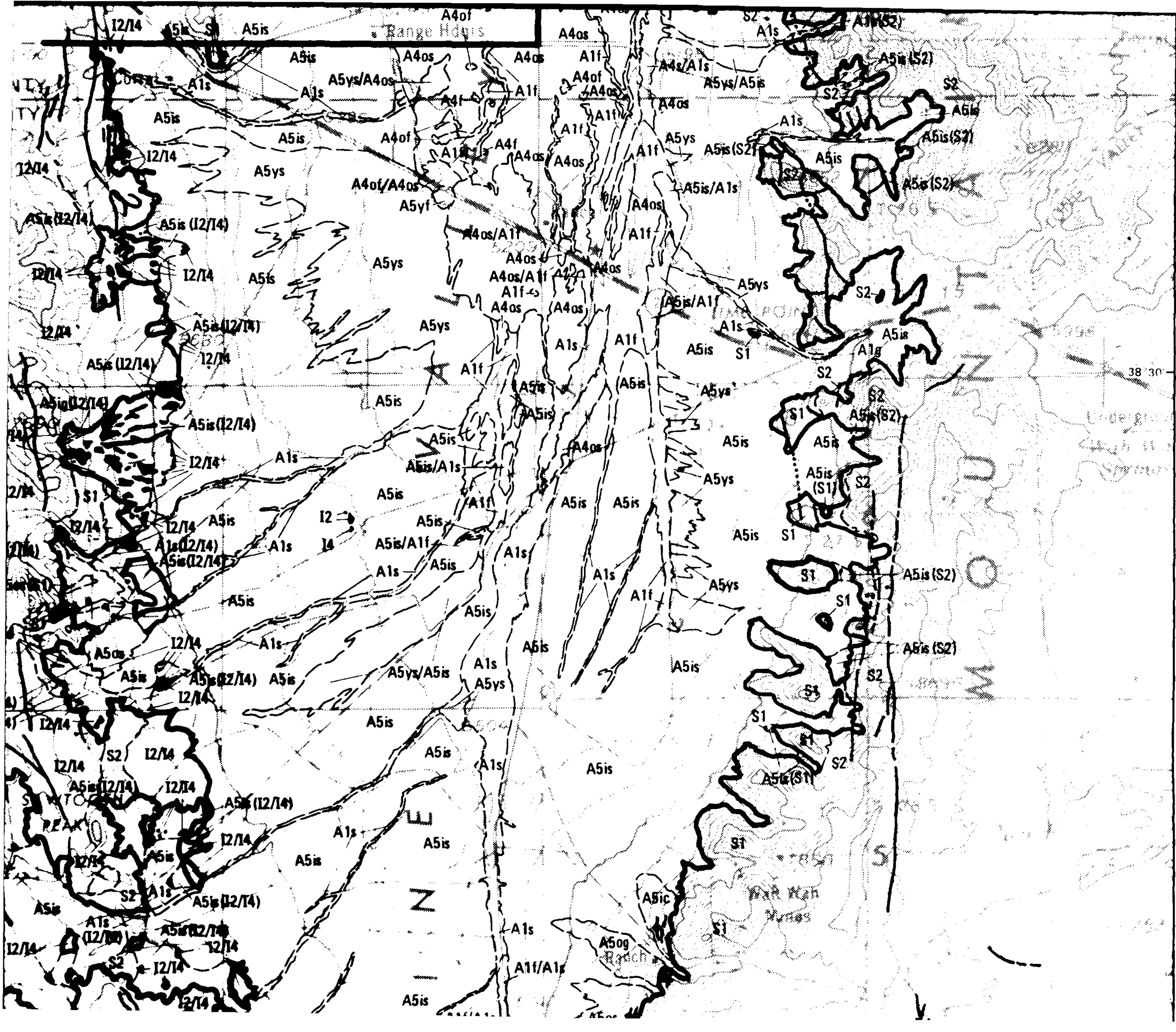
DRAWING 3-1

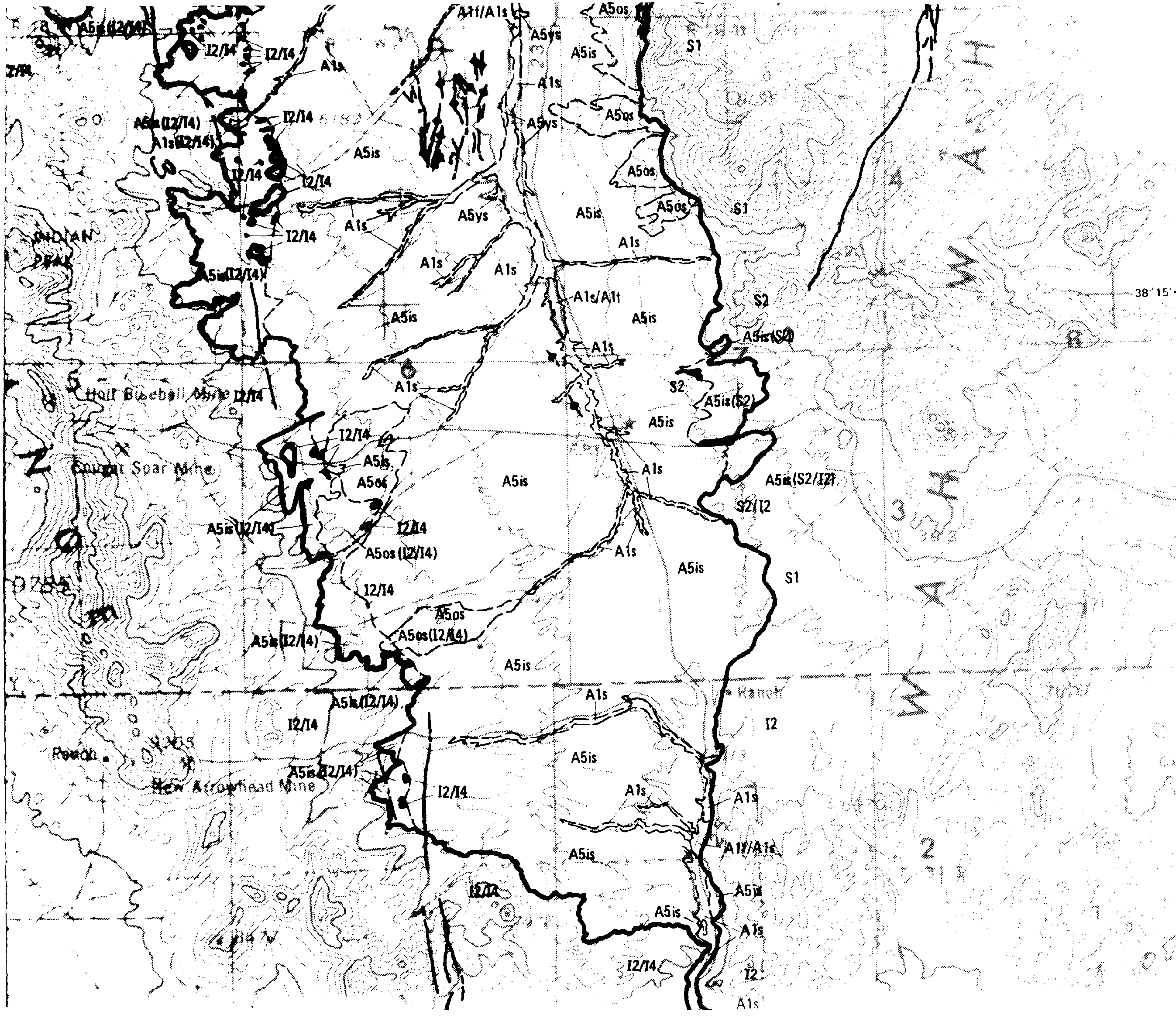
FUGRO NATIONAL, INC.

10

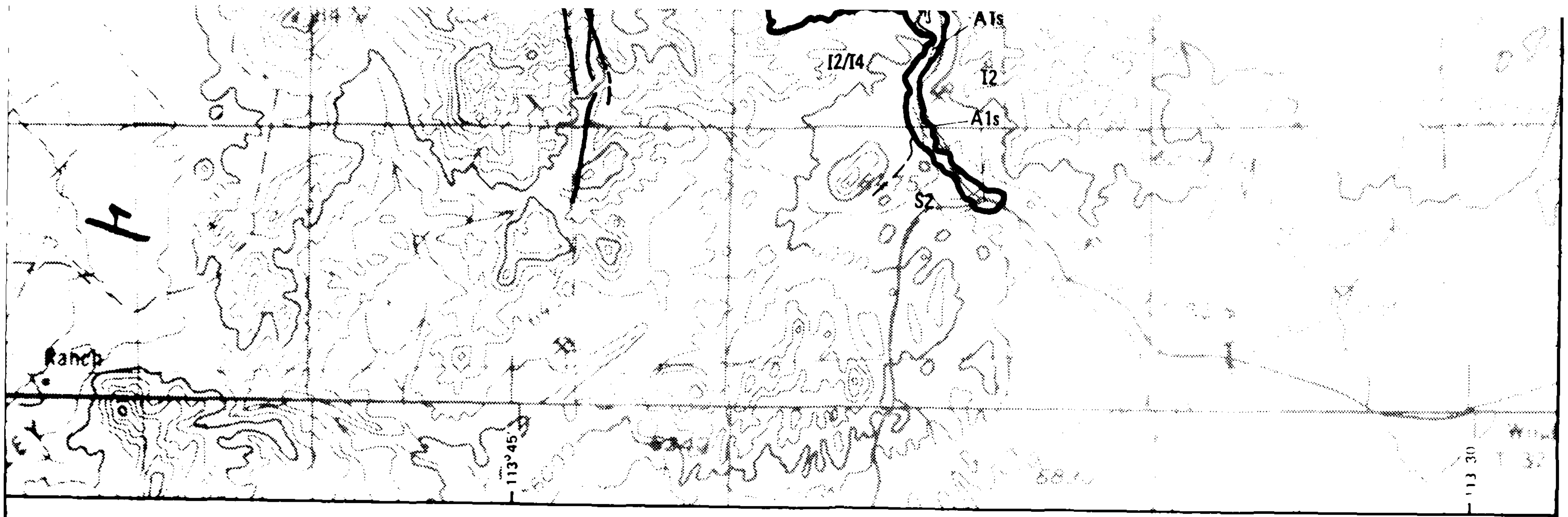
FN-TR-27-PI-I


DESERT
RANGE
EXPERIMENTAL
STATION
CRYSTAL PEAK
MIDDLE
GRASSY COVE
113°45'
38 45'


Range Hdqts
A4of
A4os
A4f
A4s/A1s
A5ys/A4os
A5ys/A5is
A4of/A4os
A5yf
A4os/A1f
A4os/A1f
A5is/A1f
A5is/A1s
A5is/A1s
A5is/A1f
A5ys/A5is
A1f/A1s
A5is (I2/I4)
A5is (S2)
A5is (S1)
A1s (I2/I4)
A5os
A5ic
A5og
A1g
I2/I4
S1
S2
I2
I4
38°30'
Wah Wah
Ranch



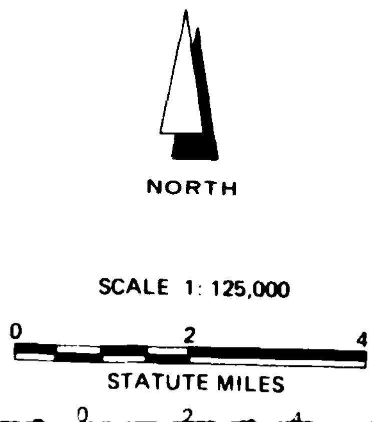
INDIAN PEAK
Holt Bluebell Mine
Cougar Spar Mine
New Arrowhead Mine
Ranch
Ranch
38°15'
A1f/A1s
A5os
A5ys
A5is
A1s
A5is (I2/I4)
I2/I4
A5os (I2/I4)
A1s (I2/I4)
A1s/A1f
S1
S2
A5is (S2)
A5is (S2/I2)
S2/I2
I2
A5os (I2/I4)



EXPLANATION

SURFICIAL BASIN - FILL DEPOSITS

A1f / A1s / A1g	Young fluvial deposits in modern stream channels and on flood plains. A1f - sandy silts and clays; A1s - silty and gravelly sand; A1g - sandy gravels.
A3s / A3d	Eolian (Wind-deposited) sediments. A3s - sheet sands; A3d - dune sands.
A4f / A4s	Young lacustrine (lake) deposits occuring on active playas. A4f - silts and clays; A4s - silty sand.
A4of / A4os	Older lacustrine (lake) deposits. A4of - silts and clays associated with old playas; A4os - silty sands associated with near shore and beach sedimentation.
A5yf / A5ys / A5yg	Young alluvial fans where deposition is now occuring. A5yf - sandy silts and clays; A5ys - silty and gravelly sands; A5yg - sandy gravels.



SCALE 1: 125,000

0 2 4
STATUTE MILES

0 2 4
KILOMETERS

A5yf A5ys A5yg	Young alluvial fans where deposition is now occuring. A5yf - sandy silts and clays; A5ys - silty and gravelly sands; A5yg - sandy gravels.
A5is A5ig A5ic	Alluvial fans of intermediate age. A5is - silty and gravelly sands; A5ig - sandy gravels; A5ic - sandy cobbles.
A5os A5og	Older alluvial fans having deep incisions and rounded crosional surfaces. A5os - silty and gravelly sands; A5og - sandy gravels.
A5is/A5ys	Unit designation for areas where two types of deposits are inseparable at map scale. The predominant unit is listed first.
A5is (I2)	A designation for an area where the unit listed first is underlain at shallow depth by the parenthetic unit.

ROCK UNITS

Igneous (I)	
I2	Undifferentiated volcanic rocks consisting of rhyolite, latite, dacite and andesite.
I4	Undifferentiated volcanic rocks consisting of welded tuffs, ash flows, igmibrites and pyroclastics.
Sedimentary (S)	
S1	Sandstone.
S2	Limestone and dolomites.

SYMBOLS

Contact between rock and basin-fill.

Contact between surficial basin-fill or rock units.

Fault, trace of surface rupture, ball on downthrown side, dashed where approximately located in bedrock, dotted where inferred in alluvium.

Tectonic lineament, probably a fault, generally expressed as a linear vegetational growth on aerial photographs.

Valley borders (north and west).

NOTES:

1. Surficial basin-fill units pertain only to the upper several feet of soil. Due to variability of surficial deposits and scale of map presentation, unit descriptions refer to the predominant soil types. Varying amounts

Sedimentary (S)

S1	Sandstone.
S2	Limestone and dolomites.

SYMBOLS

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Contact between surficial basin-fill or rock units.

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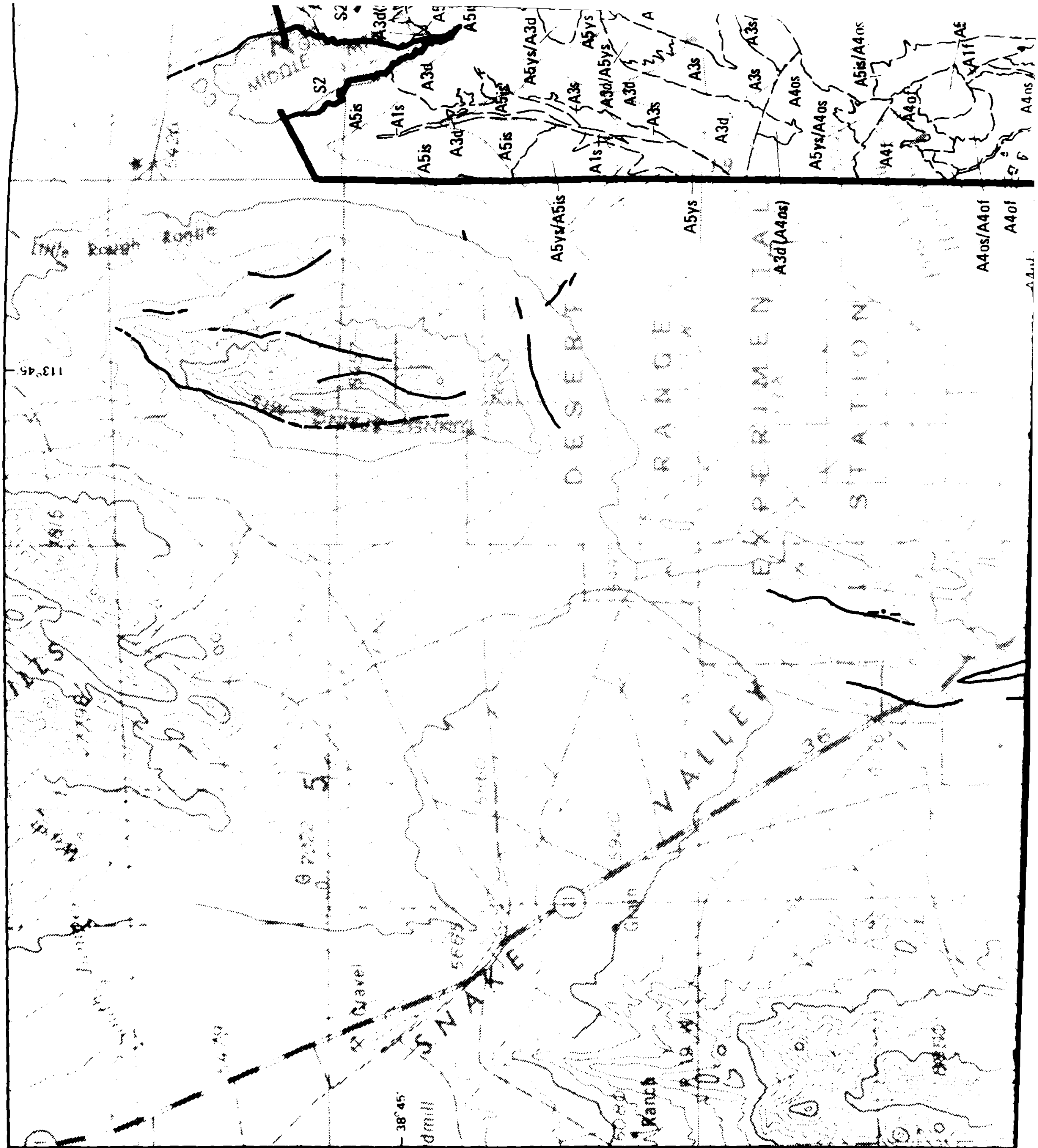
Tectonic lineament, probably a fault, generally expressed as a linear vegetational growth on aerial photographs.

Valley borders (north and west).

NOTES:

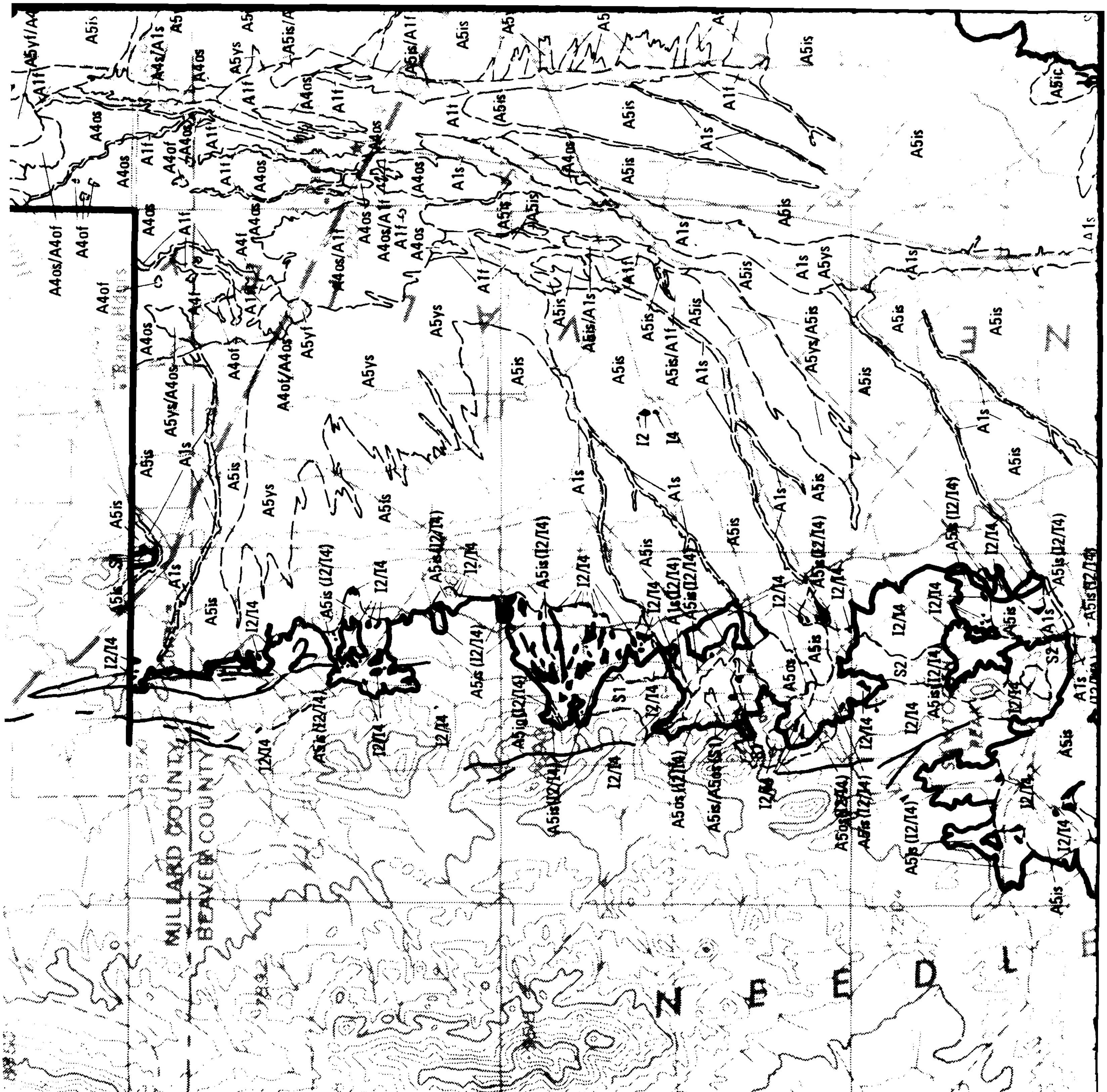
1. Surficial basin-fill units pertain only to the upper several feet of soil. Due to variability of surficial deposits and scale of map presentation, unit descriptions refer to the predominant soil types. Varying amounts of other soil types can be expected within each geologic unit.
2. The distribution of geologic data stations is presented in Volume II Drawing II-1-1. A tabulation of all station data and generalized description of all geologic units is included in Volume II Section 1.
3. Geology in areas of exposed rock from: Fugro National Inc. (1979, 1980) unpublished data. Thorman and Ketner (1979), and Stokes (1979).

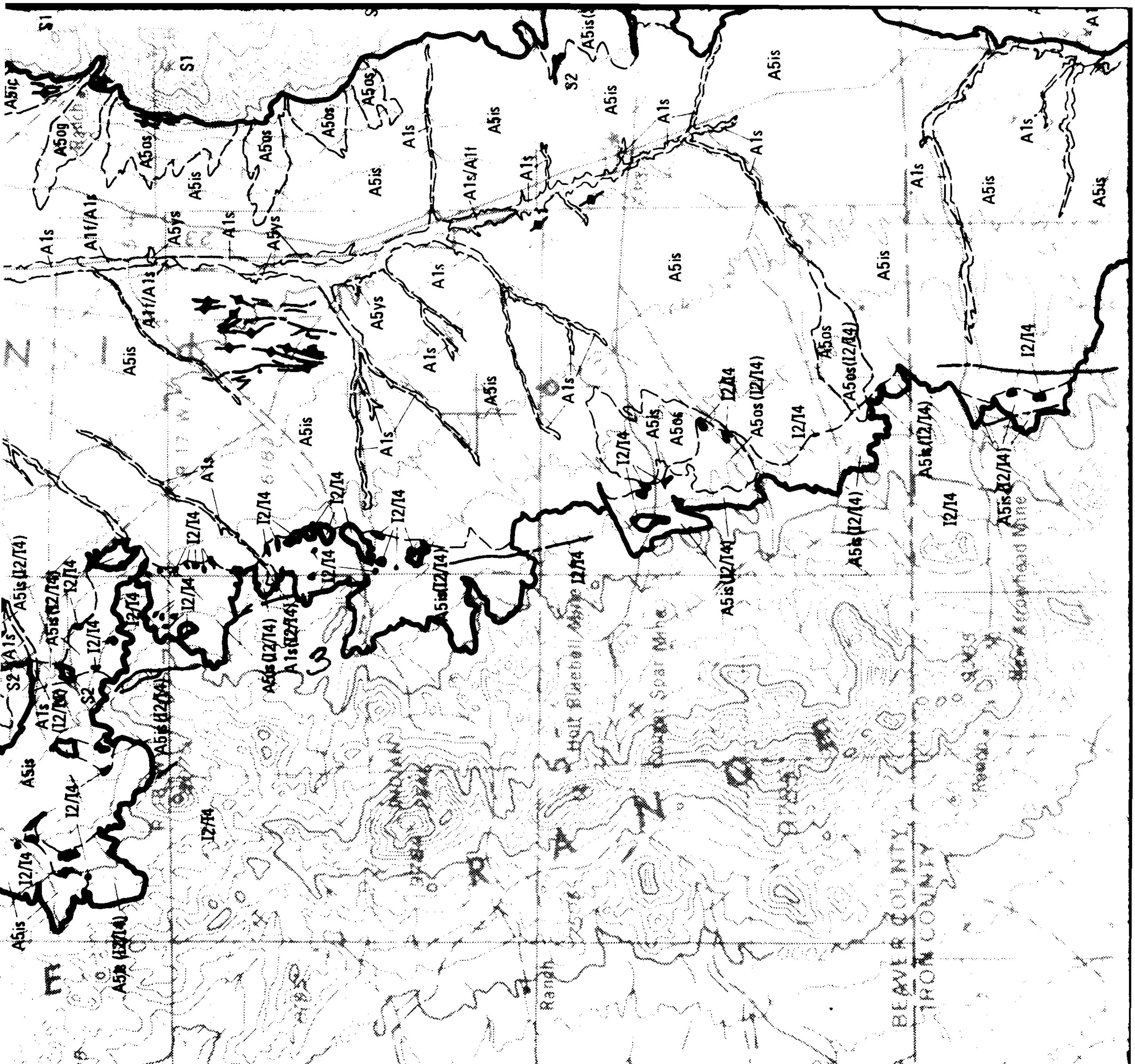
6


MIDDLE
S2
A5is
A1s
A3d
A5ys/A3d
A5ys
A3d/A5ys
A3s
A4os
A5ys/A4os
A5is/A4os
A4of
A4f
A1f
A5ys/A5is
A3d (A4os)
A4os/A4of
Little Rough Range
113°45'
DESERT RANGE EXPERIMENTAL STATION
SNAKE VALLEY
Gravel
38°45'
Ranch

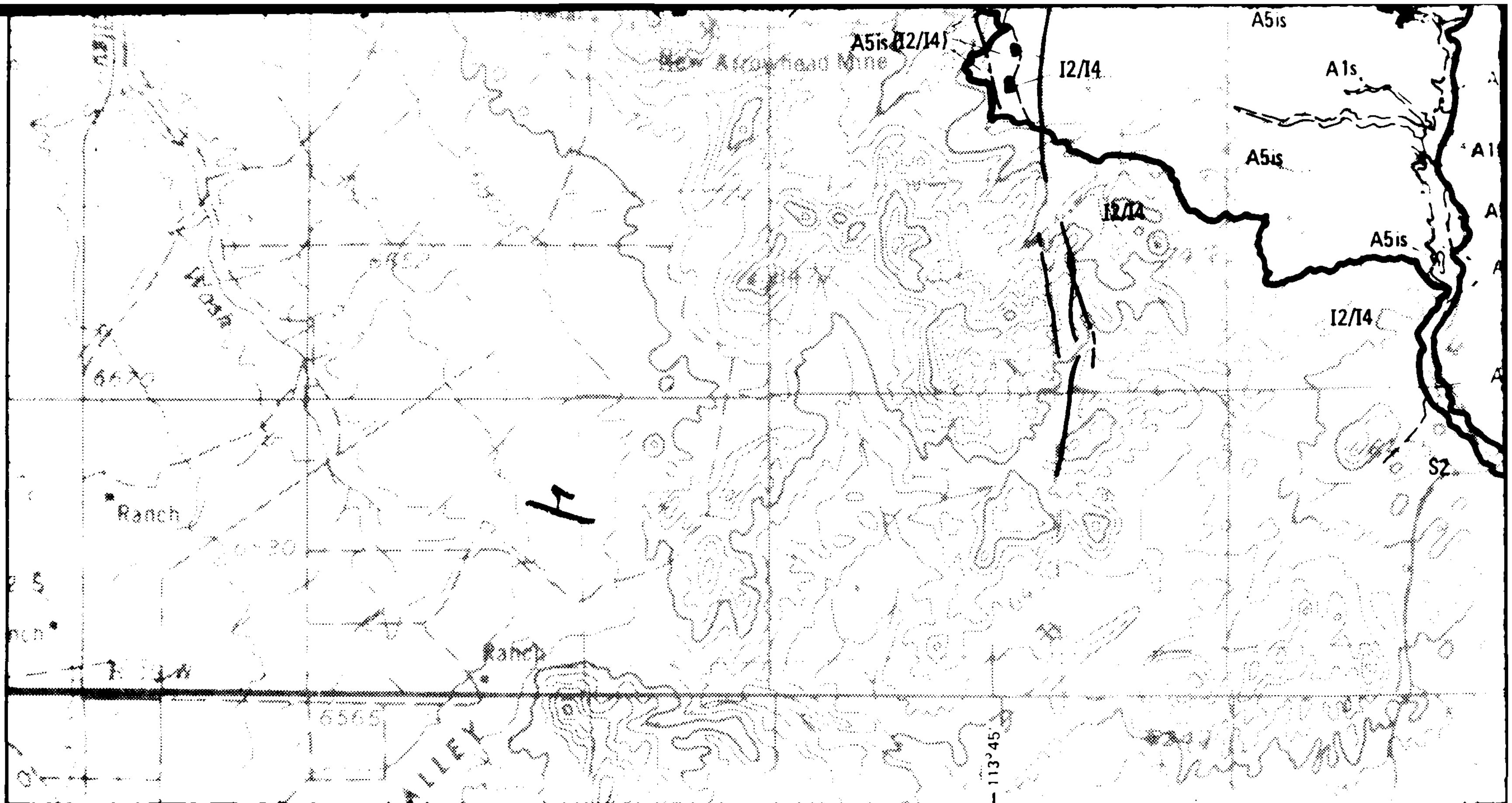
24 MAR 81

7


MILLARD COUNTY
BEAVER COUNTY
38°30'
A5is
A5ys
A1s
A1f
A4os
A4of
A4os/A4of
A5ys/A4os
A4of/A4os
A4os/A1f
A5is/A1s
A5is/A1f
A5ys/A5is
A5is (I2/I4)
I2/I4
A5os
A5os (I2/I4)
A5is/A5os
S1
S2
I2
I4
A5ic


BEAVER COUNTY
IRON COUNTY
Copper Spar Mine
Arrowhead Mine
A5is
A1s
I2/I4
A5os
A5ys
S1
S2
A5is (I2/I4)

9



10

EXPLANATION

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I4	Undifferentiated volcanic rocks consisting of welded tuffs, ash flows, igmibrites and pyroclastics.

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S2	Limestone and dolomites.

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6

SURFICIAL GEOLOGICAL UNITS

PINE VALLEY, UTAH

MX SITING INVESTIGATION

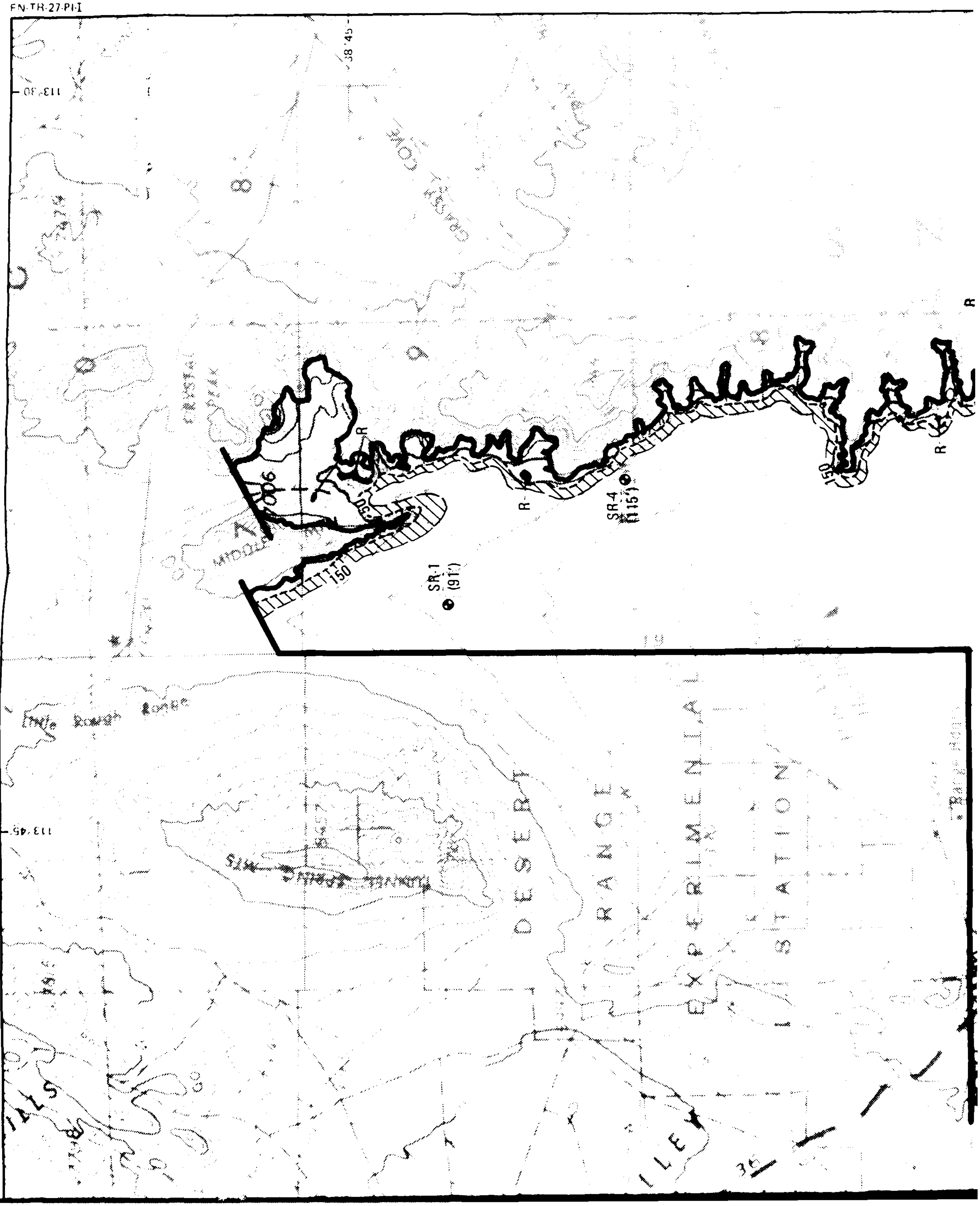
DEPARTMENT OF THE AIR FORCE – BMO

DRAWING 3-2

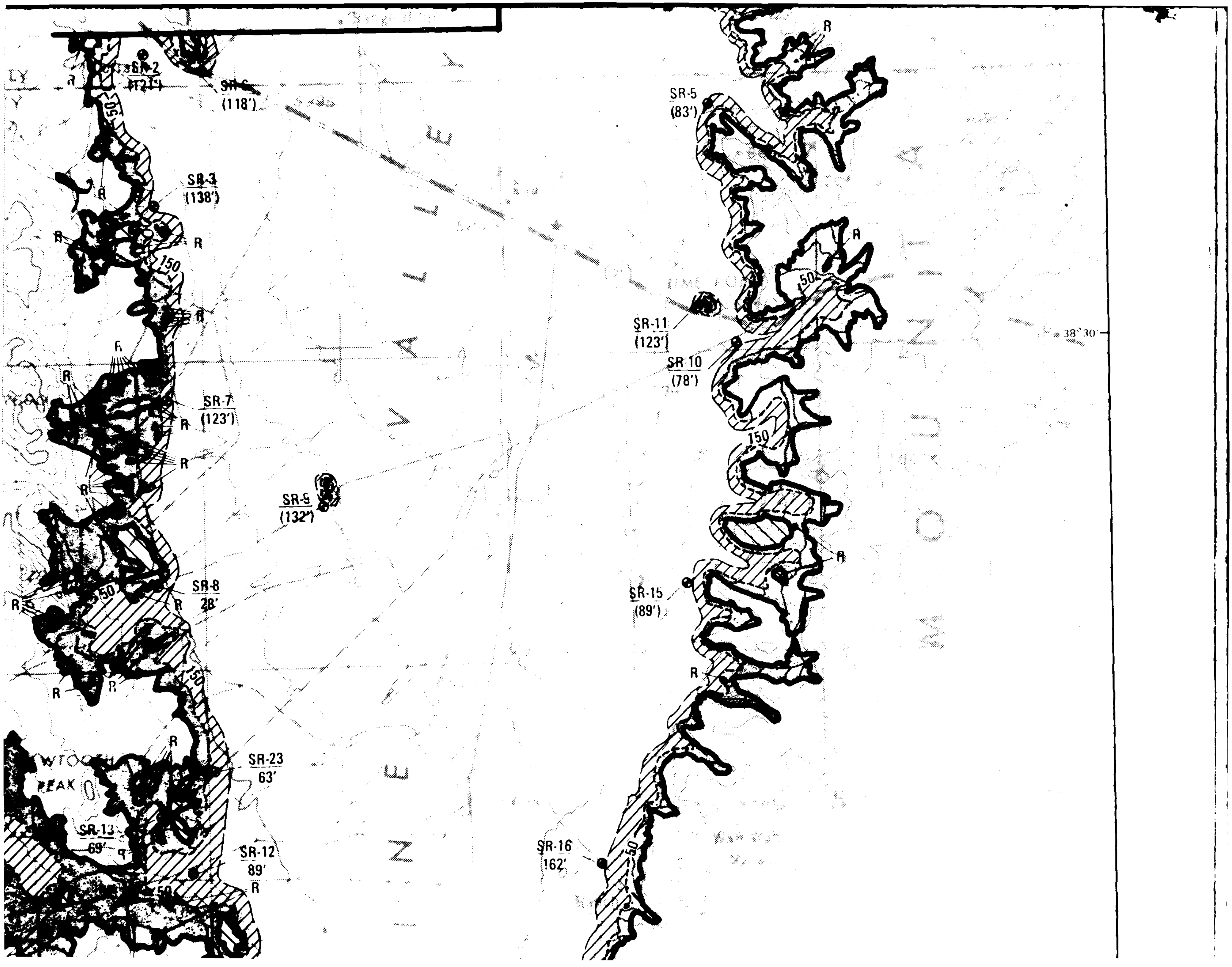
FUGRO NATIONAL, INC.

13

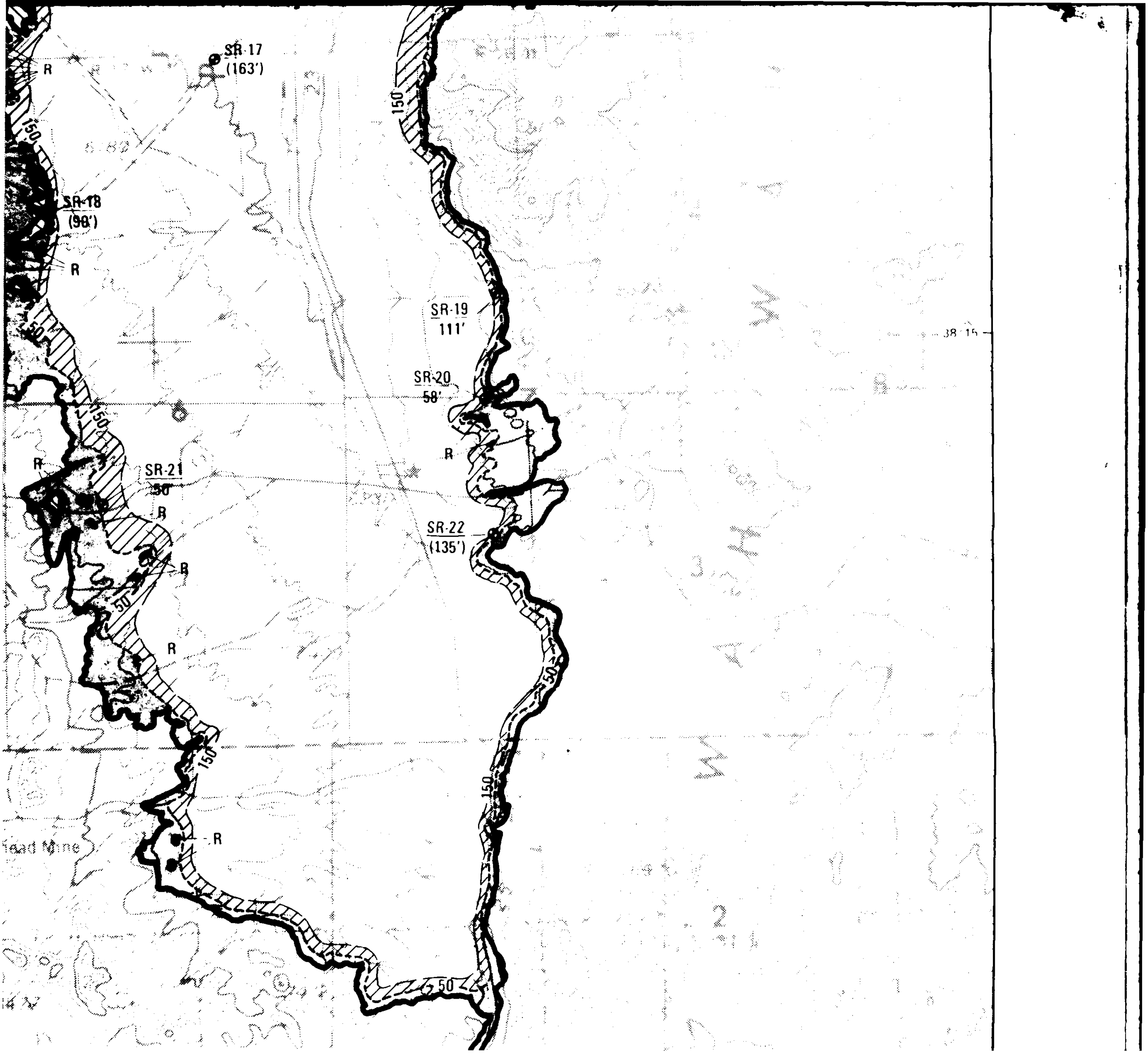
EN-TR-27-PI-I

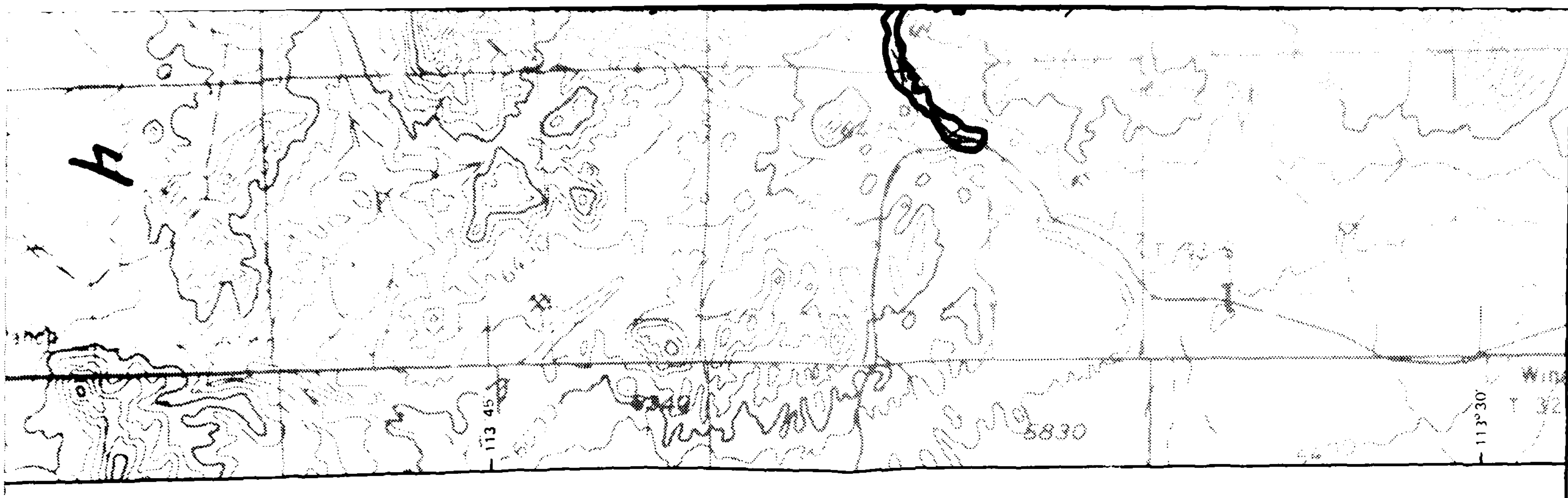


38°45'
113°30'
113°45'
CRYSTAL PEAK
SR-1
(91')
SR-4
(115')
150
DESERT RANGE EXPERIMENTAL STATION



SR-2
SR-6
(118')
SR-3
(138')
SR-7
(123')
SR-9
(132')
SR-8
28'
SR-23
63'
SR-13
69'
SR-12
89'
SR-5
(83')
SR-11
(123')
SR-10
(78')
SR-15
(89')
SR-16
162'
38°30'
V A L L E Y
M O U N T A
50
150
R
PEAK


SR-17
(163')
SR-18
(98')
SR-19
111'
SR-20
58'
SR-21
50'
SR-22
(135')
150
50
R
38°15'
Lead Mine



EXPLANATION

Contour indicates rock at a depth of approximately 50 feet (15m) - shading indicates rock less than 50 feet (15m).

Contour indicates rock at a depth of approximately 150 feet (46m) - shading indicates rock between 50 feet (15m) and 150 feet (46m).

Contact between rock and basin-fill.

Valley borders (north and west).

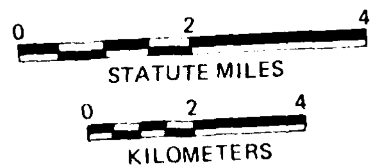
Areas of isolated exposed rock.

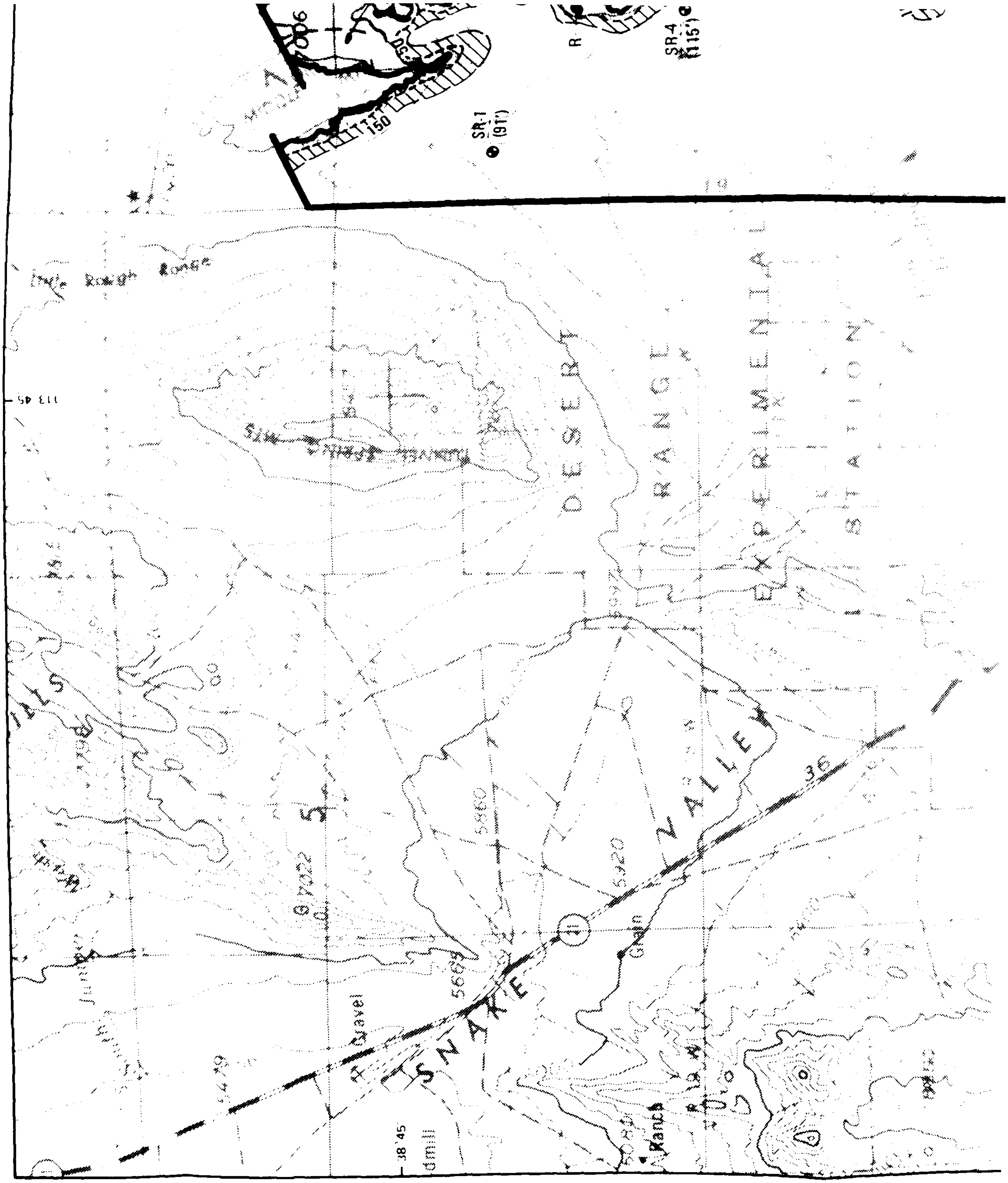
R Areas of isolated exposed rock too small for shading.

⊙ $\frac{\text{SR-7}}{199'}$ Data Source - Seismic refraction line and electrical resistivity sounding (SR); Volume I, Table 3-3.
Depth to rock or, when in parentheses, total depth at which rock not encountered.

NOTE The contours are based on geologic interpretations and the limited data points shown on the map. Some changes in contour locations can be expected as additional data are obtained.

SCALE 1: 125,000

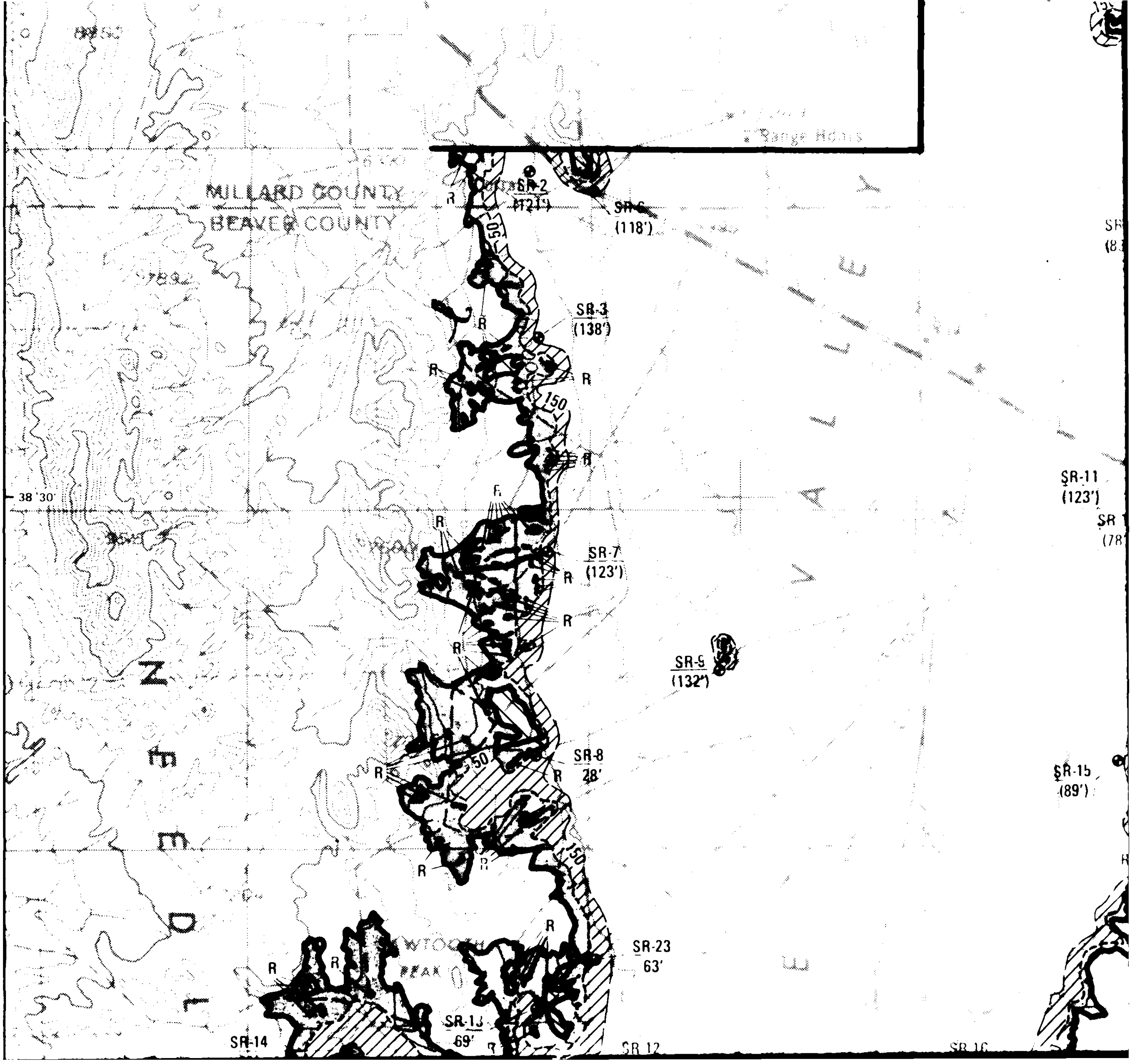


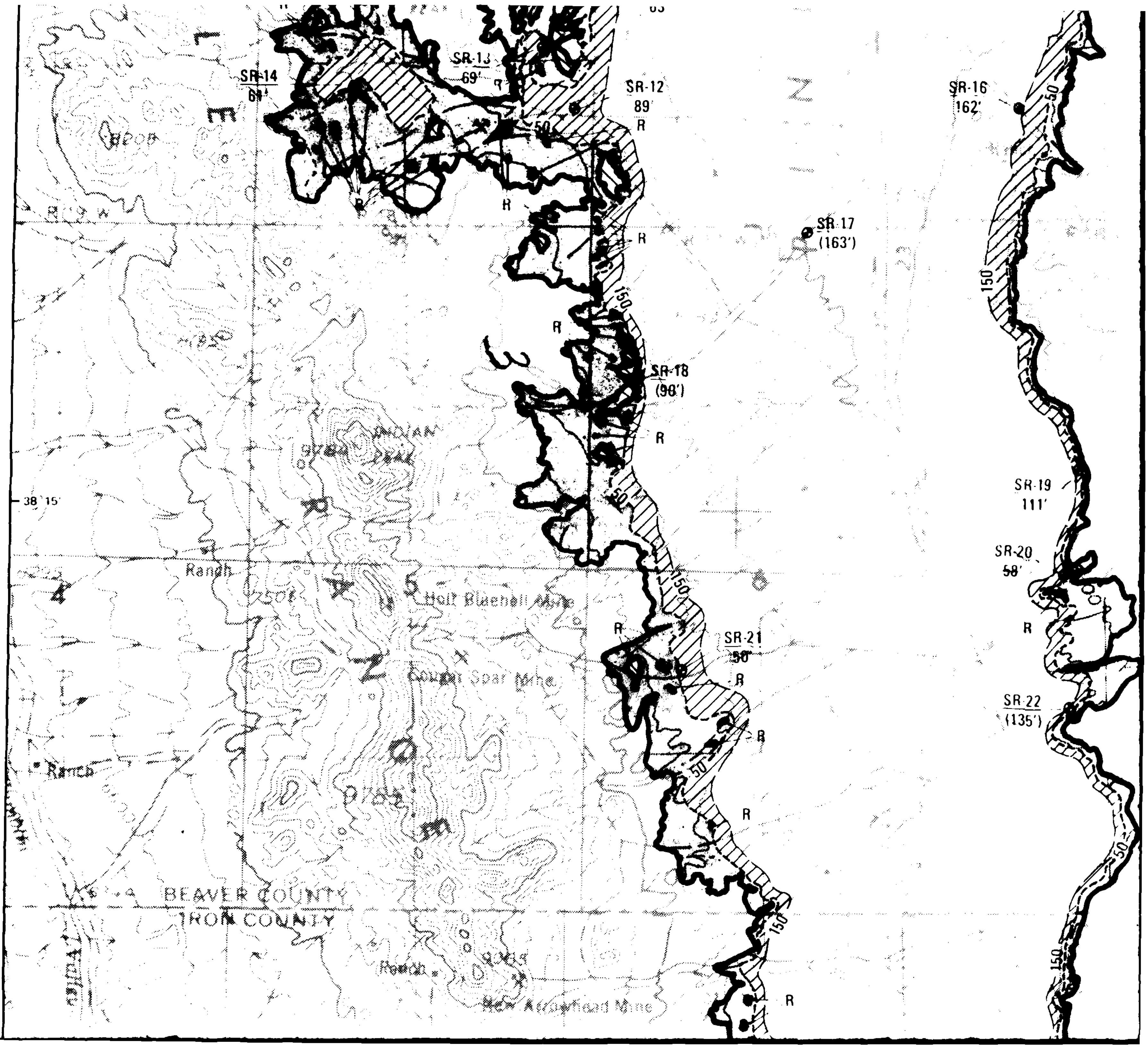

SNAKE VALLEY
DESERT RANGE EXPERIMENTAL STATION
SR-1 (91')
SR-4 (115')
150
5860
5920
5669
Gravel
Ranch
38 45
113 45
36

24 MAR 81

5

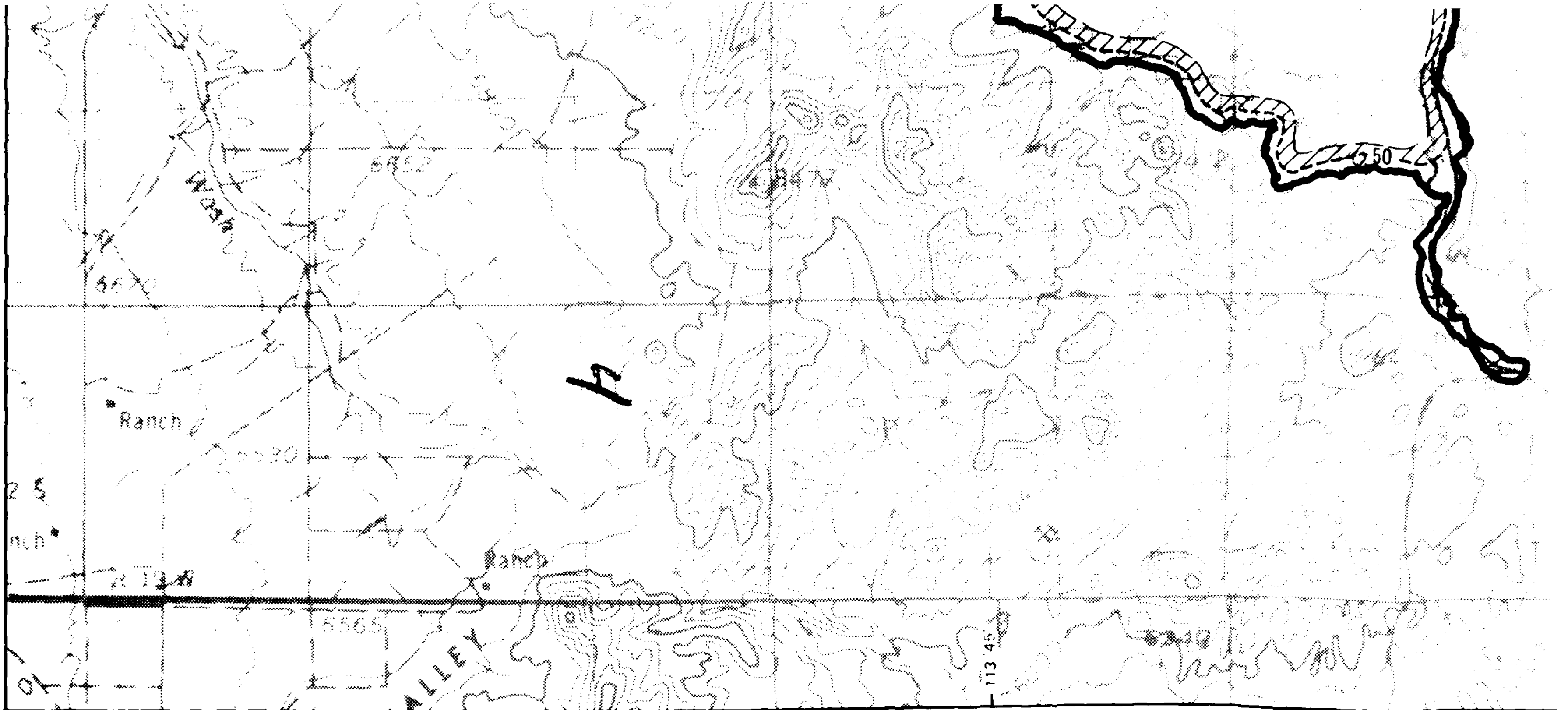
6


MILLARD COUNTY
BEAVER COUNTY
Range Hdqs
SR-2
(121')
SR-6
(118')
SR-3
(138')
SR-7
(123')
SR-9
(132')
SR-8
28'
SR-23
63'
SR-13
69'
SR-14
SR-11
(123')
SR-15
(89')
38°30'
150
50
R
N
E
E
D
L



SR-12
89'
SR-13
69'
SR-14
SR-16
162'
SR-17
(163')
SR-18
SR-19
111'
SR-20
58'
SR-21
SR-22
(135')
150
50
38°15'
Ranch
Holt Bluebell Mine
Cougar Spar Mine
New Arrowhead Mine
BEAVER COUNTY
IRON COUNTY

7



EXPLANATION

- 50 — Contour indicates rock at a depth of approximately 50 feet (15m) - shading indicates rock less than 50 feet (15m).
- 150 — Contour indicates rock at a depth of approximately 150 feet (46m) ·ading indicates rock between 50 feet (15m) and 150 feet (46m).
- Contact between rock and basin-fill.
- Valley borders (north and west).
- Areas of isolated exposed rock.
- R — Areas of isolated exposed rock too small for shading.

DEF
PINE
MX SITING INV
DEPARTMENT OF TH
FUGRO N

Contour indicates rock at a depth of approximately 50 feet (15m) - shading indicates rock less than 50 feet (15m).

150 — Contour indicates rock at a depth of approximately 150 feet (46m) - shading indicates rock between 50 feet (15m) and 150 feet (46m).

Contact between rock and basin-fill.

Valley borders (north and west).

Areas of isolated exposed rock.

R — Areas of isolated exposed rock too small for shading.

SR-7 / 199' — Data Source - Seismic refraction line and electrical resistivity sounding (SR); Volume I, Table 3-3. Depth to rock or, when in parentheses, total depth at which rock not encountered.

NOTE The contours are based on geologic interpretations and the limited data points shown on the map. Some changes in contour locations can be expected as additional data are obtained.

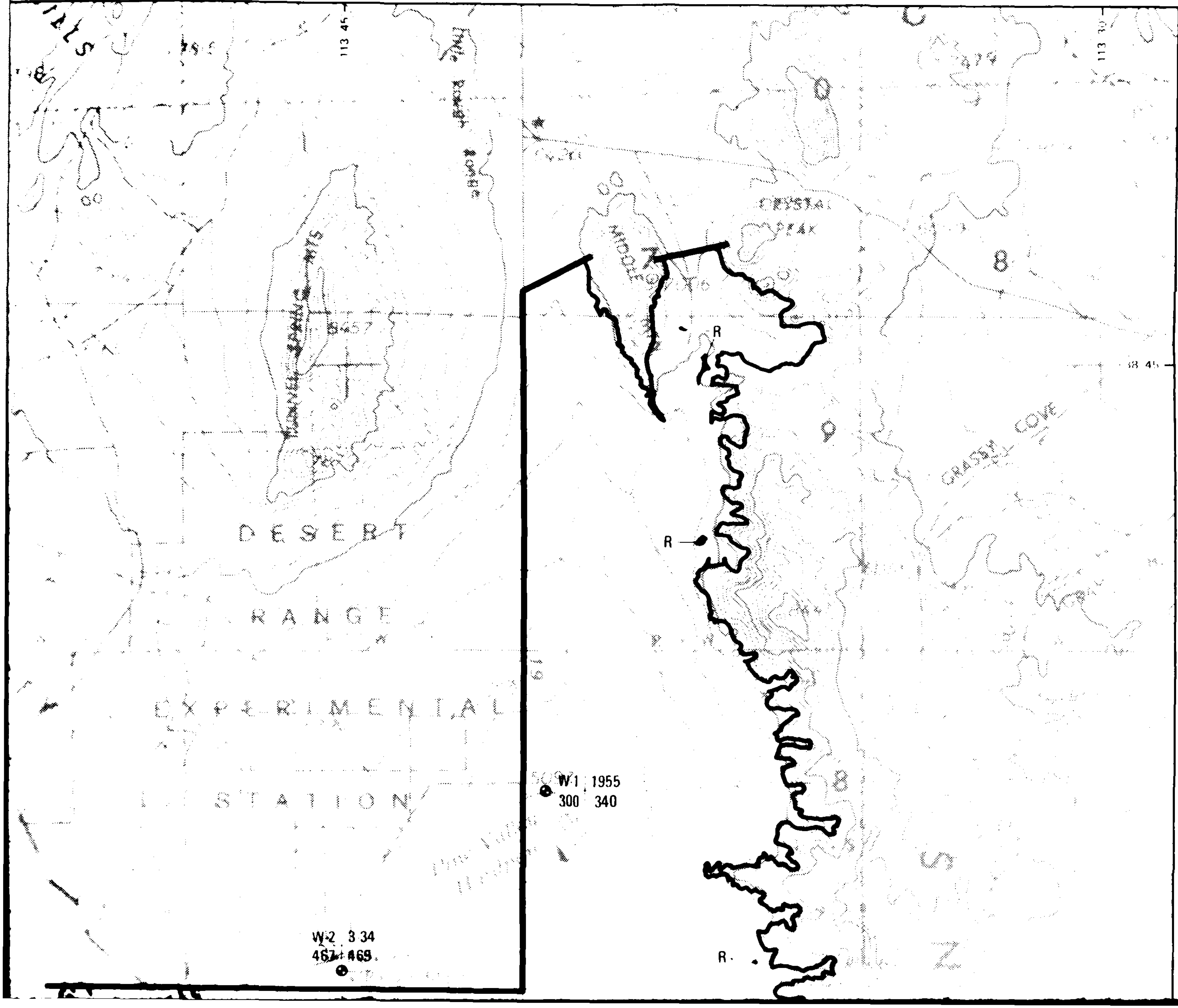
0

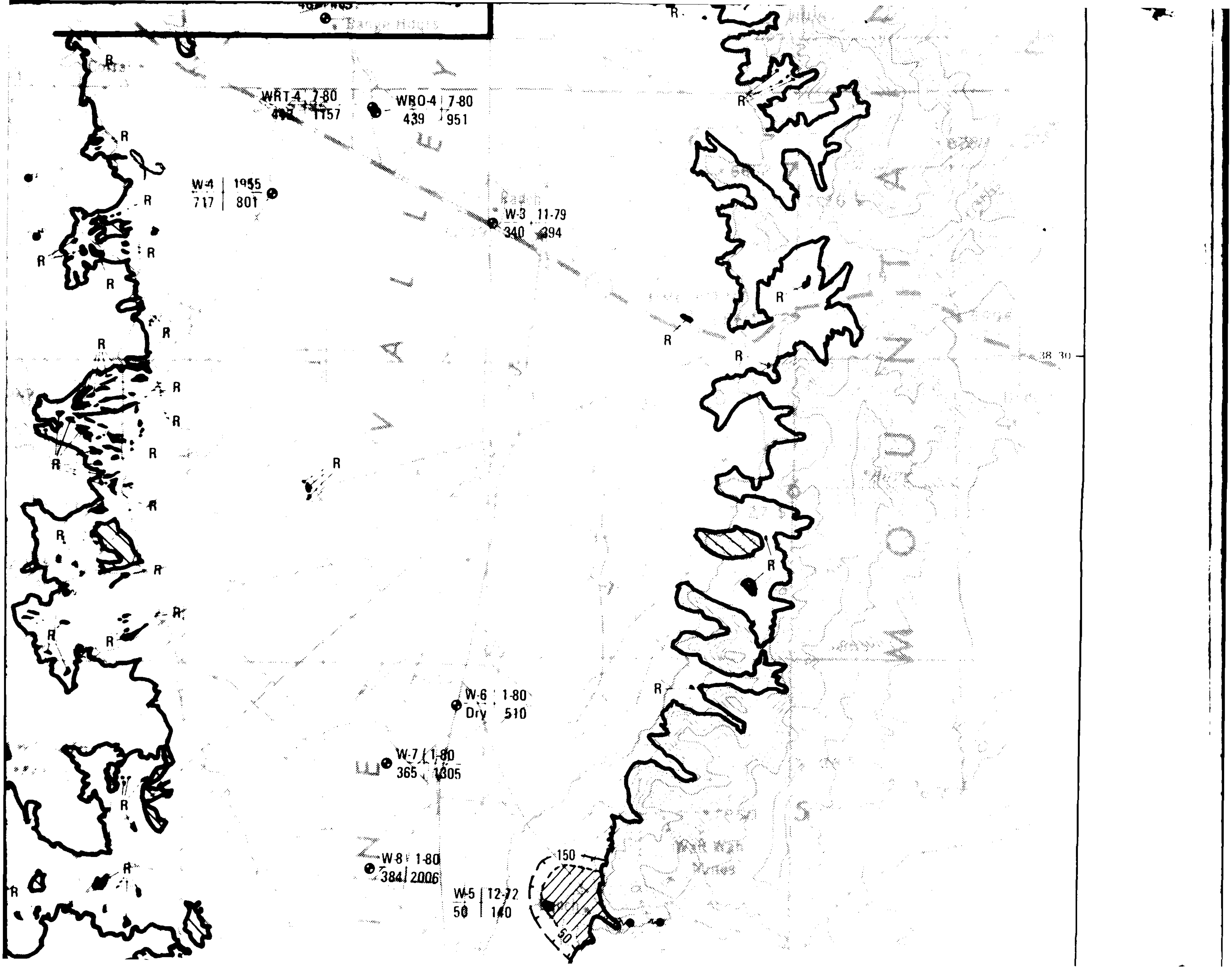
DEPTH TO ROCK
PINE VALLEY, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE BMO	DRAWING 3-3

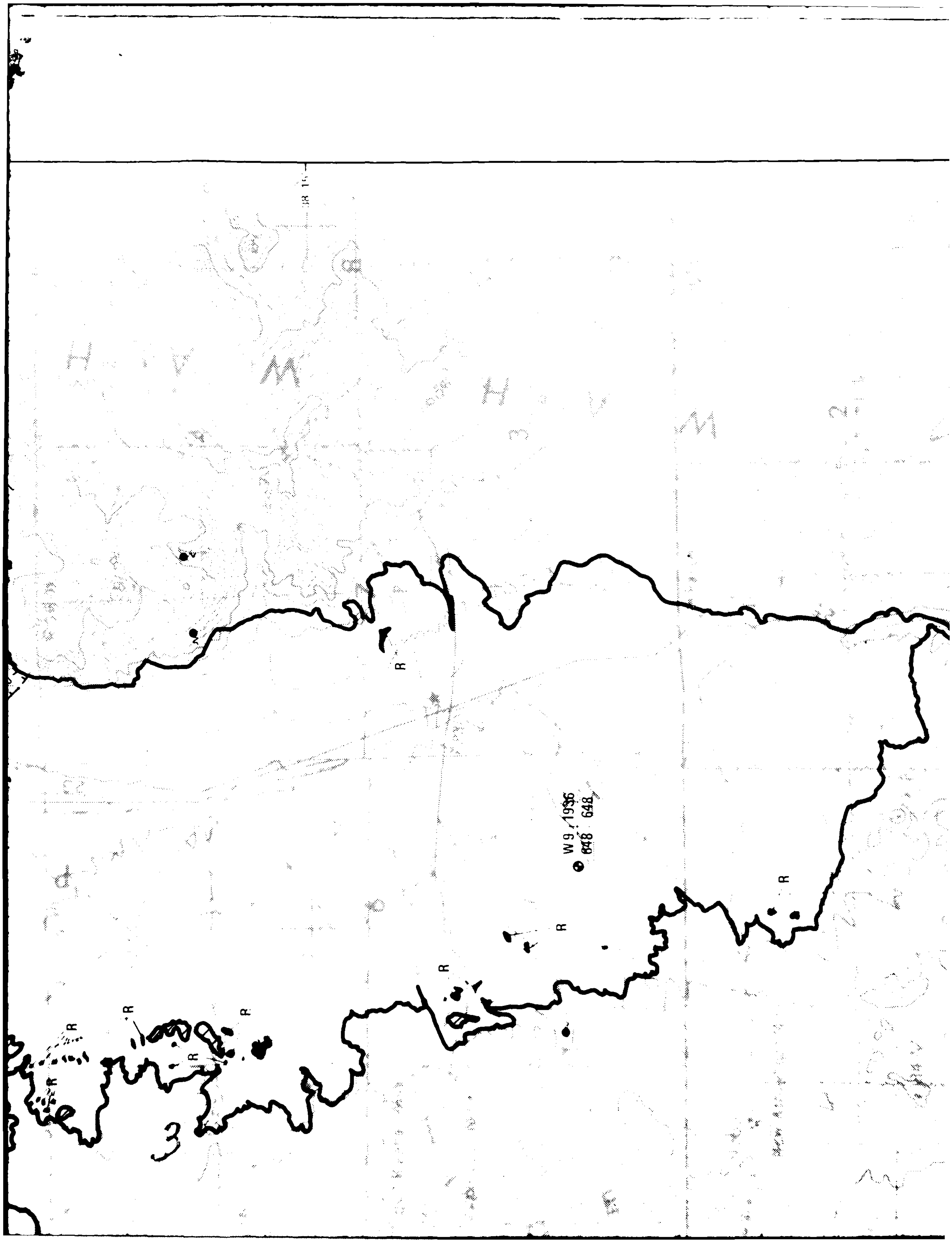
FUGRO NATIONAL, INC.

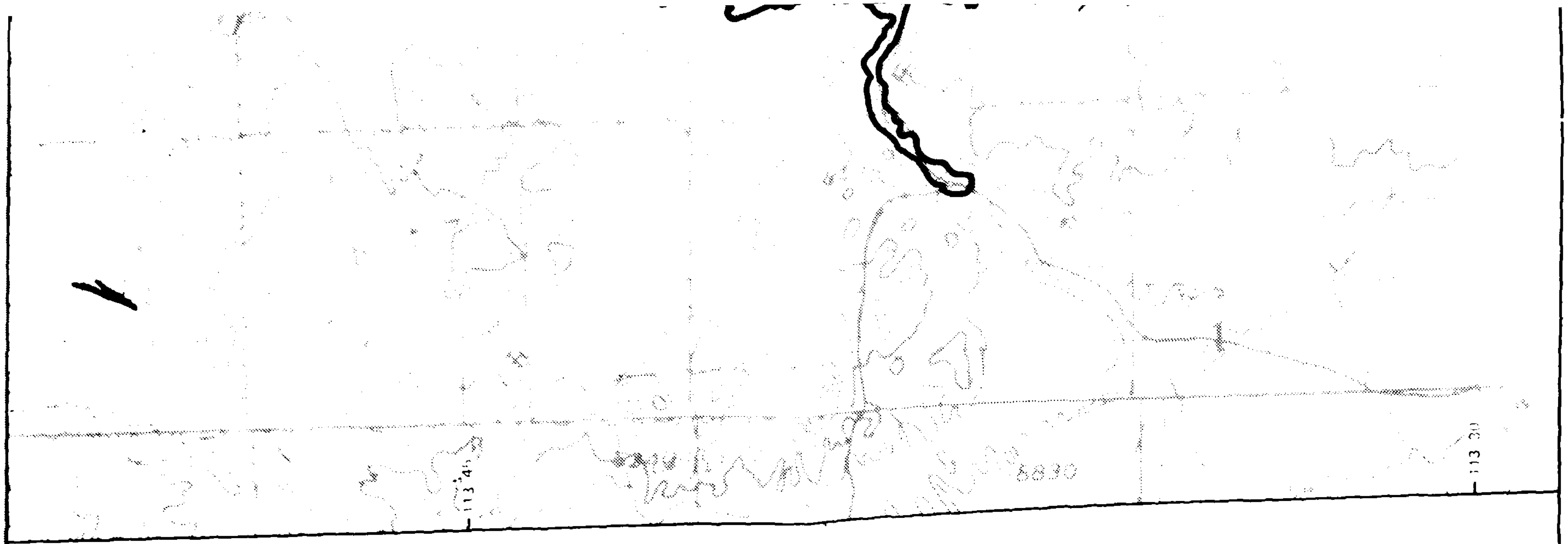
9


113 45
113 30
38 45
CRYSTAL PEAK
MIDDLE
GRASSY COVE
5457
DESERT
RANGE
EXPERIMENTAL
STATION
R
W-1 1955
300 340
W-2 3 34
467 469



WRT-4 7-80
1157
WRO-4 7-80
439 951
W-4 1955
717 801
W-3 11-79
340 394
W-6 1-80
Dry 510
W-7 1-80
365 1305
W-8 1-80
384 2006
W-5 12-72
50 140
150
50
38 30
VALLEY
MOUNTAINS
R


W9
648
R



EXPLANATION

50 — Contour indicates ground water at a depth of approximately 50 feet (15m) - shading indicates less than 50 feet (15m) to ground water.

150 — Contour indicates ground water at a depth of approximately 150 feet (46m) - hachuring indicates between 50 feet (15m) and 150 feet (46m) to ground water.

Absence of countours indicates ground water occurs at depths greater than 150 feet. Fugro National, Inc. borings, and assorted wells indicate depth to ground water generally in excess of 400 feet throughout most of Pine Valley (see Volume I, Section 3.6).

Contact between rock and basin-fill.

Valley borders (north and west).

Areas of isolated exposed rock.

R — Areas of isoloated rock too small for shading.

NORTH

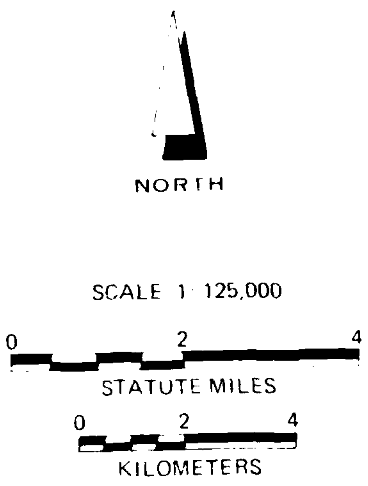
SCALE 1 125,000

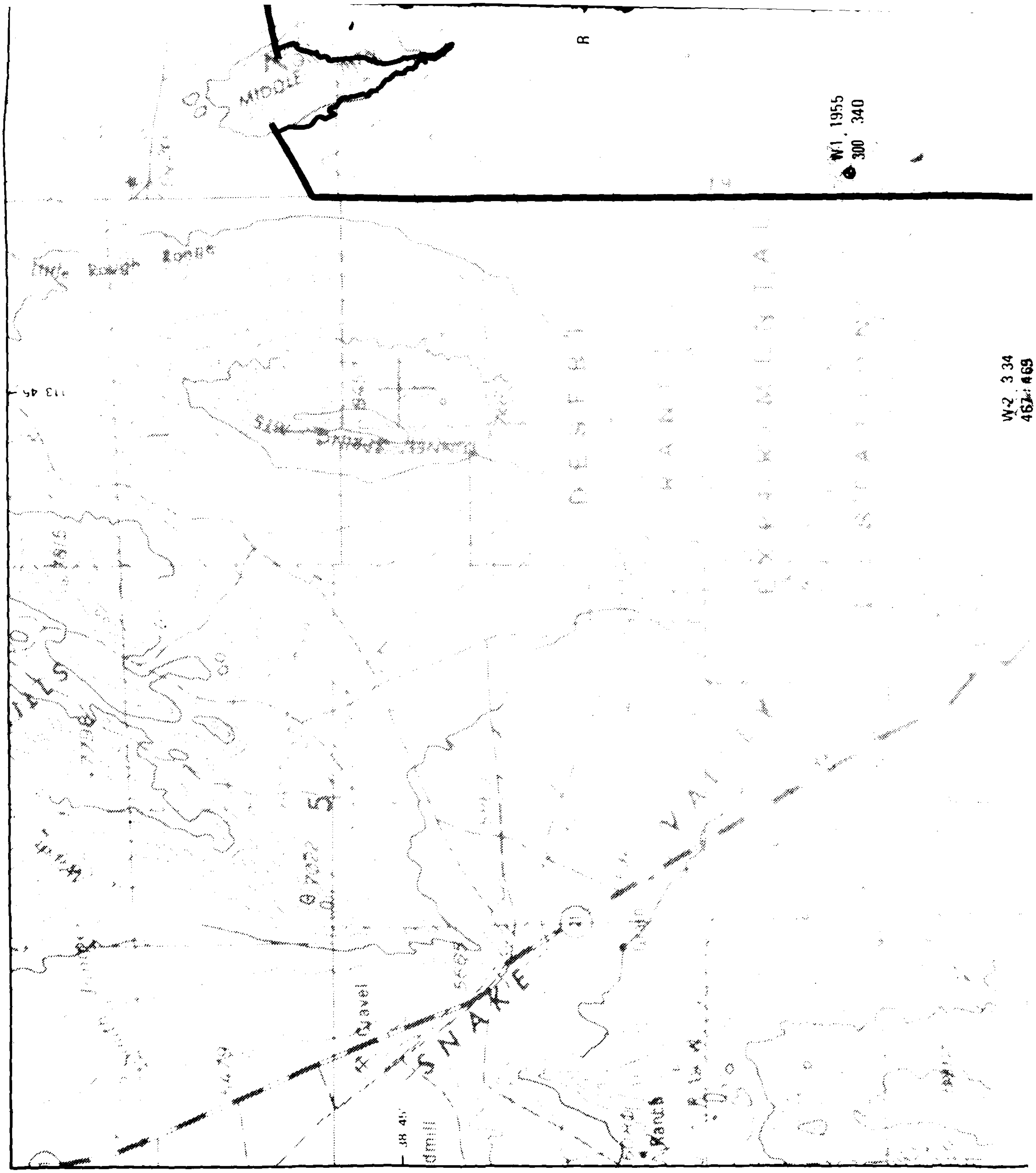
0 2 4
STATUTE MILES

0 2 4
KILOMETERS

150	Contour indicates ground water at a depth of approximately 150 feet (46m) - hachuring indicates between 50 feet (15m) and 150 feet (46m) to ground water.
	Absence of countours indicates ground water occurs at depths greater than 150 feet. Fugro National, Inc. borings, and assorted wells indicate depth to ground water generally in excess of 400 feet throughout most of Pine Valley (see Volume I, Section 3.6).
	Contact between rock and basin-fill.
	Valley borders (north and west).
	Areas of isolated exposed rock.
R	Areas of isoloated rock too small for shading.
W-3 | 11-79 / 340 | 394	Data Source - Water resources test well or observation well (WRT or WRO) or published water well (W). see Volume II, Table II-2-1. | Month - Year of water level measurement, or year when month unknown. / Depth to water (feet). | Depth of well (feet).
	Spring, indicating direction of flow.

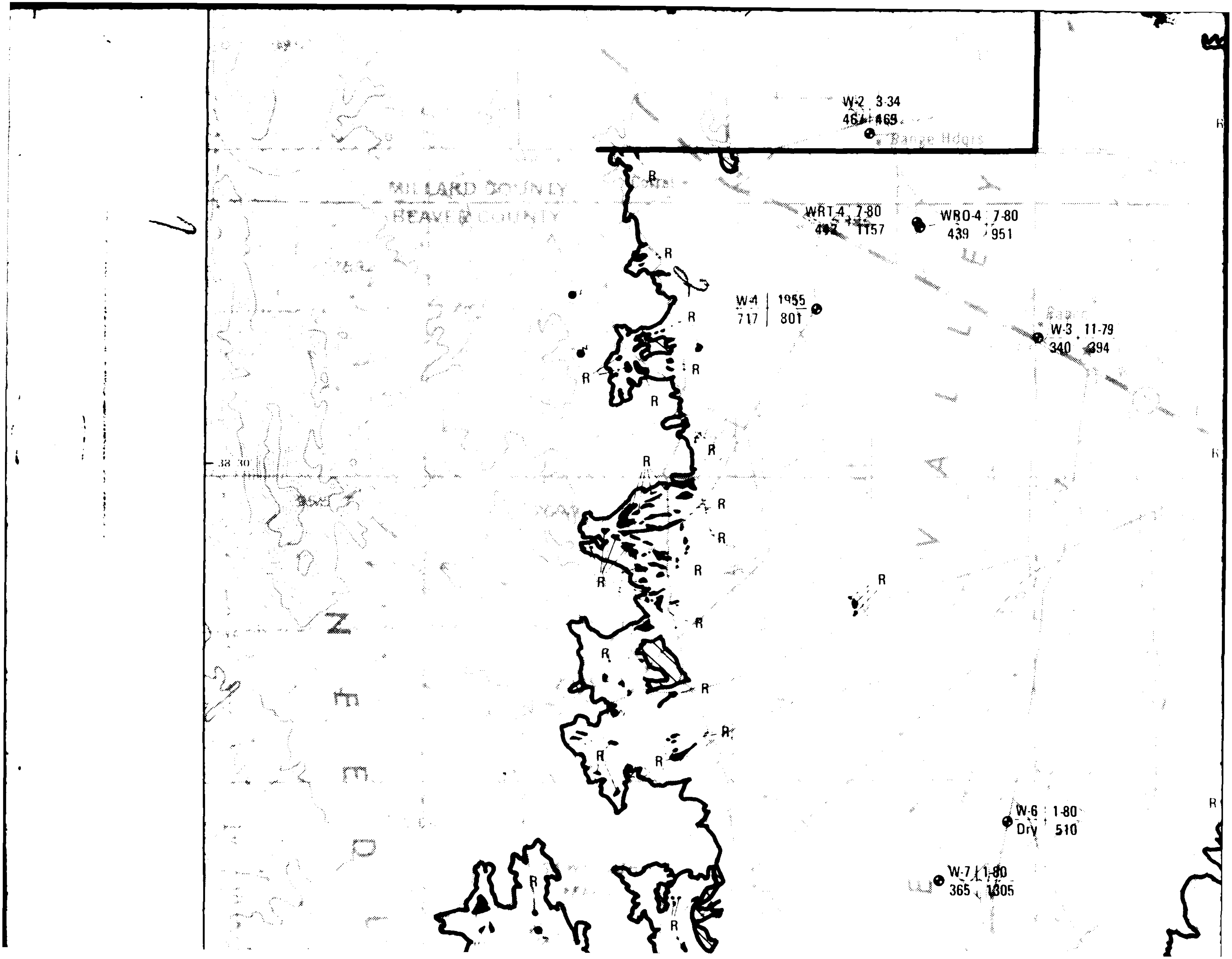
5





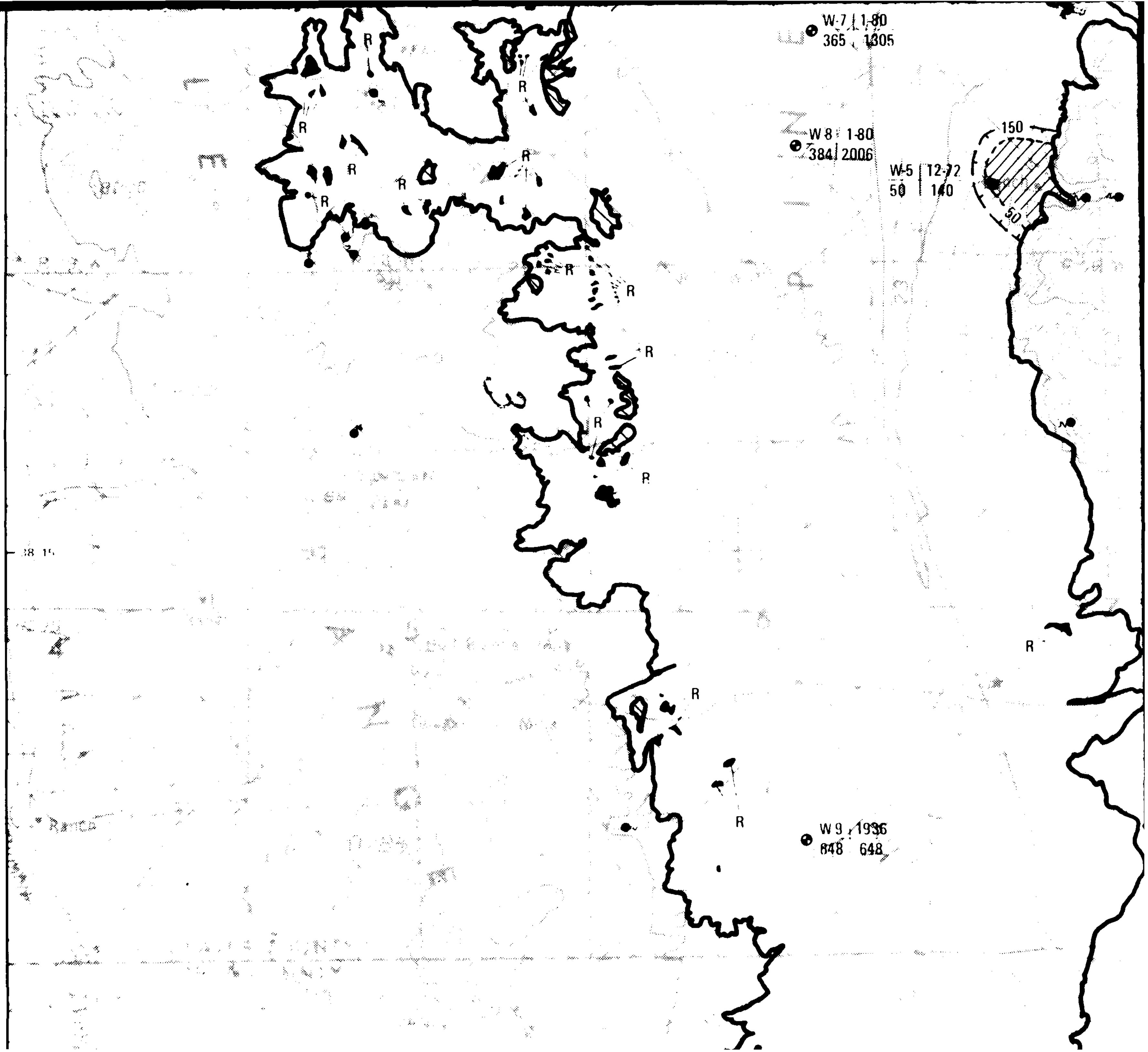
24 MAR 81

6

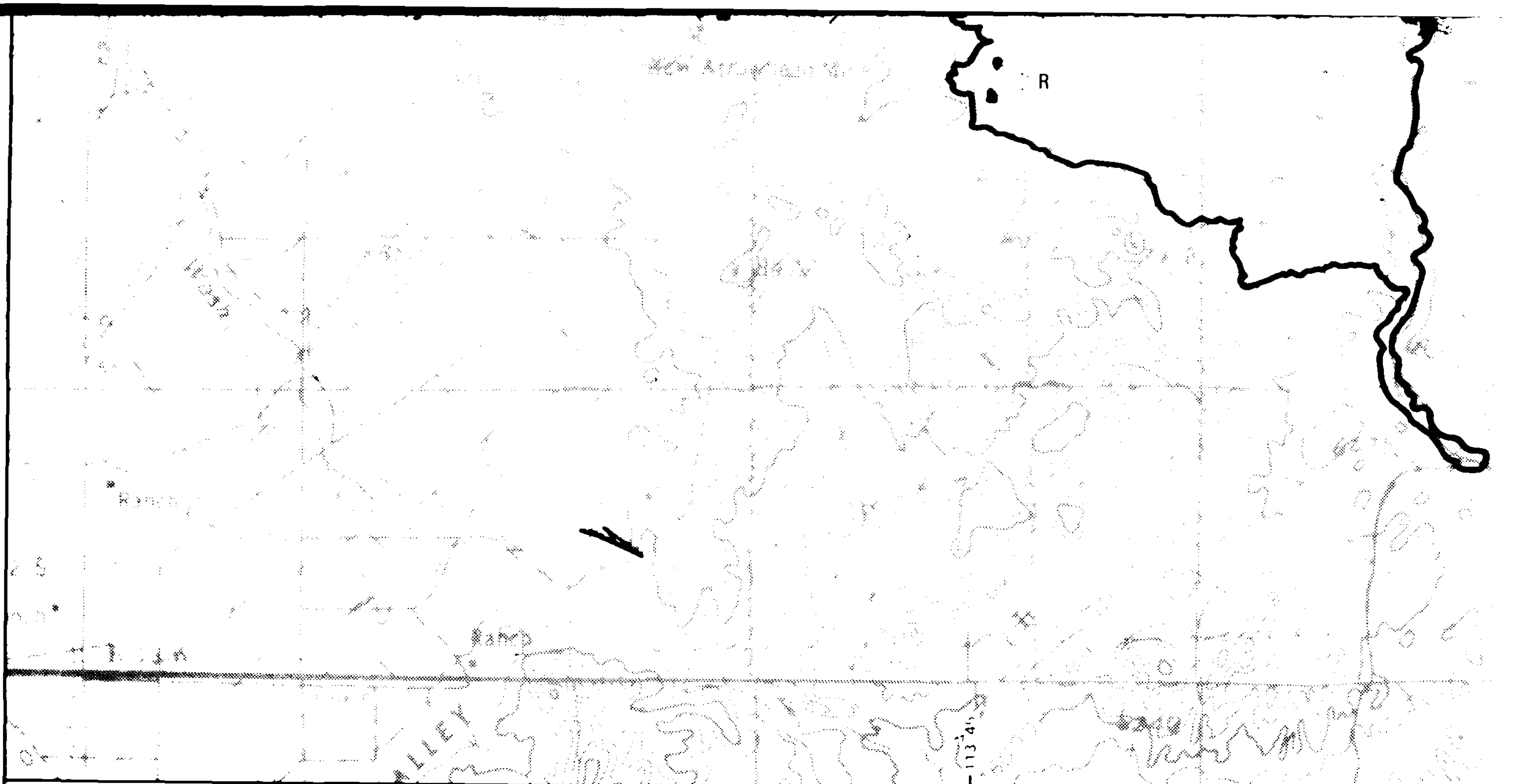


W-2 3-34
464 469
Range Hdqrs
MILLARD COUNTY
BEAVER COUNTY
WRT-4 7-80
1157
WRO-4 7-80
439 951
W-4 1955
717 801
W-3 11-79
340 394
38 30'
N
E
E
D
W-6 1-80
Dry 510
W-7 1-80
365 1305

8


W-7 1-80
365 1305
W 8 1-80
384 2006
W-5 12-72
50 140
150
50
W 9 1936
848 648
R
3
Ranch

9



EXPLANATION

50 — Contour indicates ground water at a depth of approximately 50 feet (15m) - shading indicates less than 50 feet (15m) to ground water.

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Contact between rock and basin fill.

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150 Contour indicates ground water at a depth of approximately 150 feet (46m) - hachuring indicates between 50 feet (15m) and 150 feet (46m) to ground water.

Absence of countours indicates ground water occurs at depths greater than 150 feet. Fugro National, Inc. borings, and assorted wells indicate depth to ground water generally in excess of 400 feet throughout most of Pine Valley (see Volume I, Section 3.6).

Contact between rock and basin-fill.

Valley borders (north and west).

Areas of isolated exposed rock.

R Areas of isoloated rock too small for shading.

W-3	11-79
340	394

Data Source - Water resources test well or observation well (WRT or WRO) or published water well (W), see Volume II, Table II-2-1.

Depth to water (feet).

Month - Year of water level m[...] or year when month unk[...]

Depth of well (feet).

Spring, indicating direction of flow.

5

DEPTH TO WATER
PINE VALLEY, UTAH

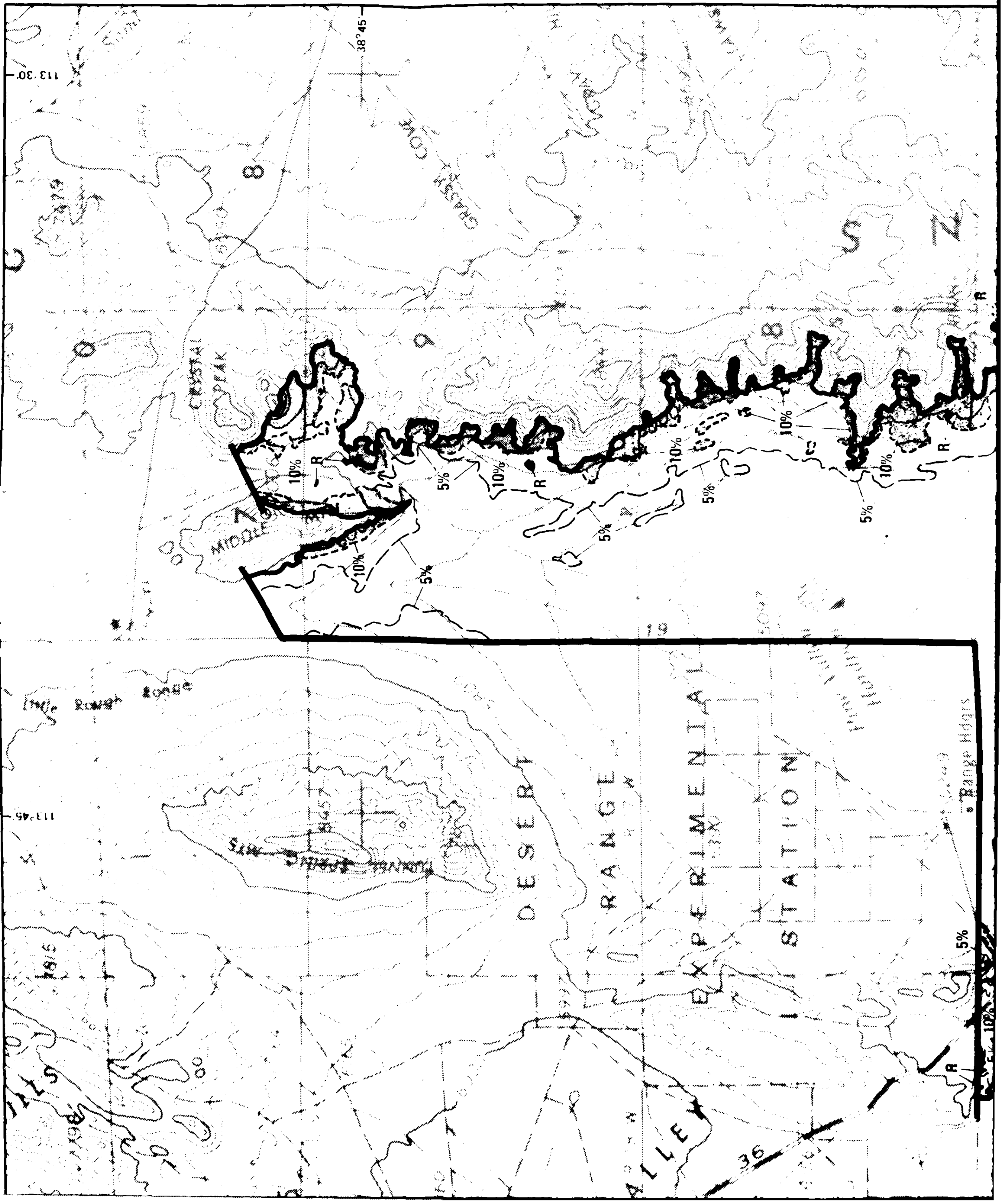
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

DRAWING 34

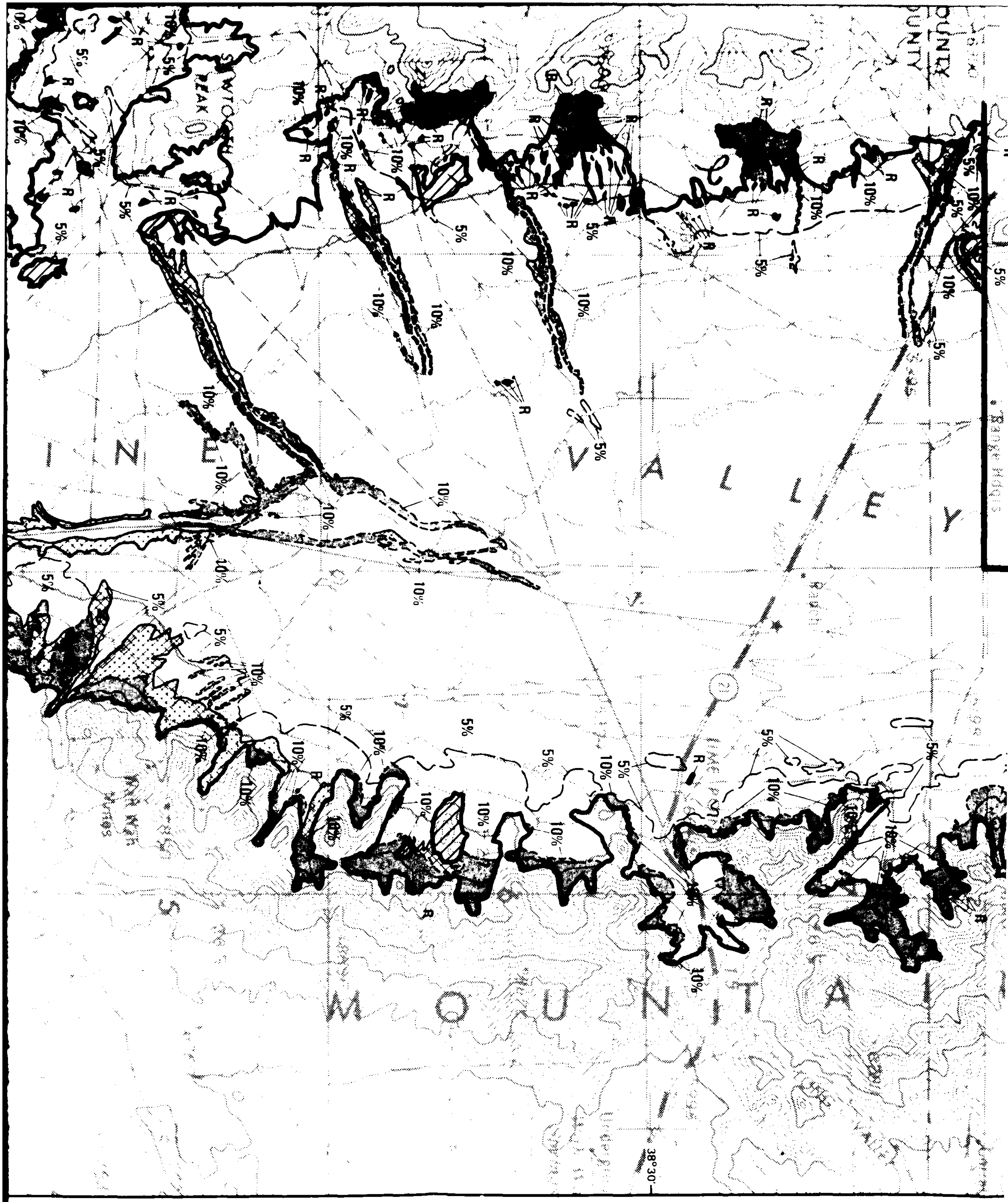
FUGRO NATIONAL, INC.

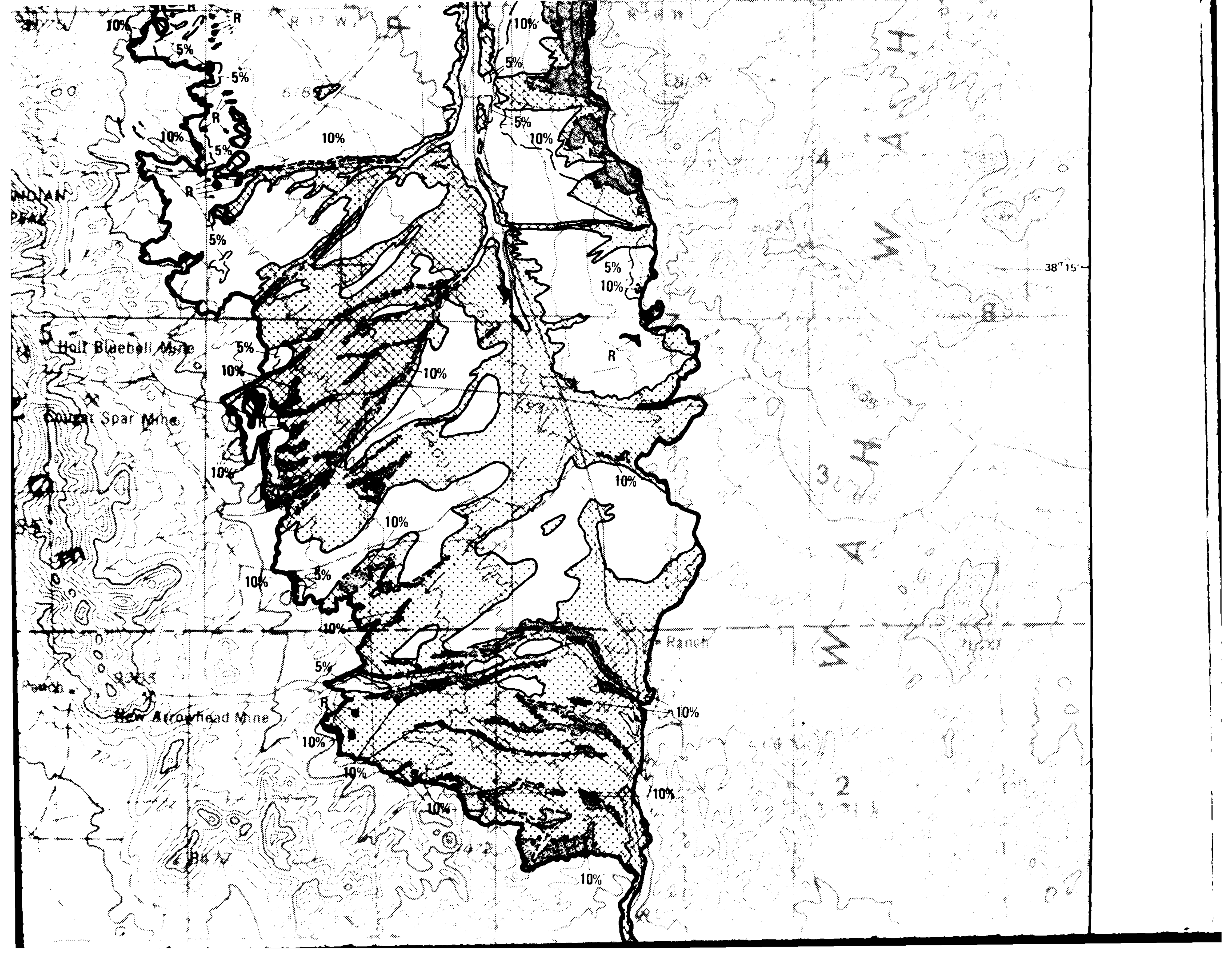
10

FN-TR-27-PI-I

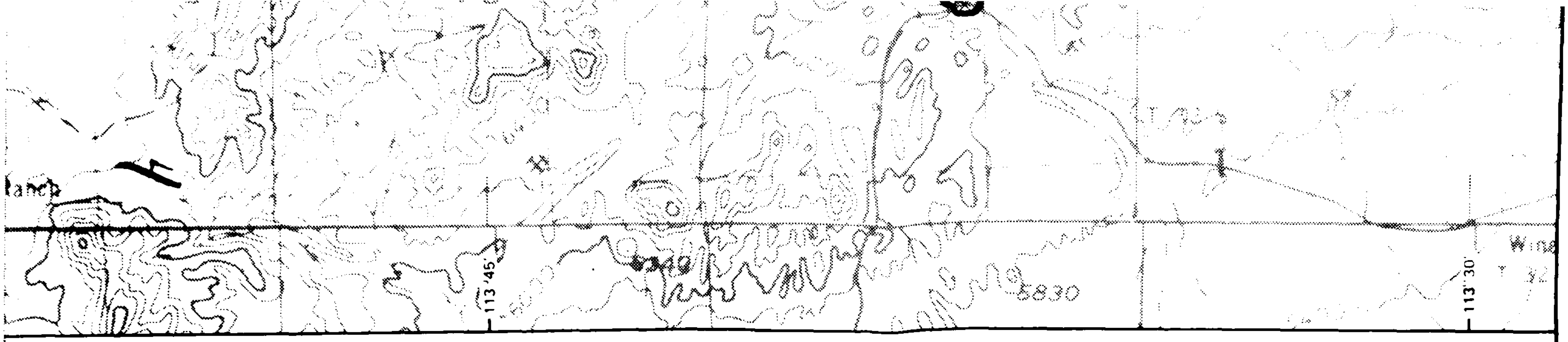


DESERT
RANGE
EXPERIMENTAL
STATION
Range Hdqrs
CRYSTAL PEAK
MIDDLE
Little Rough Range
38°45'
113°30'
113°45'
10%
5%
R
19
36


M O U N T A
V A L L E Y
I N E
38°30'
5%
10%
R

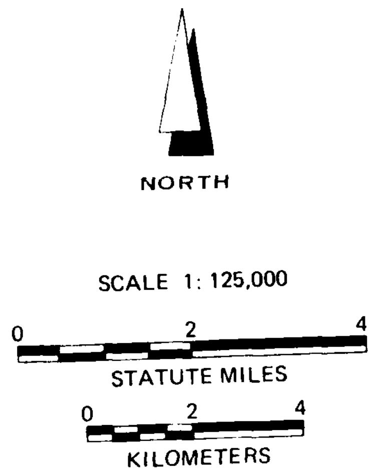


Holt Bluebell Mine
Spar Mine
New Arrowhead Mine
Ranch
38°15'
10%
5%
R

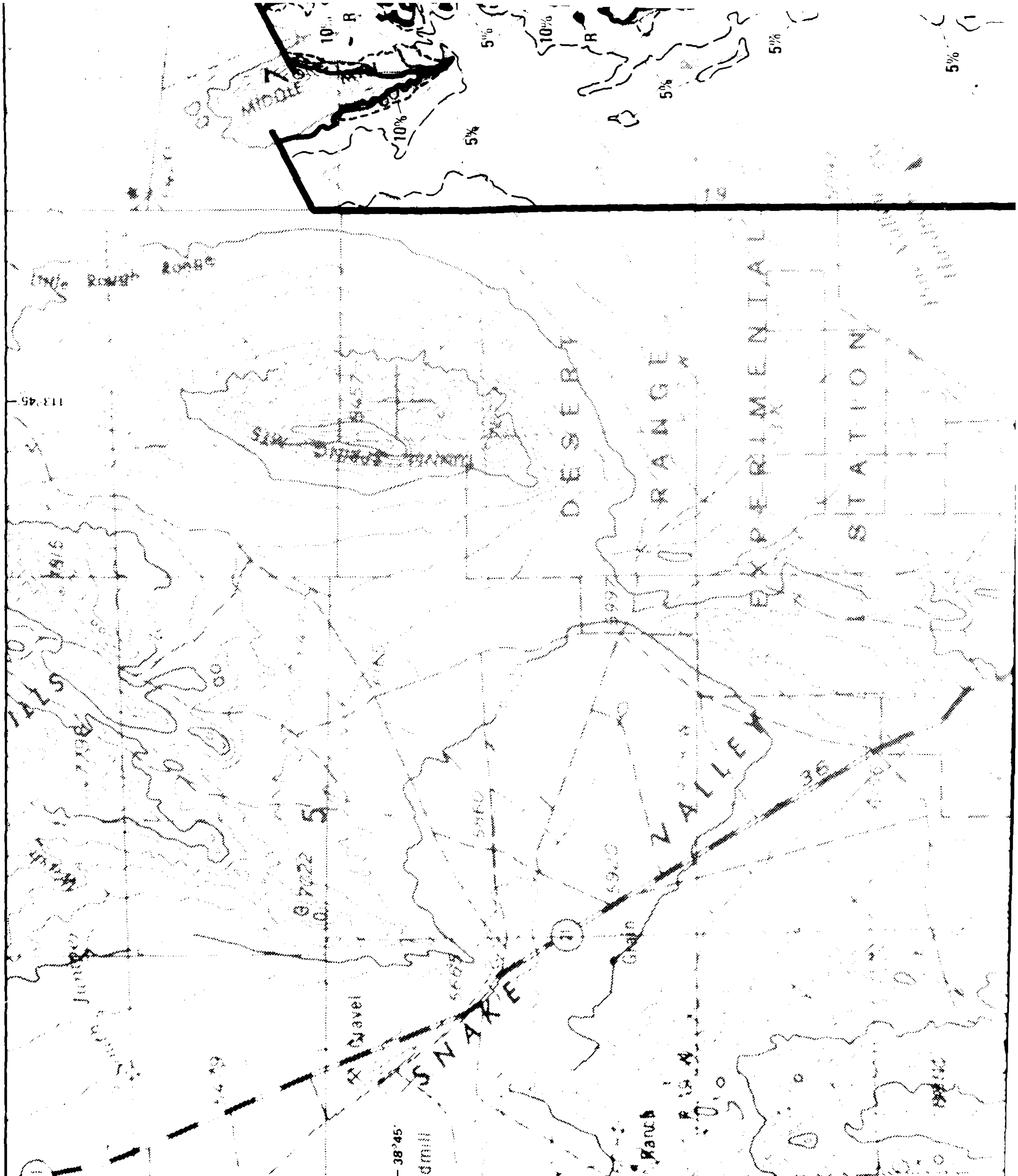


EXPLANATION

(symbol)	Contact between rock and basin fill.
(symbol)	5% Slope line.
(symbol)	10% Slope line.
(symbol)	Valley borders (north and west).
(symbol)	Area excluded, on basis of 10% slopes.
(symbol)	Terrain exclusion area.
(symbol)	Areas of isolated exposed rock.
R	Areas of isolated exposed rock too small for shading.

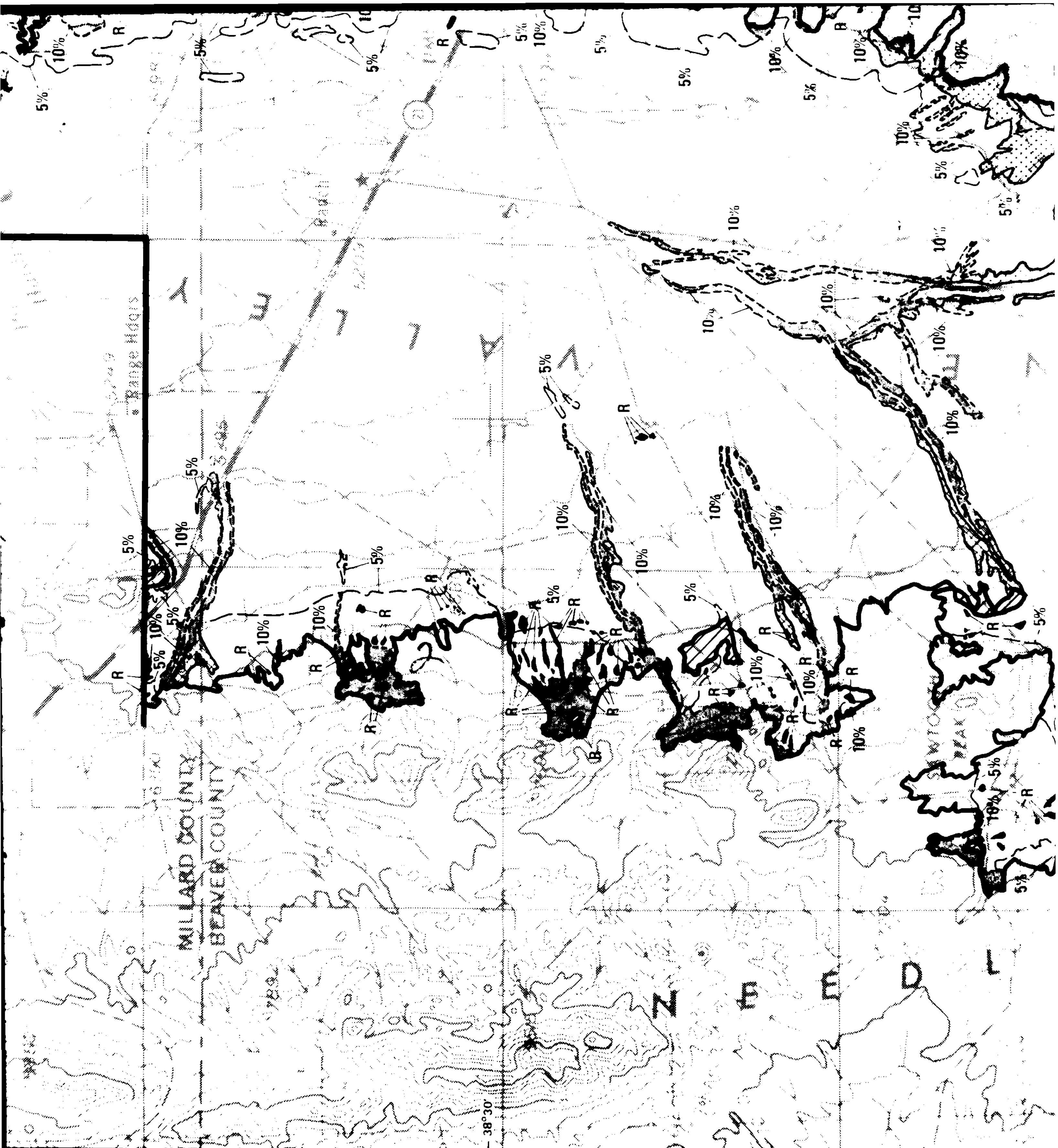


NOTE Data used in constructing this map are from (1) field observations, (2) 1 62,500 USGS topographic maps, and (3) 1.60,000 and 1 25,000 aerial photographs. Due to scale of presentation and variability of terrain conditions, this map is generalized.

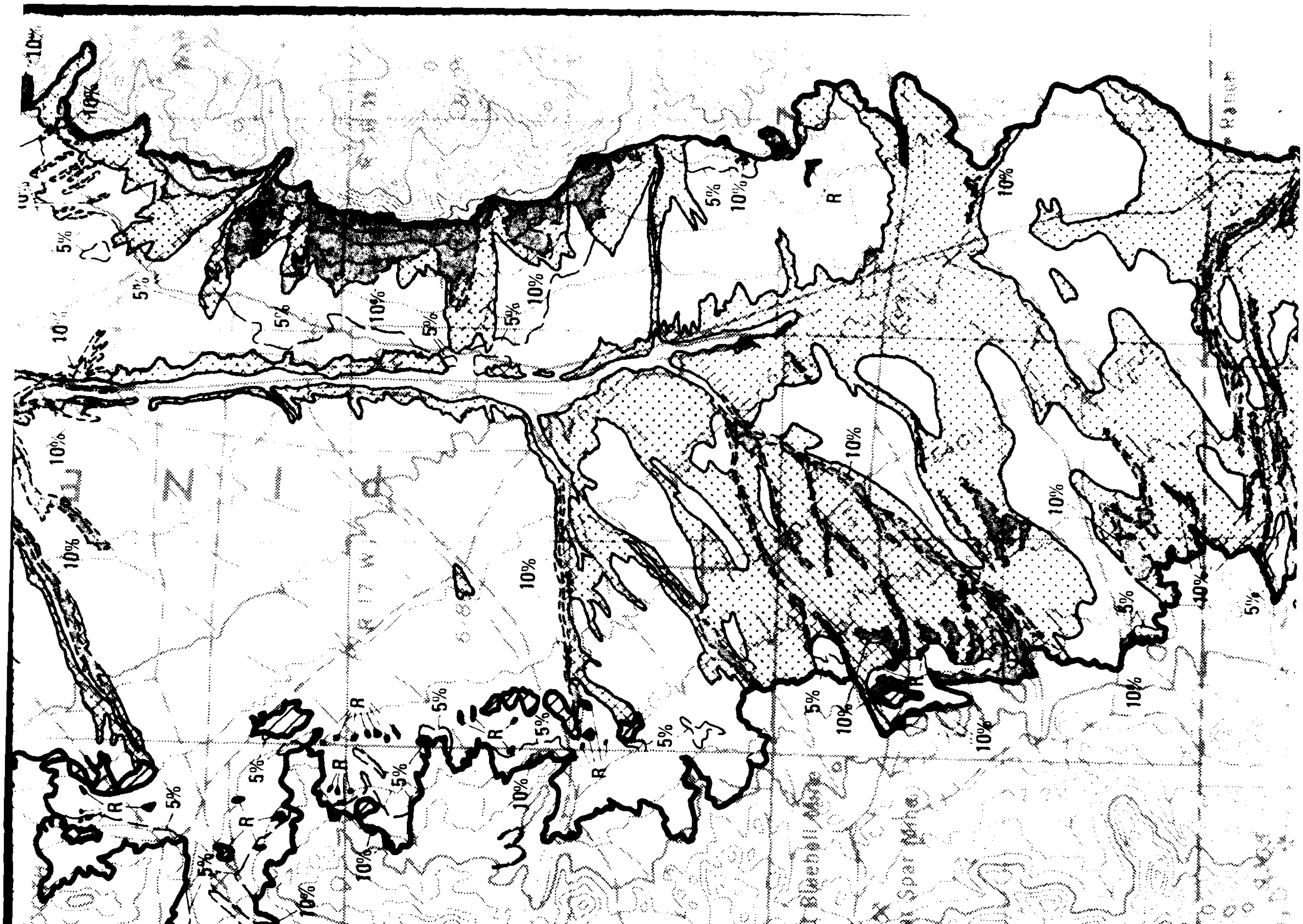

DESERT RANGE EXPERIMENTAL STATION
SNAKE VALLEY
5%
10%
Ranch
38°45'
113°45'

24 MAR 81

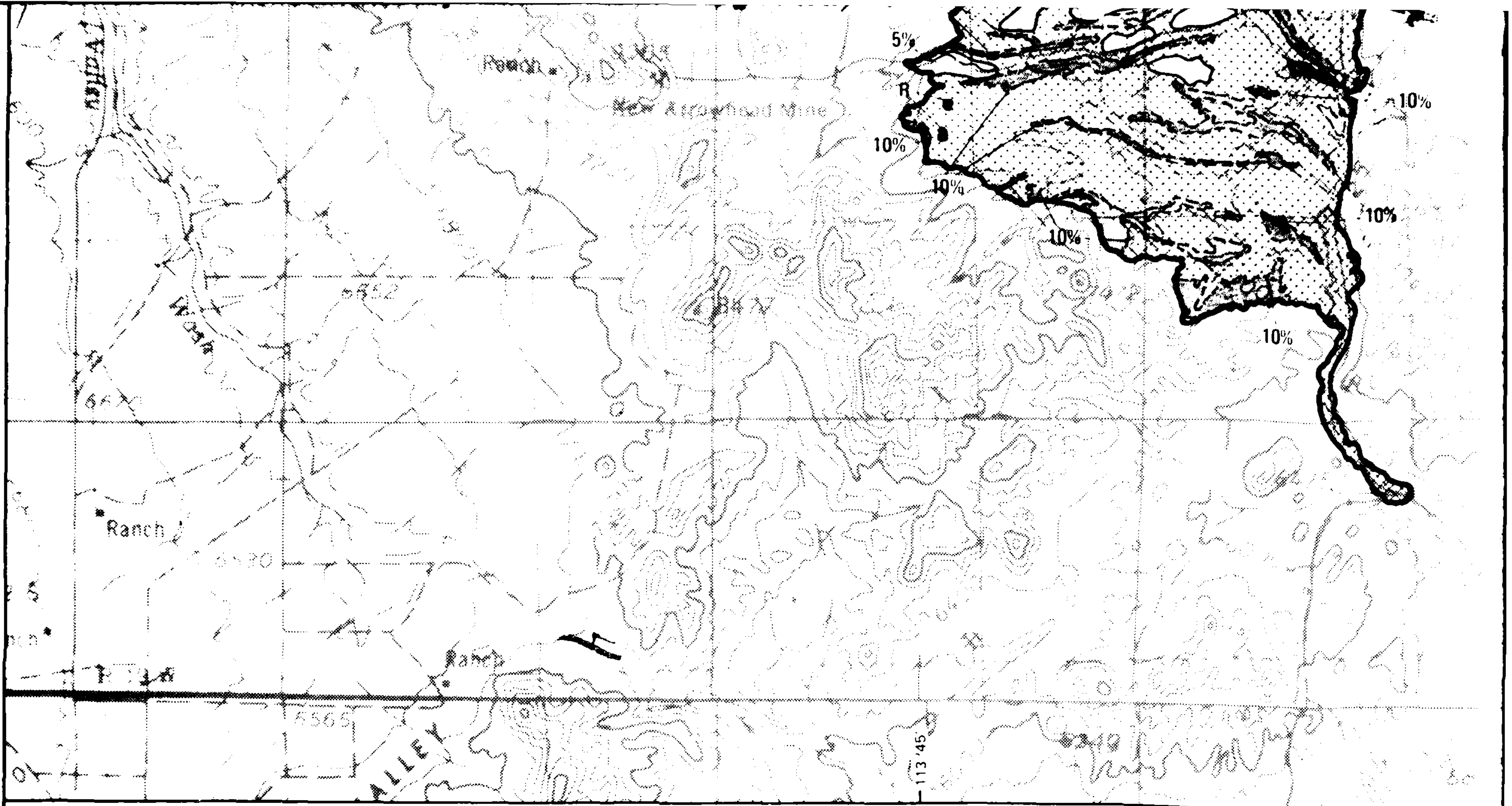
5



6


BEAVER COUNTY
IRON COUNTY
Holt Bluebell Mine
Spar Mine
Ranch
Ranch
38°15'
5%
10%
R

7



EXPLANATION

Contact between rock and basin fill.

5% Slope line.

10% Slope line.

Valley borders (north and west).

Area excluded, on basis of 10% slopes.

Contact between rock and basin fill.

5% Slope line.

10% Slope line.

Valley borders (north and west).

Area excluded, on basis of 10% slopes.

Terrain exclusion area.

Areas of isolated exposed rock.

R Areas of isolated exposed rock too small for shading.

NOTE Data used in constructing this map are from: (1) field observations, (2) 1:62,500 USGS topographic maps, and (3) 1:60,000 and 1:25,000 aerial photographs. Due to scale of presentation and variability of terrain conditions, this map is generalized.

0

TERRAIN

PINE VALLEY, UTAH

MX SITING INVESTIGATION

DEPARTMENT OF THE AIR FORCE – BMO

DRAWING

3-5

FUGRO NATIONAL, INC.

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APPENDIX

A1.0 GLOSSARY OF TERMS

ACTIVE FAULT - A fault which has had surface displacement within Holocene time (about the last 11,000 years).

ACTIVITY NUMBER - A designation composed of the valley abbreviation followed by the activity type and a unique number; may also be used to designate a particular location in a valley.

ALLUVIAL FAN - A body of stream deposits whose surface approximates a segment of a cone that radiates downslope from the point where the stream leaves a mountainous area and experiences a marked change in gradient resulting in deposition of alluvium.

ALLUVIUM - A general term for a more- or less-stratified deposit of gravel, sand, silt, clay, or other debris, moved by streams from higher to lower ground.

AQUIFER - A permeable saturated zone below the earth's surface capable of conducting and yielding water as to a well.

ARRIVAL - An event; the appearance of seismic energy on a seismic record; a lineup of coherent energy signifying the arrival of a new wave train.

ATTERBERG LIMITS - A general term applied to the various tests used to determine the various states of consistency of fine-grained soils. The four states of consistency are solid, semisolid, plastic, and liquid.

Liquid Limit (LL) - The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D 423-66).

Plastic Limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D 424-59).

Plasticity Index (PI) - Numerical difference between the liquid limit and the plastic limit indicating the range of moisture content through which a soil-water mixture is plastic.

BASIN-FILL MATERIAL/BASIN-FILL DEPOSITS - Heterogenous detrital material deposited in a sedimentary basin.

BASE LEVEL - The theoretical limit or lowest level toward which erosion constantly progresses; the level at which neither erosion or deposition takes place.

BEDROCK - A general term for the rock, usually solid, that underlies soil or other unconsolidated, surficial material. The term is also used here to include the rock composing the local mountain ranges.

BORING - A hole drilled in the ground for the purpose of subsurface exploration.

BOUGUER ANOMALY - The residual value obtained after latitude, elevation, and terrain corrections have been applied to gravity data.

BOULDER - A rock fragment, usually rounded by weathering and abrasion with an average diameter of 12 inches (305 mm) or more.

BULK SAMPLE - A disturbed soil sample (bag sample) obtained from cuttings brought to the ground surface by a drill rig auger or obtained from the walls of a trench excavation.

c - Cohesion (Shear strength of a soil not related to interparticle friction).

CALCAREOUS - Containing calcium carbonate; presence of calcium carbonate is commonly identified on the basis of reaction with dilute hydrochloric acid.

CALICHE - In general, secondary calcium-carbonate cementation of unconsolidated materials occurring in arid and semiarid areas.

CALIFORNIA BEARING RATIO (CBR) - The ratio (in percent) of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed rock base material (ASTM D 1883-73). During the CBR test, the load is applied on the circular penetration piston (3 inches^2 base area; 19 cm^2) which is penetrated into the the soil sample at a constant penetration rate of 0.05 inch/minute (1.2 mm/min). The bearing ratio reported for the soil is normally the one at 0.1 inch (2.5 mm) penetration.

CLAST - An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering (disintegration) of a larger rock mass.

CLAY - Fine-grained soil (passes No. 200 sieve [0.074 mm]) that can be made to exhibit plasticity within a range of water content and that exhibits considerable strength when air-dried.

CLAY SIZE - That portion of the soil finer than 0.002 mm.

CLOSED BASIN - A catchment area draining to some depression or lake within its area, from which water escapes only by evaporation or infiltration into the subsurface.

COARSE-GRAINED (or granular) - A term which applies to a soil of which more than one-half of the soil particles, by weight, are larger than 0.074 mm in diameter (No. 200 U.S. sieve size).

COARSER-GRAINED - A term applied to alluvial fan deposits which are predominantly composed of material (cobble) larger than 3 inches (76 mm) in diameter.

COBBLE - A rock fragment, larger than a pebble and smaller than a boulder, having a diameter between 3 and 10 inches (64 and 256 mm), being somewhat rounded or otherwise modified by abrasion in the course of transport.

COMPACTION TEST - A test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D 1557-70).

COMPRESSIBILITY - Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load.

COMPRESSIONAL WAVE - An elastic body wave in which particle motion is in the direction of propagation; the type of seismic wave assumed in conventional seismic exploration. Also called P-wave, dilatational wave, and longitudinal wave.

CONDUCTIVITY - The ability of a material to conduct electrical current. In isotropic material, conductivity is the reciprocal of resistivity. Units are mhos per meter.

CONE PENETROMETER TEST - A method of evaluating the in-situ engineering properties of soil by measuring the penetration resistance developed during the steady slow penetration of a cone (60° apex angle, 10-cm^2 projected area) into soil.

Cone resistance or end bearing resistance, q_c - The resistance to penetration developed by the cone, equal to the vertical force applied to the cone divided by its horizontally projected area.

Friction resistance, f_s - The resistance to penetration developed by the friction sleeve, equal to the vertical force applied to the sleeve divided by its surface area. This resistance consists of the sum of friction and adhesion.

Friction ratio, f_R - The ratio of friction resistance to cone resistance, f_s/q_c, expressed in percent.

CONSISTENCY - The relative ease with which a soil can be deformed.

CONSOLIDATION TEST - A type of test to determine the compressibility of a soil sample. The sample is enclosed in the consolidometer which is then placed in the loading device. The load is applied in increments at certain time intervals and the change in thickness is recorded.

CORE SAMPLE - A cylindrical sample obtained with a rotating core barrel with a cutting bit at its lower end. Core samples are obtained from indurated deposits and in rock.

DEGREE OF SATURATION - Ratio of volume of water in soil to total volume of voids.

DIRECT SHEAR TEST - A type of test to measure the shear strength of a soil sample where the sample is forced to fail on a predetermined plane.

DISSECTION/DISSECTED (alluvial fans) - The cutting of stream channels into the surface of an alluvial fan by the movement (or flow) of water.

DRY UNIT WEIGHT/DRY DENSITY - Weight per unit volume of the solid particles in a soil mass.

ELECTRICAL CONDUCTIVITY - Ability of a material to conduct electrical current.

ELECTRICAL RESISTIVITY - Property of a material which resists flow of electrical current.

EOLIAN - A term applied to materials which are deposited by wind.

EPHEMERAL (stream) - A stream or reach of a stream that flows briefly only in direct response to precipitation in the immediate locality and whose channel is at all times above the water table.

EXTERNAL DRAINAGE - Stream drainage system whose down-gradient flow is unrestricted by any topographic impediments.

EXTRUSIVE ROCK - Igneous rock that has been ejected onto the earth's surface (e.g., lava, basalt, rhyolite, andesite, detrital material, volcanic tuff, pumice).

FAULT - A plane or zone of fracture along which there has been displacement.

FAULT BLOCK MOUNTAINS - Mountains that are formed by normal faulting in which the surface crust is divided into partially to entirely fault-bounded blocks of different elevations.

FINE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are smaller than 0.074 mm in diameter (passing the No. 200 U.S. size sieve).

FINER-GRAINED - A term applied to alluvial fan deposits, which are composed predominantly of material less than 3 inches (76 mm).

FLUVIAL DEPOSITS - Material produced by river action; generally loose, moderately well-graded sands and gravel.

FORMATION - A mappable assemblage of rocks characterized by some degree of homogeneity or distinctiveness.

FUGRO DRIVE SAMPLE - A 2.50-inch- (6.4-cm) diameter soil sample obtained from a drill hole with a Fugro drive sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 one-inch- (2.54-cm) long brass sample rings. The sampler is advanced into the soil using a drop hammer.

GEOMORPHOLOGY - The study, classification, description, nature, origin, and development of present landforms and their relationships to underlying structures and of the history of geologic changes as recorded by these surface features.

GEOPHONE - The instrument used to transform seismic energy into electrical voltage; a <u>seismometer</u>, <u>jug</u>, or <u>pickup</u>.

GRABEN - An elongated crustal block that has been downthrown along faults relative to the rocks on either side.

GRAIN-SIZE ANALYSIS (GRADATION) - A type of test to determine the distribution of soil particle sizes in a given soil sample. The distribution of particle sizes larger than 0.074 mm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 0.074 mm is determined by a sedimentation process using a hydrometer.

GRANULAR - See Coarse-Grained.

GRAVEL - Particles of rock that pass a 3-inch (76.2-mm) sieve and are retained on a No. 4 (4.75-mm) sieve.

GRAVITY - The force of attraction between bodies because of their mass. Usually measured as the acceleration of gravity.

GYPSIFEROUS - Containing gypsum, a mineral consisting mostly of calcium sulfate.

HORST - An elongated crustal block that has been uplifted along faults relative to the rocks on either side.

INTERIOR DRAINAGE - Stream drainage system that flows into a closed topographic low (basin).

INTRUSIVE (rock) - A rock formed by the process of emplacement of magma (liquid rock) in preexisting rock (e.g., granite, granodiorite, quartz monzonite).

LACUSTRINE DEPOSITS - Materials deposited in a lake environment.

LINE - A linear array of observation points, such as a seismic line.

LINEAMENT - A linear topographic feature of regional extent that is thought to reflect crustal structure.

LIQUID LIMIT - See ATTERBERG LIMITS.

LOW-STRENGTH SURFICIAL SOIL - Soil which will perform poorly as a road subgrade, at its present consistency, when used directly beneath a road section.

MOISTURE CONTENT - The ratio, expressed as a percentage, of the weight of water contained in a soil sample to the oven-dried weight of the sample.

N VALUE - Penetration resistance, described as the number of blows required to drive the standard split-spoon sampler for the second and third 6 inches (0.15 m) with a 140-pound (63.5-kg) hammer falling 30 inches (0.76 m) (ASTM D 1586-67).

OPTIMUM MOISTURE CONTENT - Moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort.

P-WAVE - See Compressional Wave.

PATINA (Desert Varnish) - A dark coating or thin outer layer produced on the surface of a rock or other material by weathering.

PAVEMENT/DESERT PAVEMENT - When loose material containing pebble-sized or larger rocks is exposed to rainfall and wind action, the finer dust and sand are blown or washed away and the pebbles gradually accumulate on the surface forming a mosaic which protects the underlying finer material from wind attack. Pavement can also develop in finer-grained materials. In this case, the armored surface is formed by dissolution and cementation of the grains involved.

PERCHED GROUND WATER - Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone.

PERMEABILITY - The property of soil and/or rock material which permits liquid to pass through.

pH - An index of the acidity or alkalinity of a soil in terms of the logarithm of the reciprocal of the hydrogen ion concentration.

PHI (ϕ) - Angle of internal friction.

PIEZOMETRIC SURFACE - An imaginary surface representing the static head of ground water and defined by the level to which water will rise in a well.

PITCHER TUBE SAMPLE - An undisturbed, 2.87-inch- (73-mm) diameter soil sample obtained from a drill hole with a Pitcher tube sampler. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending upon the hardness of the material being penetrated.

PLASTIC LIMIT - See ATTERBERG LIMITS.

PLASTICITY INDEX - See ATTERBERG LIMITS.

PLAYA/PLAYA DEPOSITS - A term used in the southwest U.S. for a dried-up, flat-floored area composed of thin, evenly stratified sheets of clay, silt, or fine sand and representing the lowest part of a shallow, completely closed or undrained desert lake basin in which water accumulates and is quickly evaporated, usually leaving deposits of soluble salts.

POORLY GRADED - A descriptive term applied to a coarse-grained soil if it consists predominantly of one particle size (uniformly graded) or has a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

RANGE-BOUNDING FAULT - Usually a normal fault in which one side has moved up relative to the other and which separates the mountain front from the valley.

RELATIVE AGE - The relationship in age (oldest to youngest) between geologic units without specific regard to number of years.

RESISTIVITY (True, Intrinsic) - The property of a material which resists the flow of electric current. The ratio of electric-field intensity to current density.

ROCK UNITS - Distinct rock masses with different characteristics (e.g., igneous, metamorphic, sedimentary).

ROTARY WASH DRILLING - A boring technique in which advancement of the hole through overburden is accomplished by rotation of a heavy string of rods while continuous downward pressure is maintained through the rods on a bit at the bottom of the hole. Water or drilling mud is forced down the rods to the bit, and the return flow brings the cuttings to the surface.

S-WAVE - See Shear Wave.

SAND - Soil passing through a No. 4 (4.75-mm) sieve and retained on a No. 200 (0.075-mm) sieve.

SAND DUNE - A low ridge or hill consisting of loose sand deposited by the wind, found in various desert and coastal regions and generally where there is abundant surface sand.

SEISMIC - Having to do with elastic waves. Energy may be transmitted through the body of an elastic solid as P-waves (compressional waves) or S-waves (shear waves).

SEISMIC LINE - A linear array of travel time observation points (geophones). In this study, each line contains 24 geophone positions.

SEISMIC REFRACTION DATA - Data derived from a type of seismic shooting based on the measurement of seismic energy as a function of time after the shot and of distance from the shot, by determining the arrival times of seismic waves which have traveled nearly parallel to the bedding in high-velocity layers, in order to map the depth to such layers.

SEISMOGRAM - A seismic record.

SEISMOMETER - See Geophone.

SHEAR STRENGTH - The maximum resistance of a soil to shearing (tangential) stresses.

SHEAR WAVE - A body wave in which the particle motion is perpendicular to the direction of propagation. Also called S-Wave or transverse wave.

SHEET FLOW - A process in which storm born water spreads as a thin, continuous veneer (sheet) over a large area.

SHEET SAND - A blanket deposit of sand which accumulates in shallow depressions or against rock outcrops, but does not have characteristic dune form.

SHOT - Any source of seismic energy; e.g., the detonation of an explosive.

SHOT POINT - The location of any source of seismic energy; e.g., the location where an explosive charge is detonated in one hole or in a pattern of holes to generate seismic energy. Abbreviated SP.

SILT - Fine-grained soil passing the No. 200 sieve (0.074 mm) that is nonplastic or very slightly plastic and that exhibits little or no strength when air-dried.

SILT SIZE - That portion of the soil finer than 0.02 mm and coarser than 0.002 mm.

SITE - Location of some specific activity or reference point.

SPECIFIC GRAVITY - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

SPLIT-SPOON SAMPLE - A disturbed sample obtained with a split-spoon sampler with an outside diameter of 2.0 inches (5.1 cm). The sample consists of a split barrel which is driven into the soil using a drop hammer.

SPREAD - The layout of geophone groups from which data from a single shot are recorded simultaneously. Spreads containing 24 geophones have been used in Fugro's seismic refraction surveys.

STREAM CHANNEL DEPOSITS - See Fluvial Deposits.

STREAM TERRACE DEPOSITS - Stream channel deposits no longer part of an active stream system, generally loose, moderately well graded sand and gravel.

SULFATE ATTACK - The process during which sulfates, salts of sulfuric acid, contained in ground water cause dissolution and damage to concrete.

SURFICIAL DEPOSIT - Unconsolidated residual colluvial and alluvial deposits occurring on or near the earth's surface.

TEST PIT - An excavation made to depths of about 5 feet (1.5 m) by a backhoe. A test pit permits visual examination of undisturbed material in place.

TRENCH - An excavation by a backhoe to depths of about 15 feet (4.5 m). A trench permits visual examination of soil in place and evaluation of excavation wall stability.

TRIAXIAL COMPRESSION TEST - A type of test to measure the shear strength of an undisturbed soil sample (ASTM D 2850-70). To conduct the test, a cylindrical specimen of soil is surrounded by a fluid in a pressure chamber and subjected to an isotropic pressure. An additional compressive load is then applied, directed along the axis of the specimen called the axial load.

Consolidated-Drained (CD) Test - A triaxial compression test in which the soil was first consolidated under an all-around confining stress (test chamber pressure) and was then compressed (and hence sheared) by increasing the vertical stress. Drained indicates that excess pore water pressures generated by strains are permitted to dissipate by the free movement of pore water during consolidation and compression.

Consolidated-Undrained (CU) Test - A triaxial compression test in which essentially complete consolidation under the confining (chamber) pressure is followed by a shear at constant water content.

UNCONFINED COMPRESSION - A type of test to measure the compressive strength of an undisturbed sample (ASTM D 2166-66). Unconfined compressive strength is defined as the load per unit area at which an unconfined prismatic or cylindrical specimen of soil will fail in a simple compression test.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) - A system which determines soil classification for engineering purposes on the basis of grain-size distribution and Atterberg limits.

VALLEY FILL - See Basin-Fill Material/Basin-Fill Deposits.

VELOCITY - Refers to the propagation rate of a seismic wave without implying any direction. Velocity is a property of the medium and not a vector quantity when used in this sense.

VELOCITY LAYER - A layer of rock or soil with a homogeneous seismic velocity.

VELOCITY PROFILE - A cross section showing the distribution of material seismic velocities as a function of depth.

WASH SAMPLE - A sample obtained by screening the returned drilling fluid during rotary wash drilling.

WATER TABLE - The upper surface of an unconfined body of water at which the pressure is equal to the atmospheric pressure.

WELL GRADED - A soil is identified as well-graded if it has a wide range in grain size and substantial amounts of most intermediate sizes.

Definitions were derived from the following references:

American Society for Testing and Materials, 1976, Annual book of ASTM standards, Part 19: Philadelphia, American Society for Testing and Materials, 484 p.

Fairbridge, Rhodes W., ed., 1968, The enclyclopedia of geomorphology: Stroudsburg, Pennsylvania, Dowden, Hutchinson, and Ross, Inc., 1295 p.

Gary, M., McAfee, R., Jr., Wolf, C. L., eds., 1972, Glossary of geology: Washington, D.C., American Geological Institute, 805 p.

Merriam, G., and Merriam, C., 1977, Webster's new collegiate dictionary: Springfield, Mass., G. and C. Merriam Co., 1536 p.

Sheriff, R. E., 1973, Encyclopedic dictionary of exploration geophysics: Tulsa, Oklahoma, Society of Exploration Geophysicists, 266 p.

A2.0 EXCLUSION CRITERIA

The exclusion criteria used during the Verification studies are based on both geotechnical and cultural considerations. Land excluded for geotechnical reasons includes areas of shallow rock, shallow water, and adverse terrain. Cultural exclusions include areas near towns, lands already withdrawn from public use, and regions with potentially high economic value. The exclusion criteria are defined in Table A2-1.

FN-TR-27-PI-I

CRITERIA		DEFINITION AND COMMENTS
SURFACE ROCK AND ROCK OCCURRING WITHIN 50 FEET (15m) AND 150 FEET (46m) OF THE GROUND SURFACE		Rock is defined as any earth material which is not rippable by conventional excavation methods. Where available, seismic P-wave velocities were evaluated in the determination of rock conditions.
SURFACE WATER AND GROUND WATER OCCURRING WITHIN 50 FEET (15m) AND 150 FEET (46m) OF THE GROUND SURFACE		Surface water includes all significant lakes, reservoirs, swamps, and major perennial streams. Water which would be encountered in a 50-foot and 150-foot excavation was considered in the application of this criterion. Depths to ground water resulting from deeper confined aquifers were not considered.
TERRAIN	Percent Grade	Areas having surface gradients exceeding 10 percent or a preponderance of slopes exceeding 10 percent as determined from maps at scales of 1:125,000, 1:62,500, and 1:24,000 and by field observation.
	Drainage	Areas averaging two or more 10-foot deep drainages per 1000 feet (measured parallel to contours, as determined from maps at scales of 1:24,000 or in the field).
CULTURAL	Land Use:	All significant federal and state forests, parks, monuments, and recreational areas. All significant federal and wildlife refuges, grasslands, ranges, preserves and management areas. Indian reservations.

EXCLUSION CRITERIA VERIFICATION STUDIES, NEVADA–UTAH	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	TABLE A2-1
FUGRO NATIONAL, INC.	

A3.0 ENGINEERING GEOLOGIC PROCEDURES

The principal objectives of the field geology investigation were to:

1. Delineate surficial extent of soil types and geologic units;
2. Assess terrain conditions; and
3. Make observations helpful in defining depth to rock and water.

Aerial photographs (1:60,000 scale black and white; 1:25,000 scale color) served as the base on which all mapping was done. Field activities were directed toward checking the photogeologic mapping.

Field checking consisted chiefly of collecting data about surficial soils at selected locations in order to refine contacts and define engineering characterisitics of photogeologic units. At each location, observations of grain-size distribution, color, clast lithology, surface-soil development, and a variety of engineering parameters were recorded (see Volume II, Geotechnical Data). Observations were made in existing excavations (borrow pits, road cuts, stream cuts) or in hand-dug test pits. Extrapolation of this data to determine surficial extent was accomplished by geologic reconnaissance over existing roads.

Of the parameters listed, grain size is the most important for engineering purposes and for this reason is included in the geologic unit designation. However, grain size is not readily mapped on aerial photos, and much of the field work involved determination of the extent of surficial deposits of a particular grain-size category (gravel, sand, or fine-grained).

Terrain data were also taken at geologic field stations. Drainage width and depth were estimated and predominant surface slope was measured. Slopes were measured over a distance of 100 to 150 feet (31 to 46 m) with an Abney hand level. For additional data, depths of major drainages encountered during geologic reconnaissance between stations were recorded on the aerial photographs.

To help refine depth-to-rock interpretations, observations were concentrated along the basin margin to identify areas of shallow rock. Observations regarding depth to water were restricted to measurements in existing wells and identification of areas with water at the surface.

A4.0 GEOPHYSICAL PROCEDURES

A4.1 SEISMIC REFRACTION SURVEYS

A4.1.1 Instruments

Field explorations were performed with a 24-channel SIE Model RS-44 seismic refraction system which consisted of 24 amplifiers coupled with a dry-write, galvanometer-type recording oscillograph. Seismic energy was detected by Mark Products Model L-10 geophones with natural frequency of 4.5 Hz. Geophones were fitted with short spikes to provide good coupling with the ground. Cables with two takeout intervals were used to transmit the detected seismic signal from the geophones to the amplifiers. Time of shot was transmitted from shot point to recording system via an FM radio link.

The degree of gain was set on the amplifiers by the instrument operators and was limited by the background noise at the time of the shot. The amplifiers are capable of maximum gain of 1.1 million. The oscillograph placed timing lines on the seismograms at 0.01-second intervals. The timing lines form the basis for measuring the time required for the energy to travel from the shot to each geophone.

A4.1.2 Field Procedures

Each seismic refraction line consisted of a single spread of 24 geophones with a distance of 410 feet (125 m) between end points. Geophone spacing provided six intervals of 25 feet (7.6 m) at both ends of the line and 11 central intervals of 10 feet (3 m). Six shots were made per spread at locations 65 feet (20 m), 190 (58 m), and 305 feet (93 m) left and right of the spread center. The recording system was located between geophones 12 and 13.

The explosive used was "Kinestik" which was transported to the site as two nonexplosive components, a powder and a liquid. The components were mixed in the field to make an explosive compound. Charges ranged in size from one-third to five pounds and were buried from 1 to 5 feet (0.3 to 1.5 m) deep. Charges were detonated using Reynold's exploding bridge wire (EBW) detonators instead of conventional electric blasting caps. Use of EBWs provides maximum safety against accidental detonation and extremely accurate "time breaks" (instant of detonation). Relative elevations of geophones and shot points were obtained by level or transit where lines had more than 2 or 3 feet (0.6 to 0.9 m) of relief.

A4.1.3 Data Reduction

The travel times for compressional waves from the shots to the geophones were obtained from the seismograms by visual inspection. These times were plotted at their respective horizontal distances and best fit lines were drawn through the points to obtain apparent velocities for materials below the seismic line.

A combination of delay time and ray tracing methods was used in a computer program to obtain depth to refracting horizons from the time-distance information.

A4.2 ELECTRICAL RESISTIVITY SURVEYS

A4.2.1 Instruments

Electrical resistivity measurements were made with a Bison Instrument model 2350B resistivity meter which provides current to the earth through two electrodes and measures the potential (voltage) drop across two other electrodes.

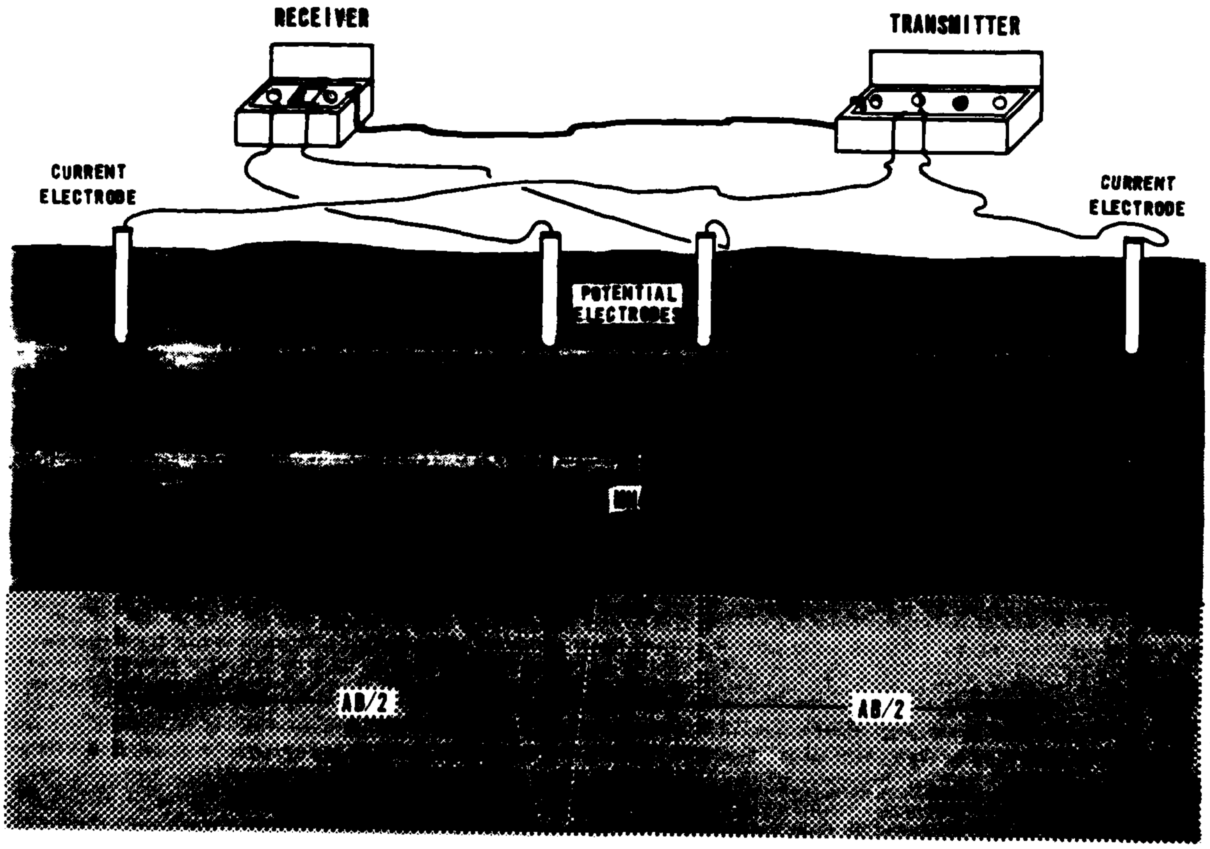
A4.2.2 Field Procedures

Electrical resistivity soundings were made using the Schlumberger electrode arrangement. Soundings are made by successive resistivity measurements which obtain information from deeper and deeper materials. The depth of penetration of the electrical current is made greater by increasing the distance between the current electrodes. The arrangement of electrodes in the Schlumberger method is shown in Figure A4-1. The four electrodes are in a line with the two current electrodes on the ends. The distance between the current electrodes (AB) is always five or more times greater than the distance between the potential electrodes (MN).

The initial readings are made with MN equal to 5 feet (1.5 m) and AB equal to 30 feet (9 m). Successive readings were made with AB at 40, 50, 60, 80, 100, 120, 160, 200, 300, 400, 500, and 600 feet (12, 15, 18, 24, 30, 37, 49, 61, 91, 122, 152, and 183 m). MN spacing is sometimes increased one or two times as AB is expanded. This increase is required when the signal drops to a level below the meter's sensitivity. The potential drop is greater between more widely spaced electrodes (MN), so increasing MN increases the signal. When it becomes necessary to increase MN, the spacing of AB is reduced to the spacing of the previous reading. MN is then increased and a measurement is made. This provides two resistivity measurements at the same AB spacing but with different MN spacings.

A4.2.3 Data Reduction

Each apparent resistivity value is plotted versus one-half the current electrode spacing (AB/2) used to obtain it. Log-log graph paper is used to form the coordinates for the graph. A smooth curve is drawn through the points. This sounding curve forms the basis for interpreting the resistivity layering at the sounding location.



SCHLUMBERGER ARRAY
ELECTRICAL RESISTIVITY SOUNDINGS
VERIFICATION SITES, NEVADA-UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE A4-1

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A computer program that does iterative "curve-matching" is used to develop a layer model that has a theoretical resistivity curve that is similar to the field curve. Input to the program is generated by digitizing the field curve with an electronic digitizer.

A5.0 ENGINEERING PROCEDURES

Soil engineering activities consisted of the following:

1. Field activities:
   - o Borings
   - o Trenches
   - o Test Pits
   - o Surficial Samples
   - o Cone Penetrometer Tests
   - o Field CBR Tests
2. Office activities:
   - o Laboratory Tests
   - o Data Analyses and Interpretations

The procedures used in the various activities are described in the following sections.

A5.1 BORINGS

A5.1.1 Drilling Techniques

The borings were drilled at designated locations using rotary techniques.

The drilling rig was a truck-mounted Failing 1500 with hydraulic pulldown. The borings were nominally 4 7/8 inches (124 mm) in diameter and 100 to 160 feet (30 to 49 m) deep. A bentonite-water slurry was used to return soil cuttings to the surface. A tricone drill bit was used for coarse-grained soils and a drag bit for drilling in fine-grained soils.

A5.1.2 Method of Sampling

A5.1.2.1 Sampling Intervals

Soil samples were obtained at the following nominal depths as well as at depths of change in soil type.

0' to 10'	(0.0 to 3.0 m)	- Pitcher or drive - samples at 3' intervals
10' to 30'	(3.0 to 9.1 m)	- Pitcher or drive - samples at 5' intervals
30' to 120'	(9.1 to 36.6 m)	- Pitcher or drive - samples at 10' intervals
120' to 160'	(36.6 to 48.8 m)	- Pitcher or drive - samples at 20' intervals

A5.1.2.2 Sampling Techniques

a. Fugro Drive Samples: Fugro drive samplers were used to obtain relatively undisturbed soil samples. The Fugro drive sampler is a ring-lined barrel sampler with an outside diameter of 3.0 inches (76.2 mm) and inside diameter of 2.50 inches (63.5 mm). It contains 12 individual 1-inch- (25.4-mm) long rings and is attached to a 12-inch- (30-cm) long waste barrel.

The sampler was advanced using a downhole hammer weighing 300 pounds (136 kg) with a drop of 24 inches (61.0 cm).

The number of blows required to advance the sampler for a 6-inch (15-cm) interval were recorded. Samples obtained were retained in the rings, placed in plastic bags with manually twisted top ends and sealed in plastic sample containers. Each sample was identified with a label indicating job number, boring number, sample number, depth range, Unified Soil Classification Symbol (USCS) (Table A5-1), and date. Ring samples were placed in foam-lined steel boxes.

b. Pitcher Samples: The Pitcher sampler was used to obtain undisturbed soil samples. The primary components of this sampler are an outer rotating core barrel with a bit and an inner, stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending on the hardness of the material penetrated. The average inside diameter of the sampling tubes used was 2.87 inches (73 mm). Before placing the Pitcher tube in the outer barrel, the tube was inspected for sharpness and protrusions.

The Pitcher sampler was then lowered to the bottom of the boring and the thin-walled sampling tube advanced into the soil ahead of the rotating cutting bit by the weight of the drill rods and hydraulic pulldown. The thin-walled sampling tube was retracted into the core barrel and the sampler was brought to the surface. After removal of the sampling tube from the core barrel, the length of the recovered soil sample was measured and recorded. Before preparing and sealing the tube, the drilling fluid in the Pitcher tube was removed. Cap plugs were taped in place on the top and bottom of the Pitcher tube and sealed with wax. When Pitcher samples could not be retrieved without disturbance, they were clearly marked as "disturbed." Each sealed Pitcher tube was labeled as explained under "Fugro Drive Samples" and then placed vertically in foam-lined wooden boxes.

c. Bulk Samples: Bulk samples from rotary drilling were obtained by screening the returning drilling fluid to obtain wash samples. Recovered samples were placed in plastic bags and labeled as previously explained.

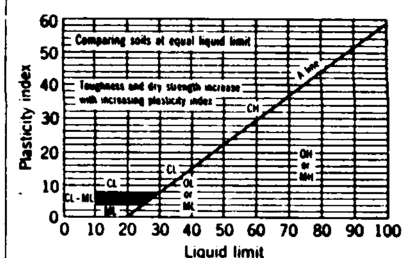
d. Split-Spoon Samples: Split-spoon samplers were used to obtain disturbed, but representative, soil samples continuously in the top 10.5 feet (3.2 m). The soil samples were classified and disposed of in the field. The split-spoon sampler consisted of a barrel shoe, a split barrel or tube, a solid sleeve, and a sampler head. The inside diameter of the sampler shoe is 1.375 inches (35 mm) and the length is about 18 inches (45.7 cm). Sampling with the split barrel-sampler is accomplished by

Major Divisions		Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)	Group Symbols[a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria
Coarse-grained soils: More than half of material is *larger* than No. 200 sieve size[b] (The No. 200 sieve size is about the smallest particle visible to naked eye) — Gravels: More than half of coarse fraction is larger than No. 4 sieve size (For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size)	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
		Predominantly one size or a range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for *GW*
	Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics	Atterberg limits below "A" line, or *PI* less than 4 — Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
		Plastic fines (for identification procedures, see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, with *PI* greater than 7
Sands: More than half of coarse fraction is smaller than No. 4 sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	*SW*	Well graded sands, gravelly sands, little or no fines	Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
		Predominantly one size or a range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for *SW*
	Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 5 — Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
		Plastic fines (for identification procedures, see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits below "A" line with *PI* greater than 7

Laboratory classification criteria (coarse-grained soils): Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5% — *GW, GP, SW, SP*; More than 12% — *GM, GC, SM, SC*; 5% to 12% — *Borderline* cases requiring use of dual symbols.

Identification Procedures on Fraction Smaller than No. 40 Sieve Size

Major Divisions		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols[a]	Typical Names	Information Required for Describing Soils
Fine-grained soils: More than half of material is *smaller* than No. 200 sieve size	Silts and clays, liquid limit less than 50	None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses
		Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
		Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions
	Silts and clays, liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)
		Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils		Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity chart
for laboratory classification of fine grained soils

From Wagner, 1957.

[a] *Boundary classifications*. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW–GC*, well graded gravel-sand mixture with clay binder.

[b] All sieve sizes on this chart are U.S. standard.

Field Identification Procedure for Fine Grained Soils or Fractions

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shaking):

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):

After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):

After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eight inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

UNIFIED SOIL CLASSIFICATION SYSTEM
PINE VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE A5-1

FUGRO NATIONAL, INC.

driving the sampler into the ground with a 140-pound (63.6-kg) hammer dropped 30 inches (76 cm). The number of blows required to drive the sampler the last 12 inches (30.4 cm) was recorded as the Standard Penetration Resistance (N value).

A5.1.3 Logging

All soils were classified in the field by the procedures outlined in Section A5.5, "Field Visual Soil Classification," of this Appendix. Rock encountered in the borings was described according to classifications given in Travis (1955) and Folk (1974). The following general information was entered on the boring logs at the time of drilling: boring number; project name, number, and location; name of drilling company and driller; name of logger and date logged; and method of drilling and sampling, drill bit type and size, driving weight and average drop as applicable. As drilling progressed, the soil samples recovered were visually classified as outlined in Section A5.5, "Field Visual Soil Classification," and the description was entered on the logs. Section A5.5 also discusses other pertinent data and observations made, which were entered on the boring logs, during drilling.

A5.1.4 Sample Storage and Transportation

Samples were handled with care; drive sample containers being placed in foam-lined steel boxes, while Pitcher samples were transported in foam-lined wooden boxes. Particular care was exercised by drivers while traversing rough terrain to avoid disturbing the undisturbed samples. Whenever ambient air temperatures fell below 32°F (0°C), all samples were stored in heated rooms during the field work and transported to Fugro National's Long Beach laboratory in heated cabins in back of pickup trucks.

A5.2 TRENCHES, TEST PITS, AND SURFICIAL SAMPLES

A5.2.1 Excavation Equipment

The trenches, test pits, and surficial samples were excavated using a rubber tire-mounted Case 580C backhoe with a maximum depth capability of 14 feet (4.3 m).

A5.2.2 Method of Excavation

Unless caving occurred during the process of excavation, the trench width was nominally 2 feet (0.6 m). Trench depths were typically 10 to 14 feet (3.0 to 4.3 m) and length was 14 feet (4.3 m). Test pits were nominally 2 feet (0.6 m) wide, 5 feet (1.5 m) deep, and ranged from 5 to 10 feet (1.5 to 3.0 m) in length. Surficial sample excavations were typically 2 feet (0.6 m) wide, 2 feet (0.6 m) deep, and about 3 to 5 feet (0.9 to 1.5 m) long. The trench and test pit walls were vertical. However, where surface materials were unstable, the trench walls were sloped back to a safe angle to prevent sloughing during the completion of excavation and logging. The excavated material was deposited on one side at least 4 feet (1.2 m) from the edge of the trenches in order to minimize stress loads at the edges. The excavations were backfilled with the excavated material and the ground surface was restored to a condition as conformable with the surrounding terrain as practical.

A5.2.3 Sampling

The following sampling procedures were generally followed for all trenches, test pits, and surficial samples.

- Representative bulk soil samples (large or small) were obtained in the top 2 feet (0.6 m). If the soil type changed in the top 2 feet (0.6), bulk samples of both the soil types were obtained. In addition, bulk samples of all soil types encountered at different depths in the excavation were obtained. For each soil type in the top 2 to 3 feet (0.6 to 0.9 m), two large bulk samples (weighing about 50 pounds [22.7 kg] each) were taken. Bulk samples from other depths were limited to one bag. When soils from two locations were similar, only a small bag sample weighing about 2 pounds (0.9 kg) was taken from the second location.

- All large bulk samples were placed first in plastic bags and then in cloth bags. The small bulk samples were placed in small plastic bags. All sample bags of soil were tied tightly at the top to prevent spillage and tagged with the following information: project number; trench, test pit, or surficial sample number; bulk sample number; depth range in feet; Unified Soil Classification symbol; and date. The samples were transported to the field office for storage and then to Fugro National's Long Beach office in pickup trucks.

A5.2.4 Logging

The procedures for field visual classification of soil and rock encountered from the trenches, test pits, and surficial samples were basically the same as the procedures for logging of borings (Section A5.1.3). For excavations shallower than 4 feet (1.2 m) technicians entered the excavations and logged them. Logging of the excavations deeper than 4 feet (1.2 m) was accomplished from the surface and by observing the backhoe bucket contents. All trench walls were photographed prior to backfilling.

Each field trench, test pit, and surficial sample log included trench, test pit, or surficial sample number; project name, number and location; name of excavator; type of excavation equipment; name of logger; and date logged. As excavations proceeded, the soil types encountered were visually classified and described as outlined in Section A5.4, "Field Visual Soil

Classification." Section A5.4 also discusses other pertinent data and observations made which were entered on the logs during excavation.

A5.3 CONE PENETROMETER TESTS

A5.3.1 Equipment

The equipment consisted of a truck-mounted [17.5 tons (15,877 kg) gross weight] electronic cone penetrometer equipped with a 15-ton (13,608 kg) fiction cone (cone end resistance capacity of 15 tons (13,608 kg) and 4.5-ton (4082 kg) limit on the friction sleeve). All operating controls, recorder, cables, and auxiliary equipment were housed in the specially designed vehicle which was completely self-contained. The penetrometer, the key element of the system, contained the necessary load cells and cable connections. One end of the unit was threaded to receive the first sounding rod. When carrying out the tests, hollow rods with an outside diameter of 1.42 inches (3.6 cm) and a length of 3.3 feet (1.0 m) were used to push down the cone.

The hydraulic thrust system was mounted over the center of gravity of the truck, permitting use of the full 17.5-ton (15,877 kg)truck weight as load reaction.

The cone had an apex angle of 60° and a base area of 2.3 in^2 (15 cm^2). The resistance to penetration was measured by a built-in load cell in the tip and was relayed to the surface recorder via cables in the sounding rods. The friction sleeve, having an area of 31.8 in^2 (205 cm^2), was fitted above the cone base. The local friction was measured by load cells mounted in the friction sleeve and recorded in the same manner as the end resistance. The end resistance and friction resistance were recorded on a strip chart.

A5.3.2 Test Method

Tests were performed in accordance with ASTM D 3441-75T, "Tentative Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil." Basically, the test was conducted by positioning the electronic cone penetrometer truck over the designated area for testing, setting the outriggers on the ground surface, checking the level of the rig, then pushing the cone into the ground at a rate of 0.79 inch/sec (2 cm/sec) until refusal (defined as the capacity of the cone, friction sleeve, or hydraulics system) or the desired depth of penetration was reached. As a general rule, the depth of penetration did not exceed 33 feet (10 m). If refusal was reached within the top 2 or 3 feet (0.6 or 1 m), the test was performed again a few feet away from the first location. Details of the test such as refusal reached, depth, cone used, etc., were entered on a log sheet.

A minimum of three cone penetrometer tests were performed at all field California Bearing Ratio (CBR) test locations.

A5.4 FIELD CALIFORNIA BEARING RATIO (CBR) TESTS

A5.4.1 Equipment

The equipment used to conduct the field CBR tests was as described in the U.S. Army Corps of Engineers' Technical Manual 5-30. Other equipment for conducting a field density test by the sand cone method (ASTM D 1556-64, Test for Density of Soil in Place by the Sand-Cone Method) and the "Speedy Moisture Meter" for field determination of soil moisture content were also included. Picks, spades, and shovels were used to excavate the CBR test pits.

A5.4.2 Test Method

Field CBR tests were generally performed at two depths at each designated location. The procedures for conducting the CBR tests were as described in the U.S. Army Corps of Engineers' Technical Manual (TM) 5-30, pages 2-86 to 2-96. Tests were performed in small hand-excavated test pits at depths ranging from 6 to 30 inches (15 to 76 cm) below ground surface. Testing was not attempted where numerous cobbles or heavily cemented soils were encountered. Three CBR tests were performed at each depth and the results recorded. Generally, a field density test (ASTM D 1556-64, Test for Density of Soil in Place by the Sand-Cone Method) and moisture content determination (by Speedy Moisture Meter Method) were performed at the CBR test depths. Sealed samples were brought to the laboratory and moisture contents were verified.

A5.4.3 Sampling

At each CBR test location, large bulk samples of soils from test depths were obtained. See Section A5.2.3, "Sampling," for trenches, test pits, and surficial samples for details.

A5.4.4 Logging

Field CBR test results, field density test results, and moisture content determinations were recorded at the time of each test. All soil samples were classified and logged in accordance with the procedures outlined in Section A5.5, "Field Visual Soil Classification."

A5.5 FIELD VISUAL SOIL CLASSIFICATION

A5.5.1 General

All field logging of soils was performed in accordance with the procedures outlined in this section. Soil samples were visually classified in the field in general accordance with the pro-...res of ASTM D 2488-69, Description of Soils (Visual-Manual ...ure). The ASTM procedure is based on the Unified Soil ...ion System (see Table A5-1). It describes several ... manual methods which can be used in the field to estimate the USCS soil group for each sample. The following section details several of the guidelines used in the field for describing soils, drilling and excavating conditions, and unusual conditions encountered.

A5.5.2 Soil Description

Soil descriptions entered on the logs of borings, trenches, test pits, and surficial samples generally included those listed below.

Coarse-Grained Soils	Fine-Grained Soils
USCS Name and Symbol	USCS Name and Symbol
Color	Color
Range in Particle Size	Consistency
Gradation (well, poorly)	Moisture Content
Density	Plasticity
Moisture Content	Reaction to HCl
Particle Shape	
Reaction to HCl	

Some additional descriptions or information recorded for both coarse- and fine-grained soils included: degree of cementation, secondary material, cobbles and boulders, and depth of change in soil type.

Definitions of some of the terms and criteria used to describe soils and conditions encountered during the investigations follow.

a. USCS Name and Symbol: Derived from Table A5-1, the Unified Soil Classification System. The soils were first designated as coarse- or fine-grained.

Coarse-grained soils are those in which more than half (by weight) of the particles are visible to the naked eye. In making this estimate, particles coarser than 3 in. (76 mm) in diameter were excluded. Fine-grained soils are those in which more than half (by weight) of the particles are so fine that they cannot be seen by the naked eye. The distinction between coarse- and fine-grained can also be made by sieve analysis with the No. 200 sieve (.074 mm) size particle considered to be the smallest size visible to the naked eye. In some instances, the field technicians describing the soils used a No. 200 sieve to estimate the amount of fine-grained particles. The coarse-grained soils are further divided into sands and gravels by estimating the percentage of the coarse fraction larger than the No. 4 sieve (about 1/4 inch or 5 mm). Each coarse-grained soil is then qualified as silty, clayey, poorly graded, or well graded as discussed under plasticity and gradation.

Fine-grained soils were identified in the field as clays or silts with appropriate adjectives (clayey silt, silty clay, etc.) based on the results of dry strength, dilatancy, and plastic thread tests (see ASTM D 2488-69 for details of these tests).

Dual USCS symbols and adjectives were used to describe soils exhibiting characteristics of more than one USCS group.

b. Color: Color descriptions were recorded using the following terms with abbreviations in parentheses.

White (w)	Green (gn)
Yellow (y)	Blue (bl)
Orange (o)	Gray (gr)
Red (r)	Black (blk)
Brown (br)	

Color combinations as well as modifiers such as light (lt) and dark (dk) were used.

c. Range in Particle Size: For coarse-grained soils (sands and gravels), the size range of the particles visible to the naked eye was estimated as fine, medium, coarse, or a combined range (fine to medium).

d. Gradation: Well graded indicates a coarse-grained soil which has a wide range in grain size and substantial amounts of most intermediate particle sizes. A coarse-grained soil was identified as poorly graded if it consisted predominantly of one size (uniformly graded) or had a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

e. Density or Consistency: The density or consistency of the in-place soil was estimated based on the number of blows required to advance the Fugro drive or split-spoon sampler, the drilling rate (difficulty) and/or hydraulic pulldown needed to drill, visual observations of the soil in the trench or test pit walls, ease (or difficulty) of excavation of trench or test pit, or trench or test pit wall stability. For fine-grained soils, the field guides to shear strength presented below were also used to estimate consistency.

- Coarse-grained soils - GW, GP, GM, GC, SW, SP, SM, SC (gravels and sands)

Consistency	N-Value (ASTM D 1586-67), Blows/Foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	>50

o Fine-grained Soils - ML, MH, CL, CH (Silts and Clays)

Consistency	Shear Strength (ksf)	(kN/m^2)	Field Guide
Very Soft	<0.25	<12.0	Sample with height equal to twice the diameter, sags under own weight
Soft	0.25-0.50	12.0-23.9	Can be squeezed between thumb and forefinger
Firm	0.50-1.00	23.9-47.9	Can be molded easily with fingers
Stiff	1.00-2.00	47.9-95.8	Can be imprinted with slight pressure from fingers
Very Stiff	2.00-4.00	95.8-191.5	Can be imprinted with considerable pressure from fingers
Hard	>4.00	>191.5	Cannot be imprinted by fingers

f. Moisture Content: The following guidelines were used in the field for describing the moisture in the soil samples:

Dry : No feel of moisture
Slightly Moist: Much less than normal moisture
Moist : Normal moisture for soil
Very Moist : Much greater than normal moisture
Wet : At or near saturation

g. Particle Shape: Coarse-grained soils

Angular : Particles have sharp edges and relatively plane sides with unpolished surfaces

Subangular: Particles are similar to angular but have somewhat rounded edges

Subrounded: Particles exhibit nearly plane sides but have well-rounded corners and edges

Rounded : Particles have smoothly curved sides and no edges

h. Reaction to HCl: As an aid for identifying cementation, some soil samples were tested in the field for their reaction to dilute hydrochloric acid. The intensity of the HCl reaction was described as none, weak, or strong.

i. Degree of Cementation: Based on the intensity of the HCl reaction and observation, the degree of cementation of a soil layer was described as weak to strong. Also, the following stages of development of caliche (cemented) profile were indicated where applicable.

Stage	Gravelly Soils	Nongravelly Soils
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments
III	Many interpebble fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Increasing carbonate impregnation

j. Secondary Material: Example - Sand with trace to some silt

Trace	5-12%	(by dry weight)
Little	13-20%	(by dry weight)
Some	>20%	(by dry weight)

k. Cobbles and Boulders: A cobble is a rock fragment, usually rounded or subrounded, with an average diameter between 3 and 12 inches (76 and 305 mm). A boulder is a rock fragment, usually rounded by weathering or abrasion, with an average diameter of 12 inches (305 mm) or more. The presence of cobbles and/or boulders was identified by noting the sudden change in drilling difficulty or cuttings in borings or by visual observation in excavations. An estimate of the size, range, and percentage of cobbles and/or boulders in the strata was recorded on the logs.

l. Depth of Change in Soil Type: During drilling of borings, the depth of changes in soil type was determined by observing samples, drilling rates, changes in color or consistency of drilling fluid, and relating these to depth marks on the drilling rods. In excavations, strata thicknesses were measured with a tape. All soil type interfaces were recorded on the logs by a horizontal line at the approximate depth mark.

In addition to the observations recorded relating to soil descriptions, remarks concerning drilling difficulty, loss of drilling fluid in the boring, water levels encountered, trench wall stability, ease of excavation, and other unusual conditions were recorded on the logs.

A5.6 LABORATORY TESTS

Laboratory tests were performed on selected representative undisturbed and bulk samples. All laboratory tests (except chemical tests) were performed in Fugro National's Long Beach laboratory. The chemical tests were conducted by Pomeroy, Johnson, and Bailey Laboratories of Pasadena, California. All tests were performed in general accordance with the American Society for Testing and Materials (ASTM) procedures. The types of tests performed and their ASTM designations are summarized as follows.

Type of Test	ASTM Designation
Unit Weight	D 2937-71
Moisture Content	D 2216-71
Particle-Size Analysis	D 422-63
Liquid Limit	D 423-66
Plastic Limit	D 424-59
Triaxial Compression	D 2850-70
Unconfined Compression	D 2166-66
Direct Shear	D 3080-72
Consolidation	D 2435-70
Compaction	D 1557-70
California Bearing Ratio (CBR)	D 1883-73
Specific Gravity	D 854-58
Water Soluble Sodium	D 1428-64
Water Soluble Chloride	D 512-67
Water Soluble Sulfate	D 516-68
Water Soluble Calcium	D 511-72
Calcium Carbonate	D 1126-67
Test for Alkalinity (pH)	D 1067-70

A5.7 DATA ANALYSIS AND INTERPRETATION

A5.7.1 Preparation of Final Logs and Laboratory and Field Test Summary Sheets

The field logs of all borings, trenches, test pits, and surficial sample excavations were prepared by systematically combining the information given on the field logs with the laboratory test results. The resultant logs include generally the following information: description of soil types encountered; sample types of intervals, lithology (graphic soil column); estimates of soil density or consistency; depth locations of changes in soil types; remarks concerning trench wall stability; drilling difficulty, cementation, and cobbles and boulders encountered; and the total depth of exploration. Laboratory test results presented in the logs include dry density and moisture content; percent of gravel, sand, and fines; and liquid limit and plasticity index. Also, miscellaneous information such as surface elevation, surficial geologic unit, date of activity, equipment used, and dimensions of the activity is included on the log.

Field CBR test summary sheets were prepared and include the following information for each test site: depth of test; USCS soil type; grain-size distribution and plasticity (from laboratory testing); in-situ dry unit weight and moisture content (from laboratory testing); average field CBR values; and remarks concerning cementation and induration.

Laboratory data were summarized in tables. All samples which were tested in the laboratory were listed. Results of sieve analyses, hydrometer, Atterberg limits, in-situ dry density and moisture content tests, and calculated degree of saturation and void ratio were entered on the tables. Test summary sheets for triaxial compression, unconfined compression, direct shear, consolidation, chemical, CBR, and compaction tests were prepared separately.

The Cone Penetrometer Test results consist of continuous plots of cone resistance, friction sleeve resistance, and friction ratio versus depth from ground surface. Beside the plot is shown a soil column with USCS soil types encountered at the test location. Other information presented on the log includes surface elevation and surficial geologic unit.

Volume II titled "Geotechnical Data" presents the following finalized basic engineering data.

Boring Logs	Section II - 5.0
Trench and Test Pit Logs	Section II - 6.0
Surficial Sample Logs	Section II - 7.0
Laboratory Test Results	Section II - 8.0
Field CBR Results	Section II - 9.0
Cone Penetrometer Test Results	Section II -10.0

A5.7.2 Soil Characteristics

A5.7.2.1 General

The soil characteristics are discussed in two parts, surface soils and subsurface soils. The following three tables were prepared and are presented in Sections 3.3 and 3.4 of the report.

1. Characteristics of Surficial Soils;
2. Thickness of Low Strength Surficial Soils; and
3. Characteristics of Subsurface Soils.

The following sections, A5.7.2.2 and A5.7.2.3, explain the data analyses and interpretation used in preparing the above tables.

A5.7.2.2 Surface Soils

In order to define the characteristics of the surficial soils, data from trenches, test pits, borings, surficial soil samples, cone penetrometer tests, field CBR tests, and surficial geologic maps were reviewed in conjunction with the laboratory test results. The soils were then grouped into three categories of soils with similar general characteristics. These categories, their descriptions, and associated characteristics were tabulated. This table (Characteristics of Surficial Soils, Table 3-1) includes soil descriptions by the Unified Soil Classification Systems, predominant surficial geologic units, the estimated areal extent (percent) of each category, important physical properties summarized from laboratory test results, and certain road design related data.

The important physical properties summarized include the estimated cobbles content, grain-size analyses, and Atterberg limits. Ranges for these properties were determined from the field logs and laboratory test results. These ranges are useful for categorizing soils, evaluating construction techniques, and providing data for preliminary engineering evaluations and for use by other MX participants.

Road design data presented in Table 3-1 were developed from field and laboratory tests and consist of three distinct groups:

1. Laboratory test results;
2. Suitability of soils for road use; and
3. Low strength surficial soil.

These road design related data were considered important because roads (interconnecting and secondary) constitute a major portion of the geotechically related costs. The following paragraphs briefly discuss the development of road design data.

a. Laboratory Test Results: These include ranges of maximum dry density, optimum moisture content (ASTM D 1557-70) and CBR (ASTM D 1883-73) at 90 percent relative compaction for each soil category. The maximum dry density and optimum moisture content are important quality control parameters during roadway construction. California Bearing Ratio is the ratio of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed-rock base material and is the basis for many empirical road design methods used in this country.

b. Suitability of Soils for Road Use: Included in this group is suitability of soils for use as road subgrade, subbase, or base. Parameters used to make these qualitative assessments were characteristics related to CBR, frost susceptibility, drainage, and volume change potential. The following guidelines were used in estimating the suitability of soils for road use.

1. Suitability as a road subgrade.
   - Very Good - soils which can be compacted with little effort to high CBR values (CBR >30), exhibit low frost susceptibility, fair to good drainage, and low volume change potential.
   - Good - soils which can be compacted with some effort to moderate CBR values (CBR 15-30), exhibit moderate frost susceptibility, fair drainage, and medium volume change potential.

Fair - soils which can be compacted with considerable effort to moderate CBR values (CBR 15-30), exhibit moderate to high frost susceptibility, fair to poor drainage, and medium volume change potential.

Poor - soils which require considerable effort for compaction to even low CBR values (CBR <15), exhibit high frost susceptibility, poor drainage, or high volume change potential. These soils should generally be removed and replaced with better quality material.

2. Suitability as road subbase or base.

Good - soils which exhibit negligible frost susceptibility, good drainage, and negligible volume change potential.

Fair - soils which require some treatment or processing to upgrade for use.

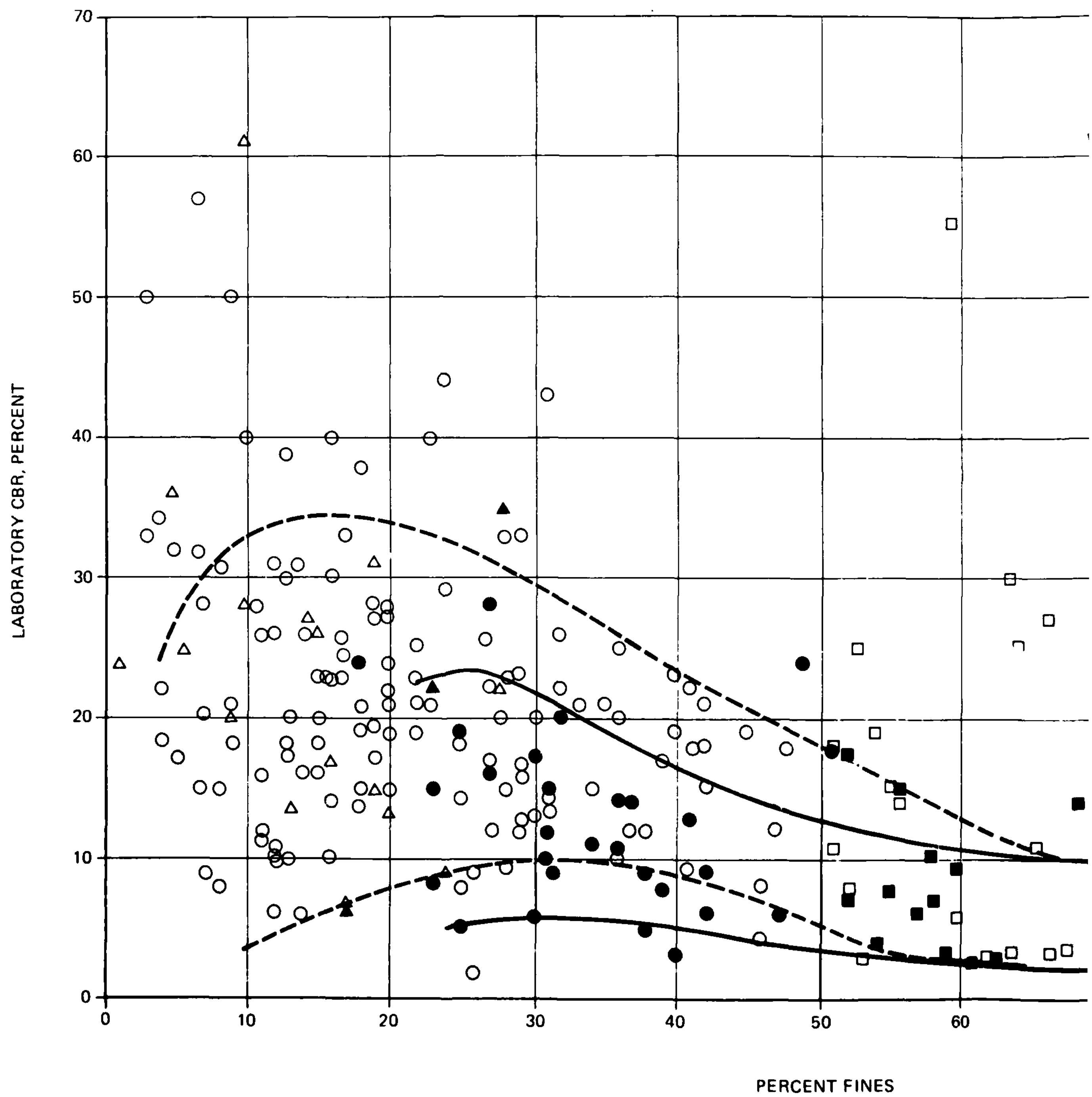
Poor - soils which would require relatively extensive processing or soil stabilization to upgrade for use.

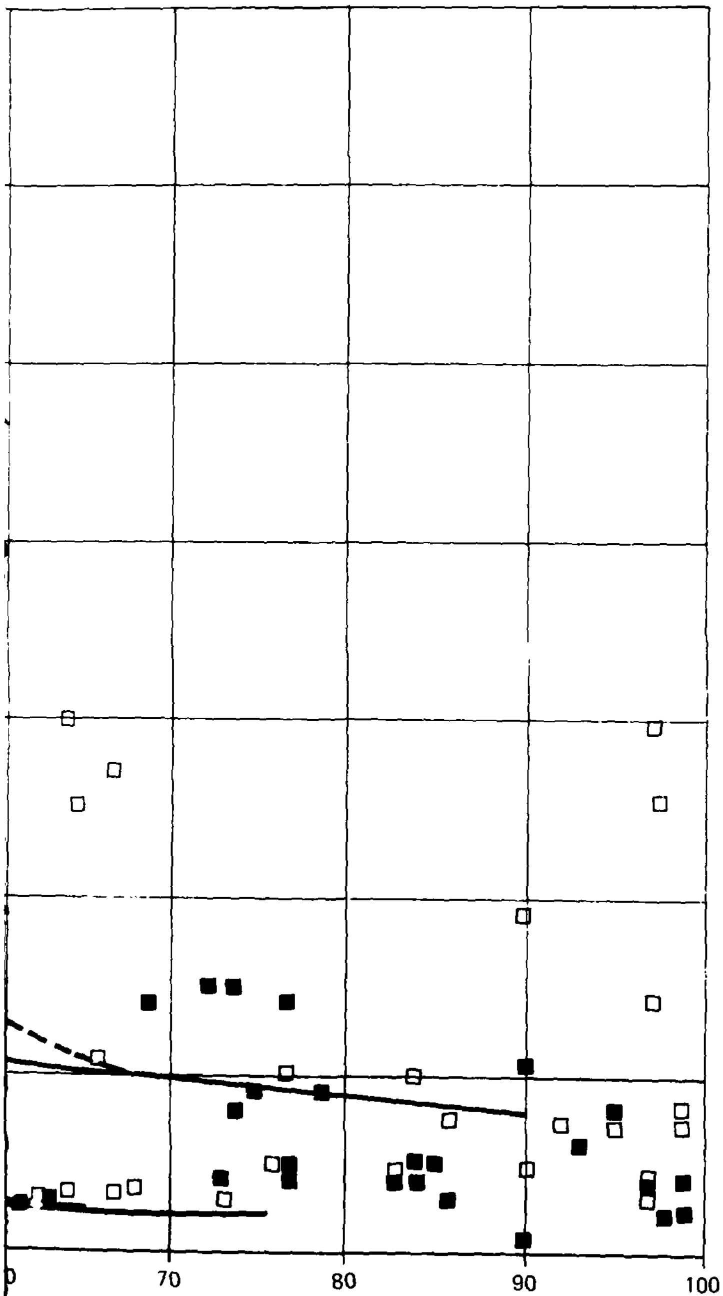
Not Suitable - soils which cannot be modified to give adequate roadway support.

The parameters used in the aforementioned suitability ratings are discussed in the following paragraphs.

i. <u>CBR Characteristics</u>: California Bearing Ratio, which is commonly used for road design, is dependent on soil type. During previous verification studies, a limited number of CBR tests were performed on several soil types which were representative of the surficial soils in the various Verification Sites. Based on these test results, a relationship between CBR and percent fines (percent passing through No. 200 sieve) was established and is shown in Figure A5-1. Envelopes for clays and granular soils with plastic fines and silts and granular soils with nonplastic fines are shown in the figure. This plot was used to estimate the range of laboratory CBR values for the various surficial soil categories.

ii. <u>Other Characteristics</u>: These characteristics pertain to frost susceptibility, drainage, and volume change potential. They were estimated based on the physical properties of the soils, results of consolidation tests (for volume change potential), published literature, and our experience. Following are the definitions of these characteristics.


LABORATORY CBR, PERCENT
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
PERCENT FINES



EXPLANATION

- △ Gravels with nonplastic fines (GM, GW, GP, GP-GM, GW-GM)
- ▲ Gravels with plastic fines (GC, GC-GM)
- ○ Sands with nonplastic fines (SP, SW, SM, SP-SM, SW-SM)
- ● Sands with plastic fines (SC, SC-SM)
- □ Silts (ML)
- ■ Clays (CL, CH, CL-ML)
- – – – – Envelope for silts and granular soils with nonplastic fines
- ——— Envelope for clays and granular soils with plastic fines

NOTES:

1. Fines correspond to soil passing through No 200 (0.074mm opening) sieve.
2. California Bearing Ratio at 90% relative compaction
3. Soil types (GM, SC) are based on Unified Soil Classification System.

2

PLOT OF LABORATORY CBR
VERSUS PERCENT FINES
VERIFICATION SITES, NEVADA-UTAH

MX SITING INVESTIGATION

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FIGURE A5-1

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1. Frost susceptibility is defined as potential for detrimental ice segregation upon freezing or loss of strength upon thawing.

Low	- negligible to little potential
Moderate	- some potential
High	- considerable potential

2. Drainage characteristics pertain to internal movement of water through soil.

Good	- materials which drain rapidly and do not tend to plug with fines
Fair	- natural internal drainage is fairly rapid but there is some tendency for plugging of voids with fines
Poor	- internal drainage is somewhat slow and plugging with fines can often occur
Practically Impervious	- materials which exhibit almost no natural internal drainage

3. Volume change potential correspo. 's to soil swelling or shrinkage due to change in moisture content.

Low	- 0 to 2 percent volume change
Medium	- 2 to 4 percent volume change
High	- > 4 percent volume change

c. Low-Strength Surficial Soil: Included in this group is extent of low-strength surficial soil. The roads for the MX system will be built on existing ground surface with minimum cut and fill. Therefore, the costs of roads depend on the consistency (or strength) of the surficial soil. In order to evaluate the strength of the surficial soils, cone penetrometer test results were used.

Low-strength surficial soil is defined as soil which will perform poorly (failure of subgrade) as a road subgrade at its present consistency when used directly beneath a road section.

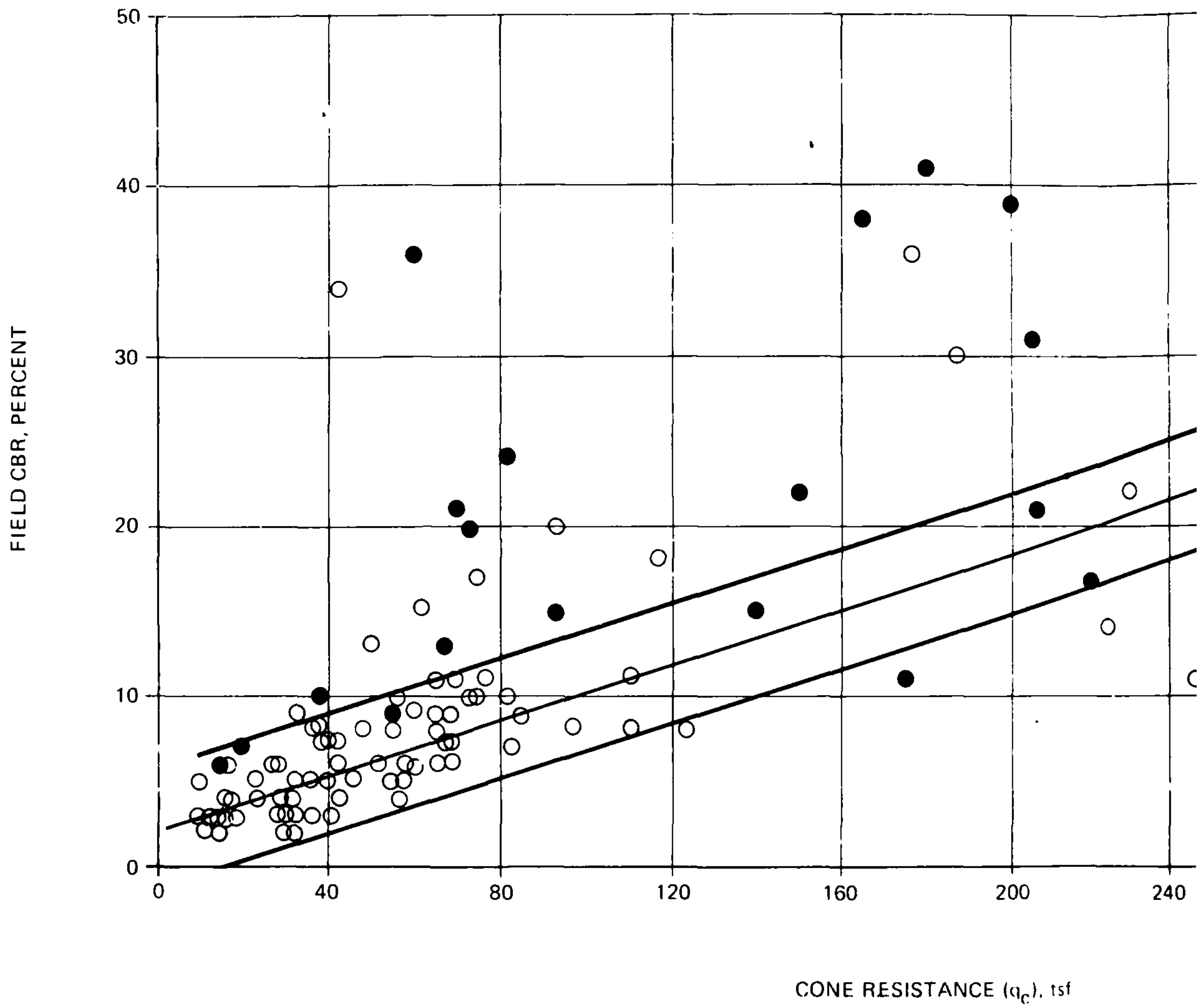
In order to define "low strength" using CPT results, the following four approaches were pursued. These approaches are subjective and qualitative and are based on our experience as well as published literature.

i. Field visual observations: During logging of the borings, the excavation of trenches, test pits, and obtaining surficial soil samples, consistency or compactness of the surficial soils was described qualitatively. A detailed comparison of the CPT results (cone end resistance) and the consistency of the soils was done for different soil types. Using engineering judgement, an upper limit cone resistance was established which encompassed a majority of the soils likely to perform poorly as road subgrades.

ii. Standard Penetration Test (SPT): SPT is very widely used and accepted in geotechnical engineering practice in this country. A study of available literature revealed that the ratio of cone resistance (q_c, tsf) to Standard Penetration Resistance (N, blows per foot) has a certain range for different soil types. In 1979 Verification studies, limited field SPTs were performed in Reveille-Railroad and Big Smoky sites. Ratios of q_c/N were computed for these tests and were found to be comparable to those reported in literature for similar soil types. Using the relationships applicable to the soils present in the Verification sites, an upper limit of cone resistance, equivalent to midrange of "medium dense" category, was established for defining the "low-strength" surficial soils.

iii. In-Situ Dry Density: A comparison was made between in-situ dry densities determined from Fugro Drive and Pitcher samples obtained from soil borings and CPT results at the same locations and depths. From this comparison, it was observed that identifiable trends do exist between cone resistance values and soil densities. An upper limit of cone resistance equivalent to midrange of "medium dense" category was established for defining the "low-strength" surficial soils.

iv. Field CBR Tests: During Verification studies, field CBR tests were performed in Reveille, Railroad, Pine, Wah Wah, Steptoe, Lake, Spring, Stone Cabin, Hot Creek, and Big Smoky valleys. The procedures for conducting the CBR tests were as described in the U.S. Army Corps of Engineers' Technical Manual (TM) 5-30, pp. 2-86 to 2-96. The test results were compared to Cone Penetrometer Tests performed at the same location. A plot of average field CBR and average cone resistance was prepared and is presented in Figure A5-2. The plot shows the results of the tests in sands only, since tests in gravel and fine-grained soils were very few. Although there is considerable scatter, the majority of the data points fall in a band which is shown in Figure A5-2. From this plot, a range of CPT resistance corresponding to low field CBR values (indicating low strength surficial soils) was established.



NOTES: 1. Data are for sands tested in Big Smoky, Reveille Railroad, Pine, Wah Wah, Spring, Lake, Stone Cabin Reveille and Hot Creek Verification Sites.

2. Band between the upper and lower limits includes 74% of all the data points, and includes 85% non caliche data points.

3. Solid points indicates caliche data points.

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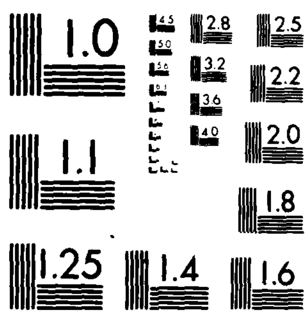
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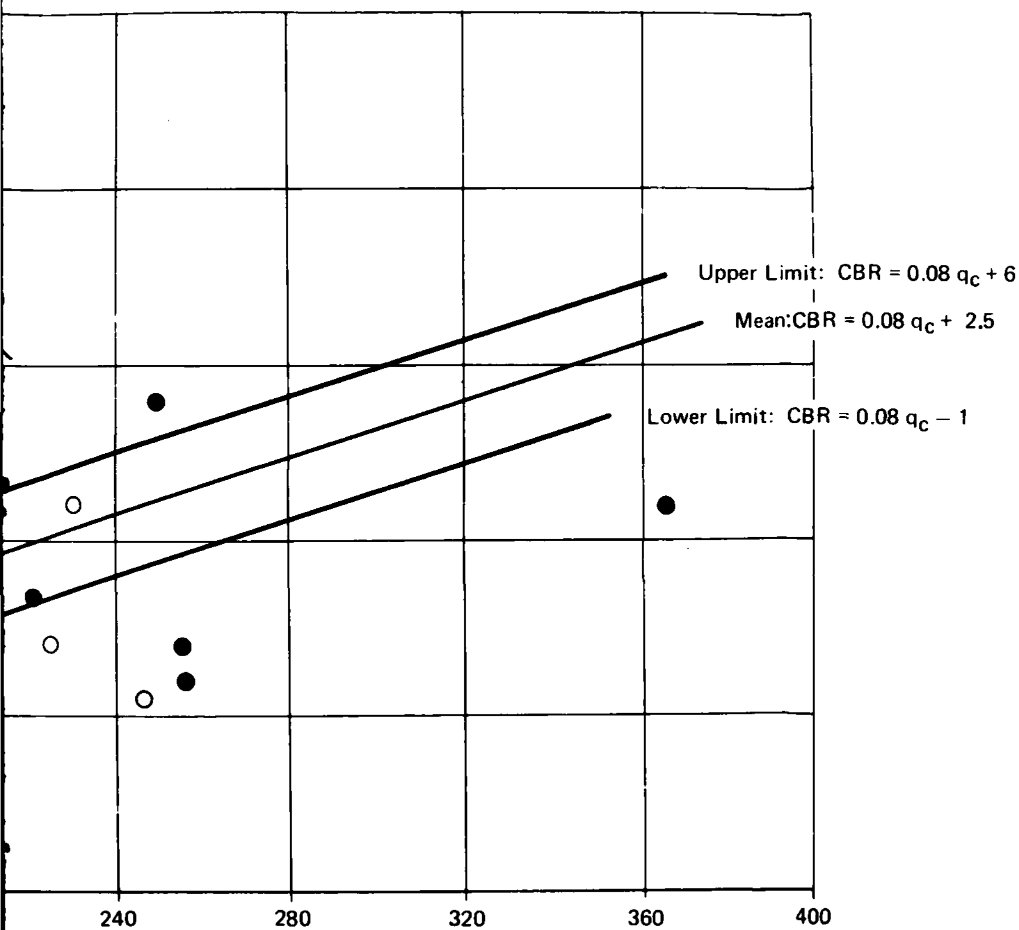

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RELATIONSHIP BETWEEN FIELD CBR
AND CPT CONE RESISTANCE
VERIFICATION VALLEYS, NEVADA–UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE BMO	FIGURE A5-2

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As a result of the preceding four approaches, the following criteria for defining low strength surficial soil were established:

q_c <120 tsf (117 kg/cm^2) for coarse-grained soils
q_c < 80 tsf (78 kg/cm^2) for fine-grained soils

These criteria are preliminary at this stage and may be revised as more data become available from future verification studies. The criteria were used to determine the extent of low strength surficial soil at each CPT location. The results are tabulated in Table 3-2, "Thickness of Low Strength Surficial Soil."

A5.7.2.3 Subsurface Soils

Characteristics of the subsurface soils were developed using data from seismic refraction surveys, borings, trenches, test pits, and laboratory tests.

The soils were divided into coarse-grained and fine-grained soils in two ranges of depth, 0 to 20 feet and 20 to 160 feet (0 to 6 m and 6 to 49 m). Physical and engineering properties of the soils were then tabulated as "Characteristics of Subsurface Soils" (Table 3-4) based on laboratory test results on representative samples. The table includes soil descriptions, Unified Soil Classification System symbols, the estimated subsurface extent of each soil group, comments on the degree of cementation, estimated cobbles content, and ranges of values from the following laboratory and field tests: dry density, moisture content, grain-size distribution, liquid limit, plasticity index, compressional wave velocity unconfined compression, triaxial compression, and direct shear.

The excavatability and stability of excavation walls of a horizontal or a vertical shelter were evaluated from the subsurface data using seismic velocities, soil types, shear strength, presence of cobbles and boulders, and cementation. Problems encountered during trench and test pit excavations and drilling of borings were also considered in the evaluation.

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