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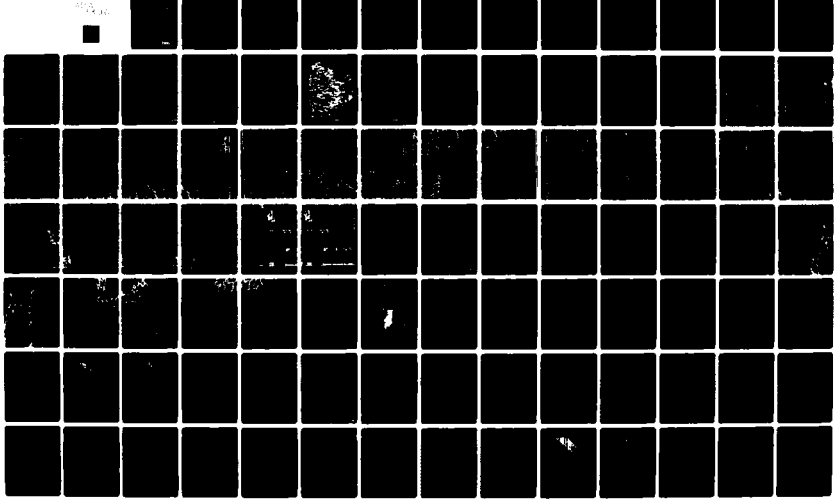

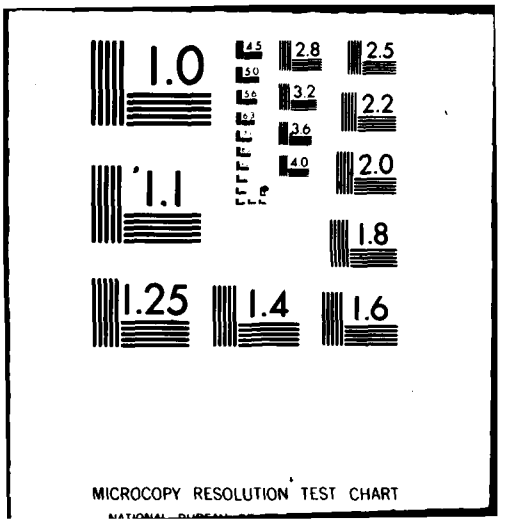
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MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

AD A113390

VERIFICATION STUDY
DELAMAR VALLEY, NEVADA
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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20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

This report presents results of geotechnical studies which were completed in Delamar Valley, Nevada. Includes basic data consisting of depth to ground water, depth to rock, boring and trench logs, seismic refraction surveys, electrical resistivity surveys, and soil profiles.

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MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

VERIFICATION STUDY - DELAMAR VALLEY
NEVADA

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 Boulevard
Long Beach, California 90807

24 March 1981

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-C-0006, CDRL Item 004A6. It contains an evaluation of the suitability of Delamar Valley, Nevada, 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.

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1.0 INTRODUCTION

1.1 PURPOSE AND BACKGROUND

This report presents the results of the geotechnical studies which were completed in Delamar Valley, Nevada, during the fall of 1979. 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.

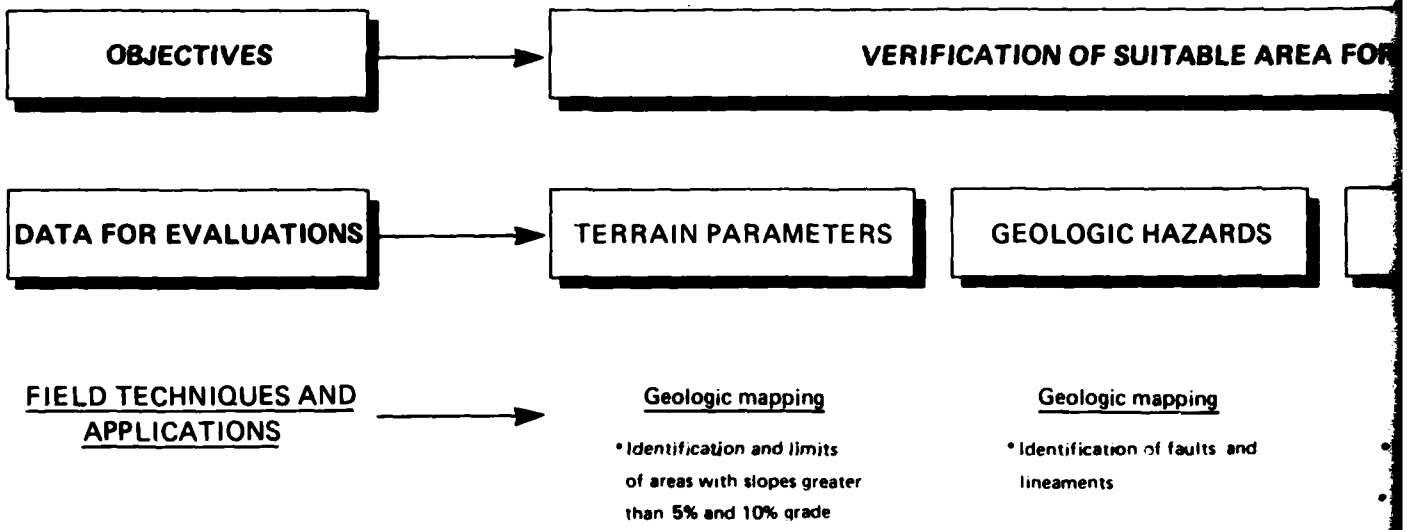
The Verification Program is the final phase of a site-selection process which started in 1977. The objective of the site-selection process is to identify and rank geotechnically suitable areas which are sufficiently large for deployment of the Missile-X (MX), an advanced intercontinental ballistic missile 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 in Figure 1-1, the Verification Program is continuing, and field work should be completed in 1981. The valleys 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 on Drawing 1-1. The boundaries will be adjusted as Verification studies are completed.

1.2 SCOPE OF STUDY

The field work in Delamar Valley was done in November and December 1979. Table 1-2 lists the types and number of field


OBJECTIVES
VERIFICATION OF SUITABLE AREA FOR
DATA FOR EVALUATIONS
TERRAIN PARAMETERS
GEOLOGIC HAZARDS
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

MX DEPLOYMENT

CHARACTERI

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

CHARACTERISTICS OF BASIN FILL

→ PRELIMINARY CONSIDER/ RECOMME

GEOPHYSICAL PROPERTIES

Seismic refraction surveys

- Compressional wave velocities
- Layering of soil

Electrical resistivity surveys

- Electrical conductivity of soils
- Layering of soil

ROAD DESIGN DATA

Trenches and test pits

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

Cone penetrometer tests

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

Laboratory tests

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

Existing data

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

EXCAVATABILITY AND STABILITY

Borings

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

Trenches and test pits

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

Laboratory tests

- Physical properties
- Engineering properties

Geologic mapping

- Distribution of geologic units

Seismic refraction surveys

- Excavatability

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SIN FILL → PRELIMINARY GEOTECHNICAL CONSIDERATIONS AND RECOMMENDATIONS

D DESIGN DATA

EXCAVATABILITY AND STABILITY

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Existing data

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Borings

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Trenches and test pits

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- Presence of cobbles and boulders

Laboratory tests

- Physical properties
- Engineering properties

Geologic mapping

- Distribution of geologic units

Seismic refraction surveys

- Excavatability

FIELD TECHNIQUES
VERIFICATION STUDIES
NEVADA–UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	TABLE 1-1

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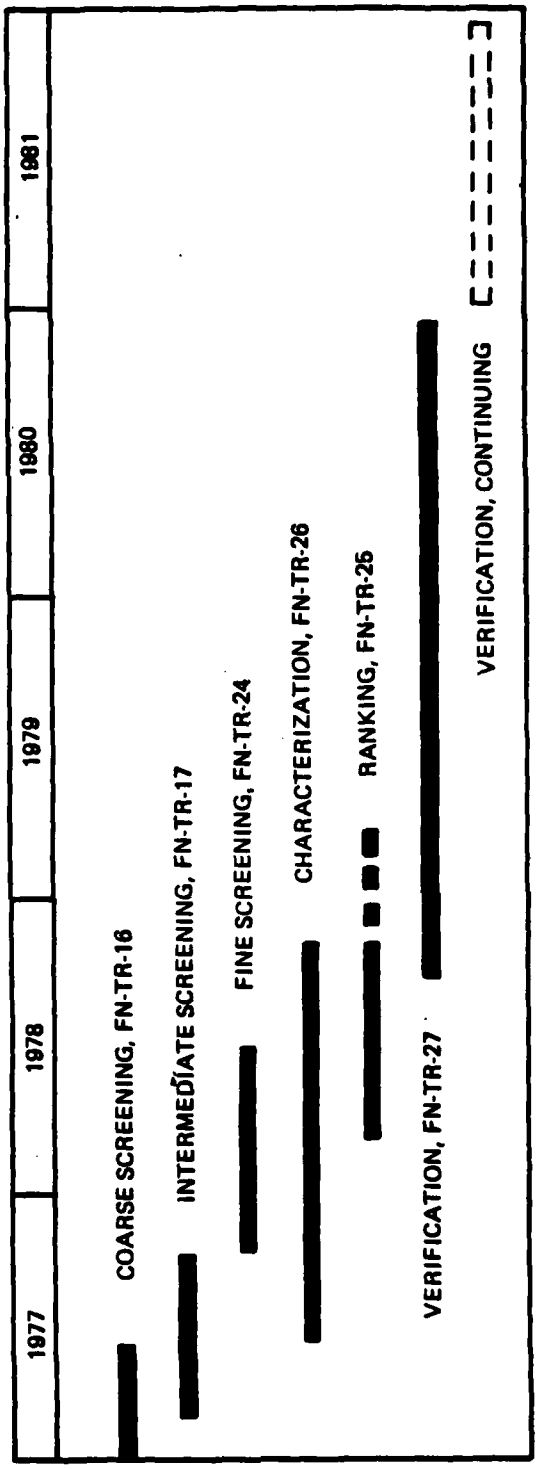

SUMMARY OF SITE-SELECTION SCHEDULE

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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GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geologic mapping stations	79
Shallow refraction	13
Electrical Resistivity	12

ENGINEERING

ACTIVITY	NO.	NOMINAL DEPTH FEET (METERS)
Borings	5	100 (30)
Trenches	5	10 - 14 (3 - 4)
	5	2 - 7 (1 - 2)
Test pits	14	2 - 5 (1 - 2)
Surficial samples	13	2 (1)
CPT Soundings	37	3 - 53 (1 - 16)

ENGINEERING—LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	83
Specific gravity	8
Sieve analysis	70
Hydrometer	3
Atterberg limits	29
Consolidation	1
Unconfined compression	4
Triaxial compression	6
Direct shear	4
Compaction	6
CBR	6
Chemical analysis	5

SCOPE OF ACTIVITIES
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

TABLE 1-2

FUGRO NATIONAL, INC.

activities that were performed in Delamar Valley. The techniques of investigation are discussed in the appendix.

Access to public land in Delamar Valley was arranged through the Las Vegas, Nevada, district office of the Bureau of Land Management (BLM). At BLM's request, all field activities were performed along existing roads or trails to minimize site disturbance. The restriction has limited the studies that could be performed in some areas. Archaeological and environmental surveys were performed at each proposed activity location. Activity locations were changed in 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 Nevada Engineer's Office, and literature describing the valley hydrology. Whenever possible, the depth to water listed for each 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 mapped within the mountain blocks or at the mountain-valley contact are of unknown age but are almost certainly of late Tertiary and/or Quaternary age. Published maps (for example Stewart and Carlson, 1978; Kleinhampl and Ziony, 1967; and Tschanz and Pampeyan, 1970) show numerous other faults within the rocks of the mountain blocks which also have probably been active under the present tectonic regime. These are not within the siting areas and thus have not been studied. The

published maps also show numerous inferred faults buried under the alluvium along the mountain-valley contacts. Since these faults have no surface expression, they cannot be verified by the reconnaissance methods used in the fault studies, but they are commonly verified by geophysical studies. These hidden faults may represent earthquake hazards.

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.

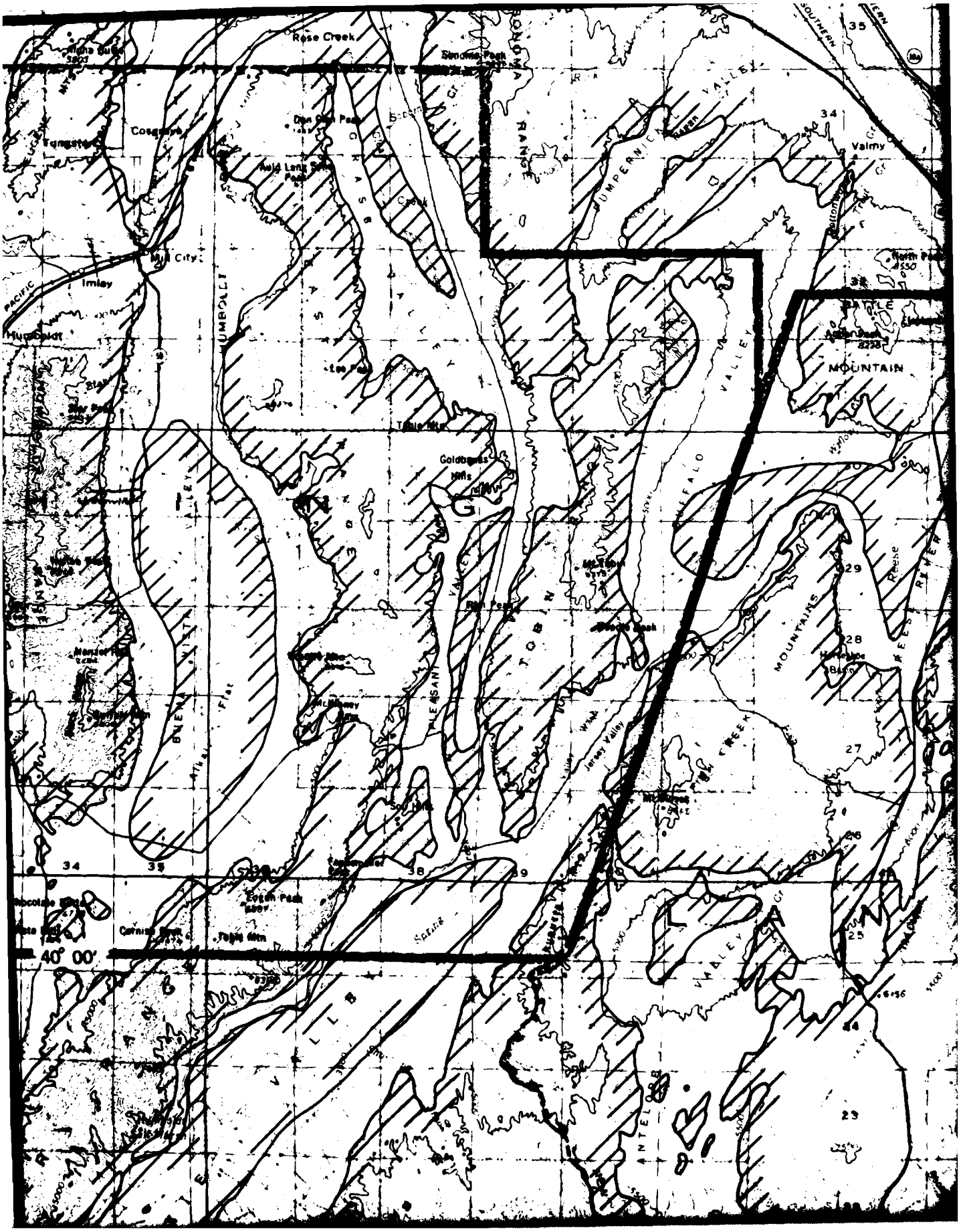
The investigations of engineering properties were designed primarily to obtain information needed for construction activities. For Verification studies, surficial soil conditions, as related to road construction, a major cost item, received particular emphasis. Emphasis was placed also on soil conditions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

Data obtained from borings, trenches, test pits, seismic refraction lines, and laboratory tests were used to estimate soil

properties to a depth of 20 feet (6 m). The data are limited since only five borings, 10 trenches, 14 test pits, and 13 seismic refraction lines were available. There may be soil conditions in the upper 20 feet (6 m) that were not encountered by these 42 data points. The number of data points available for description of the surficial soils was increased to 92 by using 13 surface samples and 37 Cone Penetrometer Test (CPT) soundings to measure in-situ properties.

The soil parameters between a depth of 20 and 100 feet (6 and 30 m) are based on data obtained from only five borings and 13 seismic refraction lines. The spacing between borings ranged from 3 to 6 miles (5 to 10 km), therefore, the data presented may not be representative of the entire valley.

The length of the seismic refraction lines was chosen to investigate the velocity profile to at least 150 feet (46 m) (the depth of interest for the vertical shelter basing mode) deep.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Sonoma Peak
Cosgrove
Tungsten
Auld Lang Syne Peak
Valmy
Mill City
Imley
Humboldt
Lee Peak
Table Mtn
Goldbanks Hills
Pleasant Valley
Jersey Valley
Buffalo Valley
Mountains
Pine Creek
Eugene Peak
Cornish Peak
Tenabo Mtn
Squaw
Valley
Antelope
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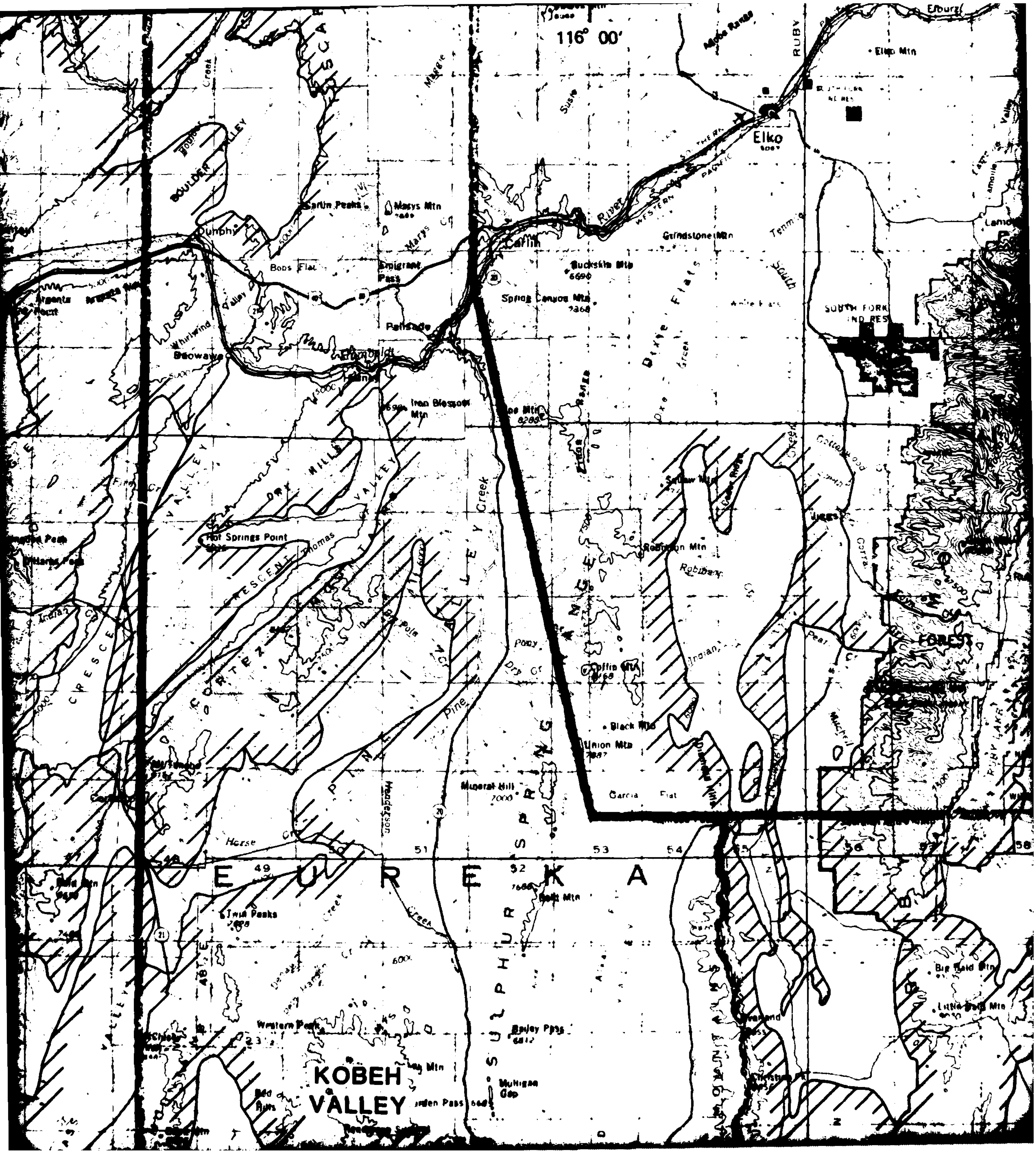
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Whirlwind Valley
Beowawe
Palisade
Iron Blossom Mtn
DRY HILLS
Hot Springs Point
CRESCENT
CORTEZ
Robinson Mtn
Coffin Mtn
Black Mtn
Union Mtn
Mineral Hill
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Garcia Flat
Pine Creek
FOREST
Horse Cr
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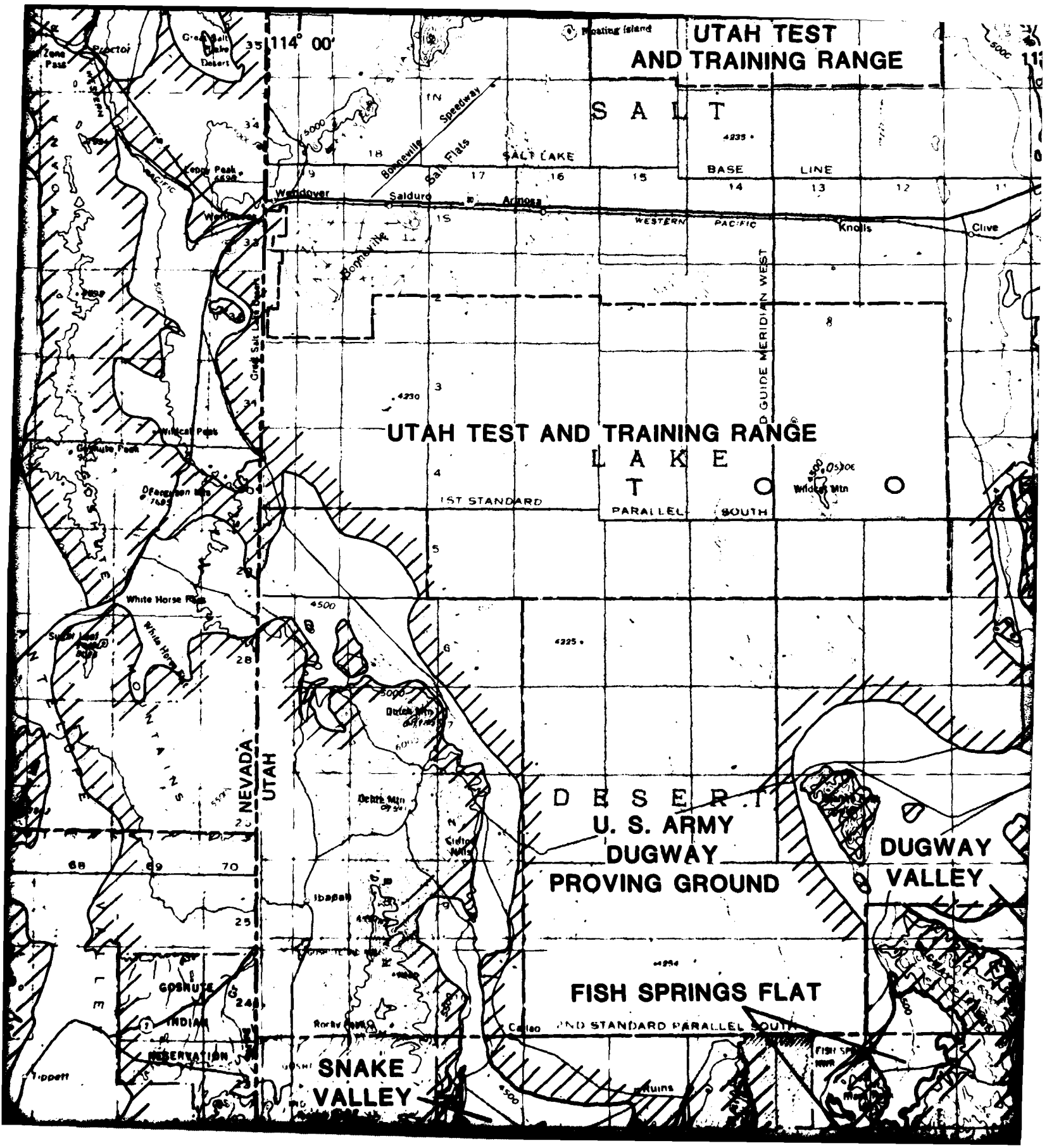
EUREKA
Twin Peaks
Western Peak
Bailey Pass
KOBEH VALLEY
Mulligan Gap
Big Bald Mtn
Little Bald Mtn

115° 00'
Elburz
Tobar
Silver Zone Pass
Shafter
Arthur
Lamoille
Decoy
Valley Mtn
Dry Lake Flat
6TH STANDARD PARALLEL
FRANKLIN LAKE
Ruby Valley
Sharp Peak
Bald Peak
Currie
Currie Hills
High Bald Pasture
5TH STANDARD PARALLEL
Cherry Creek
Tippett


UTAH TEST AND TRAINING RANGE
114° 00'
Floating Island
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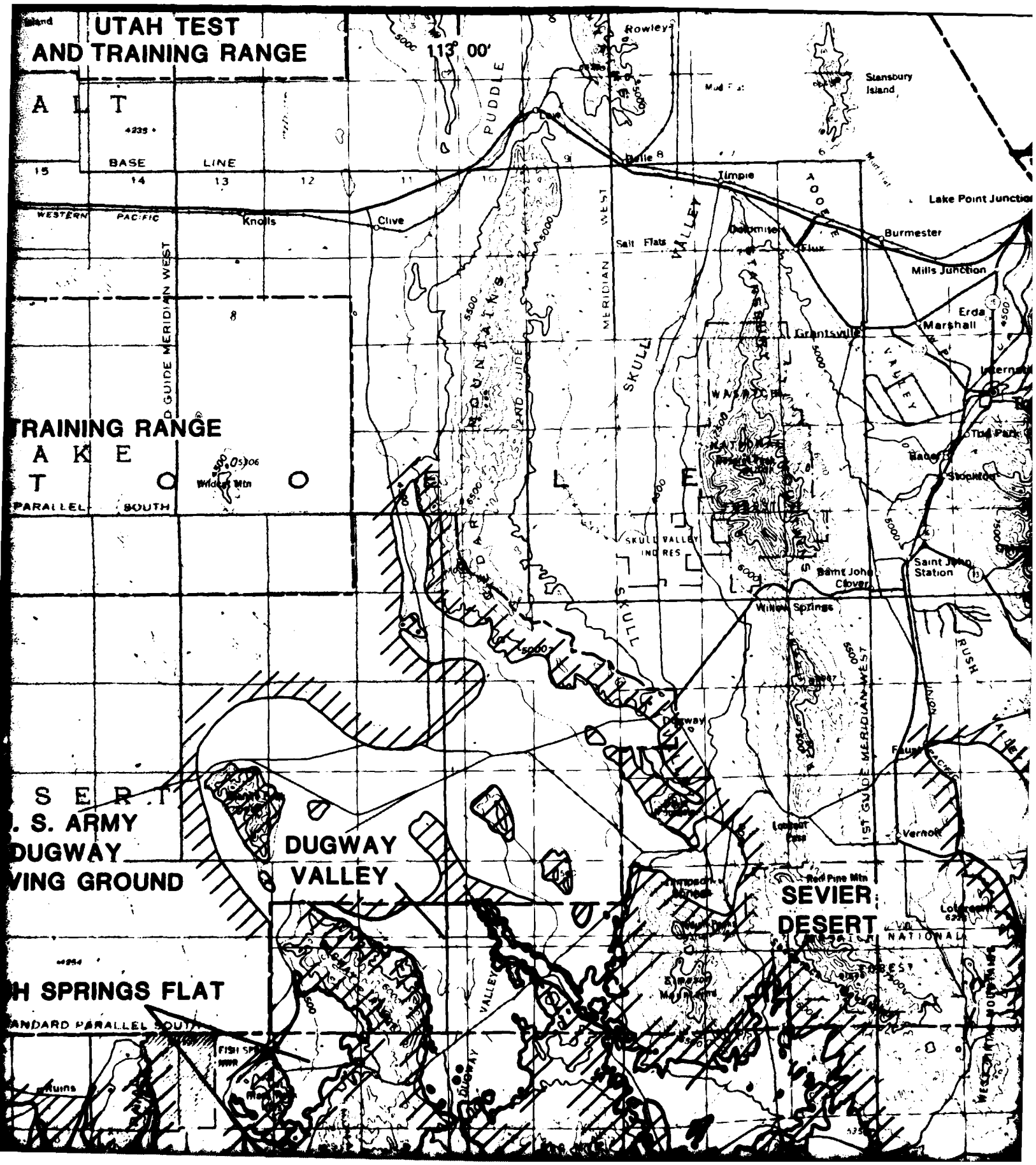
SALT LAKE
BASE LINE
Bonneville Salt Flats
Bonneville Speedway
Wendover
Salduro
Aragonia
WESTERN PACIFIC
Knolls
Clive
GUIDE MERIDIAN WEST
UTAH TEST AND TRAINING RANGE
LAKE
TOOELE
1ST STANDARD PARALLEL SOUTH
Wildcat Mtn
Wildcat Peak
White Horse Flats
NEVADA
UTAH
DESERT
U. S. ARMY
DUGWAY
PROVING GROUND
DUGWAY VALLEY
Ibapah
GOSHUTE INDIAN RESERVATION
FISH SPRINGS FLAT
2ND STANDARD PARALLEL SOUTH
Callao
SNAKE VALLEY
Ruins


UTAH TEST
AND TRAINING RANGE
113° 00'
Rowley
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Island
Mud Flat
PUDDLE
BASE
LINE
Belle
Timpie
Lake Point Junction
WESTERN
PACIFIC
Knolls
Clive
Salt Flats
Burmester
Mills Junction
Erda
Marshall
Grantsville
TRAINING RANGE
Wildcat Mtn
PARALLEL
SOUTH
SKULL
VALLEY
SKULL VALLEY
INDIAN RES
Saint John
Station
Saint John
Clover
Willow Springs
RUSH
Dugway
Vernon
Lookout
Pass
Red Pine Mtn
SEVIER
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FOREST
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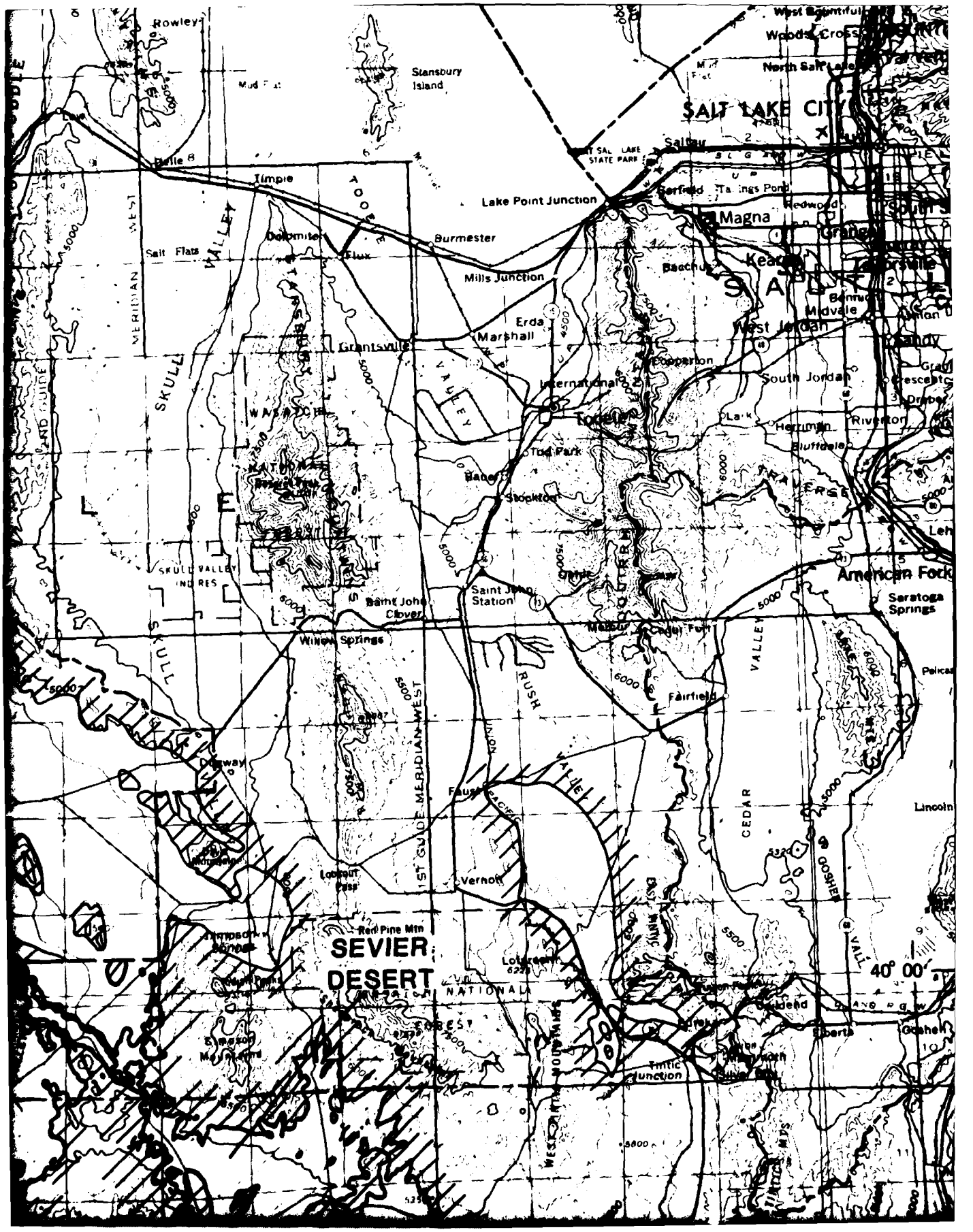
H SPRINGS FLAT
ANDARD PARALLEL SOUTH
Ruins


Rowley
Stansbury Island
Mud Flat
West Bountiful
Woods Cross
North Salt Lake
SALT LAKE CITY
Salmon
Belle
Timpie
Lake Point Junction
Garfield
Tailings Pond
Redwood
Magna
Burmester
Dolomite
Flux
Salt Flats
Mills Junction
Bacchus
Kearns
Bennion
Midvale
West Jordan
Erda
Marshall
Grantsville
Copperton
South Jordan
International
Tooele
Lark
Herriman
Riverton
Bluffdale
Tod Park
Bacon
Stockton
Saint John Station
Saint John
Clover
Willow Springs
Ophir
Mercur
Eagle Fort
American Fork
Saratoga Springs
Fairfield
Pelican
Dugway
Faust
Lincoln
Lookout Pass
Vernon
Red Pine Mtn
SEVIER DESERT
Lobster
Goldsend
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Goshen
Tintic Junction
40° 00'
SKULL VALLEY
SKULL VALLEY INDIAN RES
1ST GUIDE MERIDIAN WEST
RUSH VALLEY
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GOSHEN VALLEY
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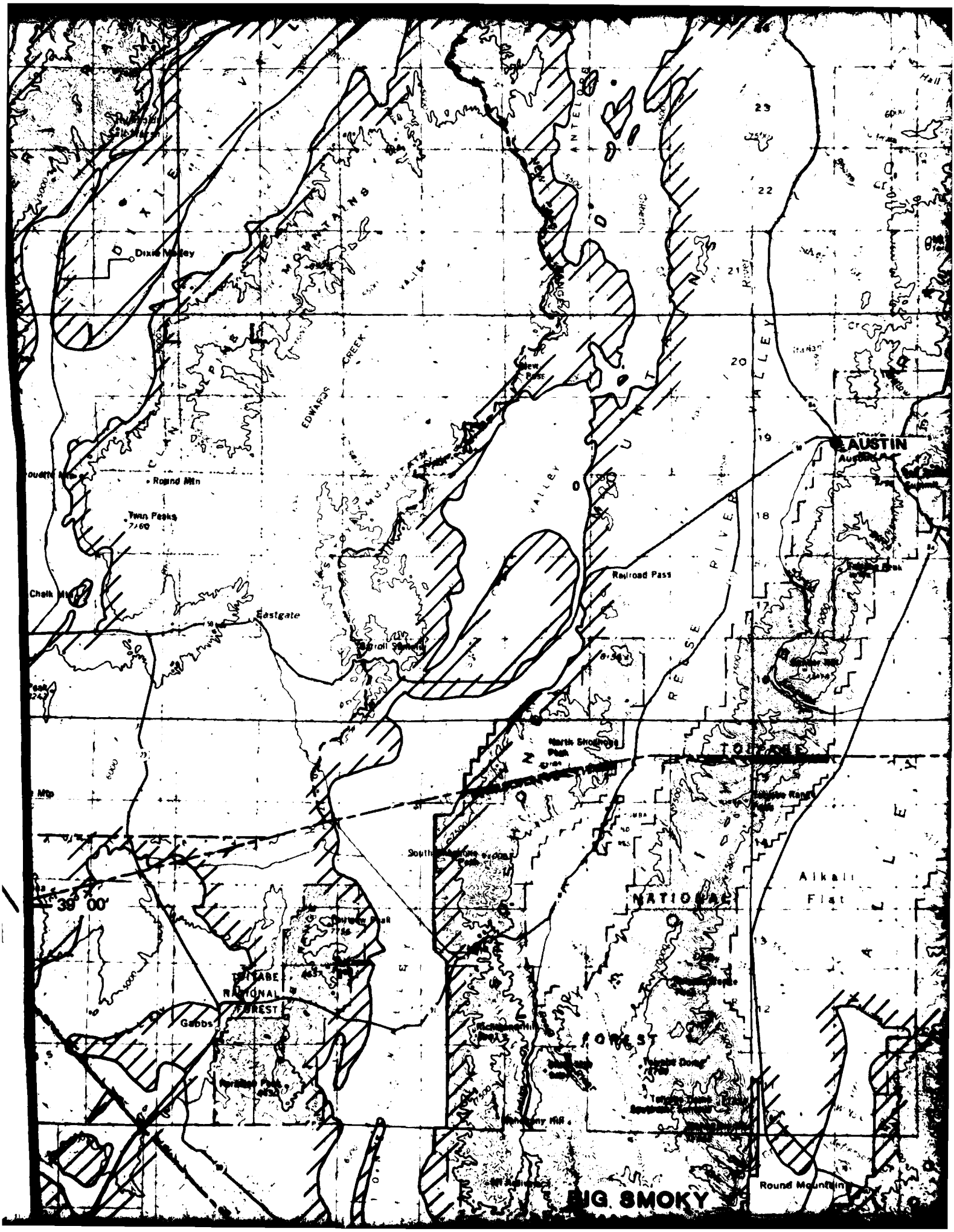
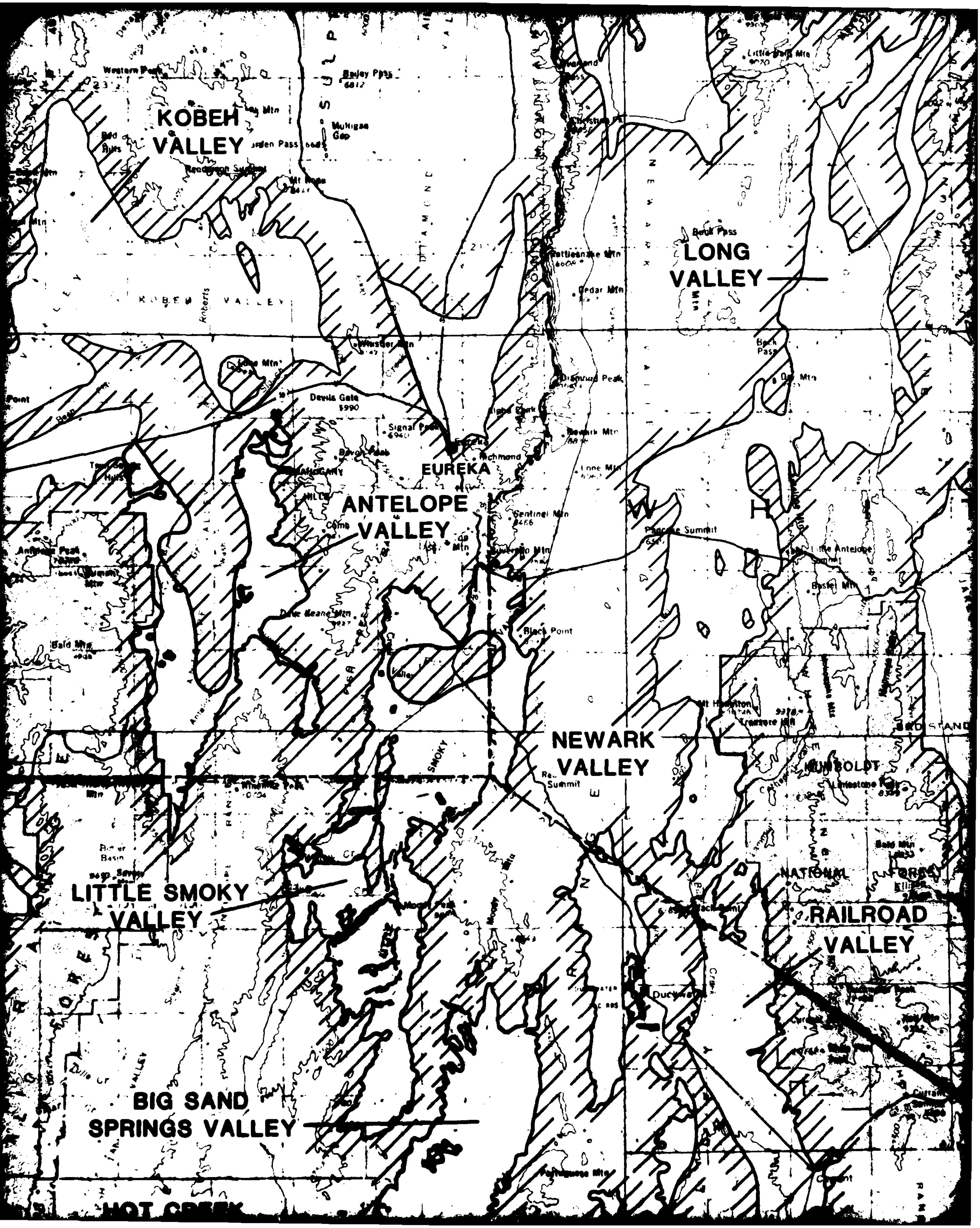
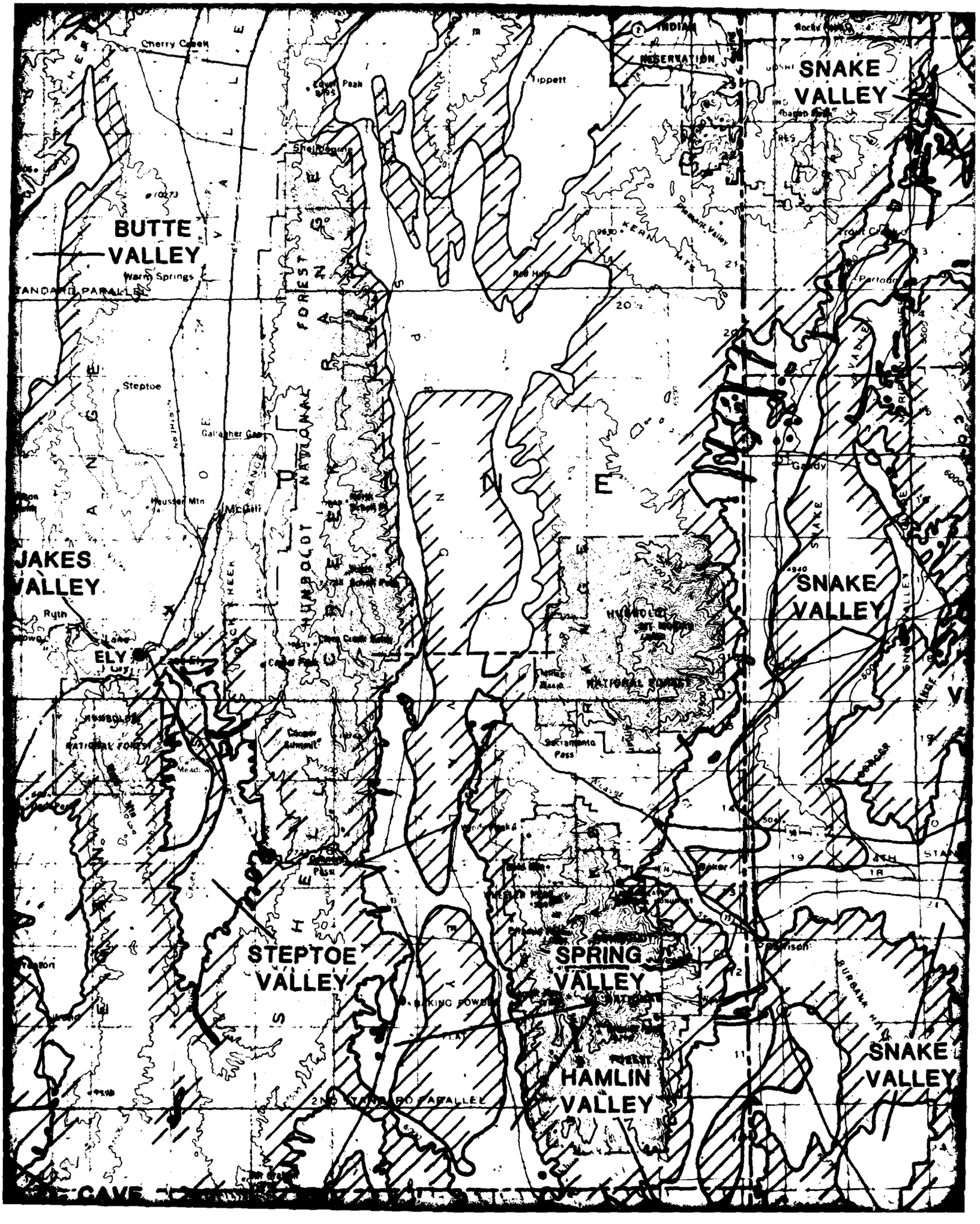

Dixie Valley
Round Mtn
Twin Peaks
7160
Chalk Mtn
Eastgate
Carroll Summit
Edwards Creek
Valley
Antelope
Dixie
Mountains
Dixie Valley
Railroad Pass
Reese River
Austin
Austin
North Shoshone Peak
Shoshone Range
Alkali Flat
39° 00'
Gabbs
Gabbs
Round Mountain
BIG SMOKY
NATIONAL
FOREST
Hall


KOBEH VALLEY
LONG VALLEY
EUREKA
ANTELOPE VALLEY
NEWARK VALLEY
LITTLE SMOKY VALLEY
RAILROAD VALLEY
BIG SAND SPRINGS VALLEY
HOT CREEK
Devils Gate
5990
Richmond
Black Point
Pancake Summit
Sentinel Mtn
Mt Hope
Bailey Pass
Mulligan Gap
Whistler Mtn
Diamond Peak
Newark Mtn
Lone Mtn
Rattlesnake Mtn
Cedar Mtn
Buck Pass
Little Bald Mtn
Western Peak
HUMBOLDT
NATIONAL
Bald Mtn
Duckwater
Currant
Summit


BUTTE VALLEY
JAKES VALLEY
STEPTOE VALLEY
SPRING VALLEY
HAMLIN VALLEY
SNAKE VALLEY
SNAKE VALLEY
SNAKE VALLEY
ELY
Steptoe
Warm Springs
Cherry Creek
Tippett
Red Hill
Baker
Garrison
Sacramento Pass
Gandy
Partoon
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HUMBOLDT NATIONAL FOREST
HUMBOLDT NATIONAL FOREST
KERN MTS
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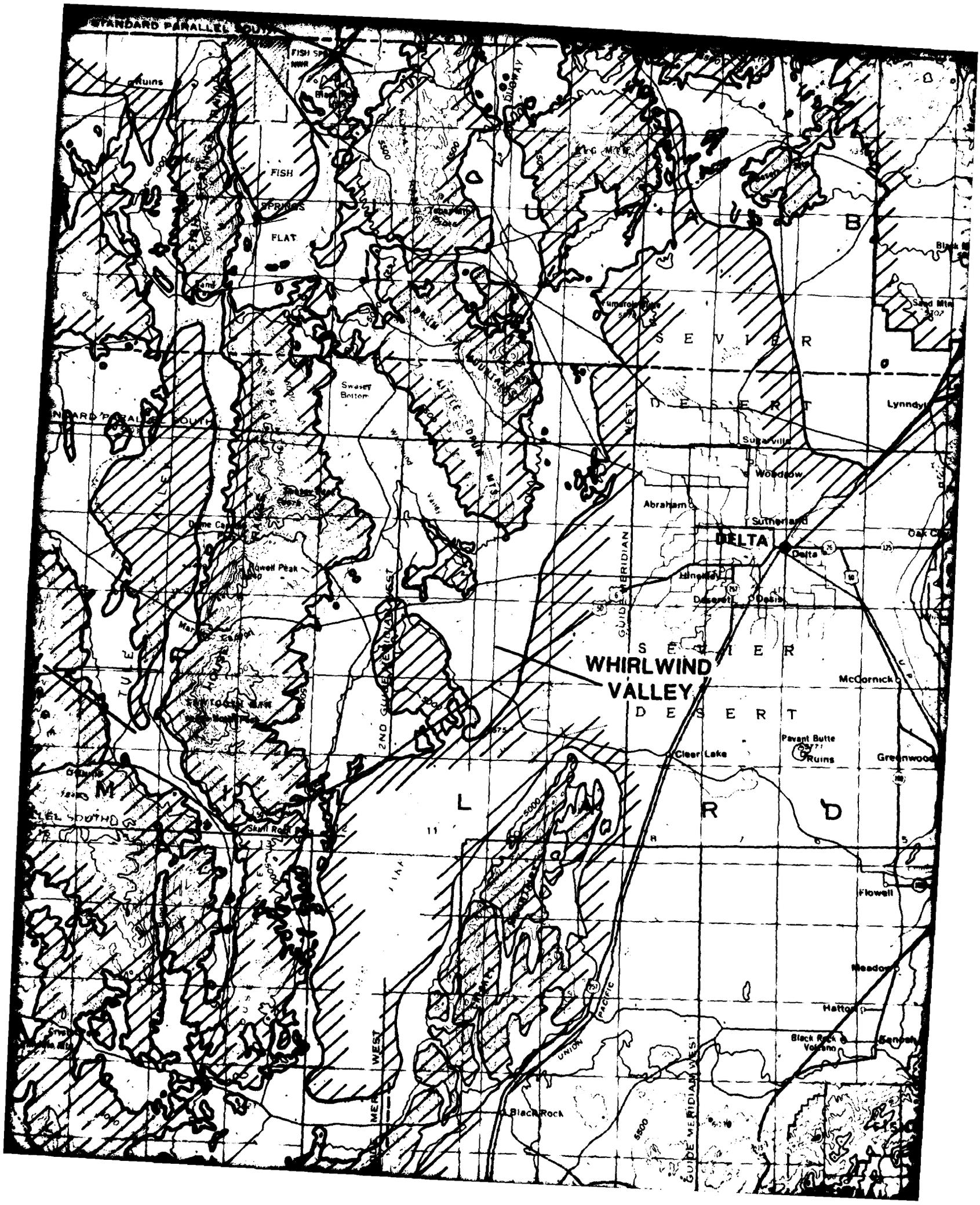
KING POWDER
2ND STANDARD PARALLEL
CAVE


STANDARD PARALLEL SOUTH
FISH SPRINGS NWR
FISH
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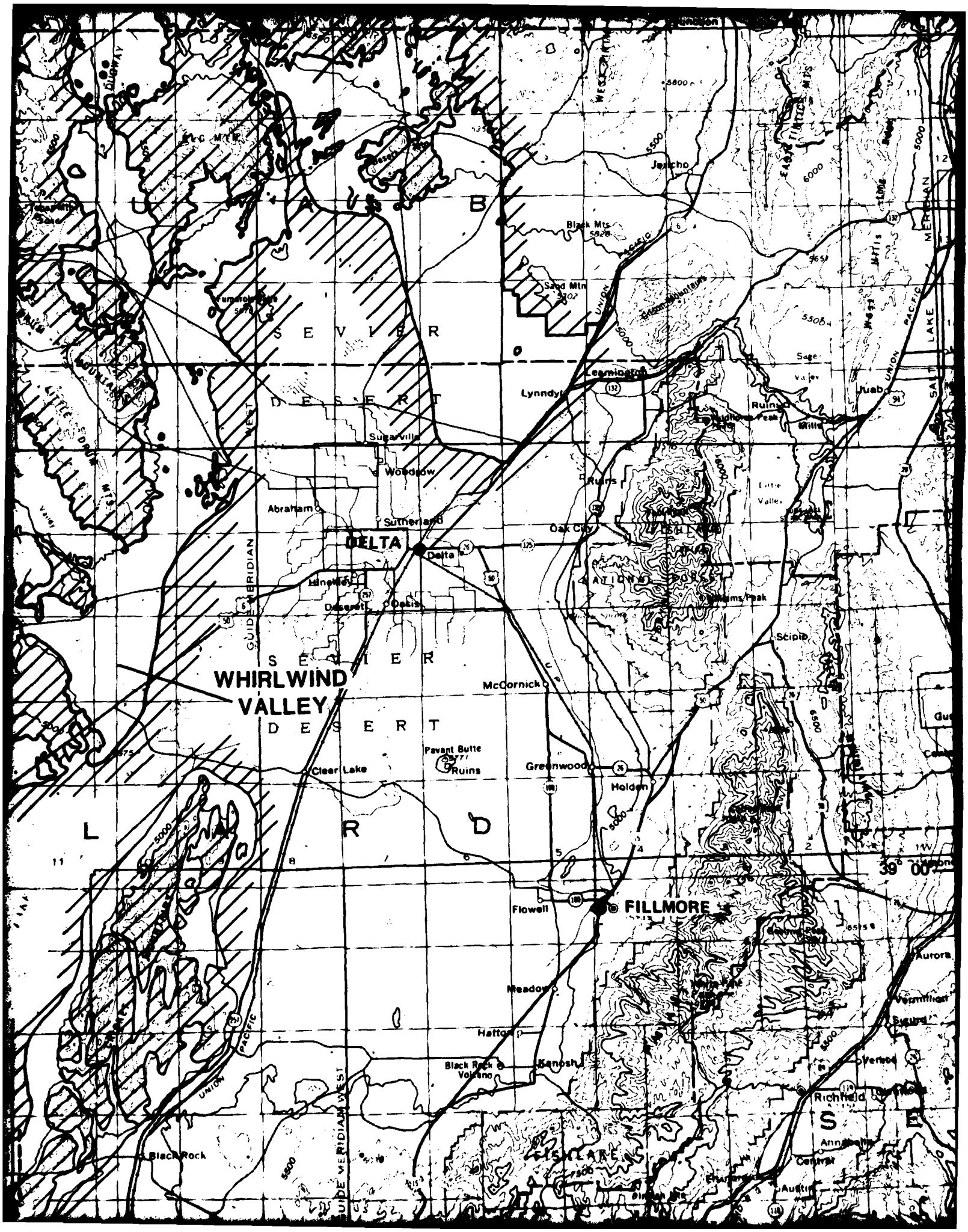
Ruins
Swasey Bottom
LITTLE DRUM MTS
DRUM MOUNTAINS
Sand Mtn
S E V I E R
D E S E R T
Lynndyl
Sugarville
Woodrow
Abraham
Sutherland
DELTA
Oak City
Delta
Hinckley
Deseret
Oasis
Rowell Peak
Dome Canyon
TUE
2ND GUIDE MERIDIAN WEST
GUIDE MERIDIAN
WHIRLWIND VALLEY
McCornick
Pavant Butte
Ruins
Clear Lake
Greenwood
Flowell
Meadow
Hatton
Black Rock Volcano
Sanpete
Black Rock
UNION PACIFIC
MERIDIAN WEST
GUIDE MERIDIAN WEST


WHIRLWIND VALLEY
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Pavant Butte Ruins
Clear Lake
Greenwood
Holden
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Meadow
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Scipio
Juab
Sage Valley
Little Valley
Richfield
Aurora
Venice
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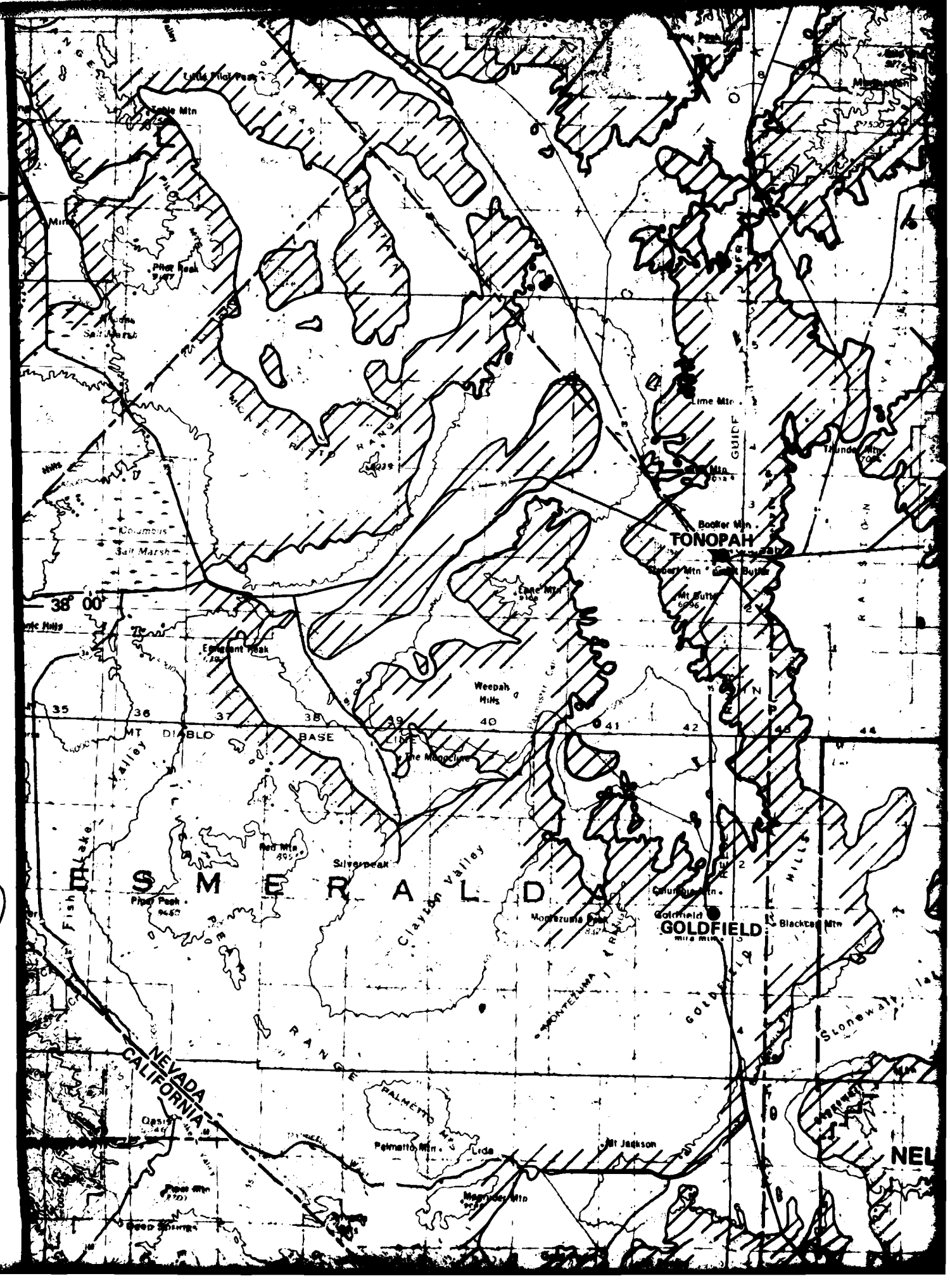
SEVIER DESERT
SEVIER DESERT
GUIDE MERIDIAN WEST
UNION PACIFIC
SALT LAKE MERIDIAN
39° 00'


Little Pilot Peak
Eagle Mtn
Pilot Peak
Salt Marsh
Columbus
Salt Marsh
Lime Mtn
Booker Mtn
TONOPAH
Mt Butler
Weepah Hills
38° 00'
Emigrant Peak
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MT DIABLO BASE LINE
The Monocline
Fish Lake Valley
Red Mtn
Silverpeak
S M E R A L D A
Pilot Peak
Clayton Valley
Montezuma Peak
Columbus Mtn
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GOLDFIELD
Blackcap Mtn
Stonewall
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CALIFORNIA
Palmetto Mtn
Lida
Mt Jackson
Magruder Mtn
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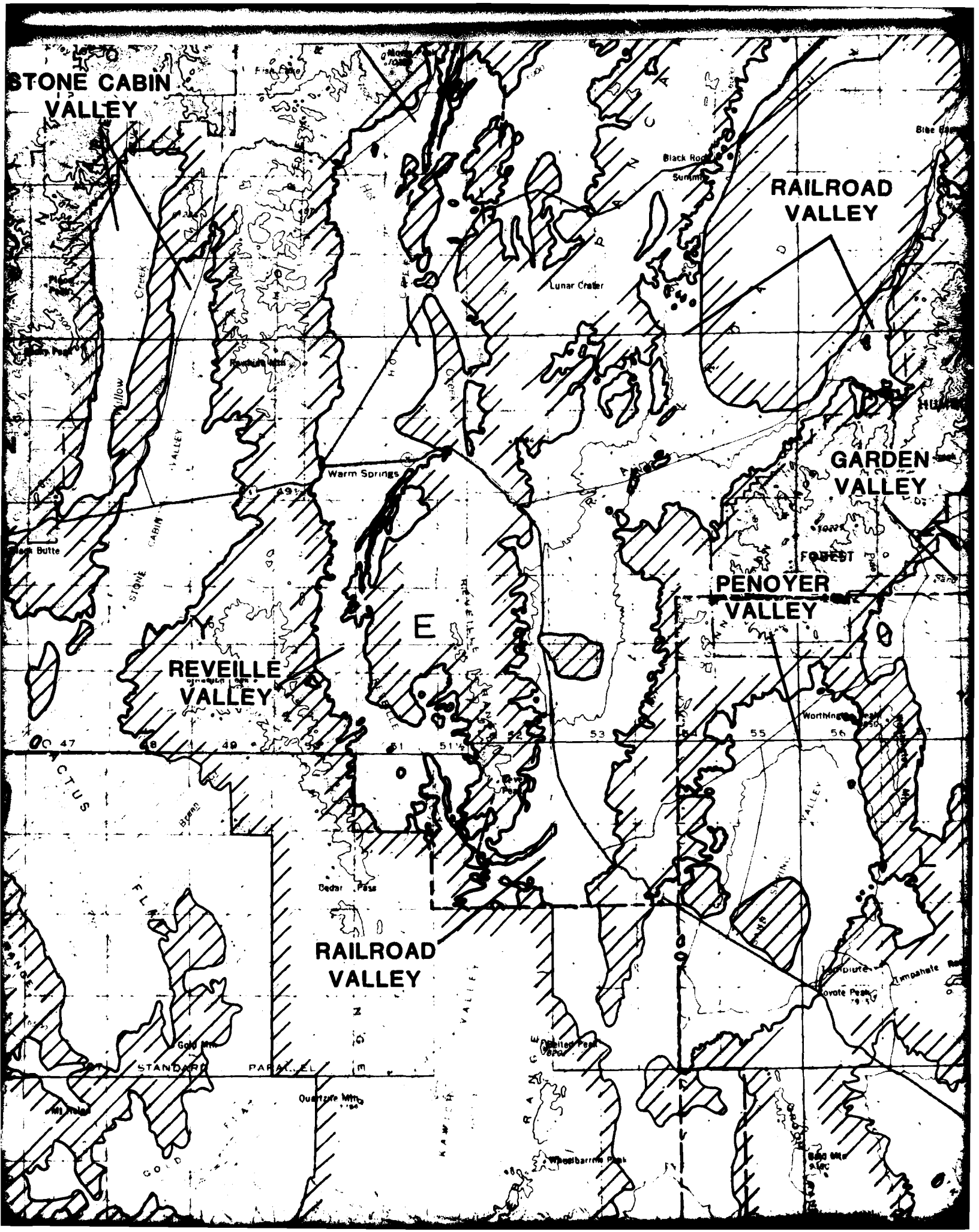
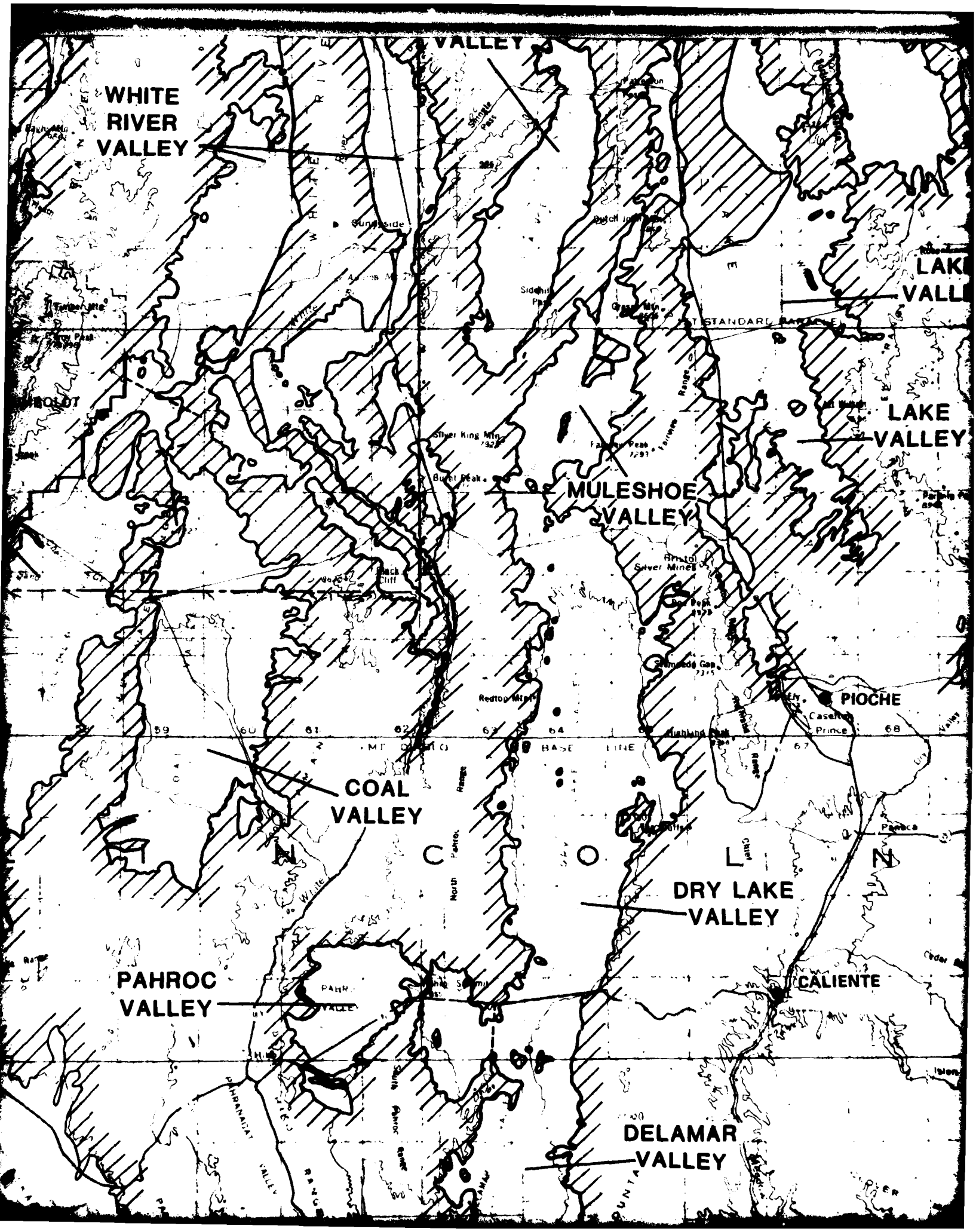
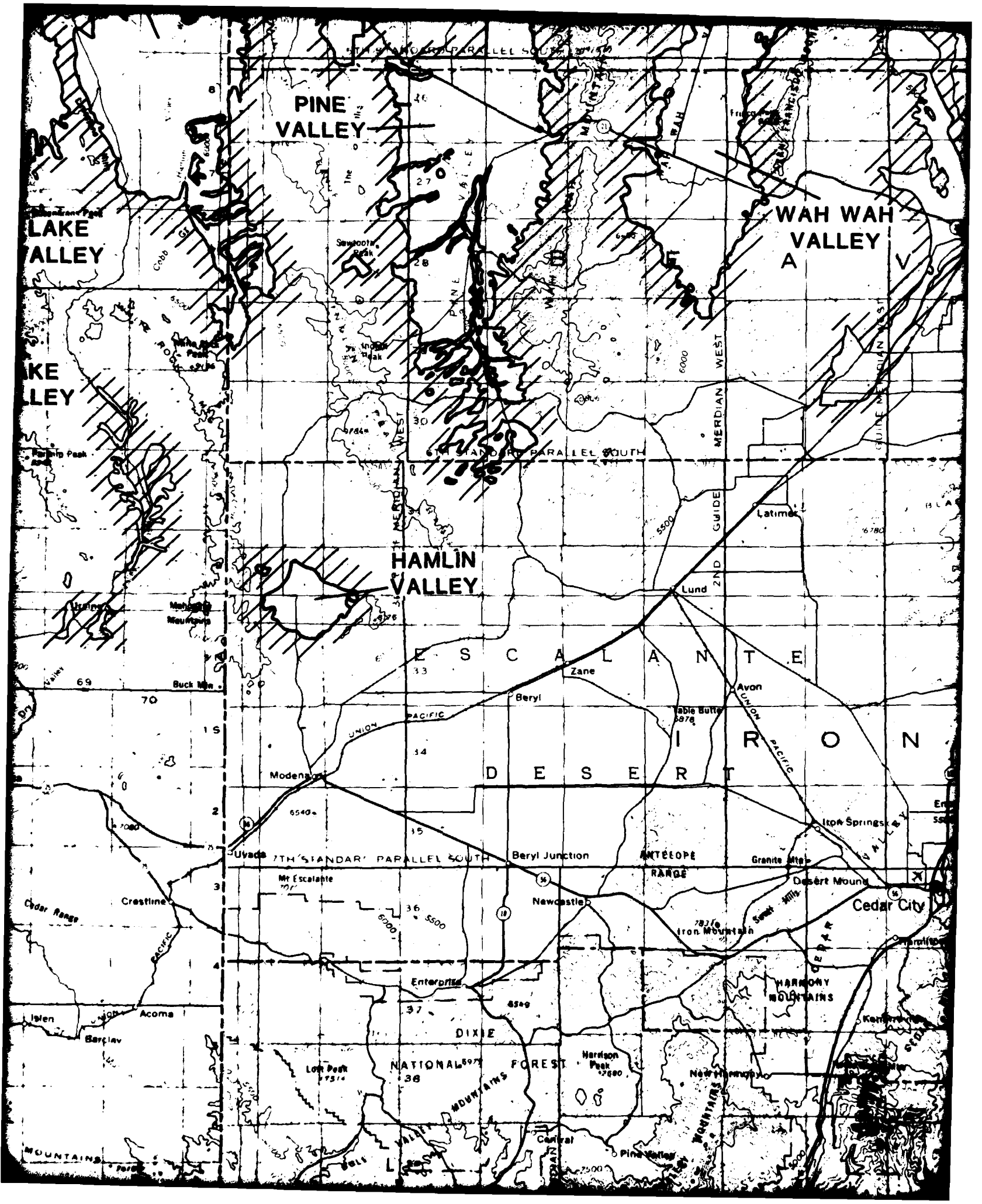
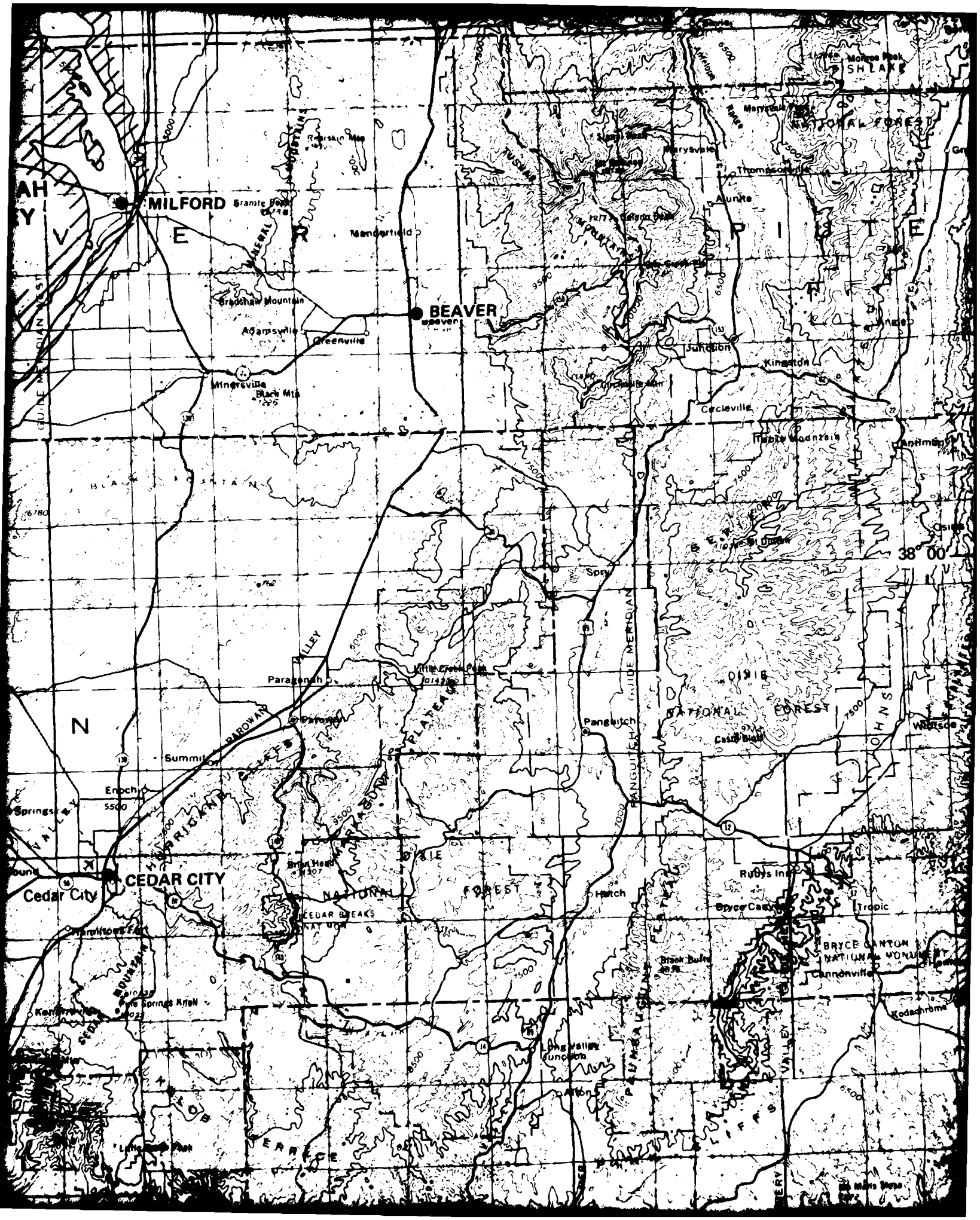

STONE CABIN VALLEY
RAILROAD VALLEY
GARDEN VALLEY
PENOYER VALLEY
REVEILLE VALLEY
RAILROAD VALLEY
Lunar Crater
Warm Springs
Black Butte
Stone Cabin Valley
Willow Creek
Reveille Valley
Cactus Flat
Cedar Pass
Worthington Peak
Coyote Peak
Timpahute Range
Quartzite Mtn
Gold Mtn
Standard Parallel
Kawich Range
Woodbarrow Peak
Bald Mtn
Forest


WHITE RIVER VALLEY
LAKE VALLEY
MULESHOE VALLEY
COAL VALLEY
DRY LAKE VALLEY
PAHROC VALLEY
DELAMAR VALLEY
PIOCHE
CALIENTE
Sunnyside
Silver King Mtn
Burnt Peak
Bristol Silver Mines
Redtop Mtns
Highland Peak
Prince
Pioche
Caliente
Pahroc
Pahranagat Valley
North Pahroc Range
South Pahroc Range
Chief Range
Highland Range
Fairview Range
Sidehill Pass
Black Cliff
BASE LINE
STANDARD
C O L N


PINE VALLEY
WAH WAH VALLEY
HAMLIN VALLEY
ESCALANTE DESERT
IRON
Latimer
Lund
Zane
Avon
Beryl
Modena
Uvada
Beryl Junction
Newcastle
Enterprise
Iron Springs
Cedar City
Desert Mound
Crestline
Acoma
Barclay
Central
Pine Valley
Kanarraville
Antelope Range
Harmony Mountains
Iron Mountain
Granite Mtn
Mt Escalante
Sawtooth Peak
Buck Mtn
Cedar Range
Dixie National Forest
Union Pacific
37th Standard Parallel South
2nd Guide Meridian West
Salt Lake Base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Minersville
Black Mtn
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Granite Peak
Marysvale
Thompsonville
Alunite
Junction
Kingston
Circleville
Antimony
Sevier
Monroe Peak
Paragonah
Parowan
Summit
Enoch
Cedar City
CEDAR CITY
Panguitch
Hatch
Bryce Canyon
Tropic
Cannonville
Kodachrome
Rubys Inn
Long Valley Junction
Alton
Kanarraville
Little Creek Peak
Brian Head
Castle Butte
Sevier Plateau
Paunsaugunt Plateau
Pink Cliffs
Sevier Valley
Parowan Valley
Cedar Mountain
Dixie National Forest
Fishlake National Forest
Bryce Canyon National Monument
Cedar Breaks National Monument
Black Mountain
Tushar Range
Mineral Range
Pavant Range
Gunnison Plateau
Black Mountain
Sevier Desert
Johns Valley
Little Creek Peak
Little Rock Peak
Mt Mars Dome
Sevier
Springs
Springs Knoll
Hamiltons Fort
Cedar Breaks
Brook Butte
Long Valley Junction
Kanarraville
Cedar City
Bryce Canyon National Monument
Dixie National Forest
Fishlake National Forest
Sevier Plateau
Paunsaugunt Plateau
Pink Cliffs
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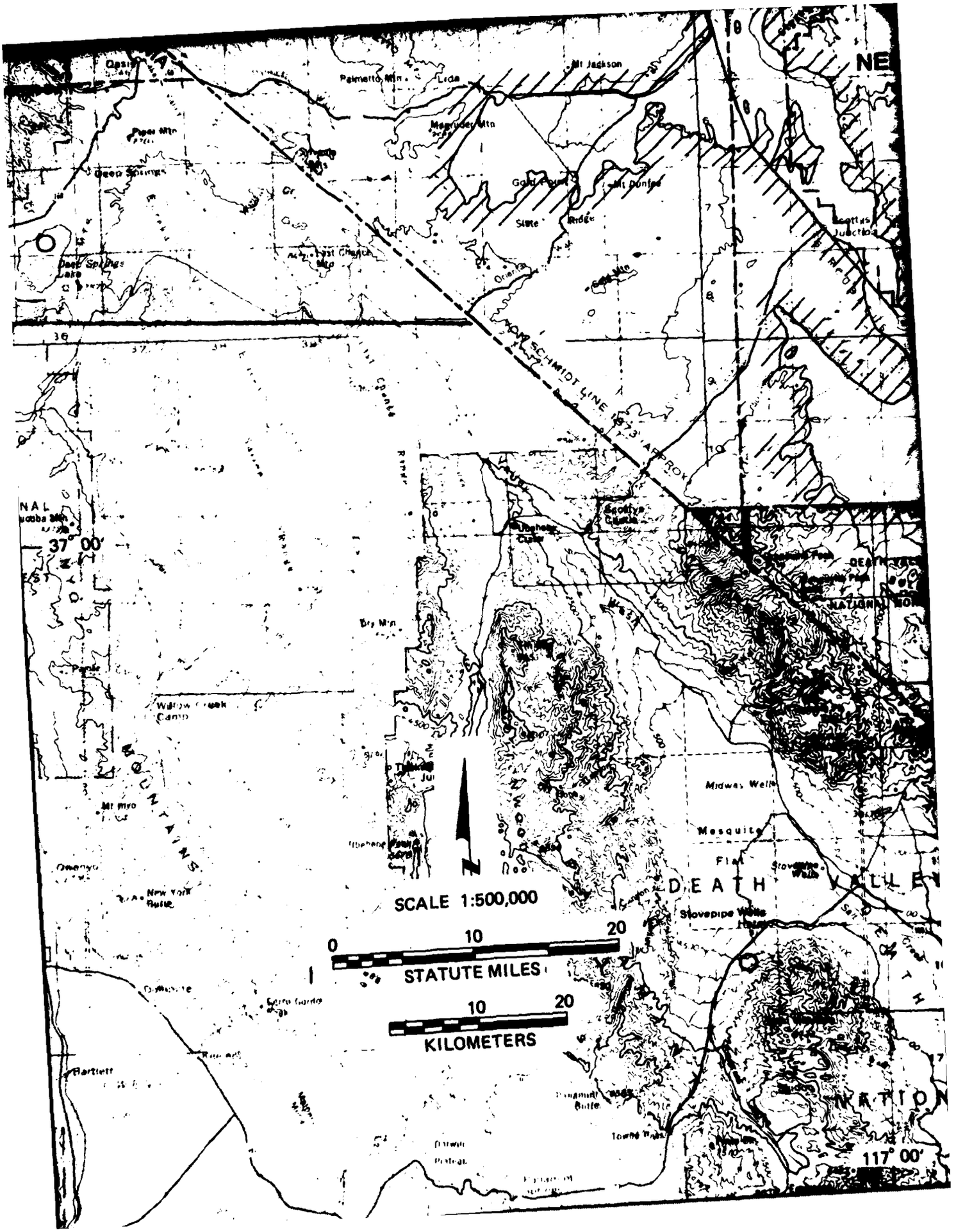
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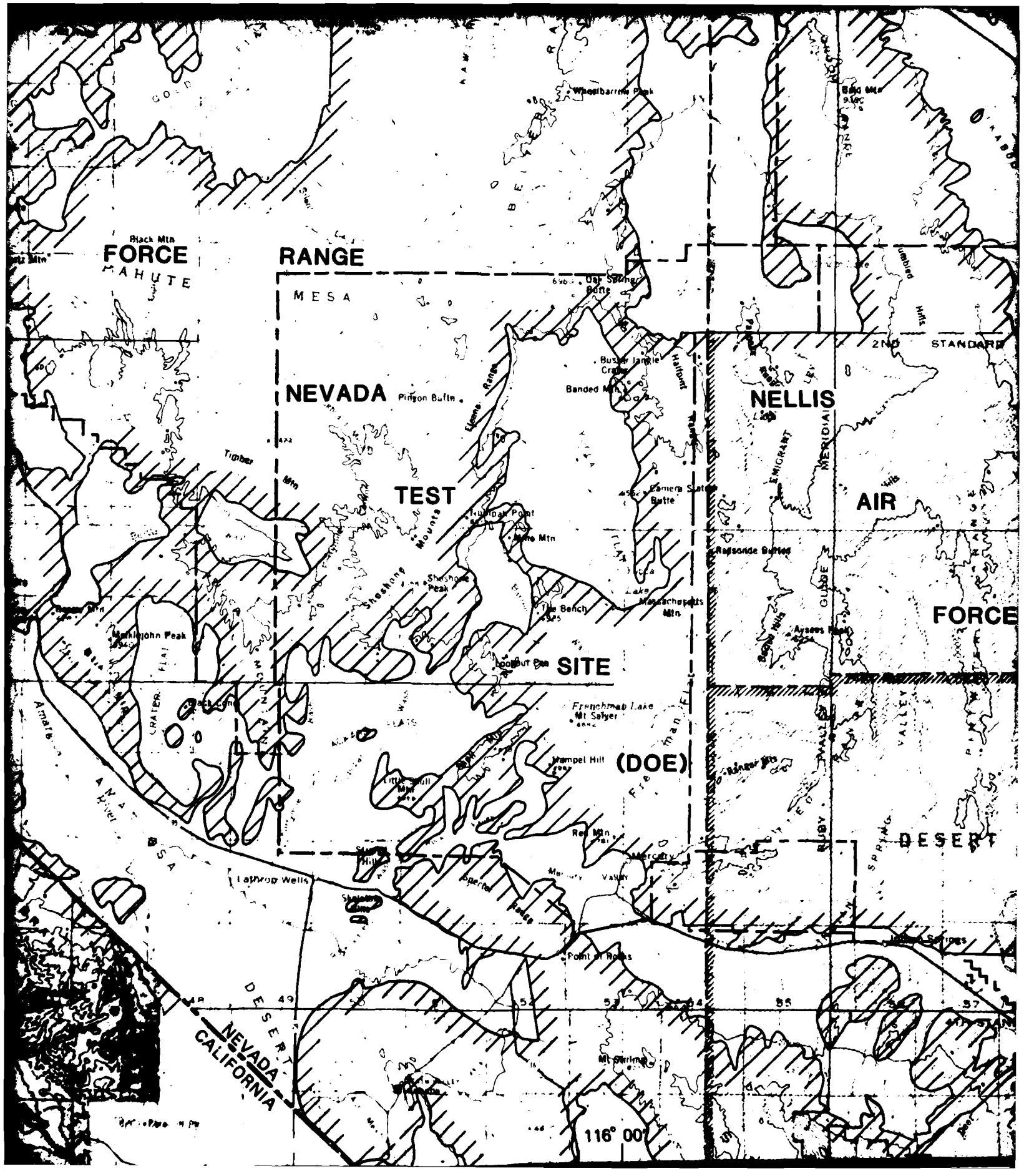
Lida
Magruder Mtn
Gold Point
Mt Dunfee
Deep Springs
Deep Springs Lake
Oasis
Paper Mtn
Scotty's Castle
Ubehebe Crater
Dry Mtn
Willow Creek Camp
Mt Hyd
New York Butte
Bartlett
Midway Well
Mesquite Flat
Stovepipe Wells
Stovepipe Wells Hotel
Towne Pass
Darwin Plateau
Darwin
Panamint Butte
SCHMIDT LINE 1973 APPROX
NATIONAL MONUMENT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Timber Mtn
Shoshone Peak
Mercury
Lathrop Wells
Point of Rocks
Mt Stirling
Frenchman Lake
Mt Salyer
Red Mtn
Massachusetts Mtn
Tie Bench
Rainbow Butte
Banded Mtn
Wheelbarrow Peak
Bald Mtn
2ND STANDARD
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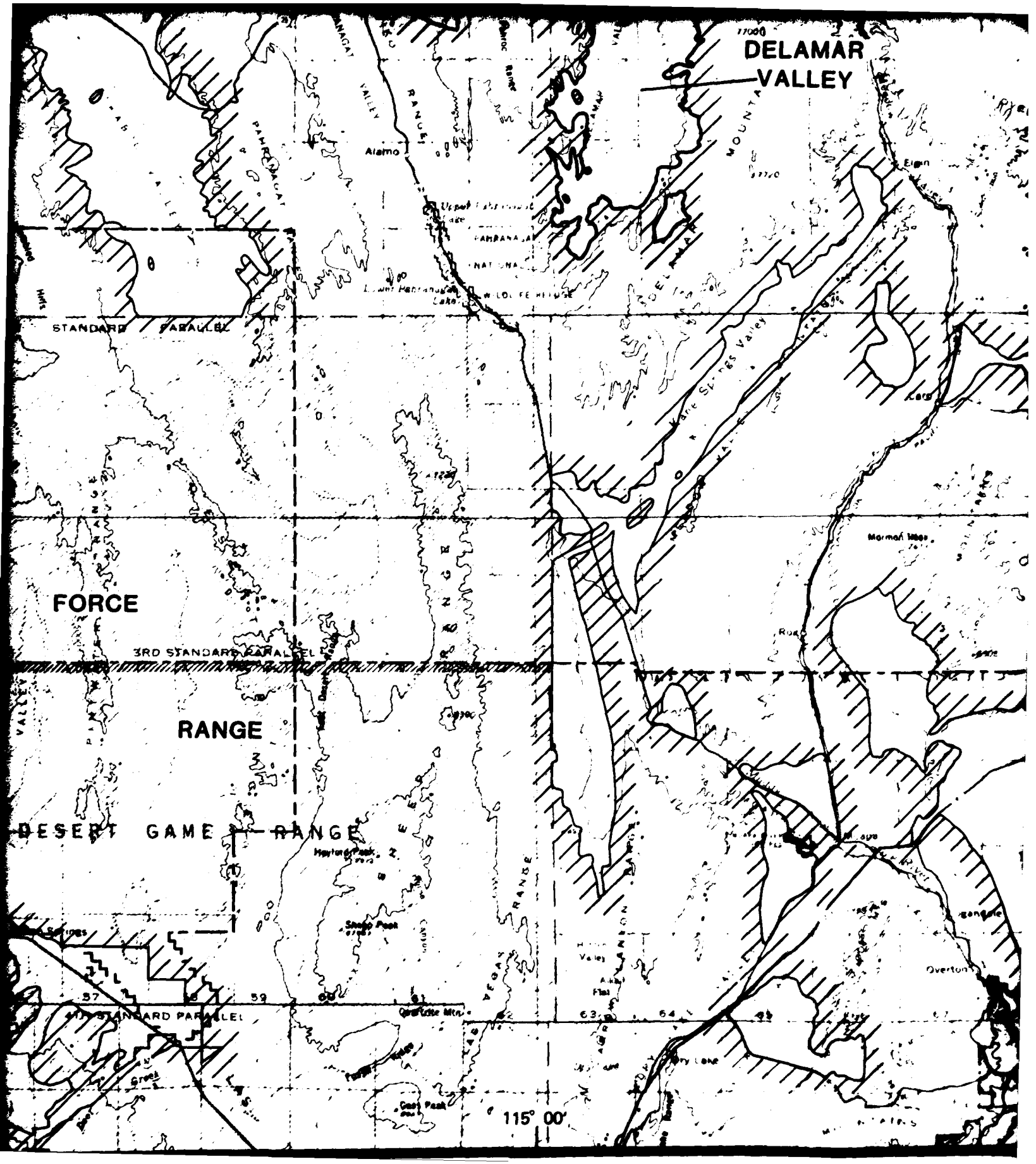
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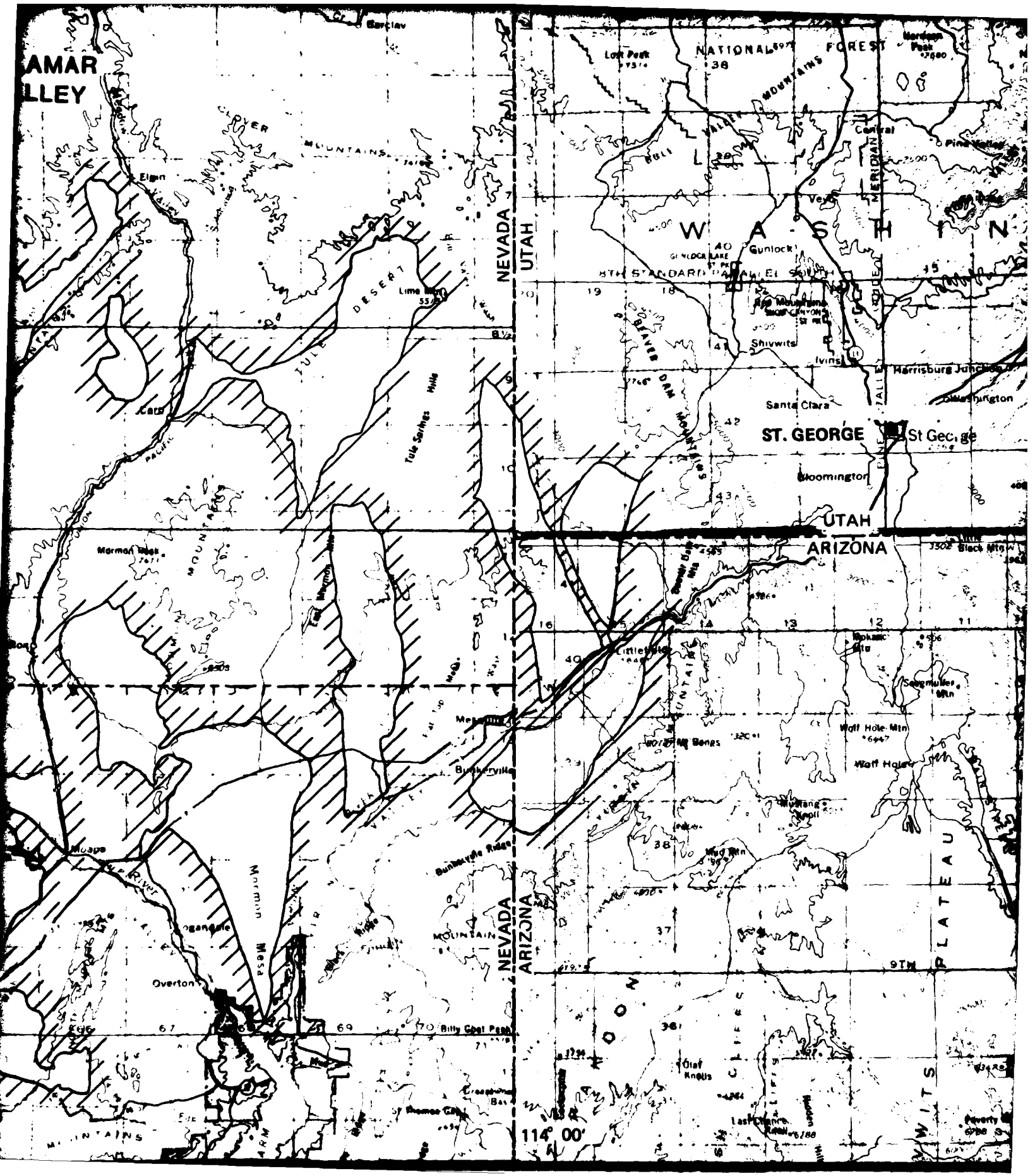
Alamo
Elgin
Caliente
Overton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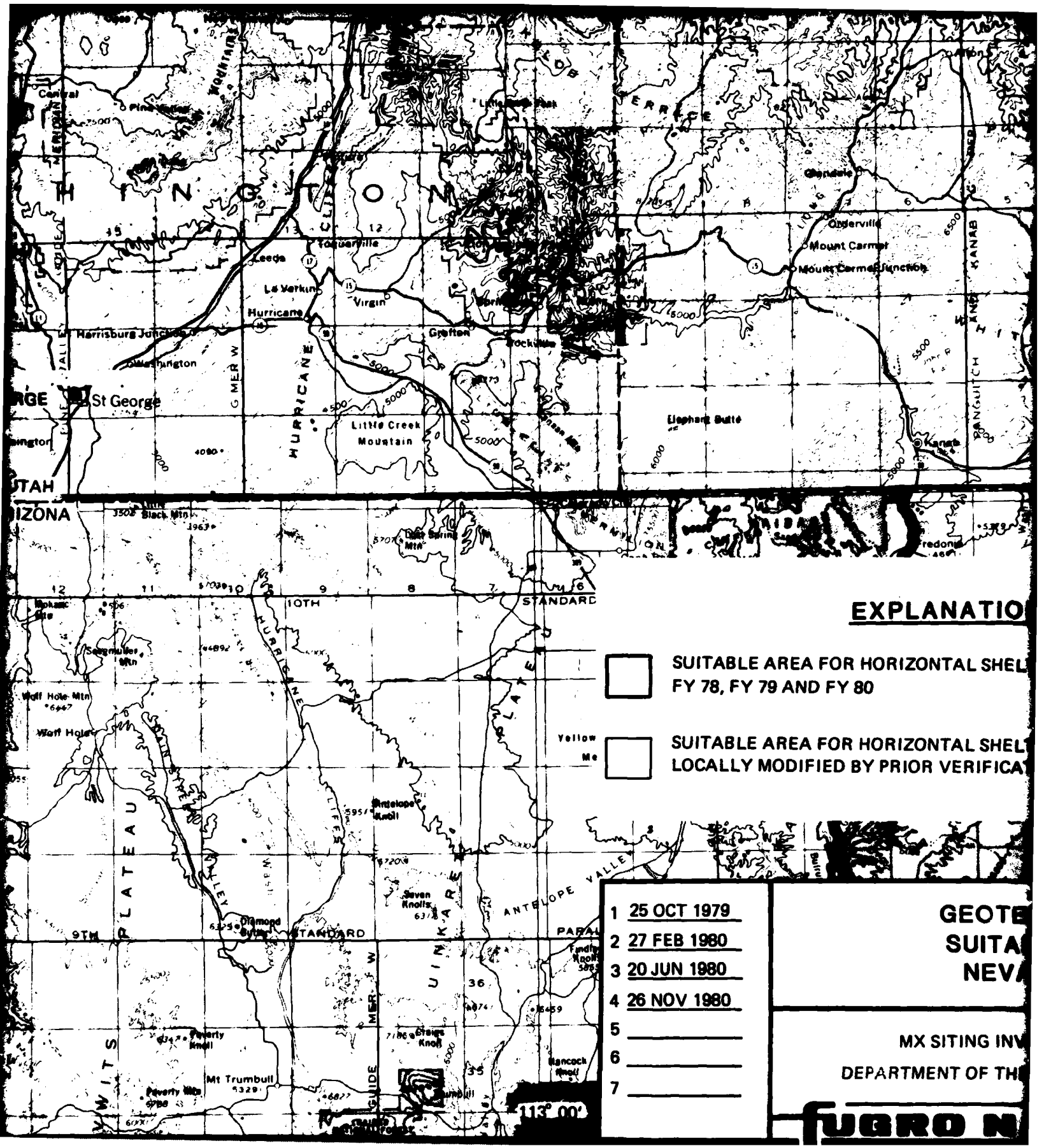
Lake
Mormon Peak
MOUNTAINS
Moapa
River
Overton
Mormon
Mesa
Bunkerville Ridge
MOUNTAIN
Billy Goat Peak
MOUNTAINS
NEVADA
UTAH
NATIONAL
FOREST
Lost Peak
Hardeys Peak
VALLEY
MOUNTAINS
Central
Pine Valley
Veyo
W A S H I N
Gunlock
STANDARD
Shivwits
Ivins
Harrisburg Junction
Washington
Santa Clara
ST. GEORGE
St George
Bloomington
UTAH
ARIZONA
Black Mtn
Littlefield
Bonners
Wolf Hole Mtn
Wolf Hole
Mud Mtn
Olaf Knolls
Last Chance Knoll
Poverty
NEVADA
ARIZONA
114° 00'
PLATEAU
SHIVWITS


EXPLANATIO
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FY 78, FY 79 AND FY 80
SUITABLE AREA FOR HORIZONTAL SHEL
LOCALLY MODIFIED BY PRIOR VERIFICA
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Leeds
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Harrisburg Junction
Washington
Grafton
Rockville
Little Creek Mountain
Elephant Butte
Kanab
Glendale
Orderville
Mount Carmel
Mount Carmel Junction
Central
Pine Valley
Little Black Peak
Black Mtn
Seegmuller Mtn
Wolf Hole Mtn
Wolf Hole
Antelope Knoll
Seven Knolls
Diamond Butte
Poverty Knoll
Mt Trumbull
Poverty Mtn
Craigs Knoll
Hancock Knoll
Fandity Knoll
Yellow
Me
10TH
9TH
STANDARD
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WITS PLATEAU
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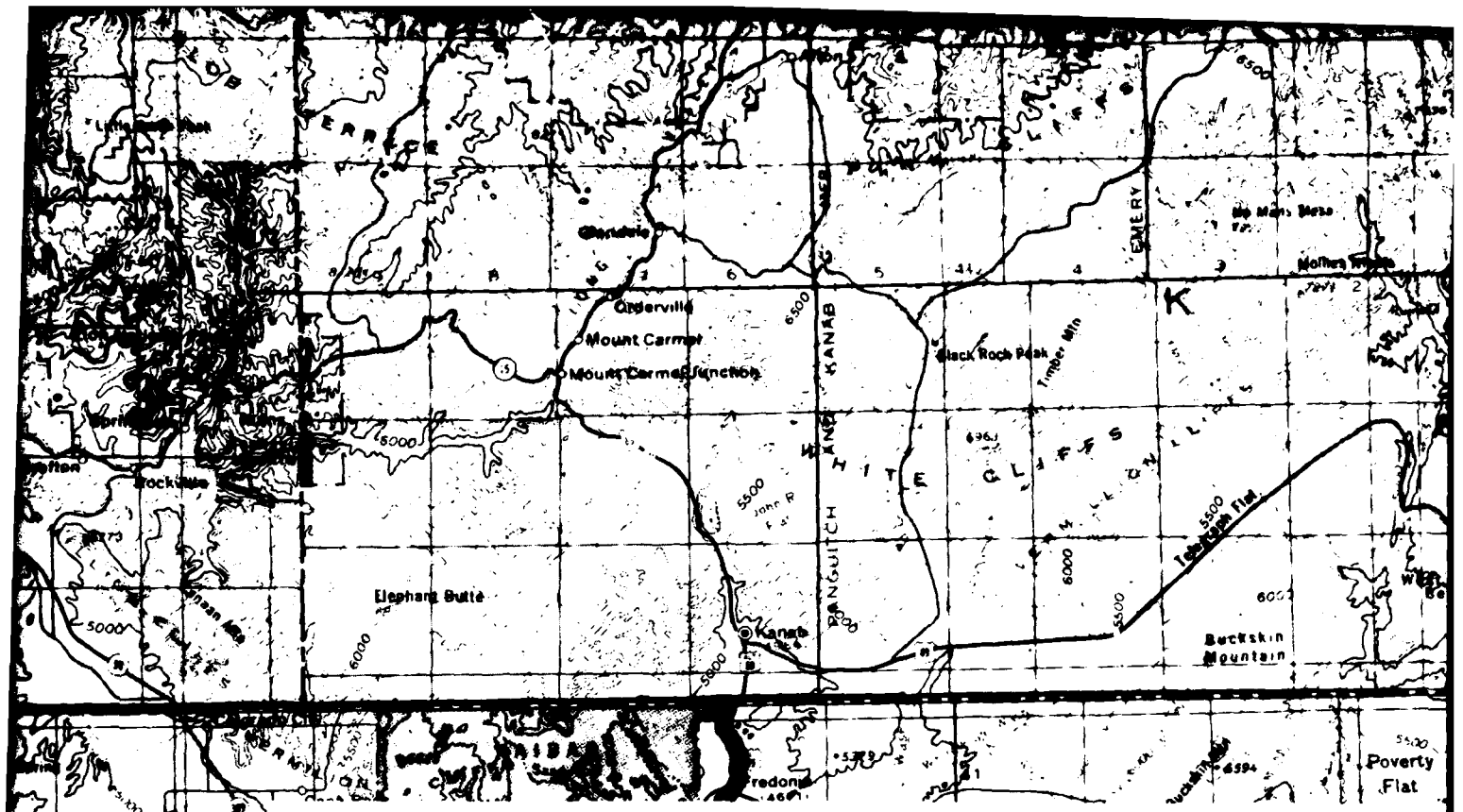
UTAH
IZONA
NEVADA



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
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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 are shown in Drawing 2-1 and listed in Table 2-1. The excluded areas are based entirely on the depth-to-rock and terrain criteria (Appendix A2.0) because no significant shallow ground water was found within Delamar Valley.

The total area of basin-fill materials in Delamar Valley, excluding rock outcrops, is 183 square miles (mi^2) (474 square kilometers [km^2]). Depth-to-rock and terrain conditions exclude 16 percent of this area for the horizontal shelter basing mode. The exclusion area is increased to 26 percent for the vertical shelter basing mode. The area interpreted to be suitable for deployment in the horizontal shelter basin mode is 154 mi^2 (399 km^2). The suitable area is reduced to 136 mi^2 (352 km^2) for the vertical shelter mode.

2.2 BASIN-FILL CHARACTERISTICS

This section contains brief descriptions of the soils in Delamar 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 85 to 95 percent of the area. They consist of gravelly, silty and/or clayey sands, and sandy gravels. Generally sandy gravels and gravelly sands dominate along the mountain fronts on the east and west valley margins.

VERIFICATION VALLEY	STATE	AREA MI^2 (KM^2)*		
		BEGINNING AREA	SUITABLE AREA	
			HORIZONTAL	VERTICAL
DELAMAR	NEVADA	183 (474)	154 (399)	136 (352)

EXCLUSIONS	AREA MI^2 (KM^2)	PERCENT REDUCTION**
< 50 FEET (15M) TO ROCK	24 (67)	14
< 150 FEET (46M) TO ROCK	45 (117)	25
< 50 FEET (15M) TO WATER	0 (0)	0
< 150 FEET (46M) TO WATER	0 (0)	0
TERRAIN ***	3 (8)	2

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

**PERCENT REDUCTIONS, BASED ON BEGINNING AREA, ARE ROUNDED OFF TO NEAREST WHOLE PERCENT. GROUND WATER DATA FROM FUGRO NATIONAL, INC. (1980).

***TERRAIN EXCLUSIONS BETWEEN 50 FEET ROCK/WATER EXCLUSIONARY CONTOUR AND VALLEY BASIN FILL/ROCK CONTACT HAVE NOT BEEN CALCULATED.

ESTIMATED SUITABLE AREA
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

TABLE 2-1

FUGRO NATIONAL, INC.

The surficial soils grade to silty and/or clayey sands going down slope toward the north-south valley axis. The sands and gravels are generally poorly graded and have variable calcium-carbonate cementation.

Fine-grained soils cover from five to 15 percent of the area. They consist of silts, clayey silts, and silty clays. In this southwestern sloping valley, the fine-grained soils settle mainly in the active playa at the southern extreme of the valley. Their plasticity ranges from nonplastic to slightly plastic.

2.2.2 Subsurface Soils

Soils in the subsurface are also predominantly coarse-grained consisting of sandy gravels, gravelly sands, sands, and silty sands. Gravels and gravelly sands commonly occur along mountain fronts and grade to finer soils toward the valley axis. The coarse-grained soils are generally medium dense to very dense below 10 to 15 feet (3.0 to 4.6 m). They are poorly graded on the west side of the valley and well graded on the east side of the valley. They contain coarse to fine sand and/or gravel, exhibit low compressibilities, and possess moderate to high shear strengths. Variation in the real extent of playas in the geologic past has resulted in local interfingering of coarse- and fine-grained deposits in the subsurface near playa margins. This occurred in the southwestern end of the valley which still maintains an active playa. Fine-grained soils (silts and clays) probably occur in about 10 to 20 percent of the subsurface and

are generally restricted to these buried lacustrine deposits in the southwest portion of the valley. The fine-grained soils are slightly 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 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 20 percent of the suitable area. 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, three clusters can be placed in Delamar Valley. The maximum grade at any shelter location in this layout would be between five and nine percent. For approximately 80 percent of the shelters, the grade would be less than five 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 2.4 feet (0.7 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 2 to 3 feet (0.6 to 0.9 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 California Bearing Ratio (CBR) tests, the in-situ granular soils, when compacted, will provide good to very good support for roads.

Fine-grained surficial soils have an areal extent of five to 15 percent of the suitable area. The measured depths of low strength averaged of 3.2 feet (1.0 m). The maximum depth measured was 9.2 feet (2.8 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 support, 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 are generally less than 6 feet (1.8 m) within 80 to 85 percent of the suitable area. Therefore, the overall cost of drainage structures for roads will be low. In the remainder of the valley, which is generally around the perimeter, the depth of drainage incision ranges from 3 to 20 feet (0.9 to 6.1 m).

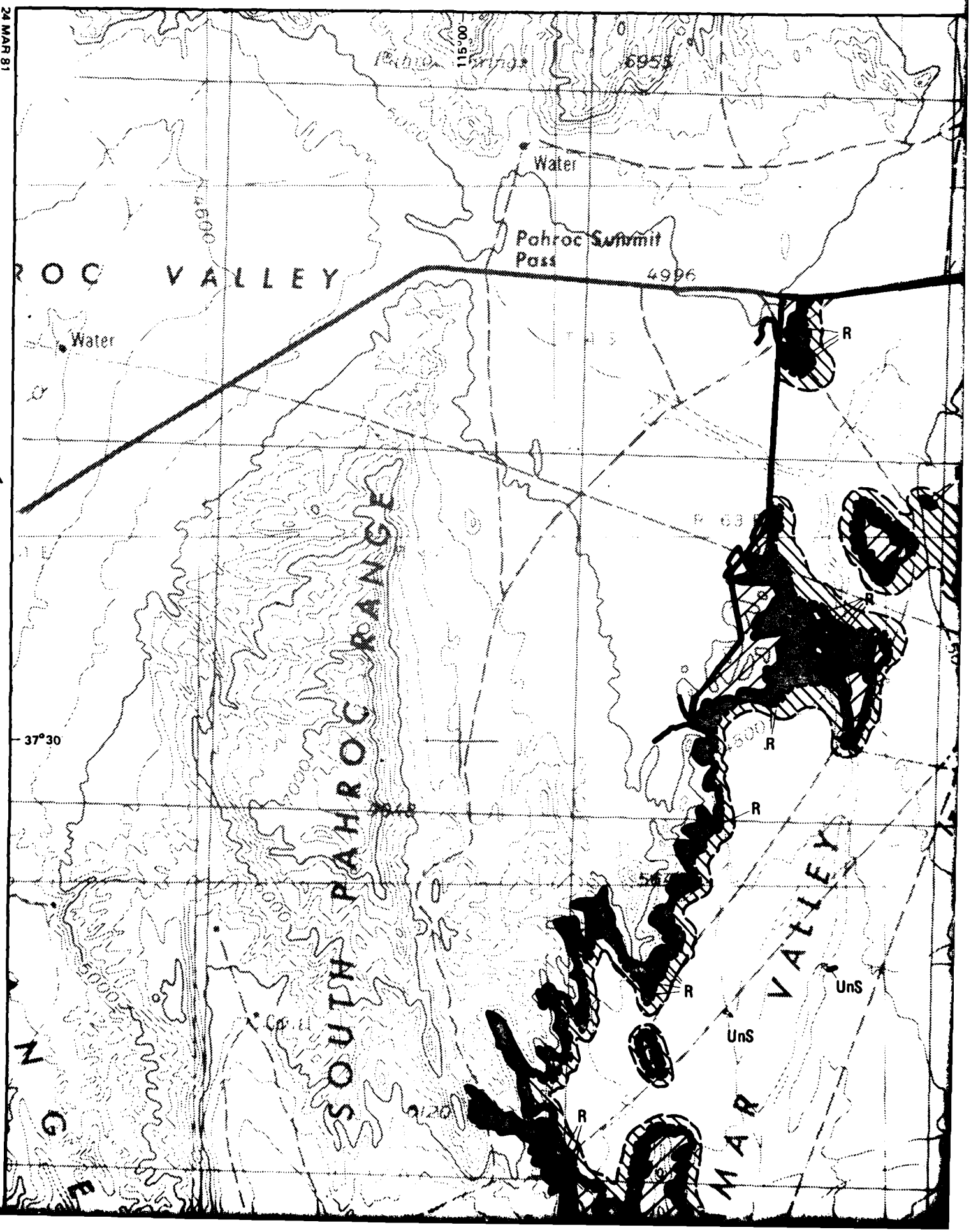
2.3.3 Excavatability and Stability

The soils in the construction zone are generally medium dense to very dense and possess various degrees of calcium carbonate cementation. Fine-grained soils occur in less than 20 percent of the subsurface.

Horizontal Shelter: Excavation for the horizontal shelter can be done using conventional equipment such as scrapers, backhoes, and bulldozers. Excavation will be easy in approximately 60 to 70 percent of the area; however, excavation will be moderately 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. 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 depends 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 6 feet (0.6 to 1.8 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.

24 MAR 81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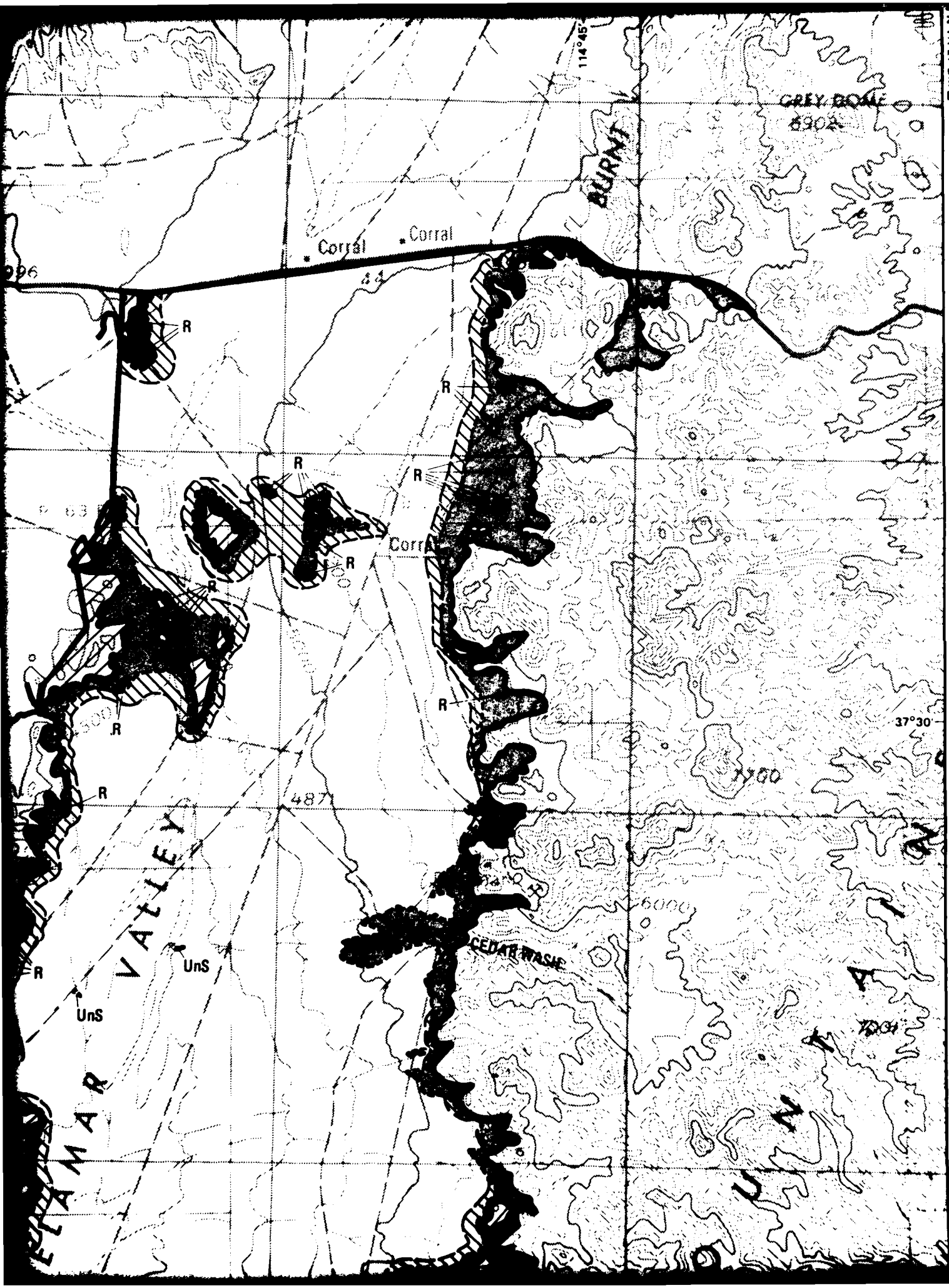
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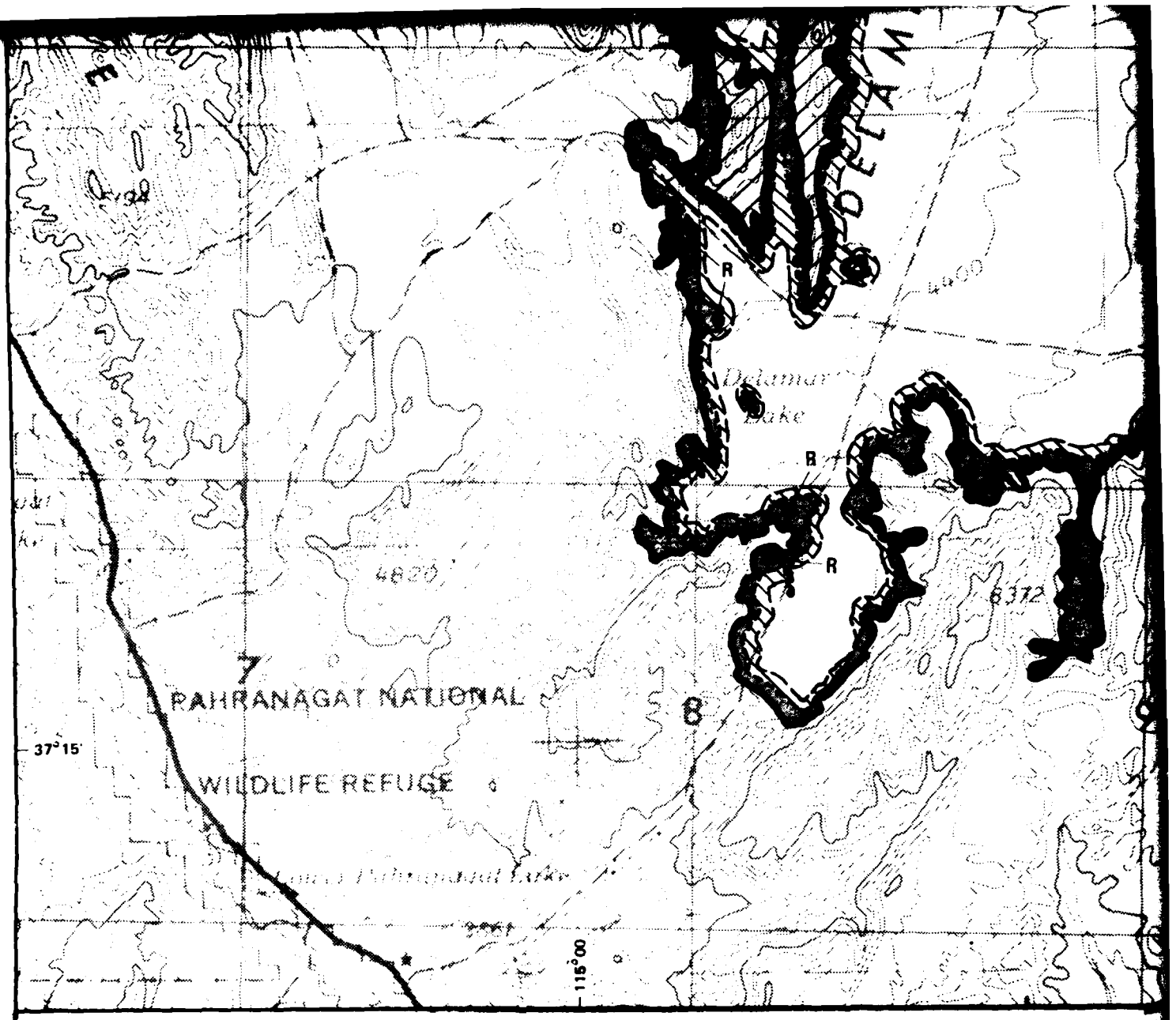

EXPLANATION

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

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

Area unsuitable for both horizontal and vertical shelter basing
of depth to rock and water, topographic/terrain, and cultural

UnS Area unsuitable for both horizontal and vertical shelter too are

Areas of isolated exposed rock.

SUITABL
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DELAMAR VAL

MX SITING INVESTIG
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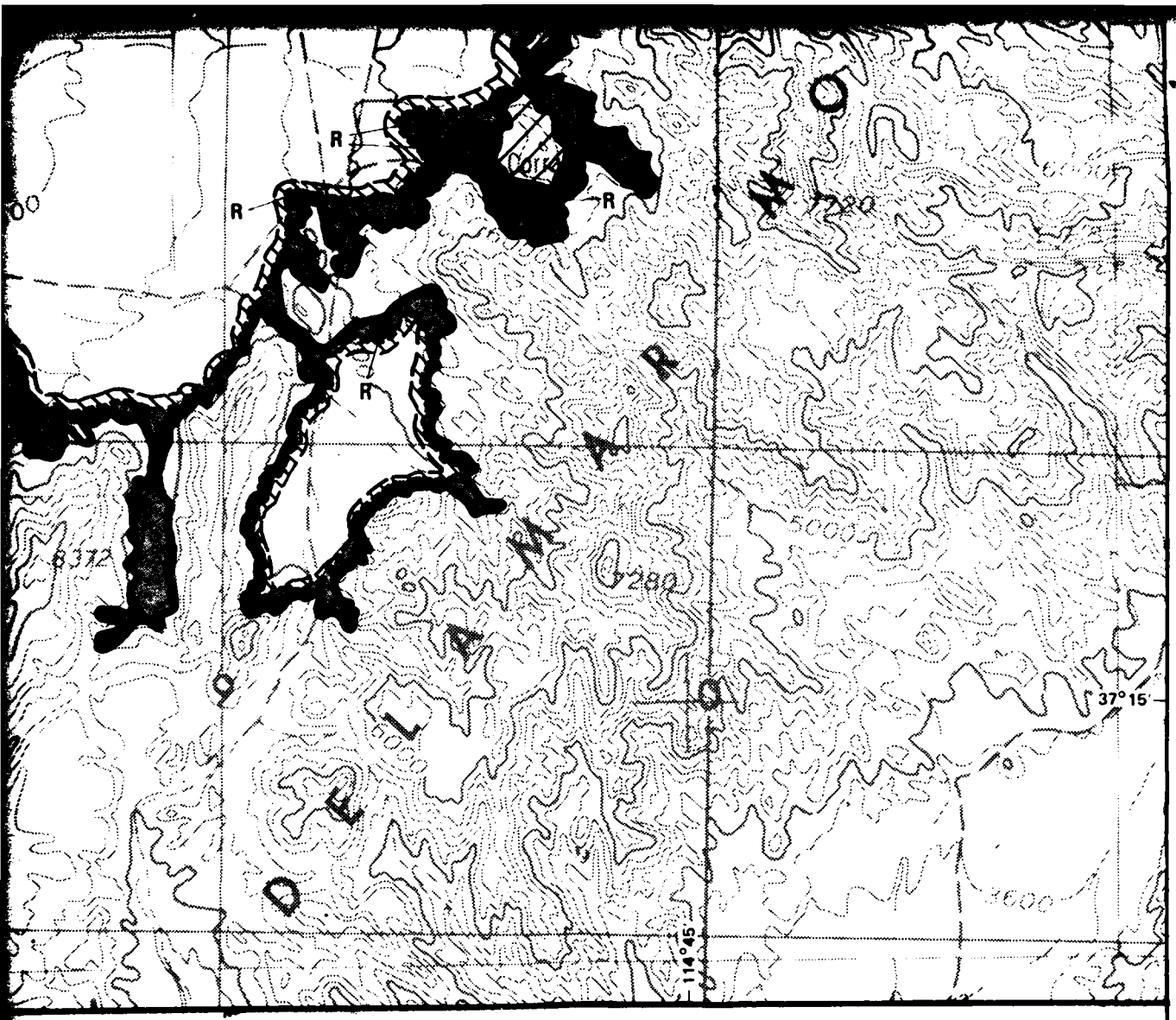

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ATION

d shelter basing modes. Depth to rock

t, not suitable for vertical shelter. Depth to rock
n 150 feet (46m).

d vertical shelter basing modes as determined from application
o/terrain, and cultural exclusions.

d vertical shelter too small for shading.

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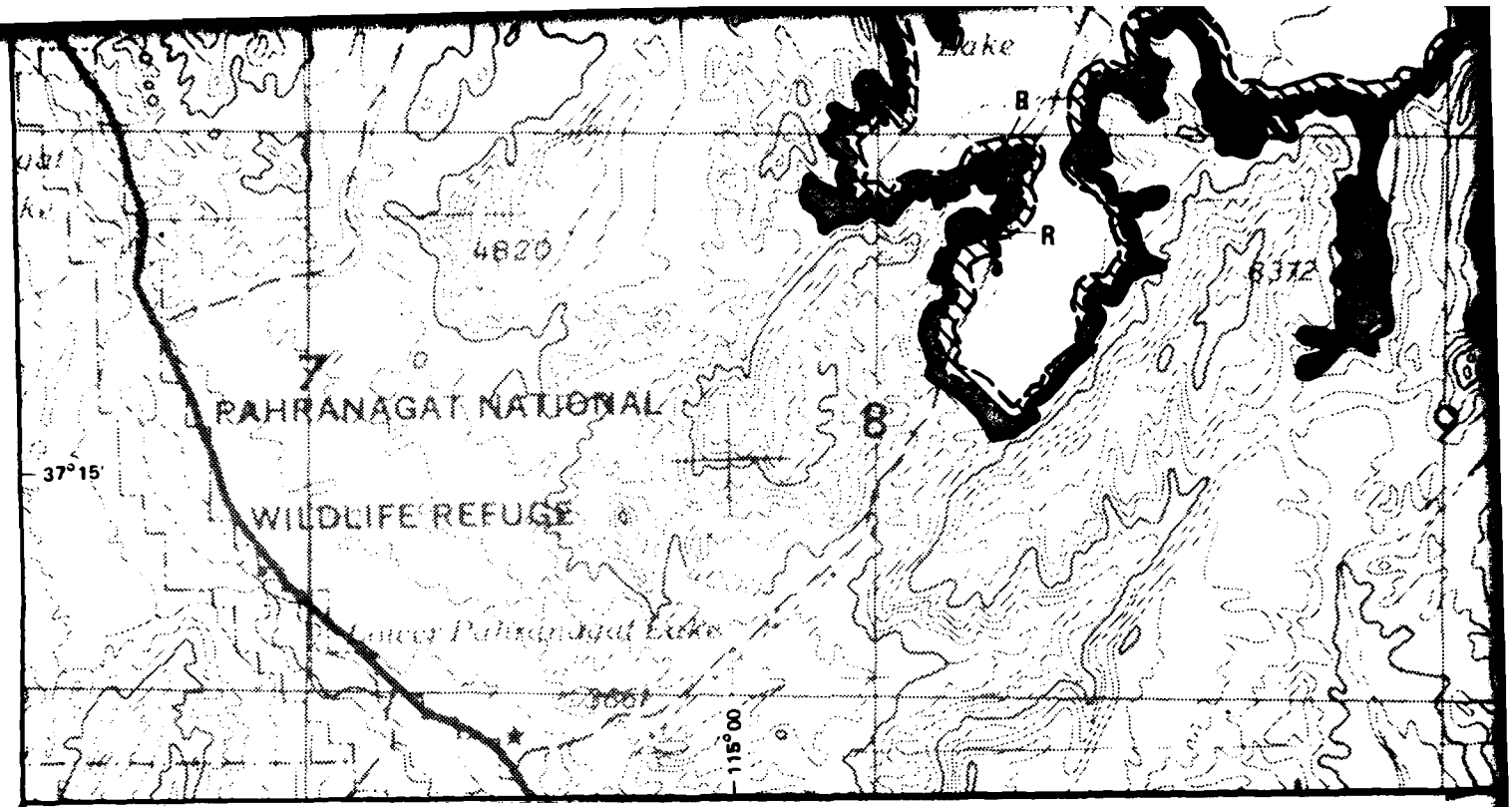
l for shading.



EXPLANATION

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

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

Area unsuitable for both horizontal and vertical shelter basing mod
of depth to rock and water, topographic/terrain, and cultural exc

UnS Area unsuitable for both horizontal and vertical shelter too small fo

Areas of isolated exposed rock.

R Areas of isolated exposed rock too small for shading.

Contact between rock and basin-fill.

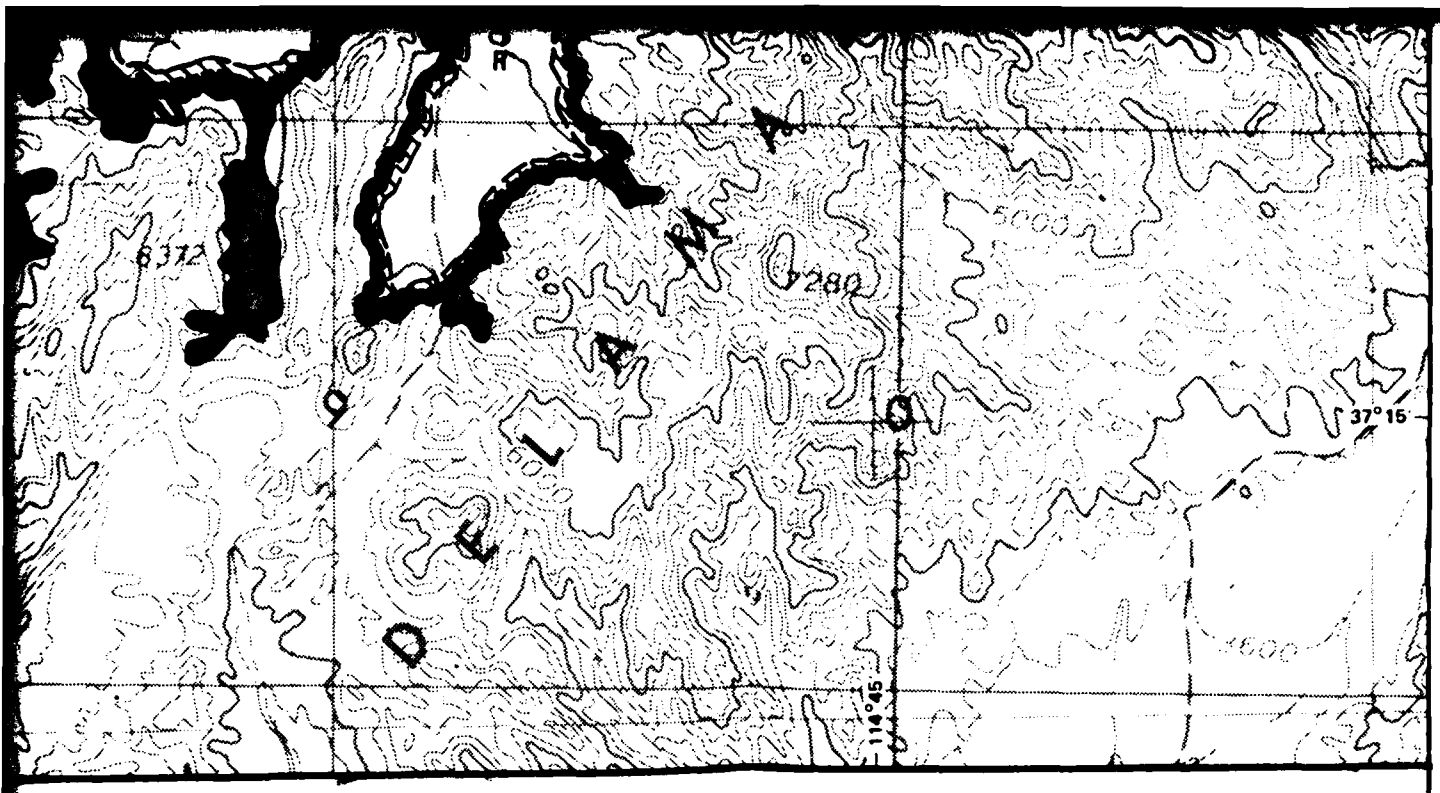
Valley borders (north and west).

SUITABLE AREA
HORIZONTAL AND VERTICAL AREA
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

DRAWING 2-1

FUGRO NATIONAL, INC.



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d vertical shelter basing modes. Depth to rock
t (46m).

helter but, not suitable for vertical shelter. Depth to rock
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ontal and vertical shelter basing modes as determined from application
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ontal and vertical shelter too small for shading.

too small for shading.

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SCALE 1: 125,000

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STATUTE MILES

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3.0 GEOTECHNICAL SUMMARY

3.1 GEOGRAPHIC SETTING

Delamar Valley is located in Lincoln County, Nevada (Figure 3-1). The valley is bounded on the east and south by the Delamar Mountains and on the west by the South Pahroc Range. U.S. Highway 93 forms the northern boundary with Dry Lake Valley. A network of gravel roads and jeep trails provide good access throughout the valley. The valley is primarily undeveloped desert rangeland. The nearest town is Caliente, Nevada, approximately 15 miles (24 km) east on U.S. Highway 93.

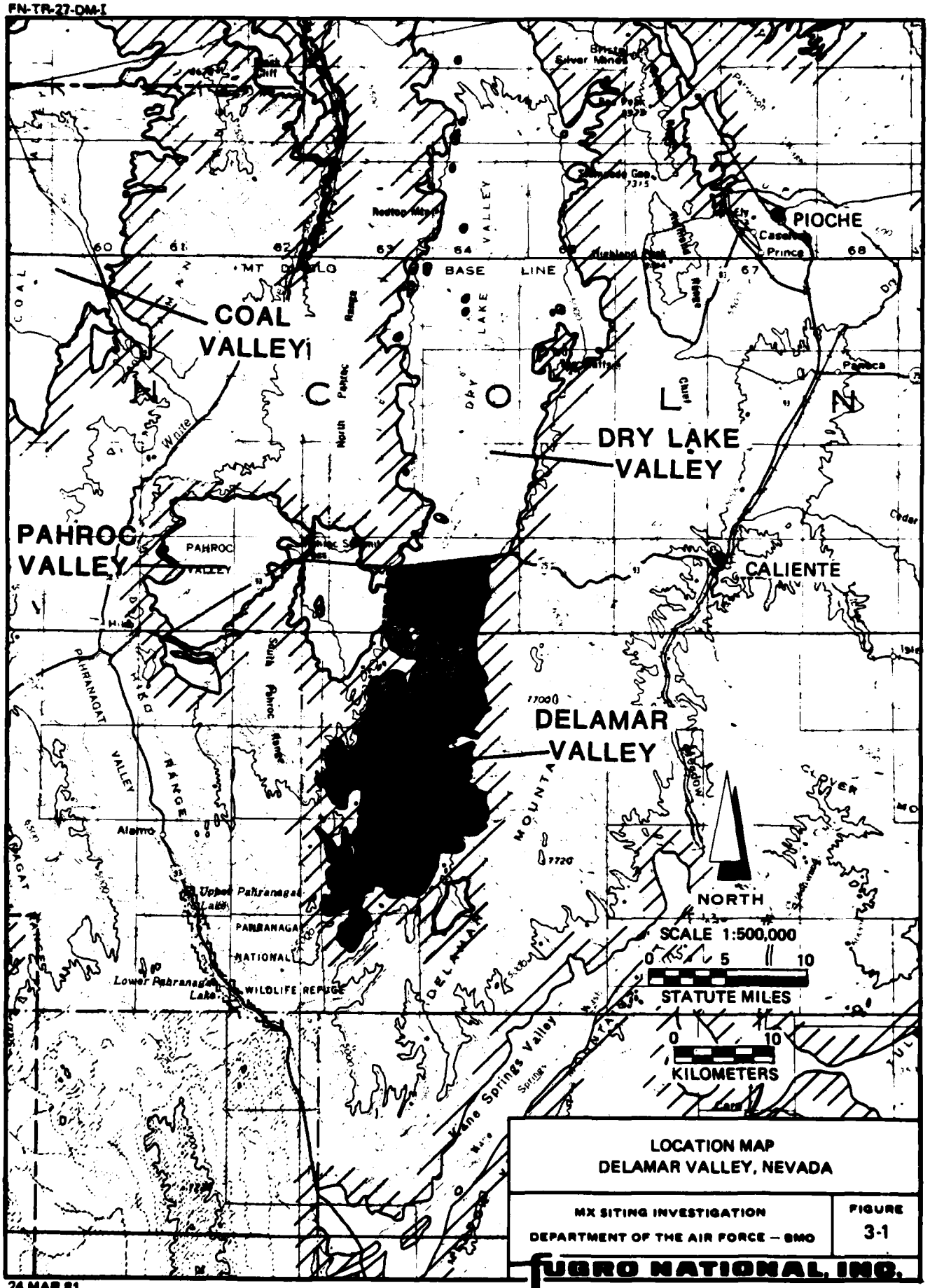
3.2 GEOLOGIC SETTING

3.2.1 Rock Types

Delamar Valley is an elongate north-south trending alluvial basin flanked on the east and west by sedimentary and volcanic rocks. The South Pahroc Range consists predominantly of Tertiary ignimbrite. Cambrian limestone and quartzite and Tertiary volcanic rocks primarily occur in the Delamar Mountains (Howard, 1978; and Tschanz and Pampeyan, 1970).

3.2.2 Structure

The geologic structure of Delamar Valley is typical of the Great Basin tectonic province in that it is a result of late Tertiary-Quaternary block faulting due to tensional stresses directed in an east-west or northwest-southeast direction. In general, the fault blocks in the Great Basin are tilted horst-and-graben structures with the valleys occupying the down-tilted or down-dropped blocks and the mountains representing the upturned



LOCATION MAP
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

FIGURE 3-1

FUGRO NATIONAL, INC.

24 MAR 81

or uplifted blocks. The major faults bounding these blocks generally trend north-south and are usually near the margins of the valleys. In a few cases, faults with other orientations and/or central valley locations occur.

Delamar Valley is a graben bounded on the east and west by major high angle, north-trending, Basin and Range normal faults (Drawing 3-2). These faults displace Quaternary alluvium in places, but elsewhere are largely inferred from the linear expression of the mountain fronts and apparent vertical stratigraphic separations. Where inferred, the basin-bounding faults do not displace surficial geologic units and are considered not to have moved within late Quaternary time.

On the east side of Delamar Valley, a late Quaternary fault scarp is present near the base of the Delamar Mountains. This short scarp occupies the same structural position as the Dry Lake fault which enters Delamar Valley from the northeast. The southerly extent of the Dry Lake fault is unknown; it may die out in northeast Delamar Valley near the end of a fault scarp in Dry Lake Valley or it may continue southward as a basin-bounding fault system in the subsurface. In the latter case, the scarp located midway along the base of the Delamar Mountains may represent localized late Quaternary fault movement along the southern portion of this subsurface system. Ground-water relationships in the region (FNI 1980b) indicate that Delamar and Dry Lake valleys are separate ground-water basins. Gravity data (FNI 1980a) suggest abruptly shallowing subsurface bedrock below

southern Dry Lake Valley. These data, together with geomorphic relationships, indicate the two valleys are separate grabens.

The master basin-bounding fault along the west side of Delamar Valley is interpreted to be the Pahroc fault. The Pahroc fault trends northward from the eastern margin of the South Pahroc Range for some 46 miles (74 km) into southern White River Valley (Tschanz and Pampeyan, 1970). Because the structural boundary of Delamar valley does not coincide with the geographic boundary for the Delamar Valley siting region, the Pahroc fault actually is within the Pahroc Valley siting region. There is no evidence for Quaternary movement on this fault in the combined Delamar-Pahroc Valley siting regions, but to the north in southeastern White River Valley, the fault displaces old Quaternary alluvium indicating this segment of the fault is probably of early Quaternary age.

East of the Pahroc fault, numerous small faults and joints of late Tertiary or younger age trend in both north-south and east-west directions. The overall structure is one of numerous small fault blocks of varying differential displacements but which have a net down-to-the-east displacement. Many of these fault blocks appear to be covered by alluvium which has been trapped within the small grabens between blocks. These faults, combined with the Pahroc fault, comprise a highly fragmented and diffused western boundary of Delamar Valley.

Bounding the south end of Delamar Valley are faults of the northeast-trending Pahranagat shear zone. The Pahranagat shear

zone consists of three major faults and several lesser breaks which together have been postulated to have about 10 to 12 miles of post Miocene left-lateral separation (Tschanz and Pampeyan, 1970; and Tschanz and others, 1979). Two of these major faults, the Buckhorn and Maynard Lake faults, trend into southern Delamar Valley. The lack of surficial displacement in Quaternary alluvium of Pleistocene lake beds suggests they were last active in latest Miocene or Pliocene time.

There are several tectonic lineaments at the center and along the east side of Delamar Valley (Drawing 3-2). The lineaments adjacent to the east side of Delamar Lake may be related to the Buckhorn fault. Those located north of the lake may be related to faults in the adjacent bedrock which form part of the structurally fragmented west side of Delamar Valley. The two en echelon lineaments located west of the site of Delamar are probably faults or cracks related to displacements on the adjacent Quaternary fault scarp.

3.2.3 Surficial Geologic Units

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

Alluvial fans of younger and intermediate relative age are the predominant surficial geologic units within Delamar Valley (Drawing 3-2). They range from sandy gravels near the eastern mountain front to sandy silts near the center of the valley. A

playa deposit is located in the southwestern portion of the valley and is fed by a fluvial system located along the central axis of the valley.

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

- Older Alluvial Fan Deposits (A5o) - This Pleistocene unit is the least extensive alluvial unit within the valley. The predominant location of this unit is adjacent to the eastern mountain flank at the outwash area of Cedar Wash where it occurs as a sandy gravel with silt. The only other location of this older alluvial unit is immediately to the north adjacent to the eastern mountain flank where it is expressed as very small gravel and sand deposits. Cementation is weak to strong with a caliche development that varies from Stage II to III. The areal extent of the unit is less than one percent of the valley.

- Intermediate Alluvial Fan Deposits (A5i) - This Pleistocene unit is the most widespread alluvial unit within the valley. It occurs along the flanks of the bordering mountain ranges and extends into the center of the valley. Those portions that exist high on the flanks of the ranges are typically underlain by shallow rock. Approximately two percent of the intermediate alluvial deposits occur as silty or sandy gravels and gravelly sands which have been deposited along the west flank of the Delamar Range. The remainder of the unit occurs as weak to moderately cemented silty or gravelly sands with caliche development that mainly varies from Stage I to III. These deposits cover approximately 42 to 48 percent of the valley.

- Younger Alluvial Fan Deposits (A5y) - Young alluvium is a widespread unit in the valley. The unit primarily occurs along the valley bottom adjacent to intermediate-age alluvial fans (A5i) and the axial drainage system. Portions of the unit do occur high on the eastern flank of the South Pahroc Range and, in some cases, are underlain by shallow rock. Composition of the deposits varies from silty sands to gravelly sands. Cementation is absent to moderate, and caliche development varies from not present to Stage I. Areal extent of the A5y deposits is approximately 35 to 40 percent of the valley.

- Fluvial and Associated Floodplain Deposits (A1) - Holocene fluvial deposits occur primarily along the central axis of the valley. Drainage is from north to south in what appears

to be a closed-drainage system that ultimately ends at Delamar Lake playa. Composition varies from silts to gravelly sands. Cementation is absent to weak, and caliche development varies from absent to Stage I.

Minor fluvial systems do occur within the mountain ranges in canyons that debouch into the valley. Deposits in the stream system that dissects the older alluvial deposit at Cedar Wash are sandy gravel. The combined fluvial deposits cover about 10 to 12 percent of the valley.

- Eolian Deposits (A3d) - These Holocene deposits consist of wind-blown sands deposited in dunes. They occupy less than one percent of the total area and occur exclusively in the northeast portion of the valley. They are composed of clean fine sand with neither cementation nor caliche development.

- Lacustrine Deposits (A4f) - This unit consists of a Holocene playa which occurs in the southwestern portion of Delamar Valley. The playa is referred to as Delamar Lake. The deposit consists of clays and silts with no cementation nor caliche development. The deposit covers 4 mi^2 (10.3 km^2), about two percent of the valley.

3.3 SURFACE SOILS

Surficial soils of Delamar 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 southern portion of the valley. Soils from the predominant surficial geologic units (those estimated to cover at least five percent of the suitable area) can be combined into the following three categories based on their physical and engineering characteristics:

1. Sandy gravels and gravelly sands (geologic units A5ys, and A5is;

2. Silty sands and clayey sands (geologic units A1s, A5ys, A5ys/A5is, and A5is); and

3. Silts and clays (geologic units A1s, A1f, and A5ys).

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.

Silty sands and clayey sands are the predominant surficial soils, covering approximately 50 to 70 percent of the area. They are widely distributed, being the major component in all areas except alluvial fans very near mountain fronts, alluvial fan deposits associated with small stream channels, and the active playa deposits in the southwestern part of the valley. The sands are coarse to fine and are poorly graded. They contain some amounts of fines and their plasticity ranges from nonplastic to slightly plastic. The fines content is highest near the playa and decreases toward the basin margin. Gravel content increases toward the mountain fronts.

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 the young alluvial fans associated with small tributary stream channels. The sands generally extend to the mountain fronts.

SOIL DESCRIPTION		Sandy Gravels and Gravelly Sands		Silty Sands an
USCS SYMBOLS		GW-GM, SW, SP, SM		SM, SC
PREDOMINANT SURFICIAL GEOLOGIC UNITS		A5ys, A5is		A1s, A5ys, A5
ESTIMATED AREAL EXTENT	%	20 - 40		50 -70
PHYSICAL PROPERTIES				
COBBLES 3 – 12 inches (8 – 30 cm)	%	0 - 4		0 - 4
GRAVEL	%	13 - 44	[7]	2 - 20
SAND	%	44 - 77	[7]	48 - 77
SILT AND CLAY	%	6 - 22	[7]	19 - 42
LIQUID LIMIT		NDA		20 - 23
PLASTICITY INDEX		NDA		NP - 8
ROAD DESIGN DATA				
MAXIMUM DRY DENSITY	pcf (kg/m³)	121.0 - 130.0 (1938 - 2083)	[3]	118.6 - 120.5 (1900 - 1930)
OPTIMUM MOISTURE CONTENT	%	8.1 - 10.5	[3]	10.5 - 12.5
CBR AT 90% RELATIVE COMPACTION	%	6 - 19	[3]	5 - 20
SUITABILITY AS ROAD SUBGRADE (1)		fair to good		fair to good
SUITABILITY AS ROAD SUBBASE OR BASE (1)		good to very good		poor to fair
THICKNESS OF LOW-STRENGTH SURFICIAL SOIL (2) — RANGE	ft (m)	0.7 - 5.6 (0.2 - 1.7)	[11]	0.3 - 6.2 (0.1 - 1.9)
THICKNESS OF LOW-STRENGTH SURFICIAL SOIL (2) — AVERAGE	ft (m)	2.0 (0.6)	[11]	2.6 (0.8)

(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

Silty Sands and Clayey Sands		Silts and Silty Clays		
SM, SC		ML, CL		
A1s, A5ys, A5ys/A5is, A5is		A1s, A1f, A5ys		
50 -70		5 - 15		
0 - 4		0		
2 - 20	[12]	0 - 2	[6]	
48 - 77	[12]	1 - 47	[6]	
19 - 42	[12]	51 - 99	[6]	
20 - 23	[2]	21 - 35	[6]	
NP - 8	[6]	NP - 10	[6]	
118.6 - 120.5 (1900 - 1930)	[2]	101.5 (1626)	[1]	
10.5 - 12.5	[2]	22.5	[1]	
5 - 20	[2]	3	[1]	
fair to good		poor		
poor to fair		not suitable		
0.3 - 6.2 (0.1 - 1.9)	[20]	0.5 - 9.2 (0.2 - 2.8)	[6]	
2.6 (0.8)	[20]	3.2 (1.0)	[6]	

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

CHARACTERISTICS OF SURFICIAL SOILS
DELAMAR VALLEY, NEVADA

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TABLE 3-1

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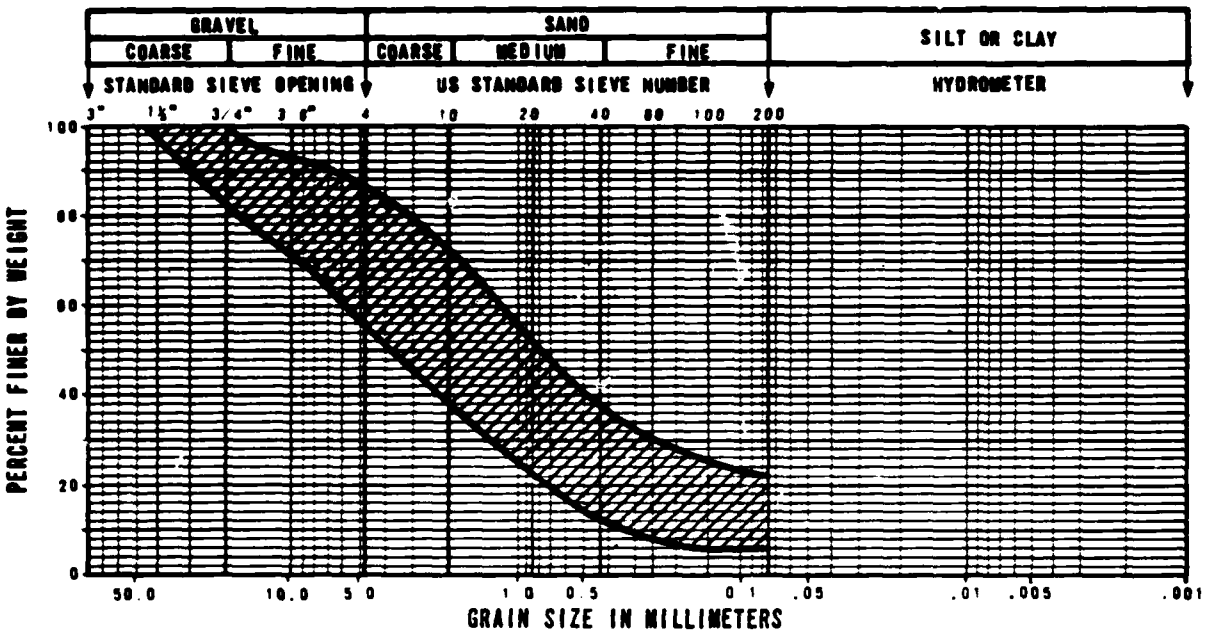
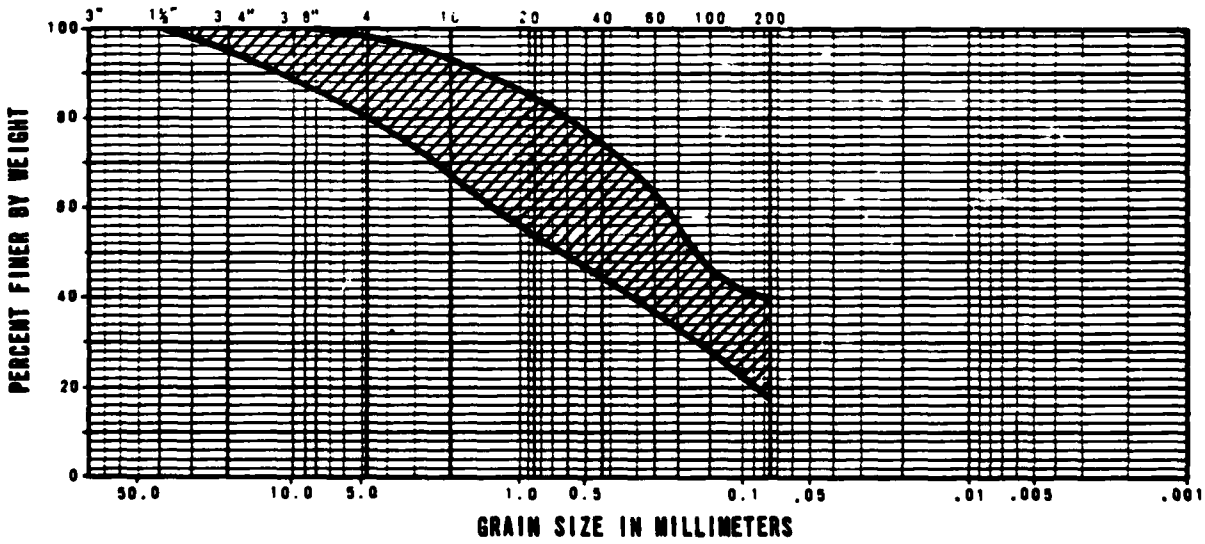
AFV-18



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



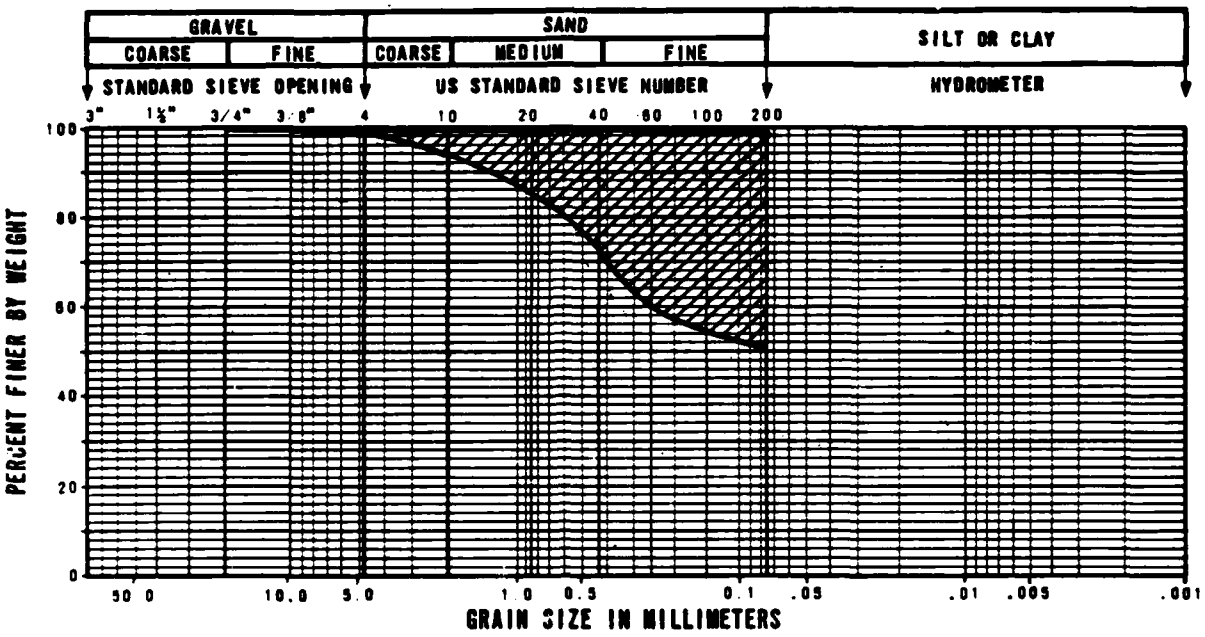
SOIL DESCRIPTION: Silty Sands and Clayey Sands from 0 to 2 feet (0 to 0.6m)

RANGE OF GRADATION OF SURFICIAL SOILS
DELAMAR VALLEY, NEVADA

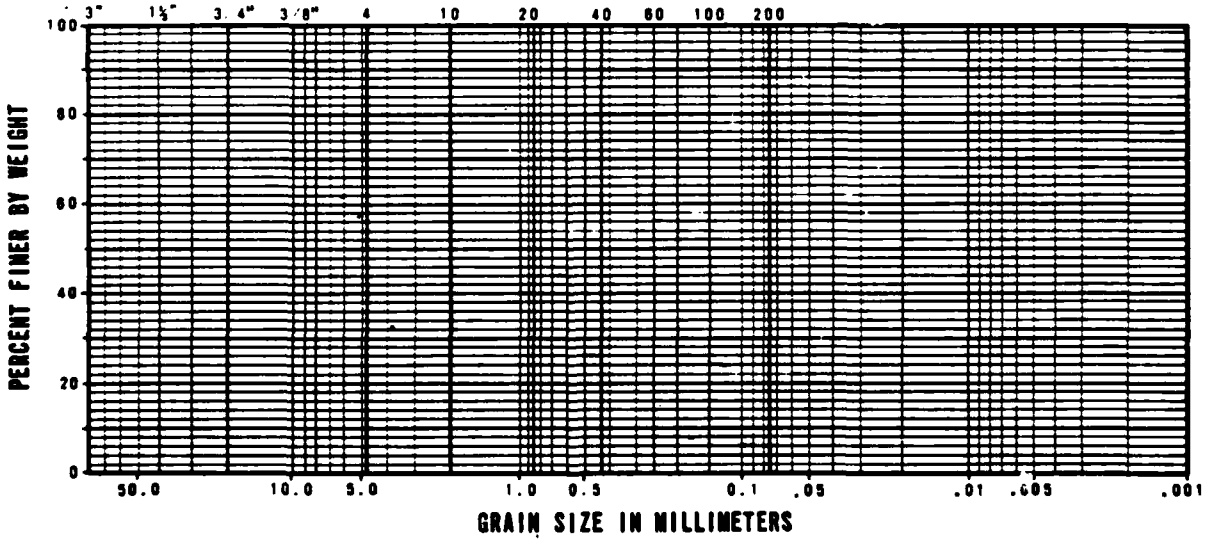
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 3-2 1 OF 2

USRD NATIONAL, INC.



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



RANGE OF GRADATION OF SURFICIAL SOILS
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - [redacted]

FIGURE
3-2
2 OF 2

FUGRO NATIONAL, INC.

Gravel content increases toward the mountain fronts with soils locally grading into gravels. Gravelly sands and sandy gravels have a wide range of particle sizes, are occasionally well graded along the eastern mountain fronts, and contain traces to some amounts of fines. Cobbles to 12 inches (30 cm) in diameter are occasionally encountered at or near the ground surface in these gravelly deposits.

Silts and clays cover approximately five to 15 percent of the valley. They consist of silts, clayey silts, and silty clays. They occur predominantly as active playa deposits in the southwestern portion of the valley. These soils contain traces to some amounts of sand. Their plasticity ranges from nonplastic to slightly plastic.

3.3.2 Low-Strength Surficial Soil

Based on the Cone Penetrometer Test (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 categories are included in Table 3-1. Sandy gravels and gravelly sands exhibit low strength to depths ranging from 0.7 to 5.6 feet (0.2 to 1.7 m), with an average of 2.0 feet (0.6 m). Silty and clayey sands exhibit low strengths to depths ranging from 0.3 to 6.2 feet (0.1 to 1.9 m), with an average of 2.6 feet (0.8 m). The variation in the extent of low-strength granular soils is due to fluctuations in

CONE PENETROMETER TEST NUMBER(1)	THICKNESS OF LOW-STRENGTH SURFICIAL SOIL,(2) FEET	METERS	SOIL TYPE (3)
C-1	1.3	0.4	SM
C-2	1.3	0.4	SM
C-3	1.0	0.3	SM
C-4	3.1	0.9	SM
C-5	1.1	0.3	SM
C-6	0.7	0.2	SW-SM
C-7	0.9	0.3	SP-SM
C-8	0.3	0.1	SM
C-9	1.6	0.5	SM
C-10	1.3	0.4	SM
C-11	2.0	0.6	SM
C-12	0.9	0.3	SW-SM
C-13	1.2	0.4	SM
C-14	0.9	0.3	GP-GM
C-15	1.0	0.3	GW-GM
C-16	0.9	0.3	SP-SM
C-17	0.4	0.1	SM
C-18	5.9	1.8	SM
C-19	5.8	1.8	SM
C-20	3.0	0.9	SM
C-21	0.8	0.2	SM
C-22	4.1	1.2	SM
C-23	6.1	1.9	SM
C-24	5.2	1.6	CL-ML
C-25	4.8	1.5	SC/SM
C-26	1.1	0.3	SM
C-27	4.9	1.5	SM
C-28	6.2	1.9	SM

CONE PENETROMETER TEST NUMBER(1)	THICKNESS OF LOW-STR SURFICIAL SOIL, FEET	METE
C-29	1.0	0.
C-30	2.3	0.
C-31	5.6	1.
C-32	4.0	1.
C-33	0.5	0.
C-34	9.2	2.
C-35	0.9	0.
C-36	1.2	0.
C-37	0.7	0.

(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 Penetrompter 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 fi strem of the

• SM/GM

• NDA –

NESS OF LOW-STRENGTH SURFICIAL SOIL,(2) FEET	METERS	SOIL TYPE (3)
1.0	0.3	ML
2.3	0.7	ML
5.6	1.7	SM
4.0	1.2	SM
0.5	0.2	ML
9.2	2.8	ML
0.9	0.3	CL-ML
1.2	0.4	SM
0.7	0.2	SM-SC

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

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

THICKNESS OF LOW-STRENGTH SURFICIAL SOIL
DELAMAR VALLEY, NEVADA

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TABLE 3-2

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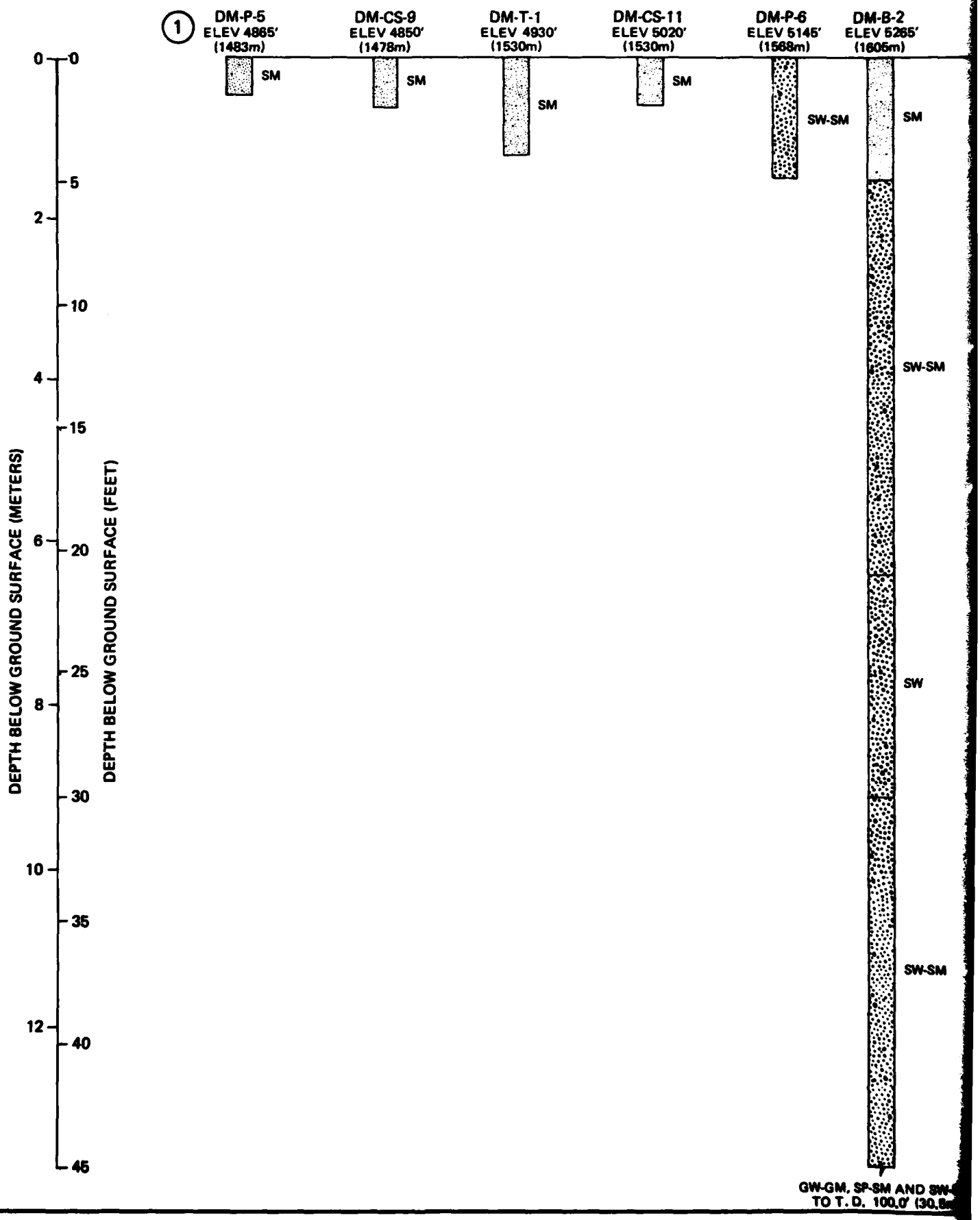
AFV-21

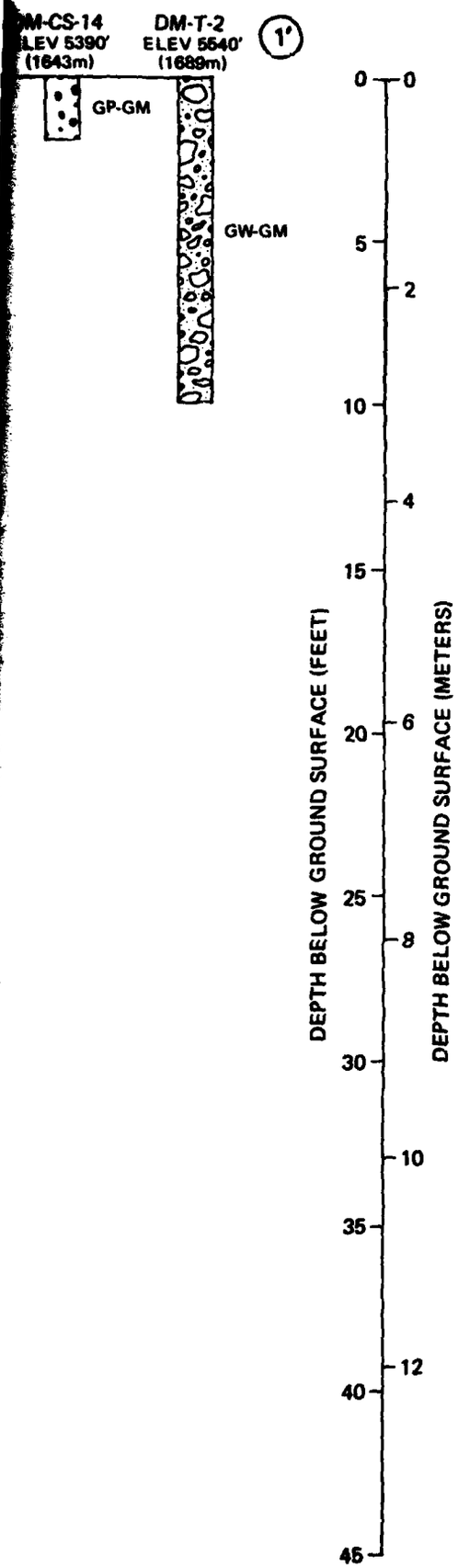
the in-situ density and calcium-carbonate cementation. Silts and clays exhibit low strength to depths ranging from 0.5 to 9.2 feet (0.2 to 2.8 m), with an average of 3.2 feet (1.0 m). The variation in the extent of low-strength, fine-grained soils is due to variations in the in-situ density, the amount of fine sand present, and calcium-carbonate cementation.

3.4 SUBSURFACE SOILS

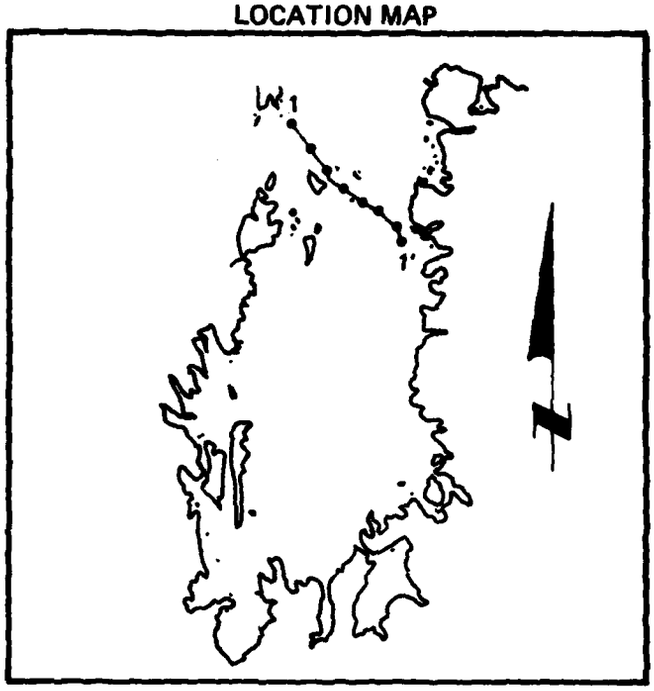
Subsurface soils are predominantly coarse-grained (granular) except in the southwestern portion of the valley where fine-grained soils predominate. The coarse-grained soils consist of sandy gravels, gravelly sands, sands, and silty sands. Subsurface soils within the southwestern portion of the valley are predominantly fine-grained and are associated with playa deposits. These fine-grained soils consist of silts, sandy clays, silty clays, and clays with plasticity ranging from slightly plastic to medium plastic. At the playa, these fine-grained soils interfinger with the coarse-grained soils. Fine-grained soils are estimated to compose 10 to 20 percent of the subsurface deposits within the suitable area boundaries. The composition of subsurface soils with depth, as determined from borings, trenches, and test pits, 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


1
DM-P-5
ELEV 4865'
(1483m)
DM-CS-9
ELEV 4850'
(1478m)
DM-T-1
ELEV 4930'
(1530m)
DM-CS-11
ELEV 5020'
(1530m)
DM-P-6
ELEV 5145'
(1568m)
DM-B-2
ELEV 5265'
(1605m)
SM
SM
SM
SM
SW-SM
SM
SW-SM
SW
SW-SM
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
45
GW-GM, SP-SM AND SW-
TO T. D. 100.0' (30.8



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 1–1'
DELAMAR VALLEY, NEVADA

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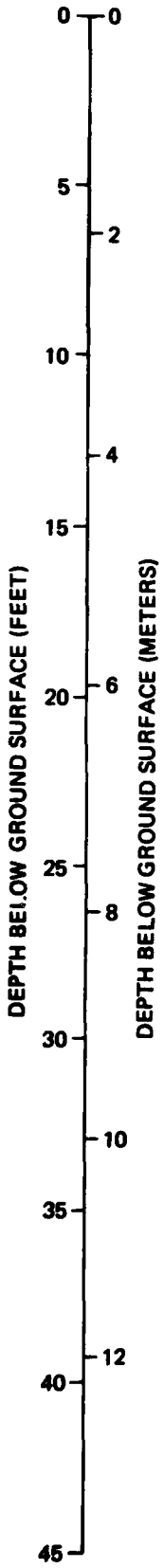
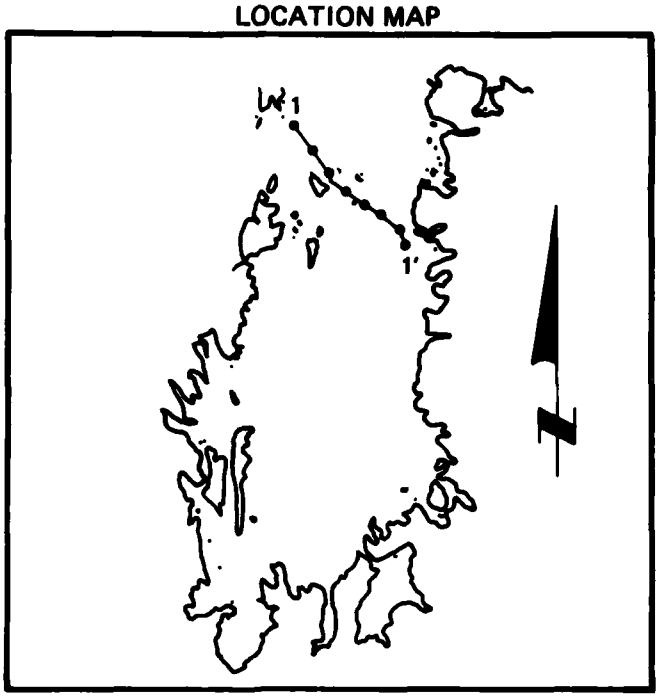
2



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 1–1'
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

FIGURE 3-3

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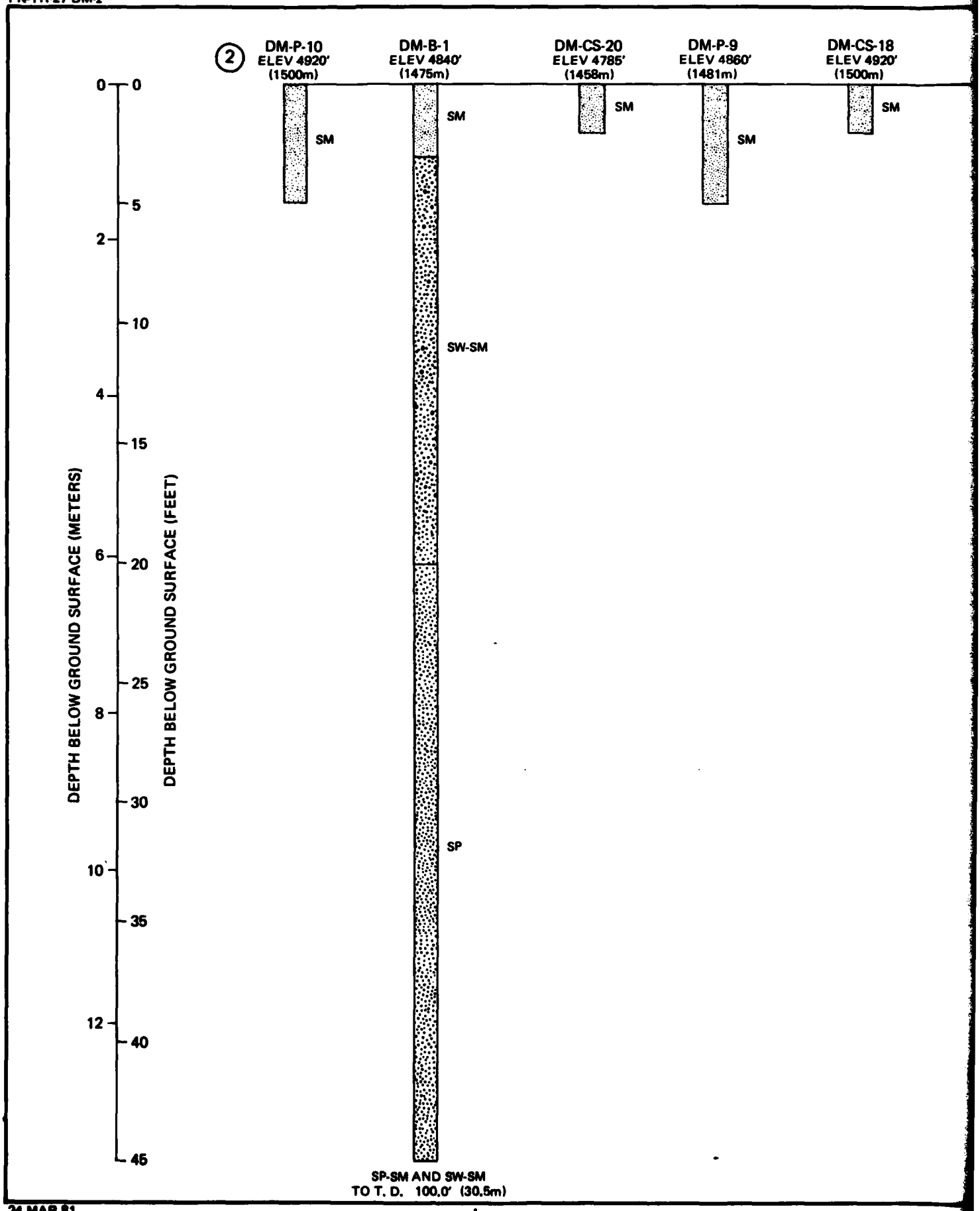
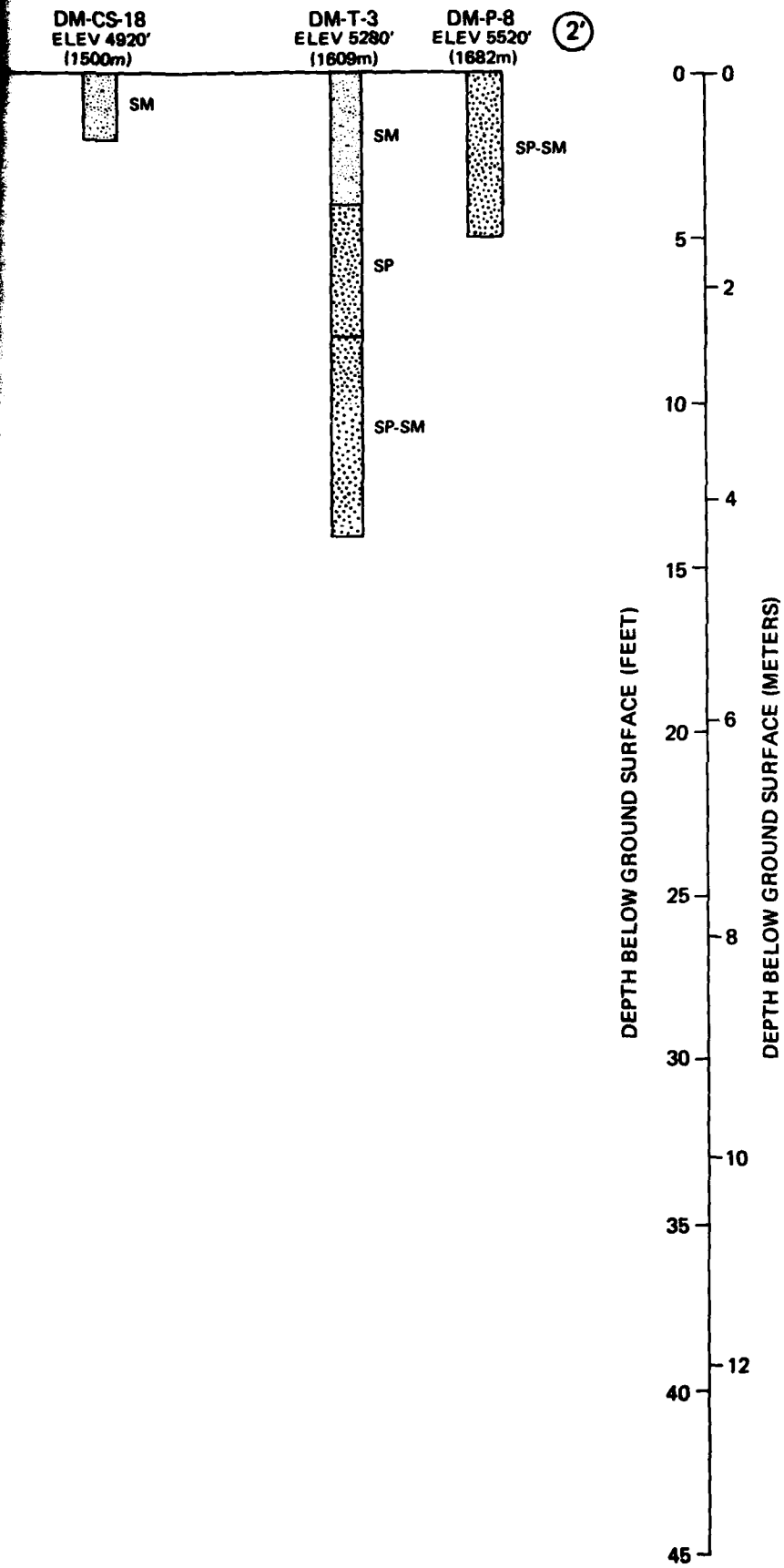
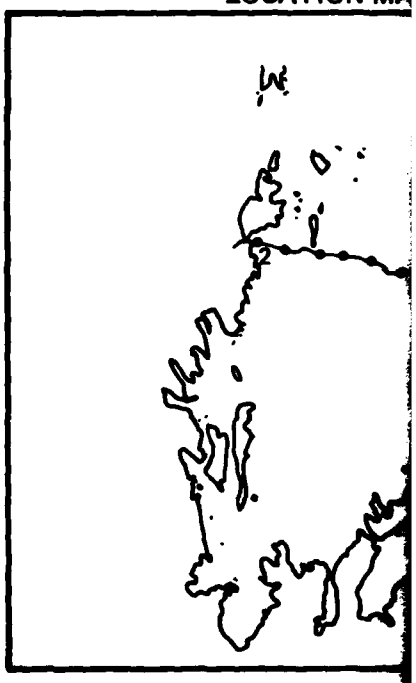

2
DM-P-10
ELEV 4920'
(1500m)
DM-B-1
ELEV 4840'
(1475m)
DM-CS-20
ELEV 4785'
(1458m)
DM-P-9
ELEV 4860'
(1481m)
DM-CS-18
ELEV 4920'
(1500m)
SM
SM
SW-SM
SP
SM
SM
SM
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
45
SP-SM AND SW-SM
TO T. D. 100.0' (30.5m)



LOCATION MA



EXPLANAT

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at Cone Penetrome

NOTES:

1. Ground-surface elevations shown at acti
2. T. D. = Total Depth.
3. Soil types shown adjacent to soil colum
   Classification System (USCS) and are a

HORIZO

STATUTE MILES 0

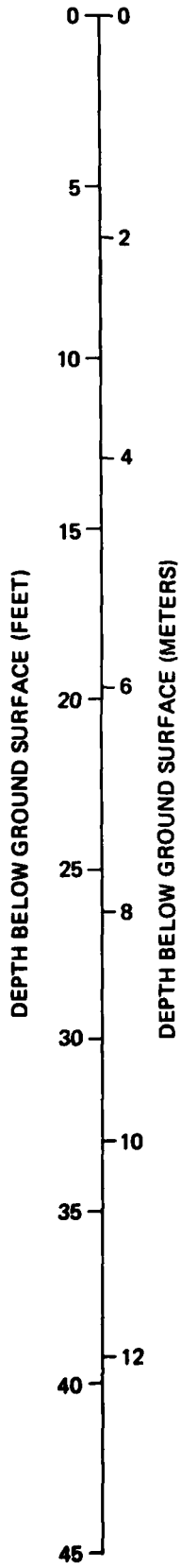
KILOMETERS 0 1

DEPART

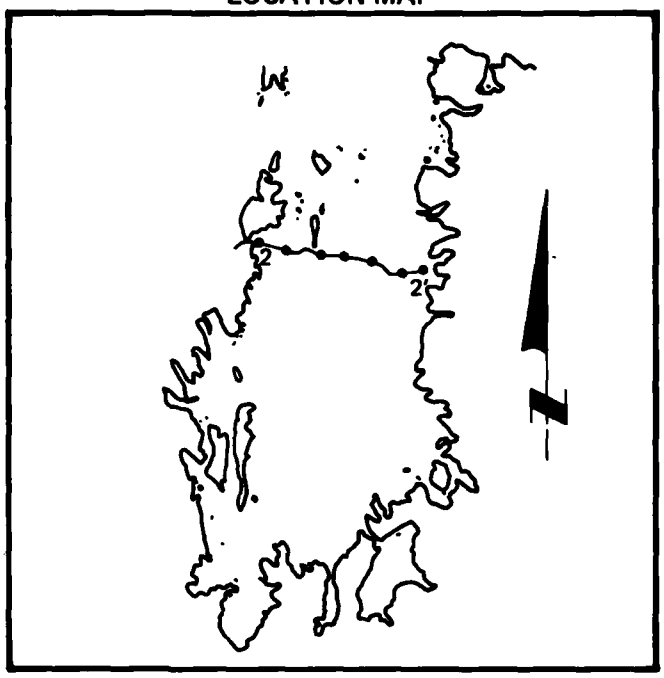
2

2'

SP-SM



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

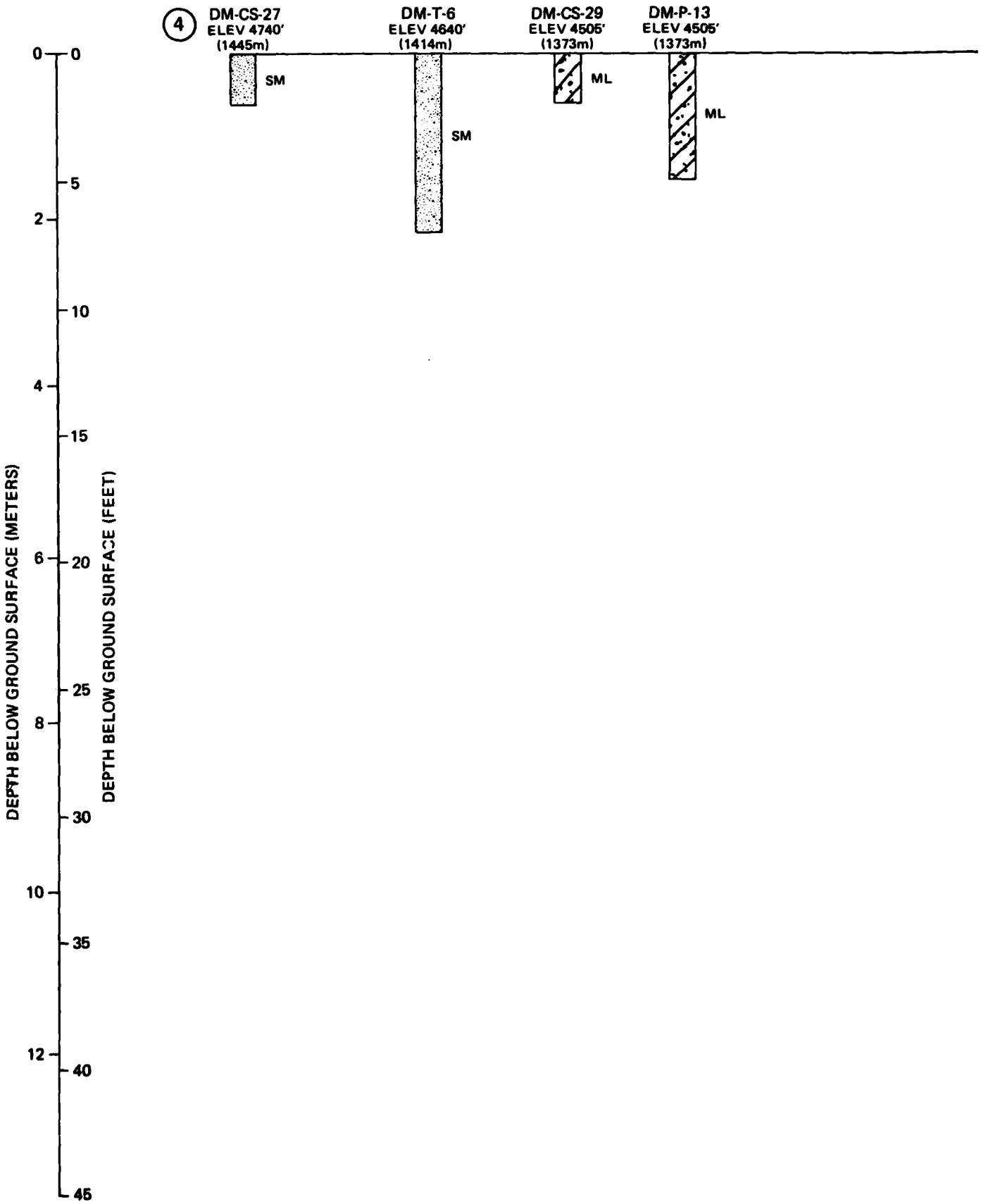
SOIL PROFILE 2–2'
DELAMAR VALLEY, NEVADA

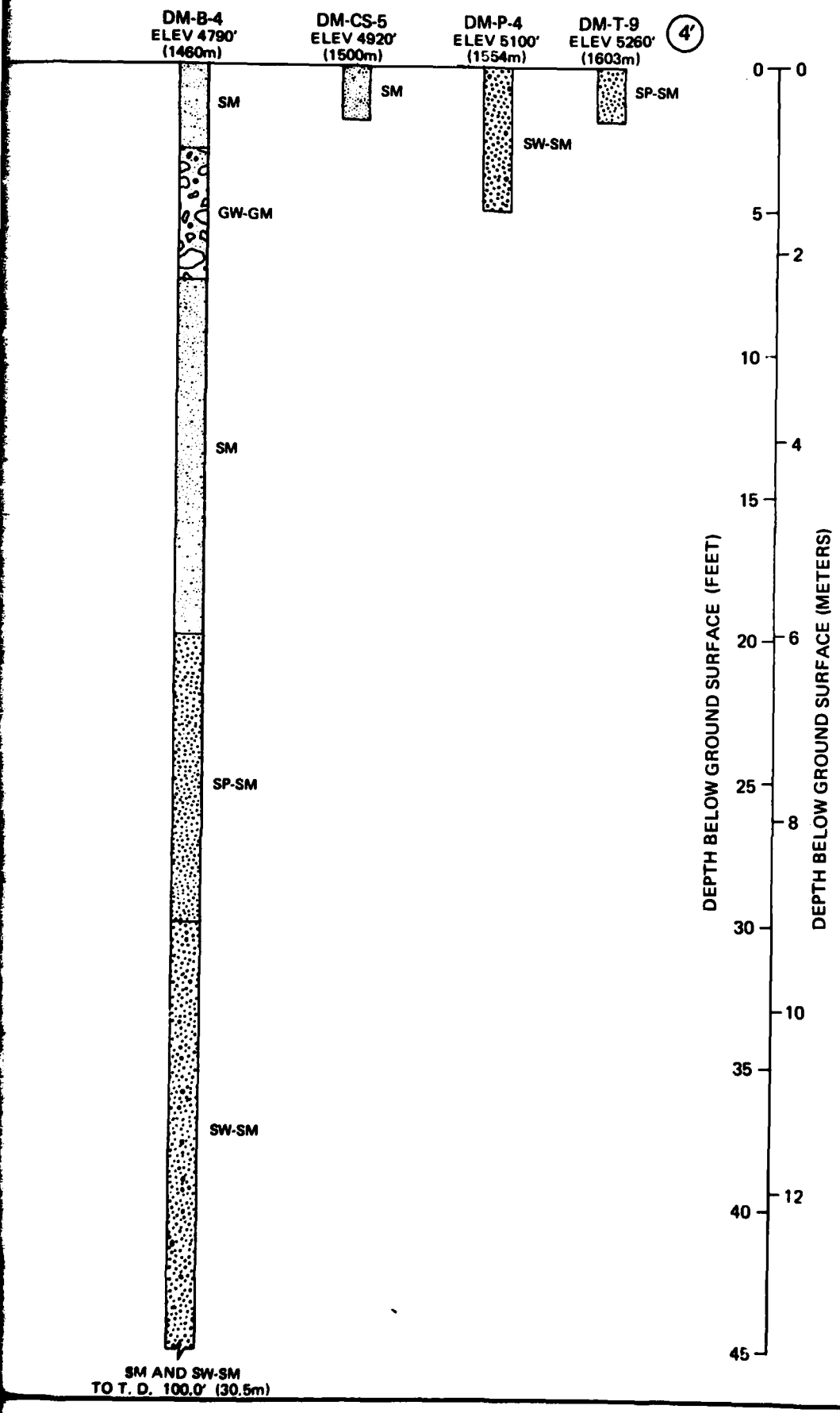
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

FIGURE 3-4

FUGRO NATIONAL, INC.

2 3


4
DM-CS-27
ELEV 4740'
(1445m)
DM-T-6
ELEV 4640'
(1414m)
DM-CS-29
ELEV 4505'
(1373m)
DM-P-13
ELEV 4505'
(1373m)
SM
SM
ML
ML
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
45



B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at

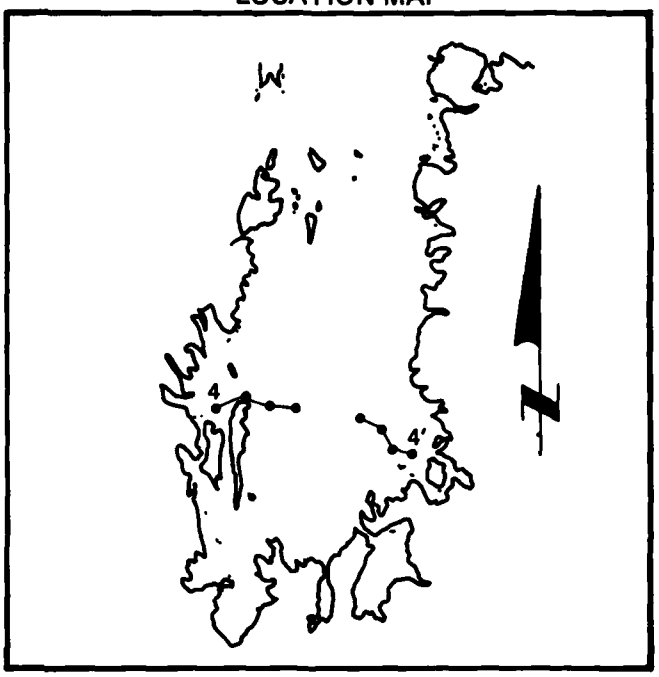
NOTES:
1. Ground-surface elevati
2. T. D. = Total Depth.
3. Soil types shown adjac
Classification System

STATUTE MILES 0
KILOMETERS 0

DEPA

2

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

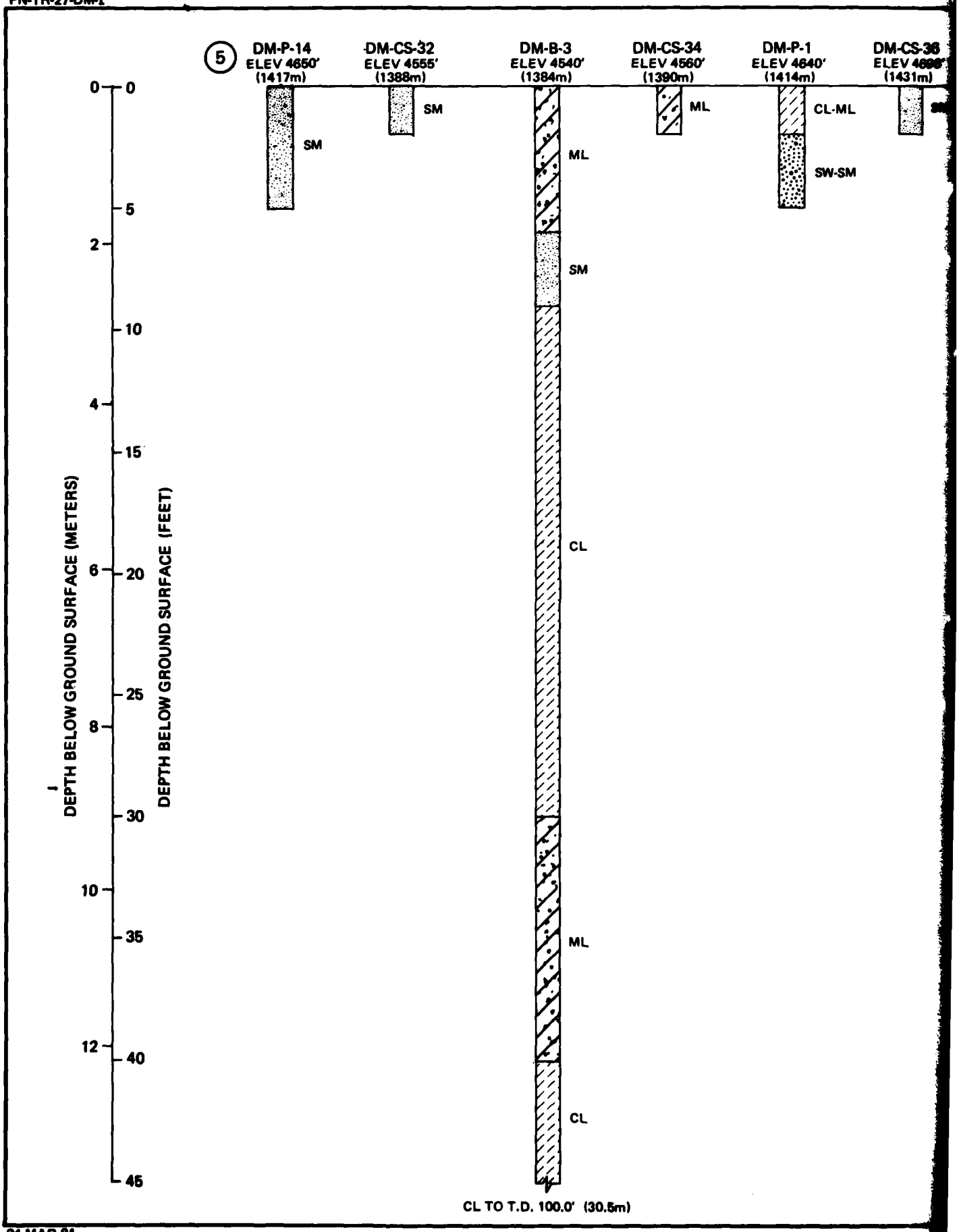
KILOMETERS 0 1 2 3

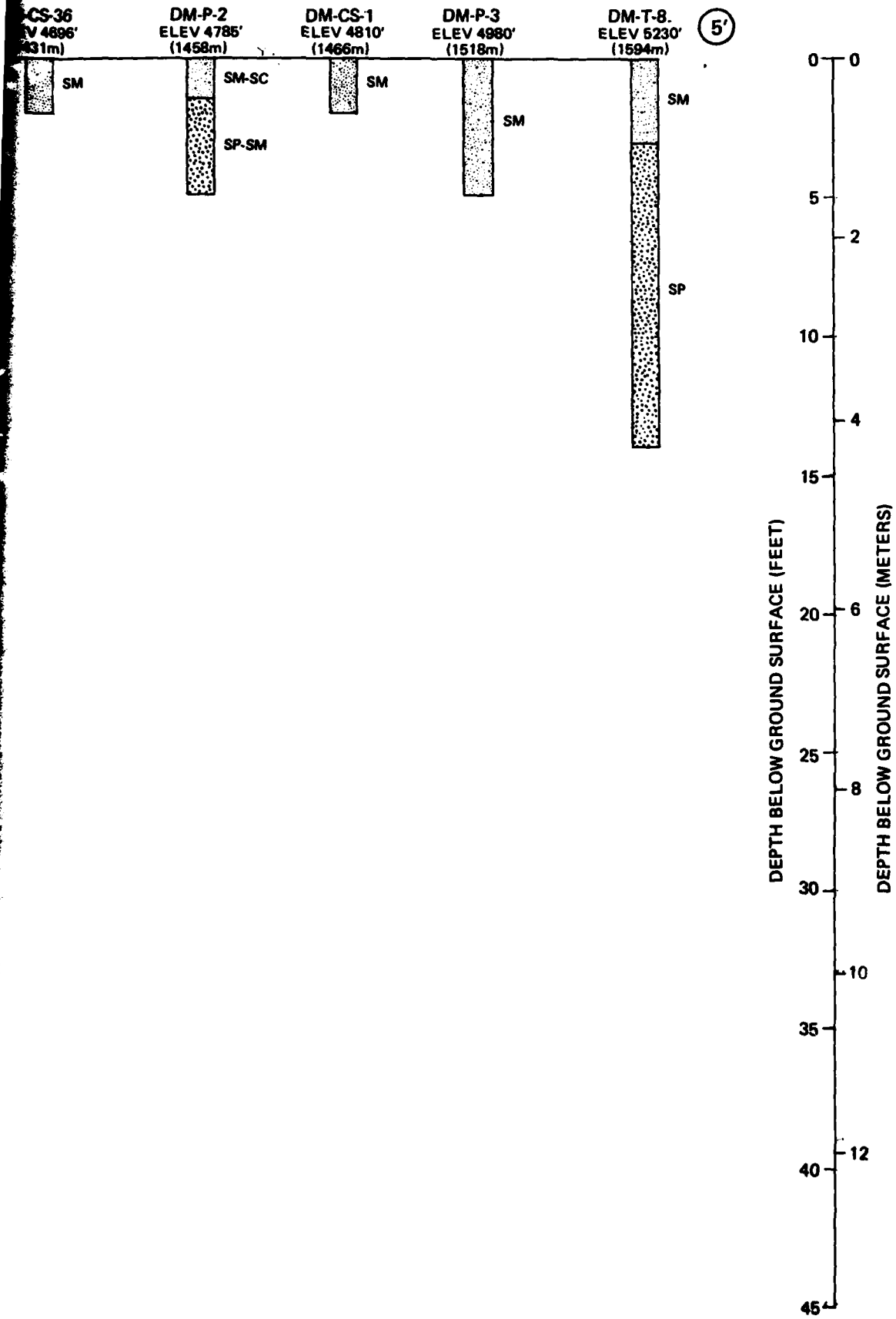
SOIL PROFILE 4–4'
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

FIGURE 3-5

FUGRO NATIONAL, INC.


5
DM-P-14
ELEV 4650'
(1417m)
DM-CS-32
ELEV 4555'
(1388m)
DM-B-3
ELEV 4540'
(1384m)
DM-CS-34
ELEV 4560'
(1390m)
DM-P-1
ELEV 4640'
(1414m)
DM-CS-36
ELEV 4696'
(1431m)
SM
SM
ML
SM
CL
ML
CL
ML
CL-ML
SW-SM
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
45
CL TO T.D. 100.0' (30.5m)

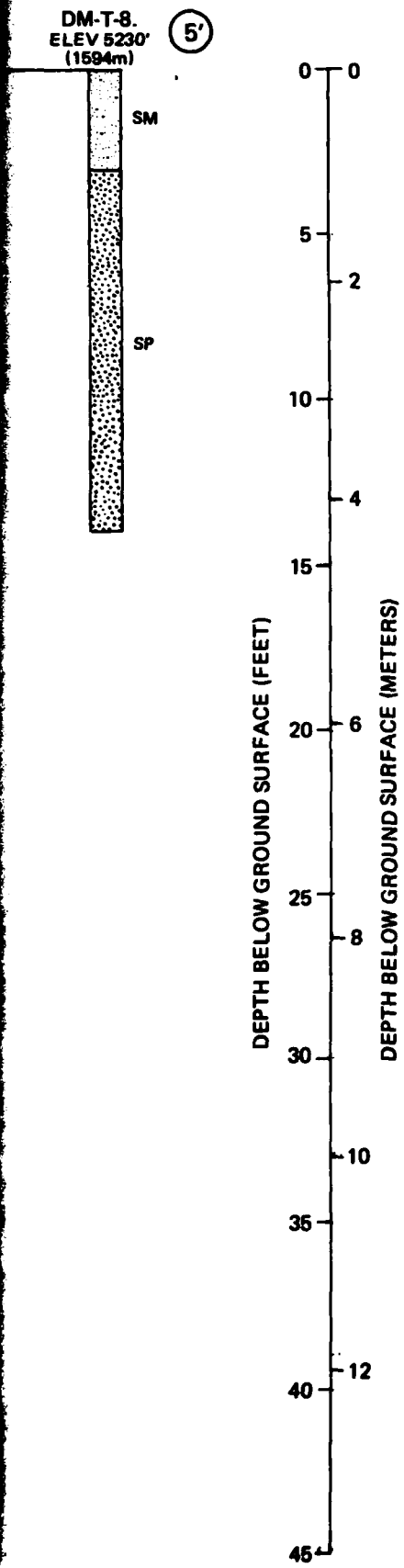


B - Boring
T - Trench
P - Test Pit
CS - Surficial soil

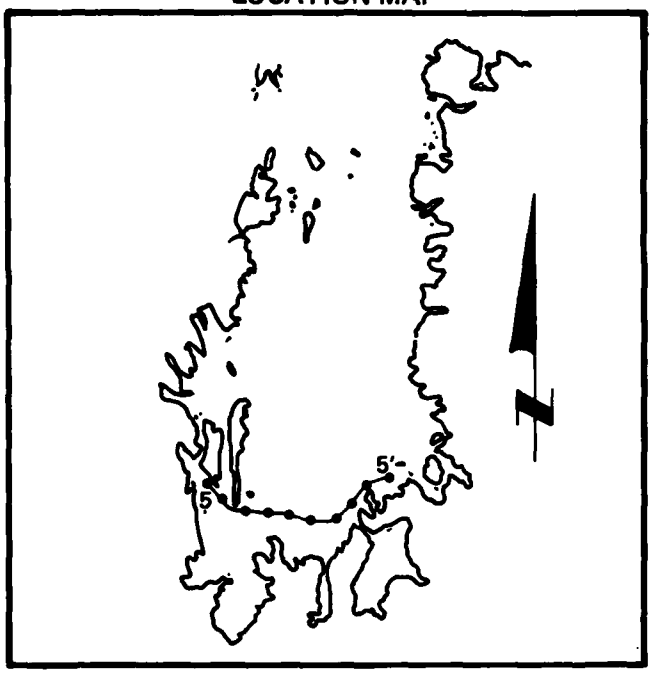
NOTES:
1. Ground-surfa
2. T. D. = Total
3. Soil types sh
Classification

STATUTE MI

KILOMETE



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

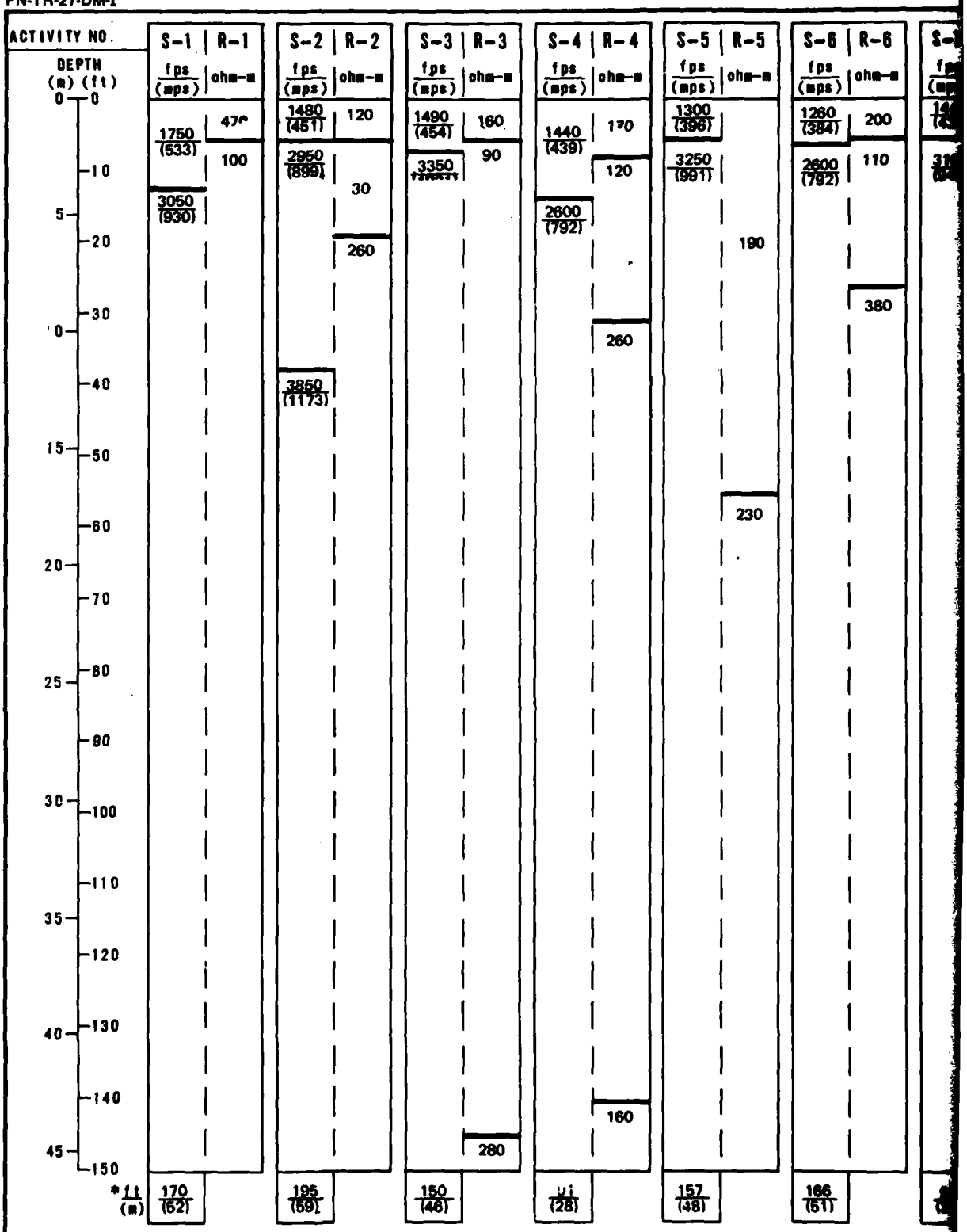
KILOMETERS 0 1 2 3

SOIL PROFILE 5–5'
DELAMAR VALLEY, NEVADA

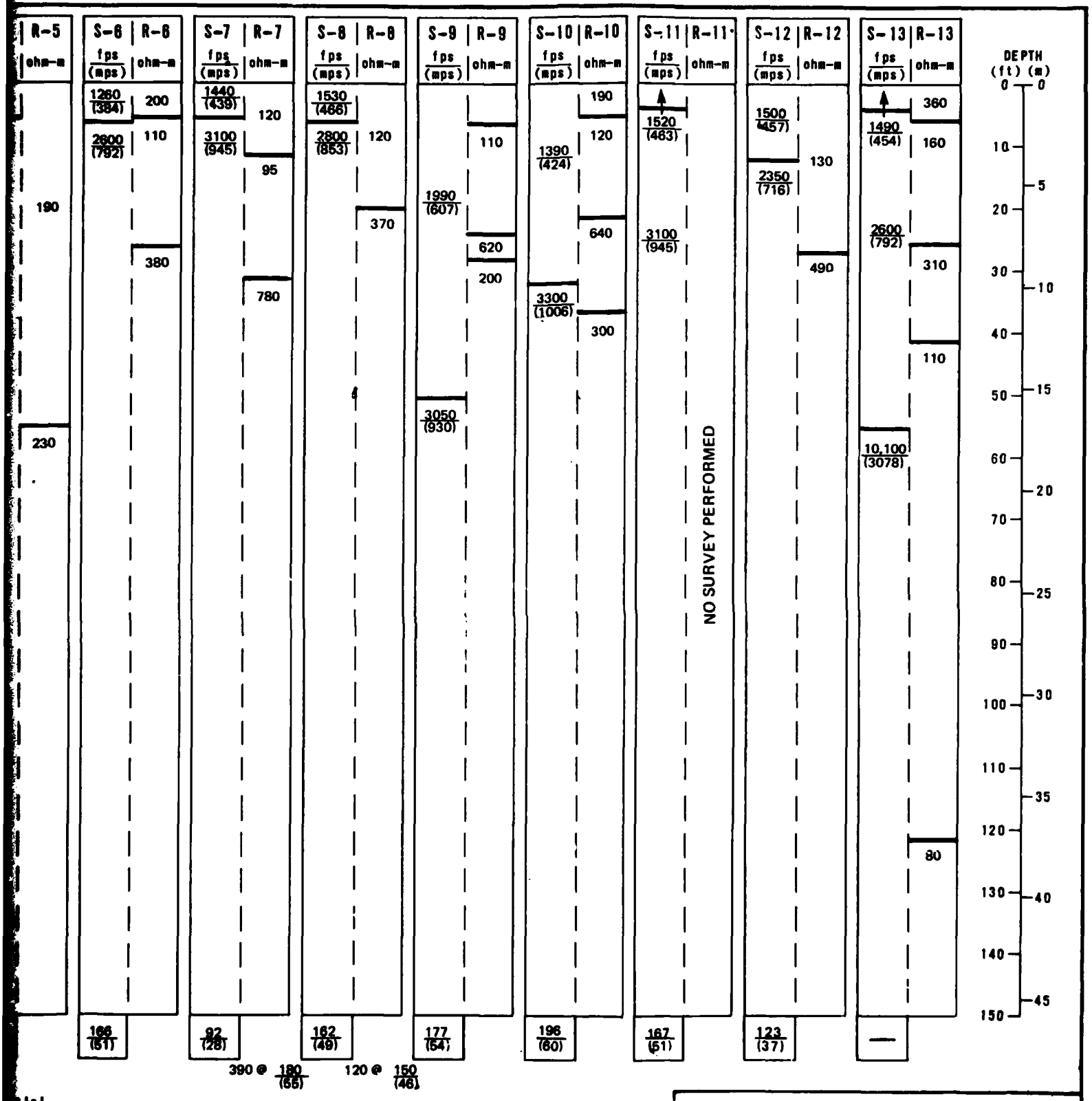
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

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 than 7000 fps (2134 mps).



SEISMIC REFRACTION AND
ELECTRICAL RESISTIVITY RESULTS
DELAMAR VALLEY, NEVADA

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-gra
	Sandy Gravels, Gravelly Sands, Sands and Silty Sands	Sandy Clays
USCS SYMBOLS	GW-GM, SW, SP,SM	CL
ESTIMATED EXTENT IN SUBSURFACE %	80 - 90	10 - 20
PHYSICAL PROPERTIES		
DRY DENSITY pcf (kg/m³)	97.1 - 123.6 (1556 - 1980) [17]	77.3 - 105.6 (1238 - 1692
MOISTURE CONTENT %	2.7 - 14.2 [17]	6.2 - 20.4
DEGREE OF CEMENTATION	none to high	moderate
COBBLES 3 - 12 inches (8 - 30 cm) %	0 - 10	0
GRAVEL %	0 - 45 [19]	0
SAND %	43 - 85 [19]	22
SILT AND CLAY %	3 - 35 [19]	78
LIQUID LIMIT	NDA	32 - 44
PLASTICITY INDEX	NP [4]	12 - 23
COMPRESSIONAL WAVE VELOCITY fps (mps)	1260 - 3350 (384 - 1021) [24]	NDA
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION S_u - ksf (kN/m²)	NDA	6.8 (326)
TRIAXIAL COMPRESSION c - ksf (kN/m²), ø°	NDA	c = 1.5, ø = (72)
DIRECT SHEAR c - ksf (kN/m²), ø°	c = 0.0 - 1.0, ø = 47 - 49* (0 - 48) [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 5 borings, 4 trenches, and 3 test pits, and results of 13 seismic refraction surveys.
- Characteristics of soils below 20 feet (6.0 meters) are based on results of tests on samples from 5 borings and results of 13 seismic refraction surveys.

- [ ] -
- NDA - No
- * - H

- 6.0m)		20' - 160' (6.0 - 49.0m)			
Fine-grained soils		Coarse-grained soils		Fine-grained soils	
Sandy Clays and Clays		Sandy Gravels, Gravelly Sands, Sands and Silty Sands		Silts, Silty Clays and Clays	
CL		GW-GM, SW, SP, SM		ML, CL	
10 - 20		80 - 90		10 - 20	
77.3 - 105.6 (1238 - 1692)	[7]	96.7 - 126.7 (1549 - 2030)	[38]	79.3 - 102.6 (1270 - 1644)	[16]
6.2 - 20.4	[7]	6.5 - 18.2	[38]	14.0 - 28.8	[16]
moderate		none to moderate		moderate	
0		0 - 10		0	
0	[1]	0 - 58	[24]	0	[1]
22	[1]	34 - 97	[24]	2	[1]
78	[1]	3 - 42	[24]	98	[1]
32 - 44	[2]	NDA		34 - 48	[7]
12 - 23	[2]	NP	[4]	15 - 24	[7]
NDA		1390 - 3850 (424 - 1173)	[17]	NDA	
6.8 (326)	[1]	NDA		3.0 - 5.0 (144 - 239)	[2]
c = 1.5, ø = 43 (72)	[1]	NDA		c = 1.0, ø = 39 (48)	[1]
NDA		c = 0.0, ø = 46 - 50 * (0)	[2]	NDA	

- [ ] - Number of tests performed.
- NDA - No data available (insufficient data or tests not performed.)
- * - High angle due to large gravels

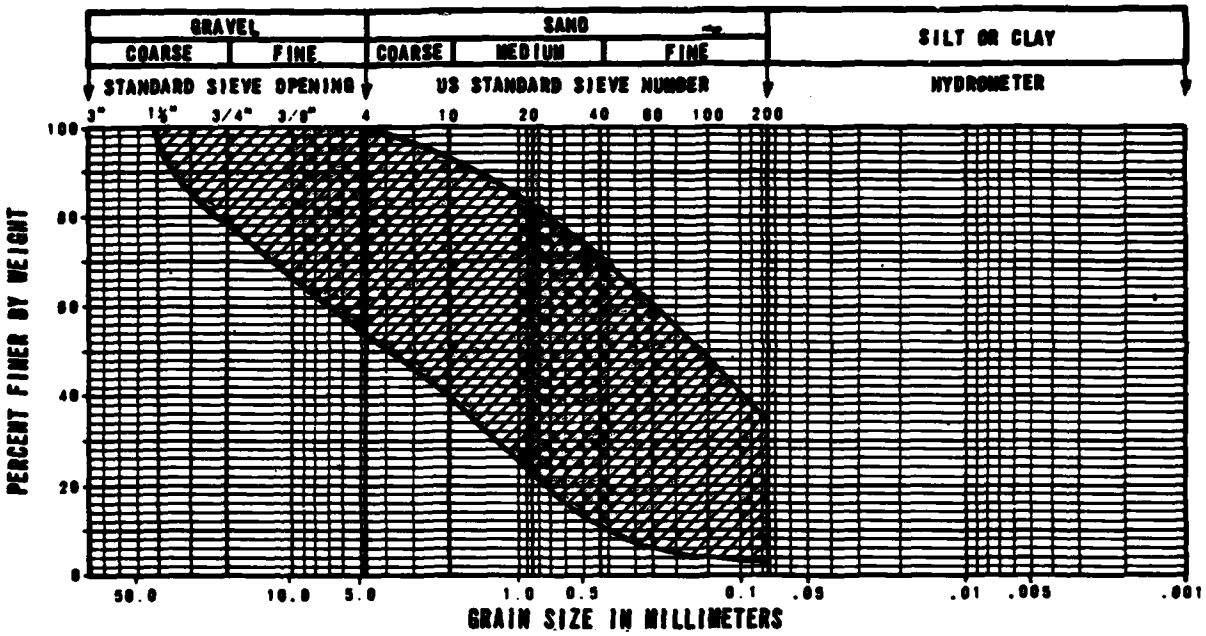
CHARACTERISTICS OF SUBSURFACE SOILS
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

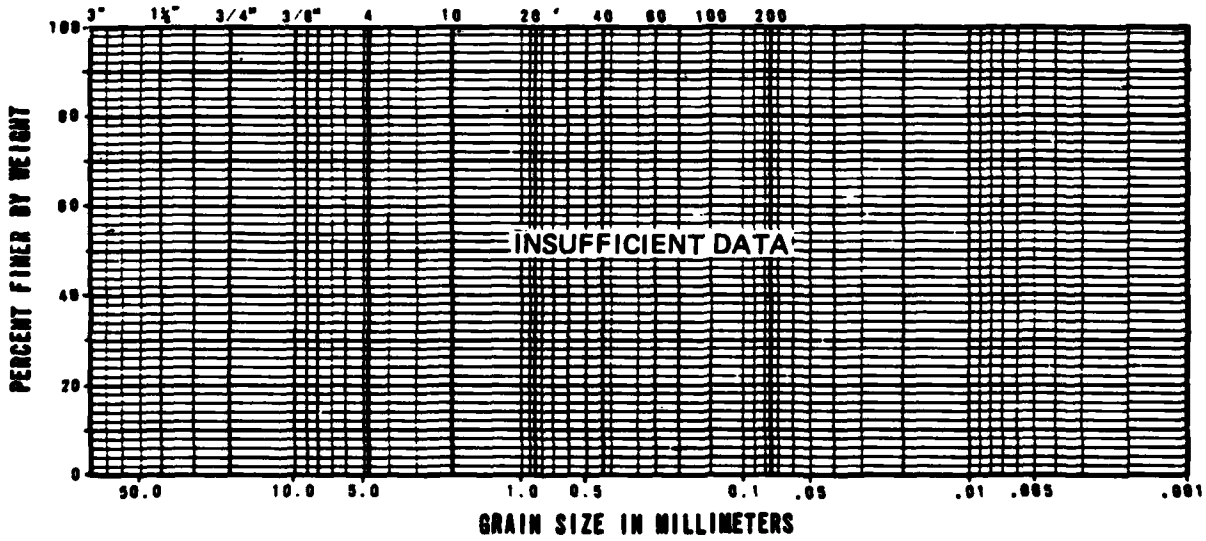
TABLE 3-4

FUGRO NATIONAL, INC.

AFV-28



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



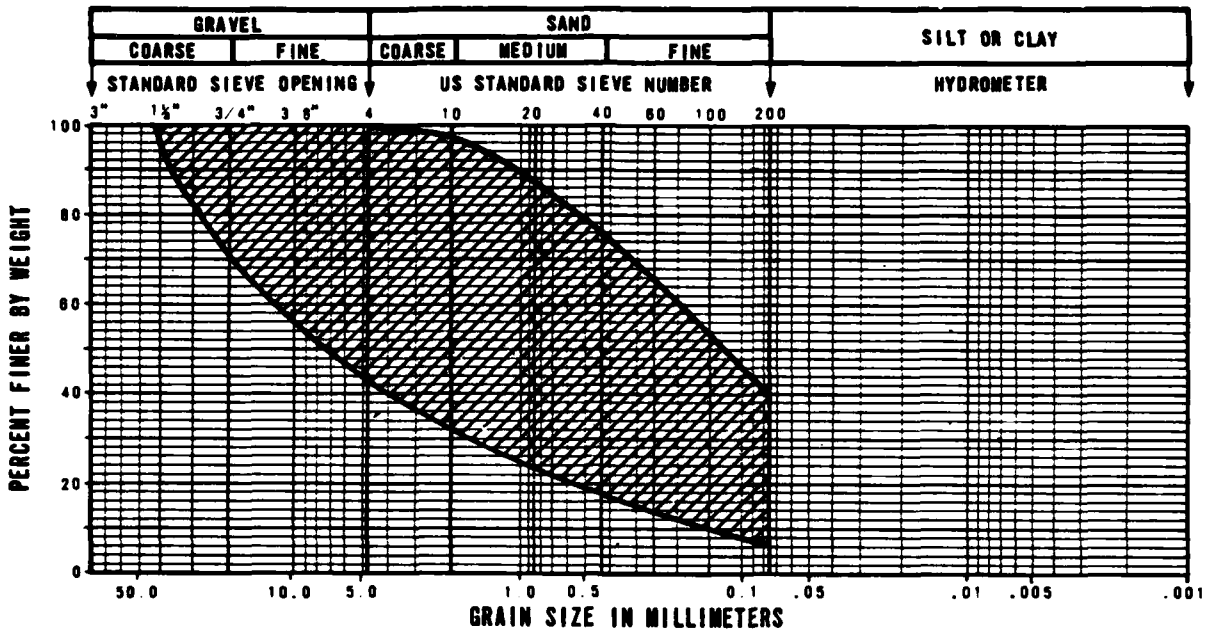
SOIL DESCRIPTION: Fine - Grained Soils
from 2 to 20 feet (0.6m to 6.0m)

RANGE OF GRADATION OF SUBSURFACE SOILS
DELAMAR VALLEY, NEVADA

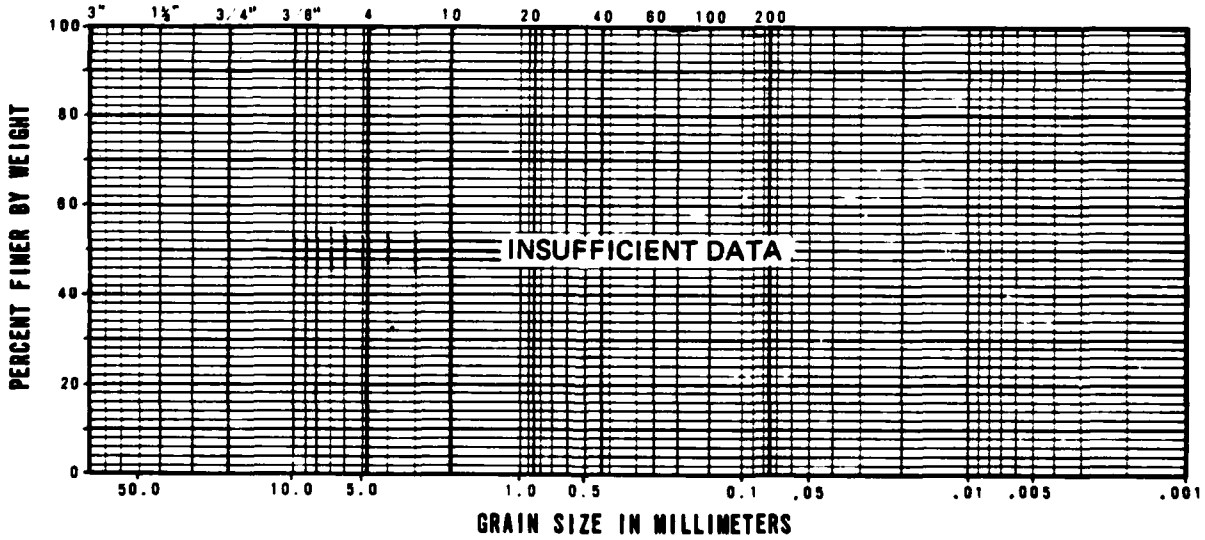
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

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
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE
3-7
2 OF 2

FUGRO NATIONAL, INC.

graded, contain coarse to fine sands and gravels, and are medium dense to very dense below 10 to 15 feet (3.6 to 4.6 m). Variable cementation occurs intermittently, but well-developed, continuous cementation is 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 hard and exhibit low to moderate compressibilities and shear strengths. Soil plasticity ranges from slightly plastic to medium plastic depending in part on the amount of fine sand present. Calcium-carbonate cementation varies from weak to moderate, depending on the age of the deposit.

The soils in the construction zone (120 feet [37 m]) have a wide range of seismic compressional wave velocities (1260 to 3850 fps [384 to 1173 mps]), depending on their composition, consistency, cementation, and moisture content. Seismic compressional wave velocities were measured in only the 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 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 0.0029 to 0.0101 mhos per meter (average 0.005 mhos per meter). At four of the 13 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 be "negligible".

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 Delamar 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 (15 m). An additional 12 percent of the valley is interpreted to contain shallow rock between depths of 50 to 150 feet (15 to 46 m).

Several areas extending outward from the mountain ranges have been interpreted to be underlain by shallow rock. In the very northeast portion of the valley on the west flank of Delamar Mountains, numerous outcrops of volcanic rock protrude through the overlying intermediate-age fans, and the area adjacent to the mountain has been interpreted to be underlain by shallow rock. Additional areas in the northwest and southeast contain large but scattered low-lying volcanic outcrops that are interpreted to be connected at shallow depth beneath the alluvial cover. Many of the small reentrant canyons are also interpreted to contain shallow rock beneath the alluvial fan and active wash deposits.

FNI borings and published well data have added to the depth-to-rock data base. One well, WR-T1 (Drawing 3-3), located in the center of the valley, penetrated 1210 feet (369 m) of basin-fill material and did not encounter rock.

3.6 DEPTH TO WATER

Drawing 3-4 shows the location of all data points used to define ground-water conditions in Delamar Valley. The sources of these data are FNI activities and Nevada State Engineers Office Well Drillers Reports.

A total of five wells W-1 through W-4, and WR-T1, were drilled in the basin-fill material. Wells W-1, and W-2 (Drawing 3-4), located in the northern part of the valley, were drilled to 61 feet (18 m) and 360 feet (110 m), respectively, without encountering water and are considered dry wells. Wells W-4 and WR-T1 (FNI water-resource well), drilled in valley-fill material, encountered water at depths greater than 200 feet (66 m). Additional hydrologic data on Delamar Valley are presented in FNI's summary report covering activities of the Water Resource Program in fiscal year 1980 (FNI-1980b).

Shallow water does occur in one reentrant canyon in Delamar Valley. Well W-3 (Drawing 3-4), located in southeastern Delamar Valley, encountered water at 63 feet (19 m). This point had already been excluded from the suitable area because of its proximity to the mountain front and location in a reentrant valley. The fact that no water was encountered above a depth of

AD-A113 390 FUGRO NATIONAL INC LONG BEACH CA F/G 13/2
VERIFICATION STUDY - DELAMAR VALLEY, NEVADA. VOLUME I. SYNTHESI--ETC(U)
MAR 81 F04704-80-C-0006
UNCLASSIFIED FN-TR-27-DM-VOL-1 NL

2 OF 2

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DATE
FILMED
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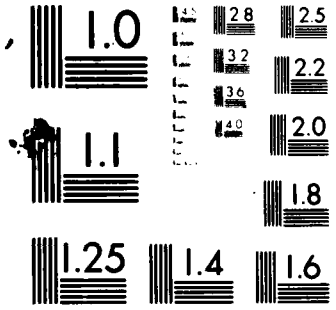

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

Results of chemical tests indicate that potential for sulfate attack of soils on concrete will be "negligible".

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 Delamar 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 (15 m). An additional 12 percent of the valley is interpreted to contain shallow rock between depths of 50 to 150 feet (15 to 46 m).

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200 feet in the valley proper explains why 50- and 150-foot (15- and 46-m) depth-to-water contours are not shown on Drawing 3-4.

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 the terrain criteria outlined on Appendix Table A2-1. Areas where slopes exceed five percent also are shown on Drawing 3-5 even though these areas are not considered to be exclusions.

Within the valley, no extreme terrain conditions exist. The only area excluded due to incision depth is the A5og unit at the outwash area of Cedar Wash on the west flank of the Delamar Mountains. Topographic slopes exceeding 10 percent are generally located proximate and parallel to the rock-alluvium contact and typically exclude small reentrants into the mountain ranges around the valley.

3.7.2 Incision Depth and Number of Drainages Per Mile

Data on drainage-incision depths and number of drainages encountered per mile were collected for Delamar Valley. Information on incision depths was obtained from field observations; the number of drainages per mile was determined from field-derived data and aerial photograph interpretation.

Applicable data were analyzed for the prevalent surficial geologic units with the results shown in Tables 3-5 and 3-6. Average values of the two drainage characteristics are reported for each prevalent surficial unit, with further breakdowns

SURFICIAL GEOLOGIC UNIT	WESTERN SIDE OF VALLEY		EASTERN SIDE OF VALLEY	
	SURFACE SLOPE, %		SURFACE SLOPE, %	
	0 - 5	5 - 10	0 - 5	5 - 10
A5ig	—	—	—	5.8 ft* 1.8 m
A5is	3.2 ft (2.6 ft) 1.0 m (0.8 m)	5.7 ft (2.5 ft) 1.7 m (0.8 m)	3.1 ft (1.4 m) 0.9 m (0.4 m)	4.7 ft (3.8 ft) 1.4 m (1.2 m)
A5ys	2.2 ft (1.2 ft) 0.7 m (0.4 m)	1.6 ft* 0.5 m	2.1 ft (1.2 ft) 0.6 m (0.4 m)	1.6 ft (0.0 ft) 0.5 m (0.0 m)
A1s	2.5 ft* 0.8 m	—	—	—
A1f	2.1 ft (1.1 ft) 0.6 m (0.3 m)	—	—	—

* LIMITED DATA ($6 \leq n \leq 10$) VALUE IS MEDIAN, NO STANDARD DEVIATION

— NO DATA OR LIMITED DATA ($n<6$)

( ) STANDARD DEVIATION

A5i INTERMEDIATE–AGE ALLUVIAL FANS

A5y YOUNG – AGE ALLUVIAL FANS

A1 FLUVIAL DEPOSITS

g GRAVELS

s SANDS

f FINES; CLAYS, SILTS

AVERAGE DRAINAGE INCISION DEPTHS OF PREVALENT SURFICIAL GEOLOGIC UNITS DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

TABLE 3-5

FUGRO NATIONAL, INC.

SURFICIAL GEOLOGIC UNIT	WESTERN SIDE OF VALLEY		EASTERN SIDE OF VALLEY	
	SURFACE SLOPE, %		SURFACE SLOPE, %	
	0 - 5	5 - 10	0 - 5	5 - 10
A5ig	—	—	—	—
A5is	9.6 (3.2)	—	15.7 (6.0)	22.9 (6.5)
A5ys	7.1 (3.2)	—	10.9 (3.4)	—
A1s	7.5*	—	—	—
A1f	—	—	—	—

* LIMITED DATA ($6 \leq n \leq 10$) VALUE IS MEDIAN, NO STANDARD DEVIATION
— NO DATA OR LIMITED DATA ($n<6$)
( ) STANDARD DEVIATION
A5i INTERMEDIATE–AGE ALLUVIAL FANS
A5y YOUNG – AGE ALLUVIAL FANS
A1 FLUVIAL DEPOSITS
g GRAVELS
s SANDS
f FINES; CLAYS, SILTS

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

AVERAGE NUMBER OF DRAINAGES PER MILE IN PREVALENT SURFICIAL GEOLOGIC UNITS DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

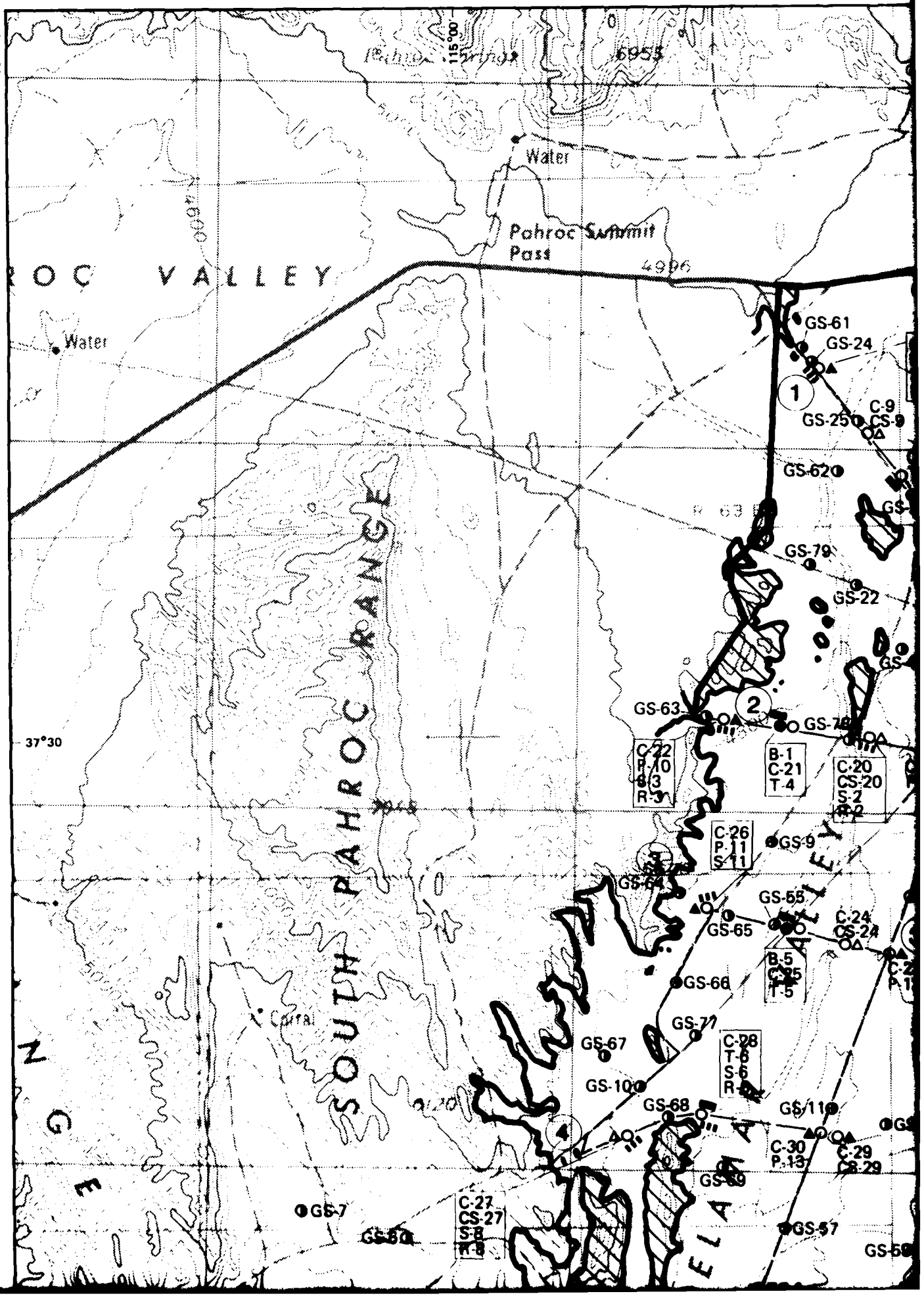
TABLE 3-6

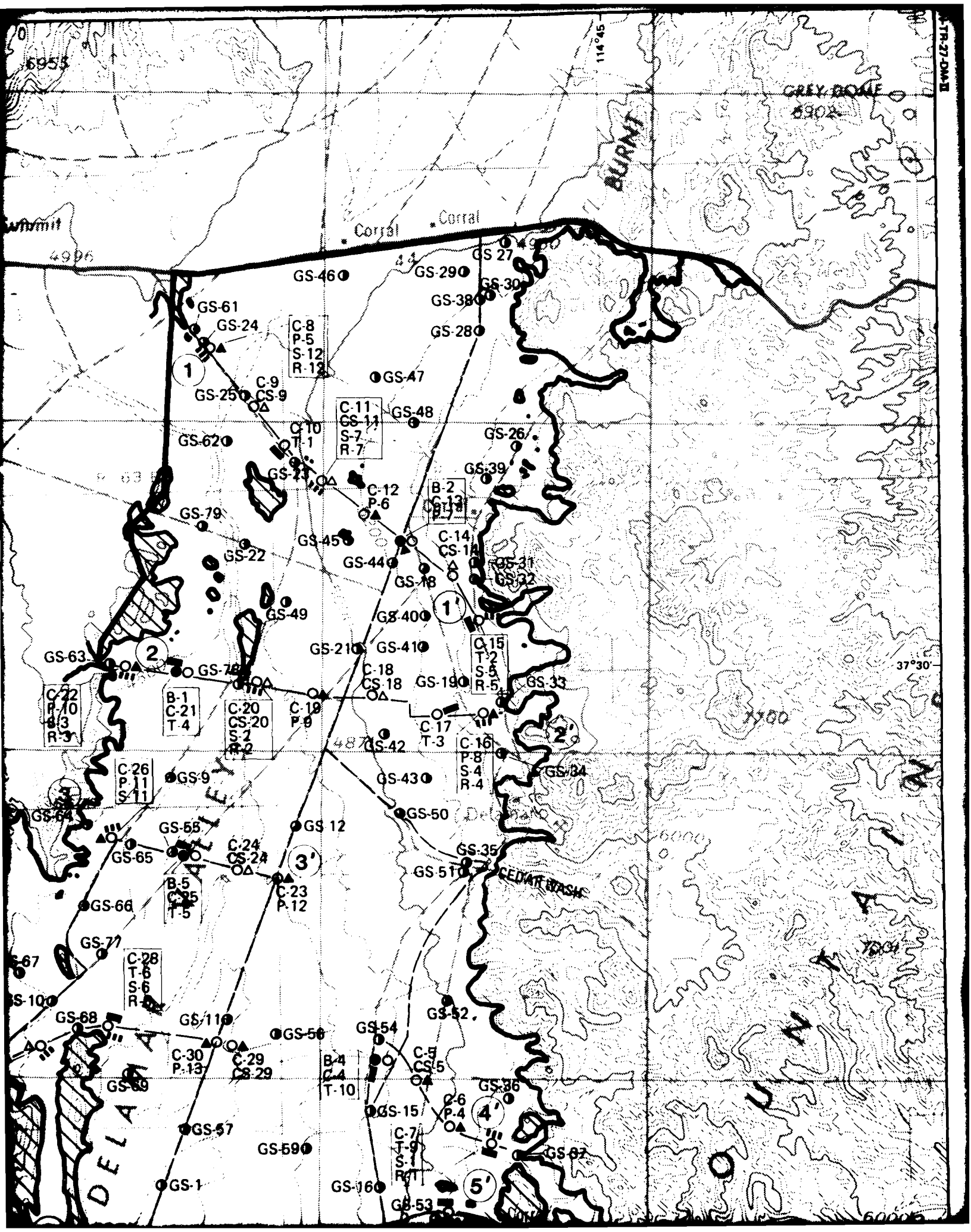
FUGRO NATIONAL, INC.

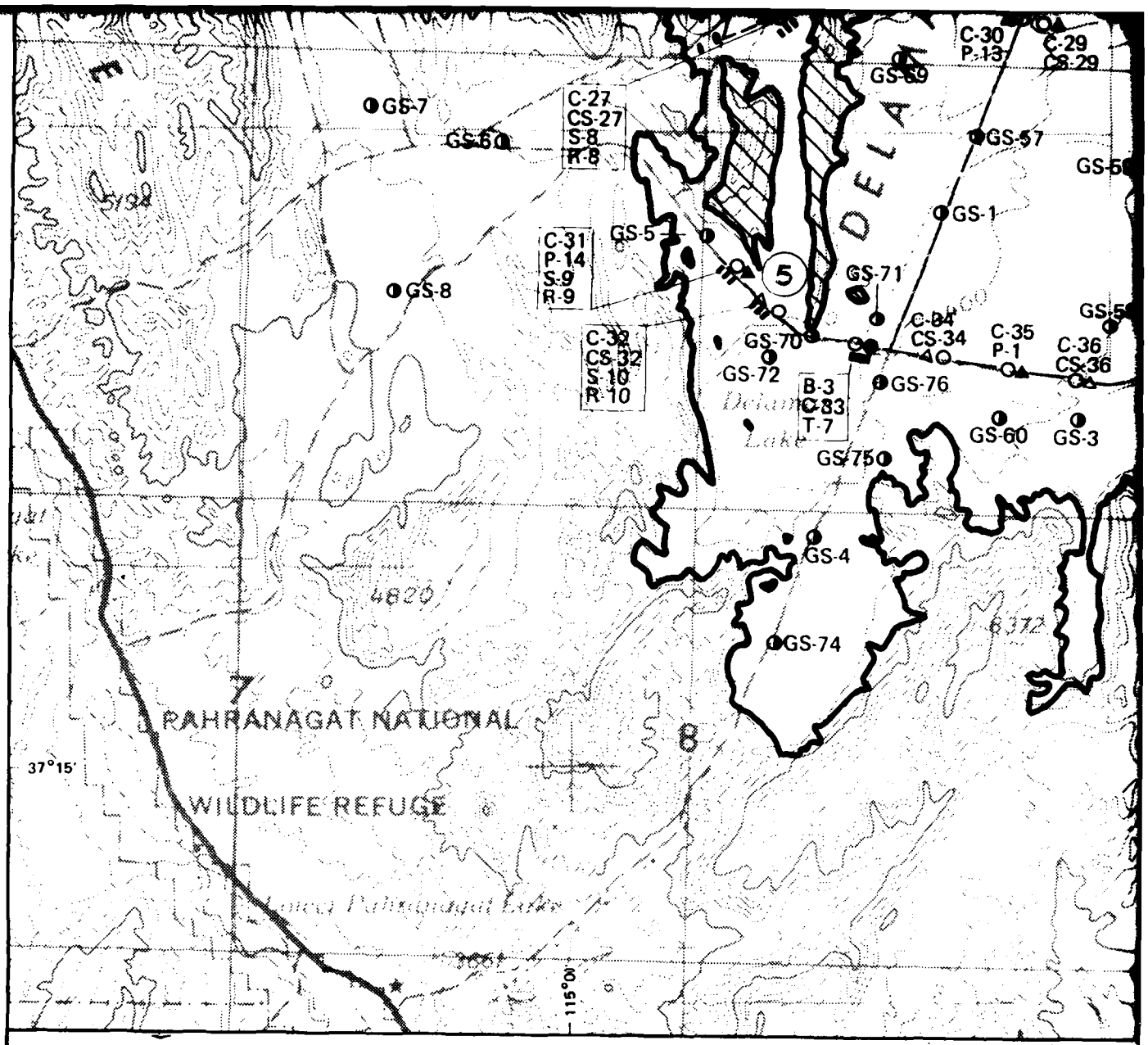
providing data on: 1) characteristics in the unit on the eastern side of the valley axial drainage versus those on the western side; and 2) characteristics in the unit where its surface slope is between five and 10 percent versus places where its slope is less than five percent.

The small areal extent of some of the surficial units resulted in limited or insufficient data for analysis. The available data show that the incisions on the western side of Delamar Valley are slightly deeper than those on the eastern side of the valley; however, the eastern side of the valley contains about one and one-half times more drainages than the western side. This change from east to west is most likely because the Delamar Mountains are higher, steeper, and receive more rainfall than the low hills bounding the west side of the valley.

24 MAR 81

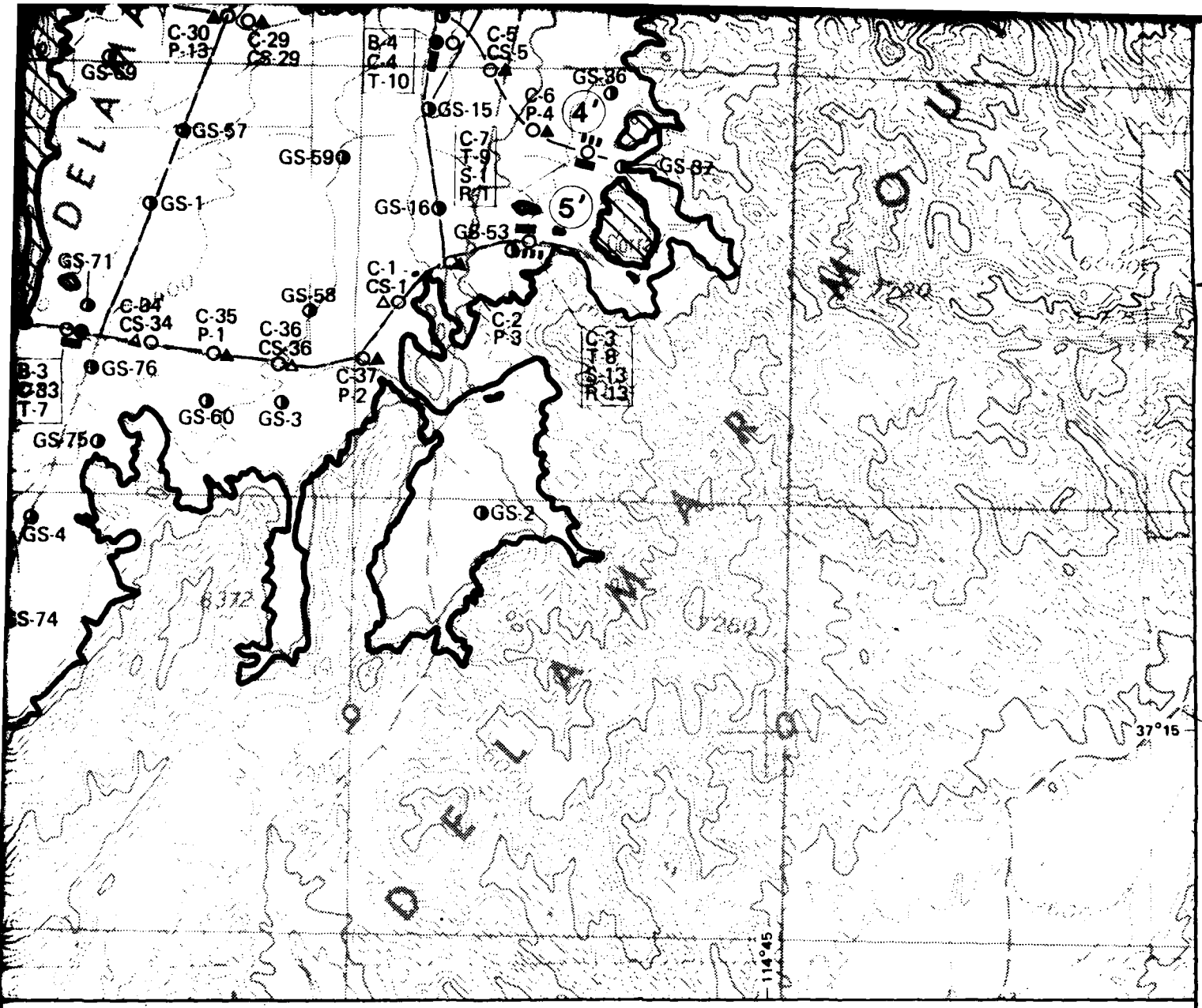

115°00'
6955
Water
Pahroc Summit
Pass
4996
ROC VALLEY
Water
SOUTH PAHROC RANGE
37°30
Corral
GS-61
GS-24
1
C-9
GS-25
CS-9
GS-62
GS-79
GS-22
GS-63
2
C-22
P-10
S-3
R-3
B-1
C-21
T-4
C-20
CS-20
S-2
C-26
P-11
S-11
GS-9
GS-64
GS-55
GS-65
C-24
CS-24
B-5
T-5
GS-66
GS-77
GS-67
C-28
T-6
S-6
GS-100
GS-68
GS-111
4
C-30
P-13
C-29
CS-29
GS-69
GS-7
C-27
CS-27
S-8
R-8
GS-57
ELAINE VALLEY


GREY DOME
6902
BURNT
Corral
Corral
114°45'
37°30'
GS-27
GS-46
GS-29
GS-30
GS-38
GS-28
GS-61
GS-24
C-8
P-5
S-12
R-12
GS-47
C-9
CS-9
GS-25
C-11
CS-11
S-7
R-7
GS-48
C-10
T-1
GS-62
GS-26
GS-23
GS-39
C-12
P-6
B-2
C-13
GS-79
GS-45
C-14
CS-14
GS-22
GS-44
GS-31
GS-32
GS-18
GS-49
GS-40
GS-21
GS-41
C-15
T-2
S-5
R-5
GS-63
GS-76
C-18
CS-18
GS-19
GS-33
C-22
P-10
S-3
R-3
B-1
C-21
T-4
C-20
CS-20
S-2
R-2
C-19
P-9
C-17
T-3
GS-42
C-16
P-8
S-4
R-4
GS-34
C-26
P-11
S-11
GS-9
GS-43
GS-64
GS-50
GS-55
GS-12
C-24
CS-24
GS-65
GS-35
GS-51
CEDAR WASH
B-5
C-25
T-5
C-23
P-12
GS-66
GS-77
C-28
T-6
S-6
R-6
GS-10
GS-68
GS-11
GS-56
GS-54
GS-52
C-30
P-13
C-29
CS-29
B-4
C-4
T-10
C-5
CS-5
GS-69
GS-36
C-6
P-4
GS-15
GS-57
C-7
T-9
S-1
R-1
GS-59
GS-87
GS-1
GS-16
GS-53
DELAMAR VALLEY
MOUNTAIN
1
1'
2
2'
3'
4'
5'



EXPLANATION

◑	GS-1	GEOLOGIC STATION
●	B-1	BORING
○	C-1	CONE PENETROMETER TEST (CPT)
△	CS-1	SURFACE SAMPLE AT CPT LOCATION
▬	T-1	TRENCH
▲	P-1	TEST PIT
▪▪▪	S-1 R-1	SEISMIC REFRACTION LINE ELECTRICAL RESISTIVITY LINE



EXPLANATION

STATION

TROMETER TEST (CPT)

AMPLE AT CPT LOCATION

NORTH

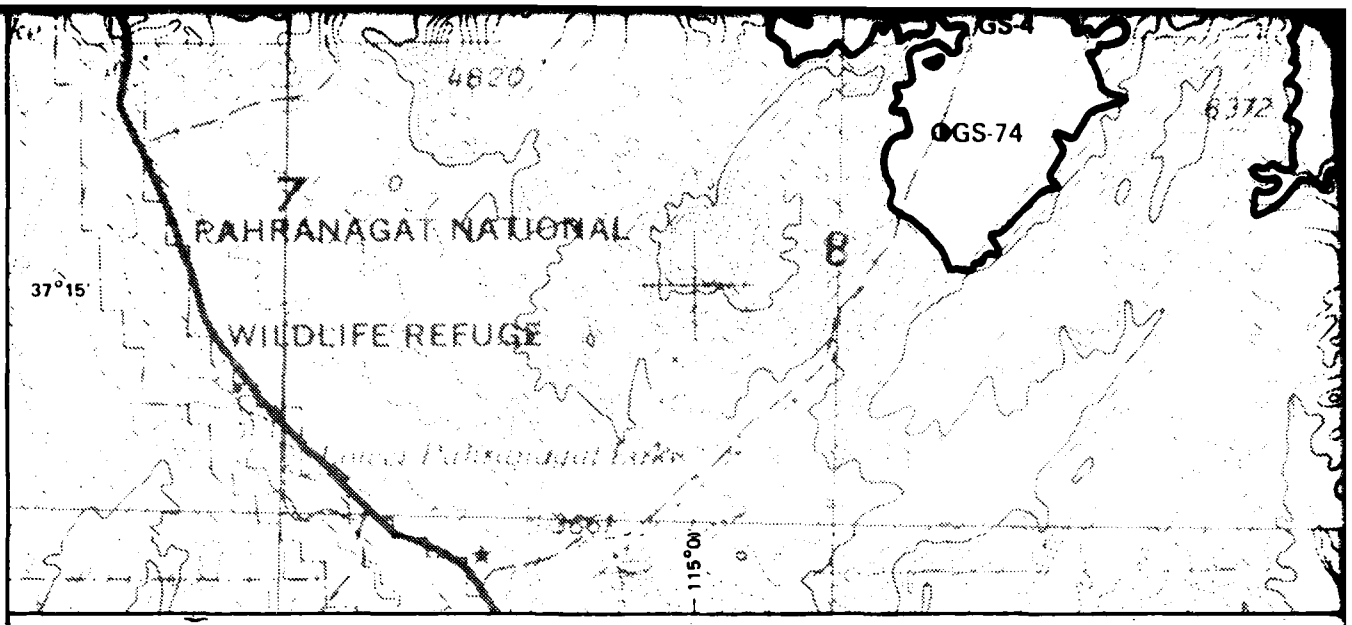
FRACTION LINE

L RESISTIVITY LINE

SCALE 1: 125,000

0 2 4

STATUTE MILES



EXPLANATIO

◑	GS-1	GEOLOGIC STATION
●	B-1	BORING
○	C-1	CONE PENETROMETER TEST (CPT)
△	CS-1	SURFACE SAMPLE AT CPT LOCATION
▬	T-1	TRENCH
▲	P-1	TEST PIT
▪▪▪	S-1 R-1	SEISMIC REFRACTION LINE ELECTRICAL RESISTIVITY LINE
(1) — — (1')		ACTIVITY LINE
▬		Contact between rock and basin fill.
▬		Valley border (north and west).
▨		Areas of isolated exposed rock.

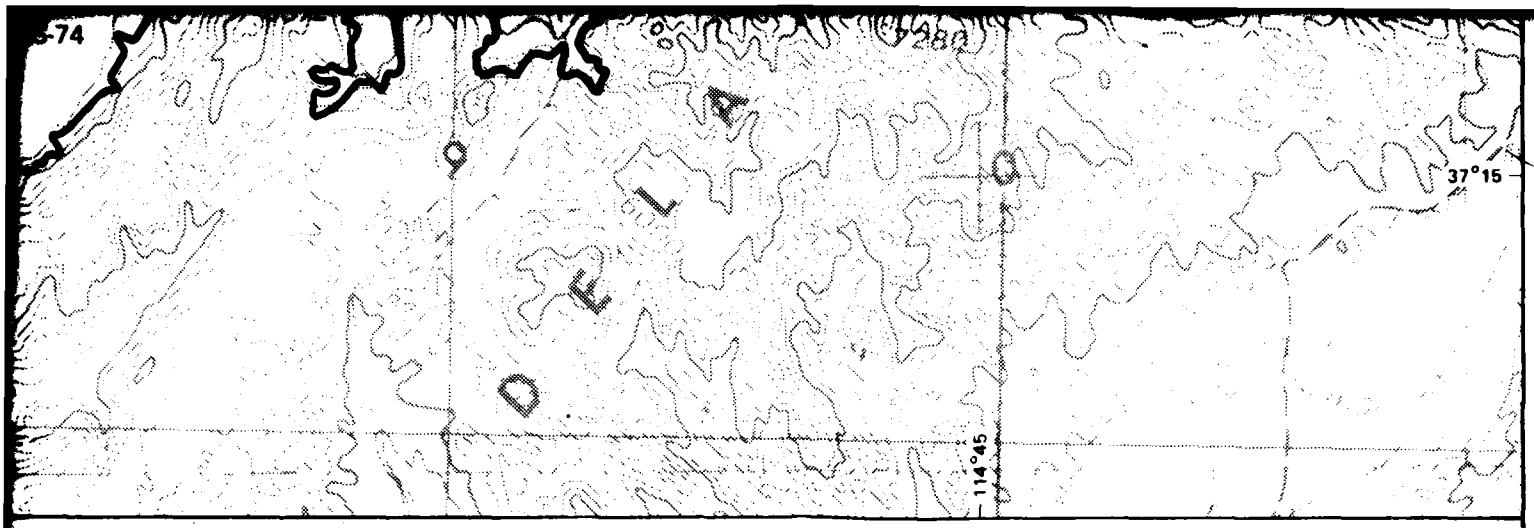
NOTE: Where multiple activities were performed at the same l
the correct location is designated by either (1) the bo
symbol or (2) the CPT symbol, if no boring was drille

ACTIVITY LOCATIONS
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

DRAWING 3-1

FUGRO NATIONAL, INC.



EXPLANATION

STATION

TROMETER TEST (CPT)

AMPLE AT CPT LOCATION

FRACTION LINE

L RESISTIVITY LINE

LINE

n rock and basin fill.

orth and west).

d exposed rock.

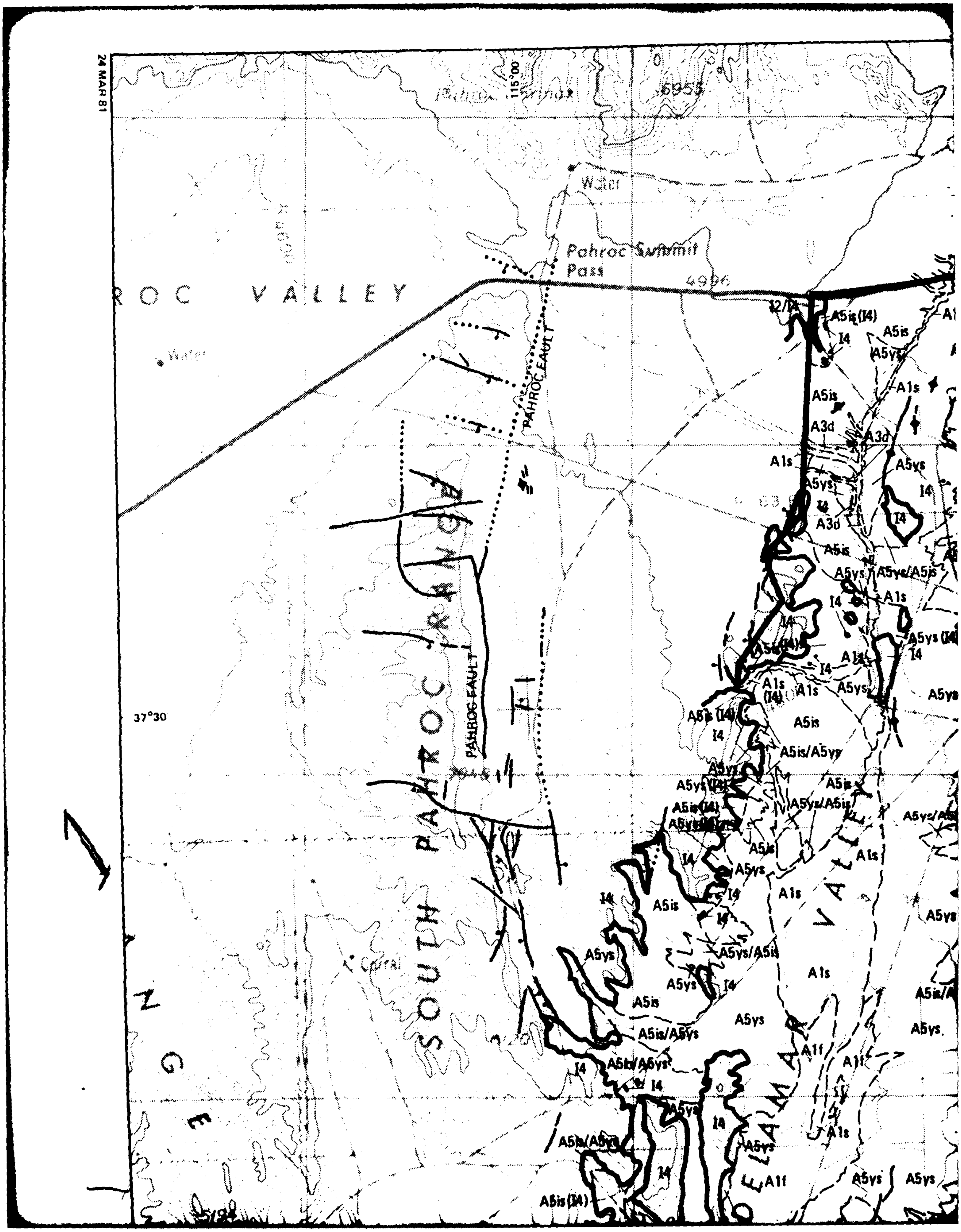
ltiple activities were performed at the same location,
st location is designated by either (1) the boring
r (2) the CPT symbol, if no boring was drilled.

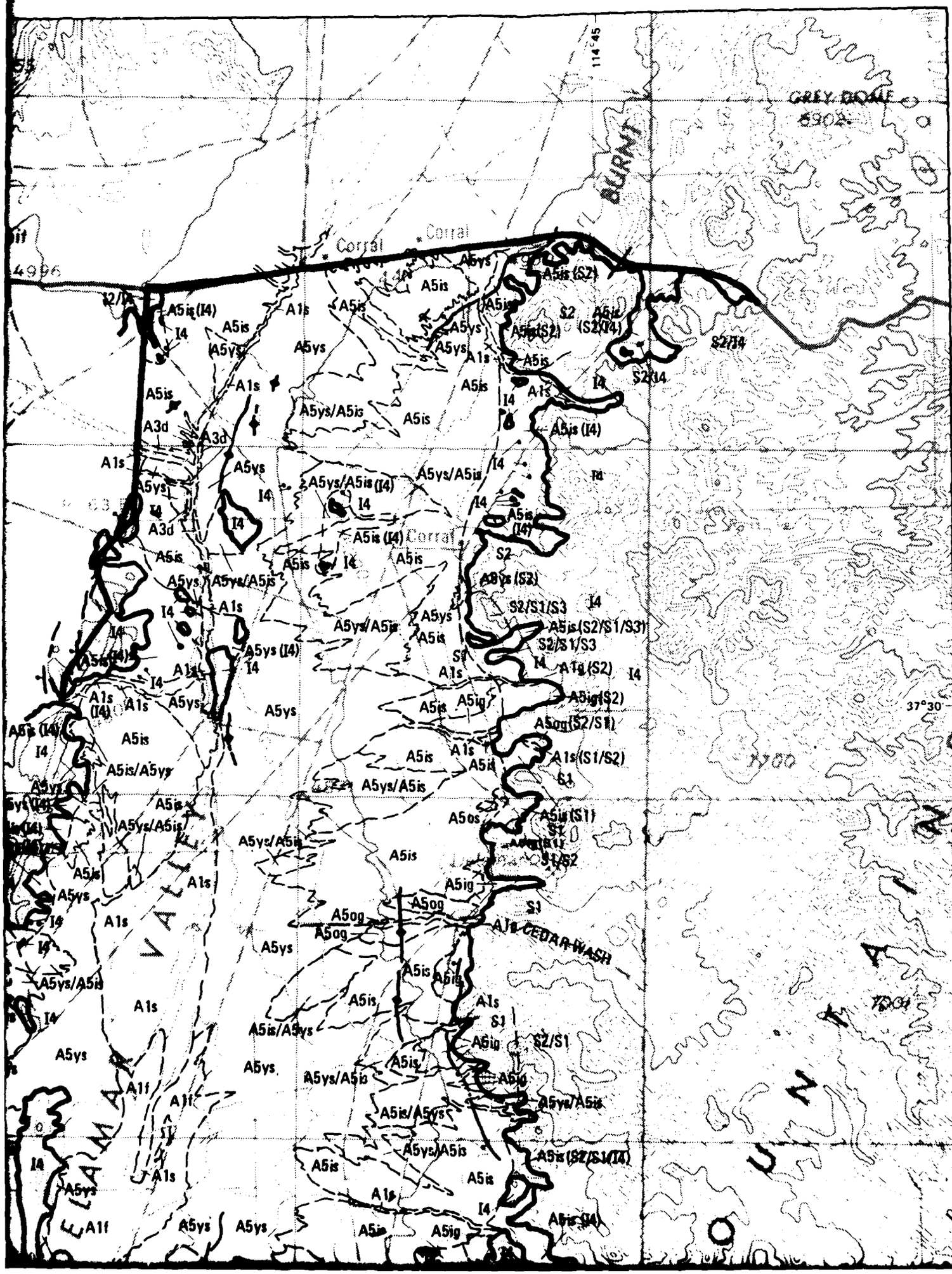
NORTH

SCALE 1: 125,000

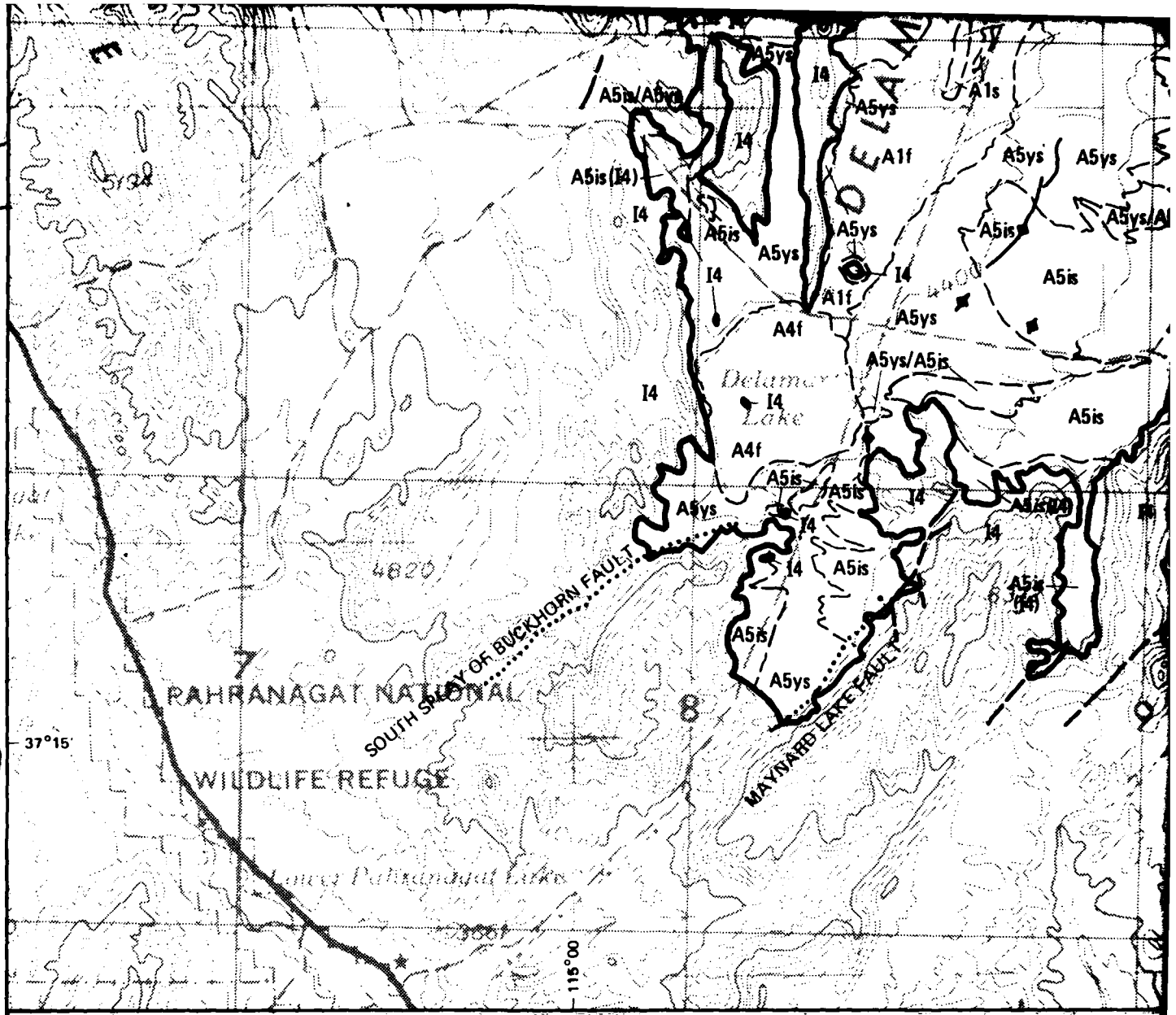
0 2 4
STATUTE MILES

0 2 4
KILOMETERS


24 MAR 81
115°00
6955
Water
Pahroc Summit
Pass
4996
ROC VALLEY
Water
PAHROC FAULT
PAHROC FAULT
SOUTH PAHROC RANGE
37°30
DELAMAR VALLEY
NGE
A5is(I4)
A5is
I4
A5ys
A1s
A5is
A3d
A3d
A1s
A5ys
A5ys
I4
I4
A3d
A5is
A5ys
A5ys/A5is
A1s
I4
A5ys (I4)
A5is(I4)
I4
A1s
A5ys
A1s
(I4)
A1s
A5ys
A5is (I4)
A5is
I4
A5is/A5ys
A5ys
A5ys(I4)
A5is
A5is(I4)
A5ys/A5is
A5ys/A5
I4
A5is
A5ys
A1s
I4
A5is
I4
A5ys
A1s
A5ys
A5ys/A5is
A5ys
I4
A1s
A5is
A5is/A5ys
A5ys
A5ys
A1f
A1f
I4
A5is/A5ys
I4
A5ys
I4
A1s
A5is/A5ys
A5ys
I4
A1f
A5ys
A5ys
A5is (I4)


114°45'
GREY DOME
6902
BURNT
Corral
Corral
Corral
4996
A5is (I4)
A5is
A1s
A5ys
A5is (S2)
S2
A5is (S2/I4)
S2/I4
A5ys/A5is
A3d
A5ys/A5is (I4)
A5is (I4)
I4
A5ys (S2)
S2/S1/S3
A5is (S2/S1/S3)
A1s (S2)
A5ig (S2)
A5og (S2/S1)
A1s (S1/S2)
A5os
A5is (S1)
S1/S2
A5ig
A5og
A1s CEDAR WASH
S2/S1
A5is (S2/S1/I4)
A1f
37°30'
7700
7900
7000
DELAMAR VALLEY
MOUNTAIN

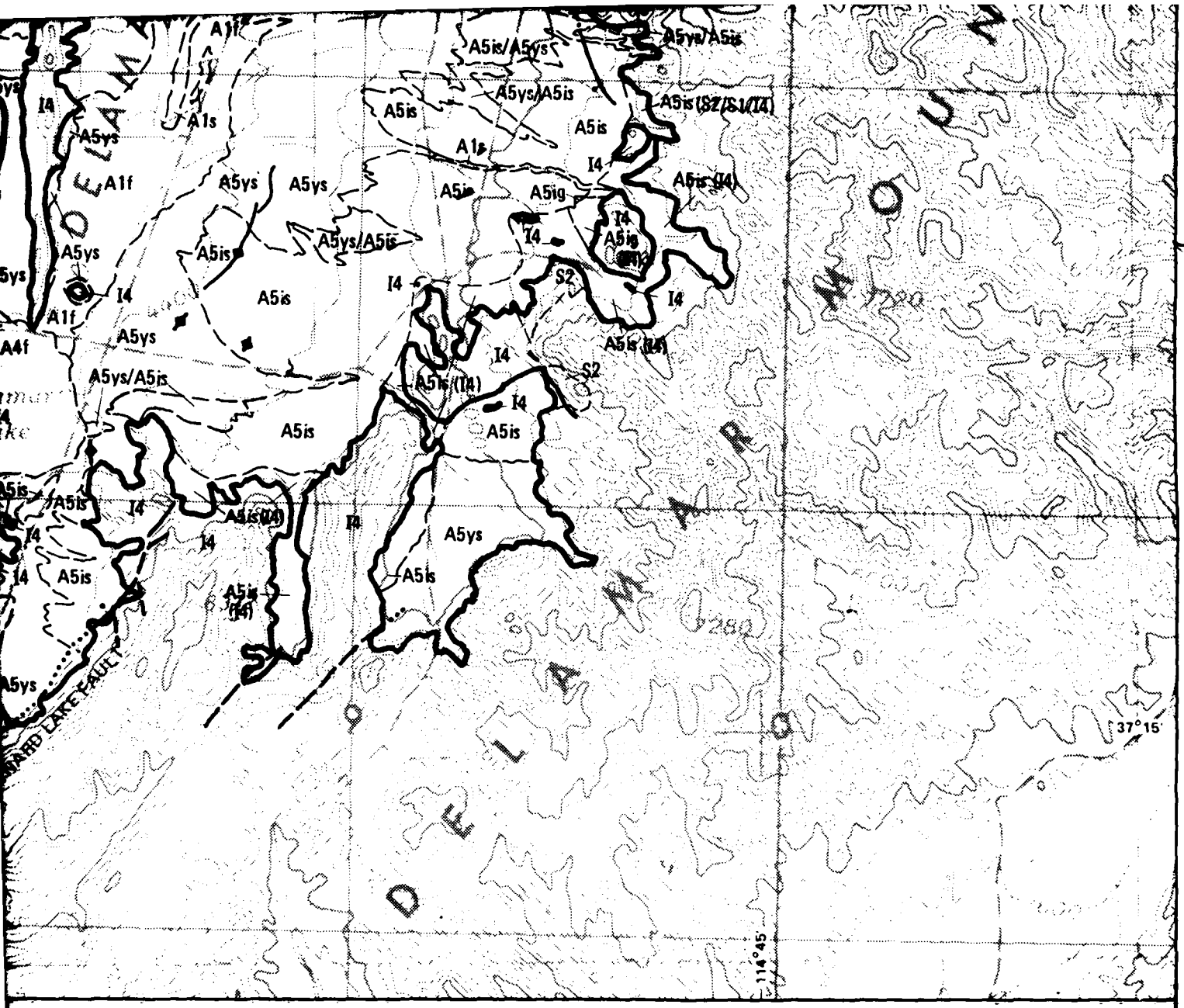
2



EXPLANATION

SURFICIAL BASIN–FILL DEPOS

A1f A1s A1g	Younger Fluvial Deposits - Modern stream channel and flood-plain dep and A1g, sandy gravel.
A3d	Eolian Deposits - Wind blown deposits of sand occuring as dunes.
A4f	Younger Lacustrine Deposits - Active playa deposits - A4f, clay.
A5ys	Younger Alluvial Fan Deposits - Alluvial fans undergoing active depos gravelly sand.
A5is	Intermediate Age Alluvial Fan Deposits - Alluvial fans undergoing acti weakly to moderately cemented silty sand and gravelly sand; and A5is



EXPLANATION

SURFICIAL BASIN–FILL DEPOSITS

- Modern stream channel and flood-plain deposits - A1f, sandy silt; A1s, silty sand;

wn deposits of sand occuring as dunes.

ts - Active playa deposits - A4f, clay.

its - Alluvial fans undergoing active deposition - A5ys; weakly cemented silty sand and

ion Deposits - Alluvial fans undergoing active erosion with no deposition - A5is

A4f	Younger Lacustrine Deposits - Active playa deposits - A4f,
A5ys	Younger Alluvial Fan Deposits - Alluvial fans undergoing ac gravelly sand.
A5is A5ig	Intermediate Age Alluvial Fan Deposits - Alluvial fans unde weakly to moderately cemented silty sand and gravelly sand and clayey gravels.
A5os A5og	Older Alluvial Fan Deposits - Highly eroded alluvial fan depo and gravelly sand; and A5og, weak to strongly cemented san
A5is/A5ys	Combination of geologic unit symbols indicates a mixture Dominant unit listed first.
A5os (S2)	Parenthetic unit underlies surface unit at shallow depth.

ROCK UNITS

Igneous (I)

I2	Undifferentiated volcanic rocks consisting of rhyolite, latite,
I4	Undifferentiated volcanic rocks consisting of welded tuffs, a

Sedimentary (S)

S1	Sandstone.
S2	Limestones and dolomites.
S3	Claystones and siltstones.

SYMBOLS

Contact between rock and basin-fill.

Contact between surficial basin-fill or rock units.

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

Tectonic lineament, probably a fault, generally expressed

Valley borders (north and west).

NOTES:

1. Surficial basin-fill units pertain only to t Due to variability of surficial deposits an unit descriptions refer to the predomina of other soil types can be expected withi
2. The distribution of geologic data statio Drawing II - 1 - 1 . A tabulation of all of all geologic units in included in Volu
3. Geology in areas of exposed rock derive (1977, 1978) unpublished data, Tschan and Carlson (1978).

SURFICIAL GEOLOGICAL UNITS
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

DRAWING 3-2

FUGRO NATIONAL, INC.

5

wn deposits of sand occuring as dunes.

ts - Active playa deposits - A4f, clay.

osits - Alluvial fans undergoing active deposition - A5ys; weakly cemented silty sand and

Fan Deposits - Alluvial fans undergoing active erosion with no deposition - A5is,
ented silty sand and gravelly sand; and A5ig, weakly to moderately cemented silty

ts - Highly eroded alluvial fan deposits - A5os, weak to strongly cemented silty sand
og, weak to strongly cemented sandy and silty gravels.

c unit symbols indicates a mixture of surficial basin-fill deposits inseparable at map scale.
et.

es surface unit at shallow depth.

ROCK UNITS

rocks consisting of rhyolite, latite, dacite and andesite.

rocks consisting of welded tuffs, ash flows, ignimbrites and pyroclastics.

s.

.

SYMBOLS

and basin-fill.

ial basin-fill or rock units.

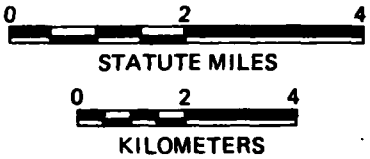
rupture, ball on downthrown side, dashed where approximately located in bedrock,
n alluvium.

obably a fault, generally expressed as a linear vegetational growth on aerial photographs.

nd west).

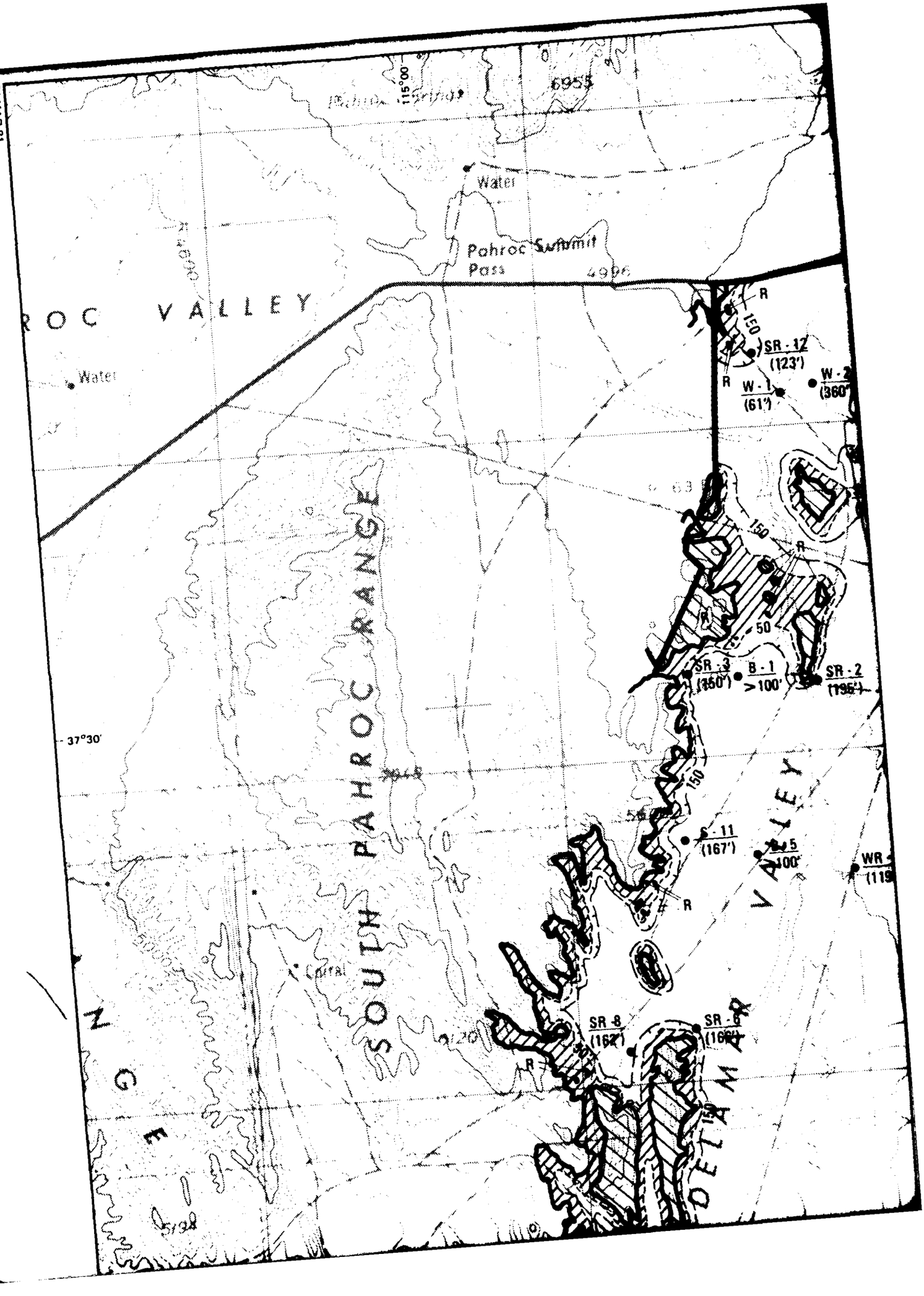
NORTH

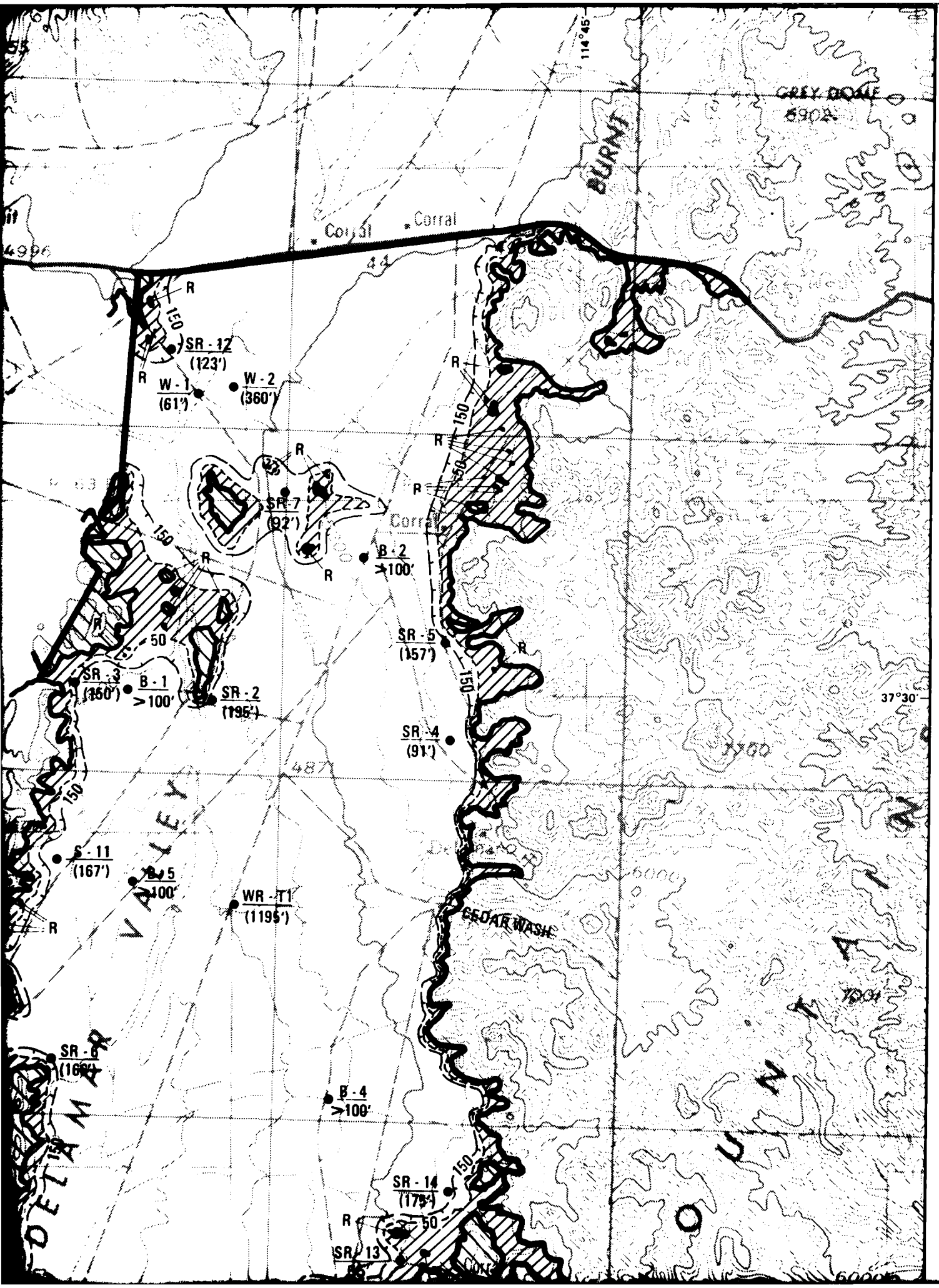
SCALE 1: 125,000

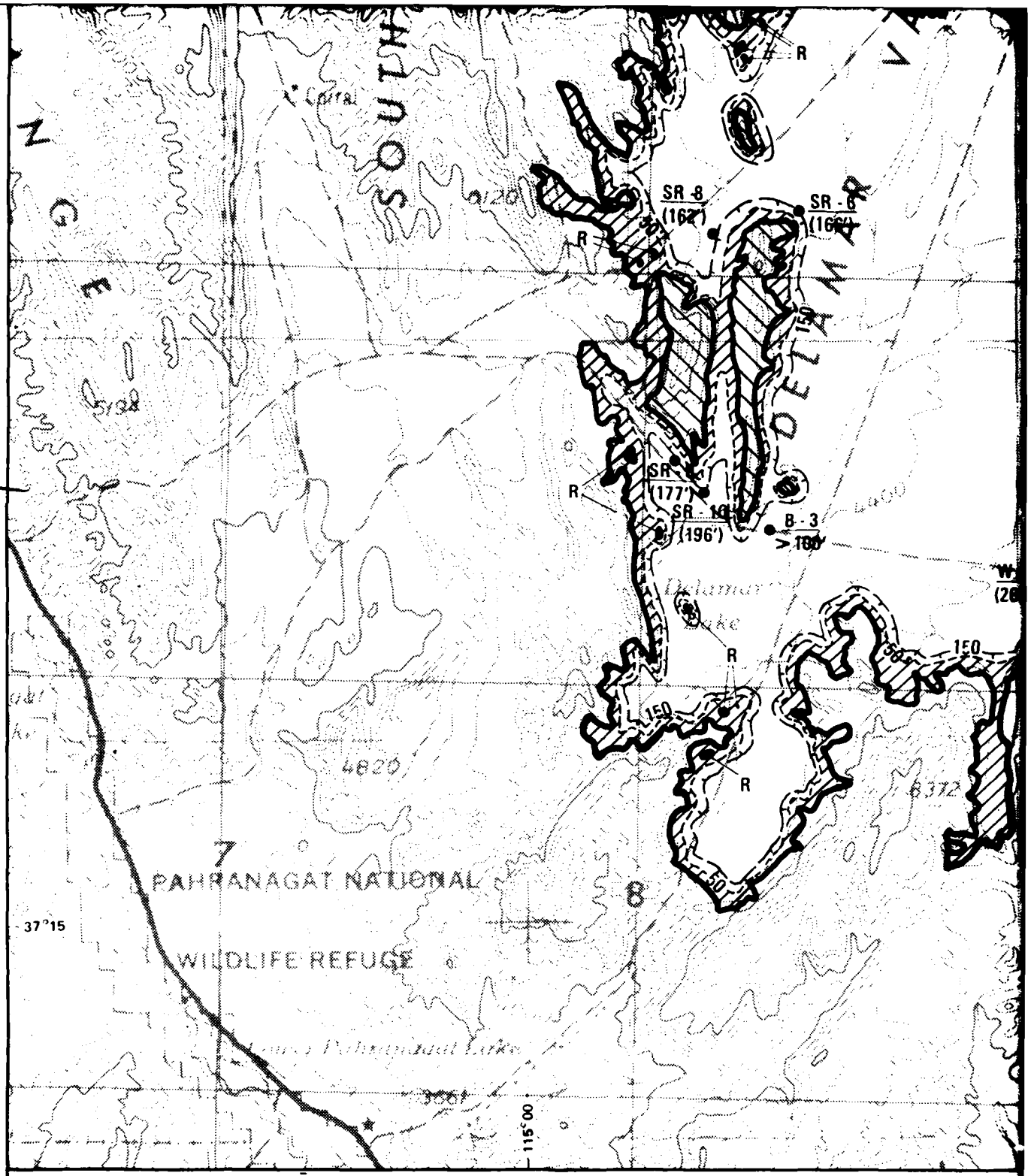


ficial basin-fill units pertain only to the upper several feet of soil.
e to variability of surficial deposits and scale of map presentation,
it descriptions refer to the predominant soil types. Varying amounts
other soil types can be expected within each geologic unit.
e distribution of geologic data stations is presented in Volume II
ing II - 1 - 1 . A tabulation of all station data and generalized description
all geologic units in included in Volume II Section 1.
ology in areas of exposed rock derived from Fugro National Inc.
77, 1978) unpublished data, Tschanz and Pampeyan (1970), and Stewart
Carlson (1978).

24 MAR 81


115°00'
6955
Water
Pahroc Summit
Pass
4996
ROC VALLEY
Water
R
150
SR - 12
(123')
R
W - 1
(61')
W - 2
(360')
150
R
R
50
SR - 3
(350')
B - 1
>100'
SR - 2
(196')
37°30'
150
S - 11
(167')
S - 5
>100'
WR -
(119
R
VALLEY
SOUTH PAHROC RANGE
Corral
SR - 8
(162')
SR - 6
(166')
R
N
G
E
DELTA

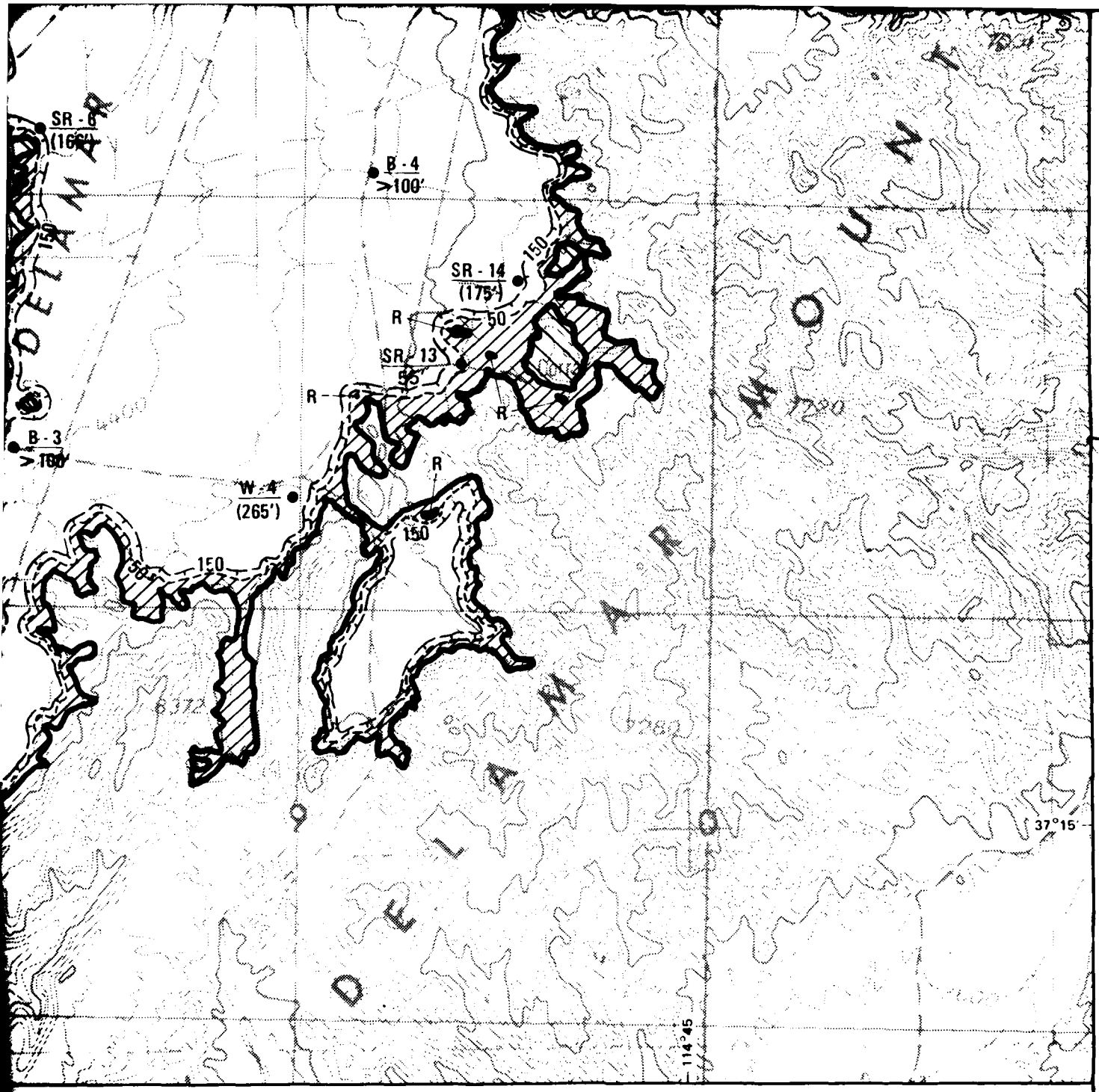

114°45'
GREY DOME
6902
BURNT
Corral
Corral
Corral
SR-12
(123')
W-1
(61')
W-2
(360')
SR-7
(92')
B-2
>100'
SR-5
(157')
SR-3
(150')
B-1
>100'
SR-2
(195')
SR-4
(91')
37°30'
B-11
(167')
B-5
>100'
WR-T1
(1195')
CEDAR WASH
SR-6
(166')
B-4
>100'
SR-14
(175')
SR-13
DETAWAR VALLEY
OUNTAIN
150
50
R



EXPLANATION

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

150 — Contour indicates rock at a depth of approximately 15 rock less than 150 feet (46m).



4

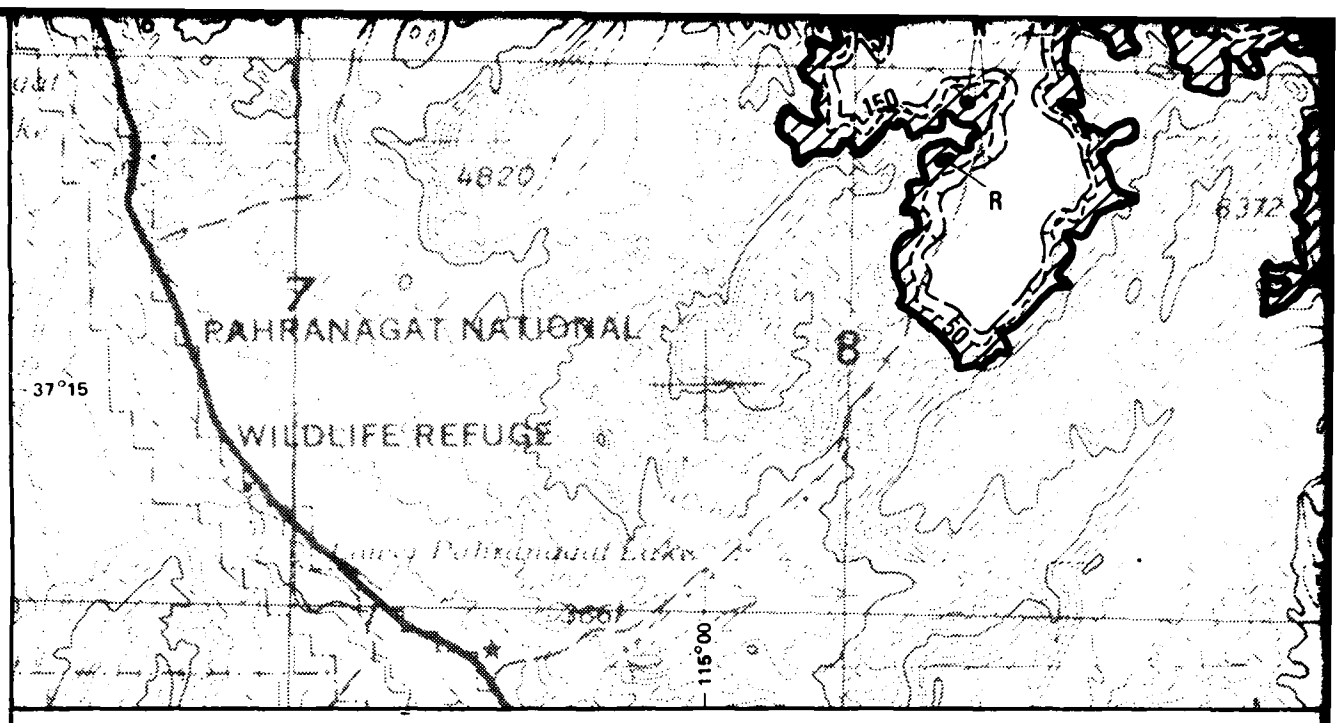
EXPLANATION

k at a depth of approximately 50 feet (15m) - shading indicates
(15m).

k at a depth of approximately 150 feet (46m) - hachuring indicates
(46m).

and basin-fill.

NORTH



EXPLANATION

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

150 — Contour indicates rock at a depth of approximately rock less than 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

B - 2 / 199' — Data Source - Fugro boring (B); seismic refraction line (S); water resources test well

Depth to rock or, when in parentheses, total

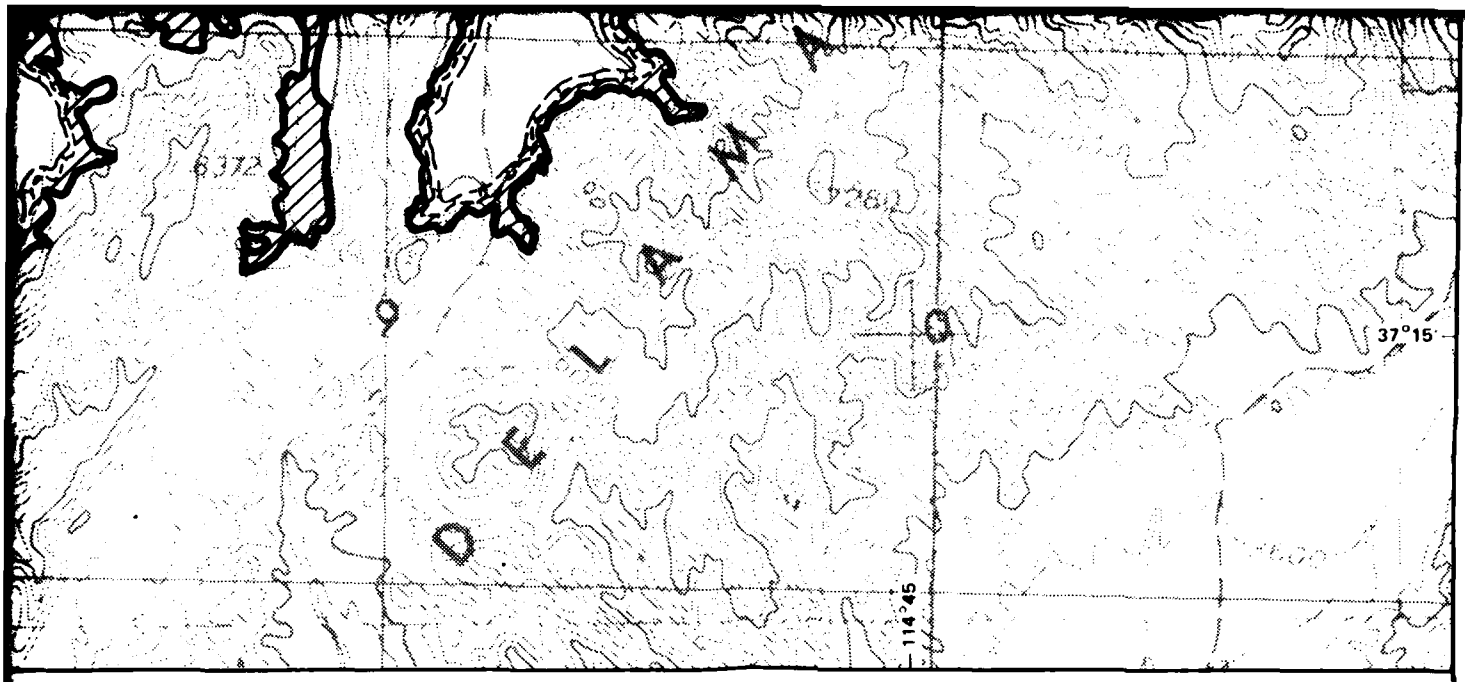
NOTE: The contours are based on geologic interpretation and the limited data points shown on the map. Changes in contour locations can be expected as additional data are obtained.

DEPTH TO ROCK
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

DRAWING 3-3

FUGRO NATIONAL, INC.



EXPLANATION

k at a depth of approximately 50 feet (15m) - shading indicates
(15m).

k at a depth of approximately 150 feet (46m) - hachuring indicates
t (46m).

and basin-fill.

and west).

ed rock.

ed rock too small for shading.

oring (B); seismic refraction line and electrical resistivity sounding (SR); seismic
); water resources test well (WR) or water well (W); Volume II, Table 2-1.

r, when in parentheses, total depth at which rock not encountered.

re based on geologic interpretations
l data points shown on the map. Some
our locations can be expected as
are obtained.

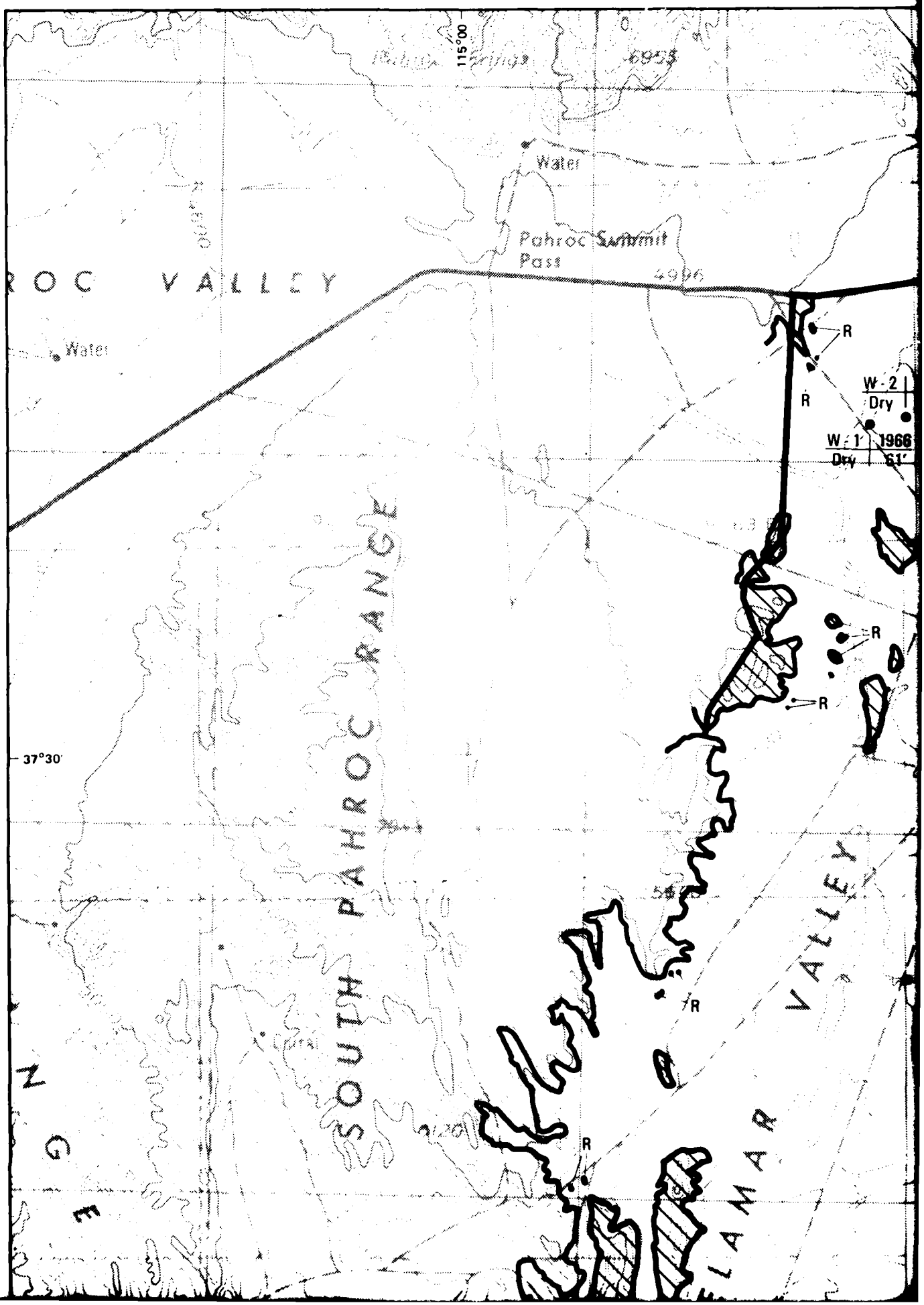
NORTH

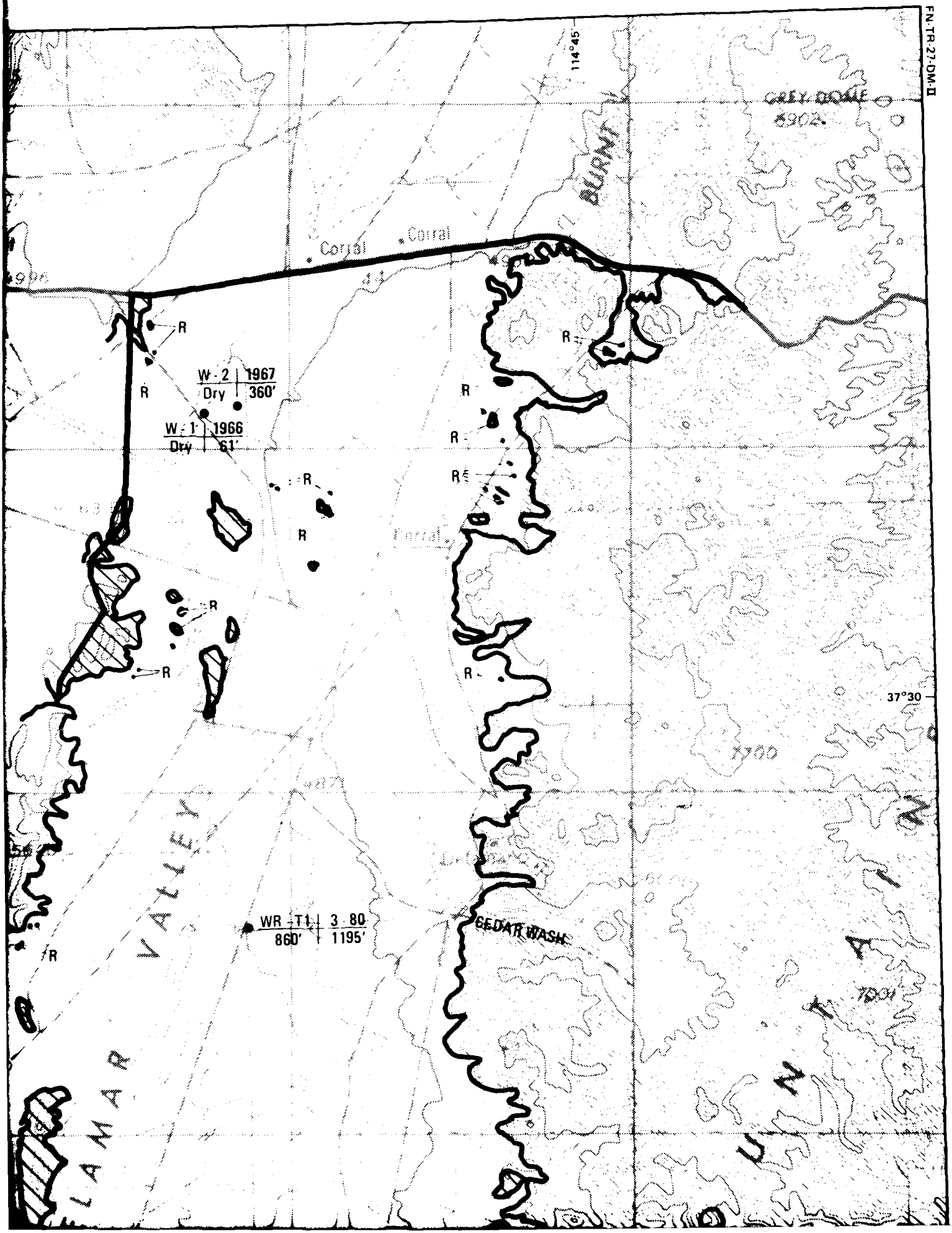
SCALE 1: 125,000

0 2 4
STATUTE MILES

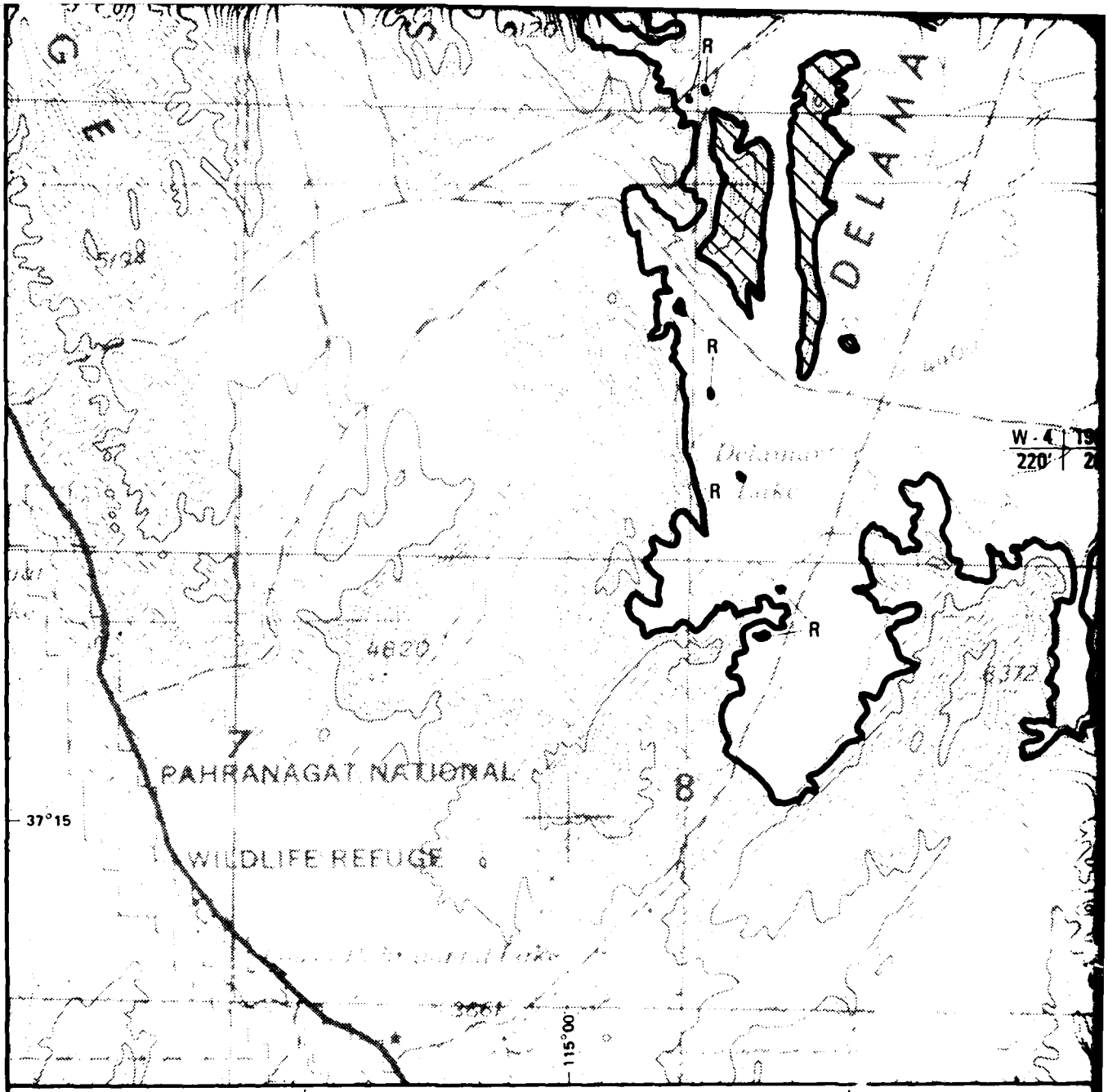
0 2 4
KILOMETERS

24 MAR 81


115°00'
Water
Pahroc Summit
Pass
4996
ROC VALLEY
Water
R
R
W-2
Dry
W-1
Dry
1966
61'
R
R
37°30'
SOUTH PAHROC RANGE
R
R
VALLEY
LAMAR
N
G
E


FN-TR-27-DM-II
114°45
GREY DOME
8902
BURNT
Corral
Corral
Corral
R
W-2 | 1967
Dry | 360'
W-1 | 1966
Dry | 61'
37°30
7900
LAMAR VALLEY
WR-T1 | 3-80
860' | 1195'
CEDAR WASH
UNTAIN
7001

2



EXPLANA

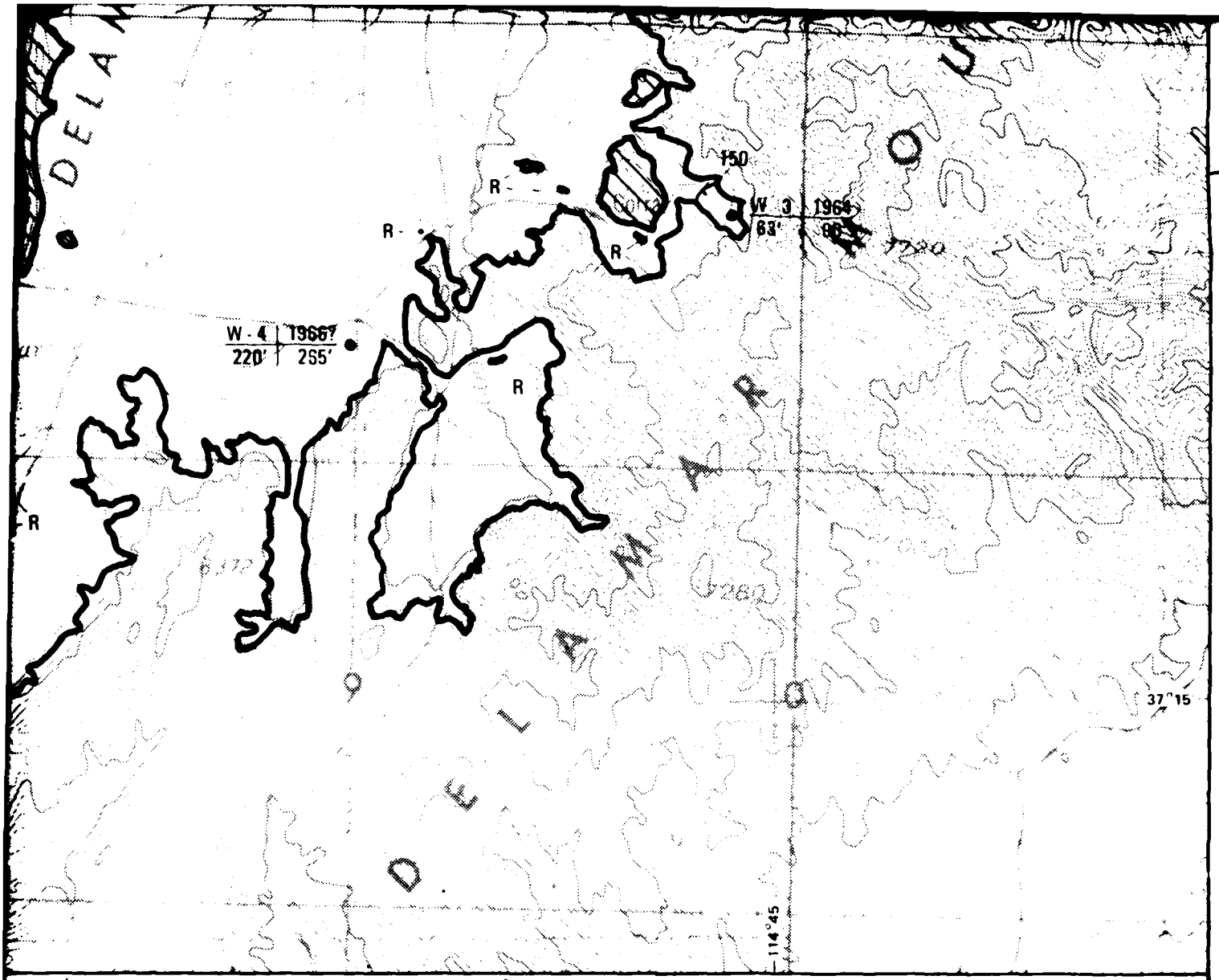
150 — Contour indicates ground water at a depth of approxi less than 150 feet (46m) to ground water.

Absence of contours indicates ground water occurs a borings, and assorted wells indicate depth to ground most of the valley (see Volume I, Section 3.0).

Contact between rock and basin-fill.

Valley borders (north and west).

Areas of isolated exposed rock.



EXPLANATION

ground water at a depth of approximately 150 feet (46m) - hachuring indicates
(46m) to ground water.

urs indicates ground water occurs at depths greater than 150 feet. Fugro National, Inc.
ted wells indicate depth to ground water generally in excess of 400 feet throughout
(see Volume I, Section 3.0).

rock and basin-fill.

rth and west).

exposed rock.

xposed rock too small for shading.

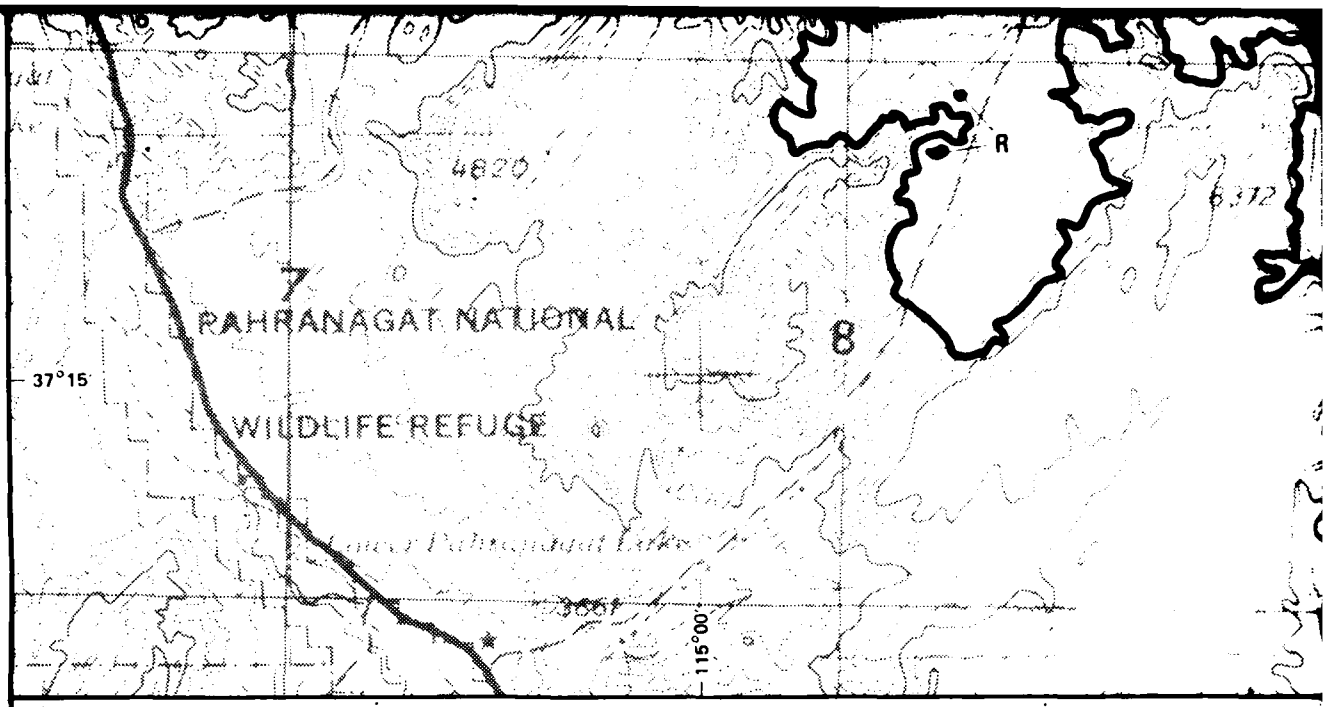
NORTH

SCALE 1: 125,000

0 2 4
STATUTE MILES

0 2 4
KILOMETERS

B



EXPLANA

150 — Contour indicates ground water at a depth of approx less than 150 feet (46m) to ground water.

Absence of contours indicates ground water occurs borings, and assorted wells indicate depth to ground most of the valley (see Volume I, Section 3.0).

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

W2 | 1977 / 75 | 700 — Data Source - Water resources (WR) or published w well (W), see Volume II, Table 2-1.

Depth to water (feet).

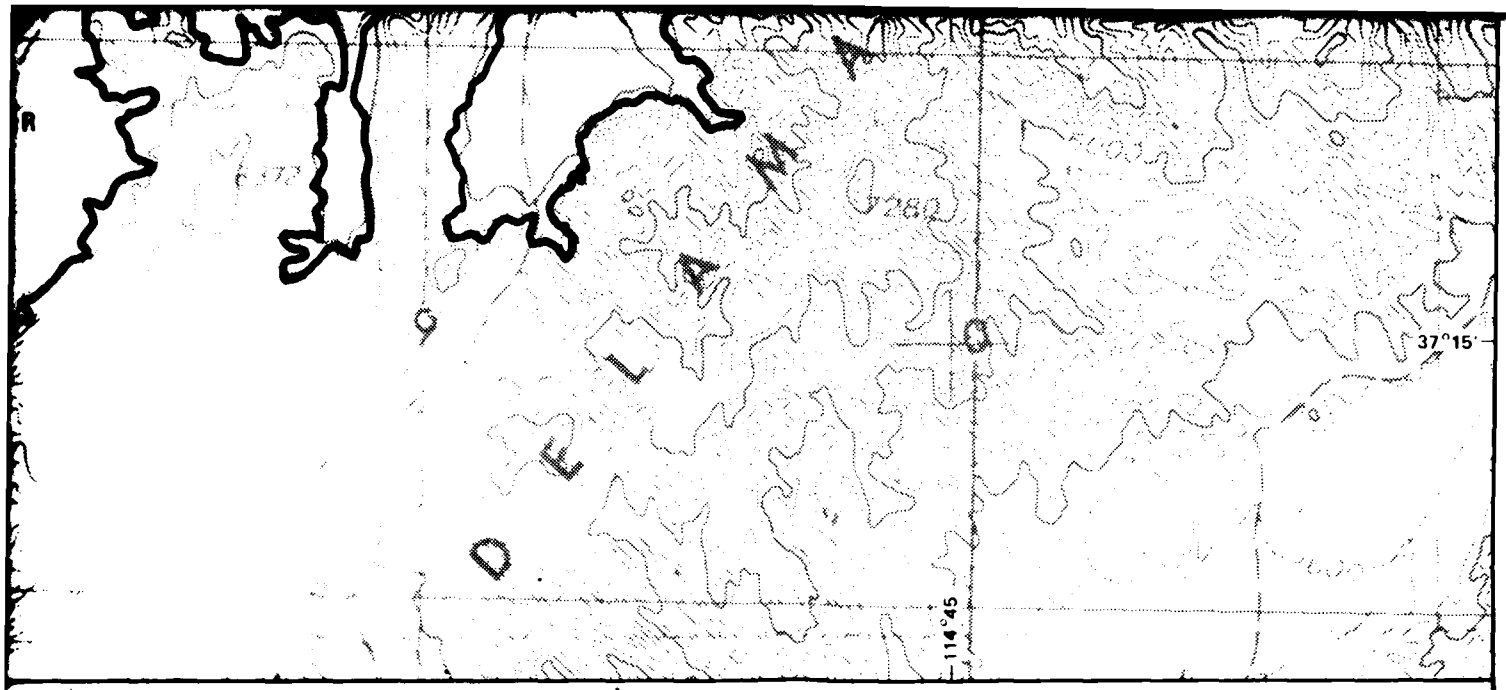
DEPTH TO WATER
DELAMAR VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

DRAWING 3-4

FUGRO NATIONAL, INC.

5



EXPLANATION

ground water at a depth of approximately 150 feet (46m) - hachuring indicates
(46m) to ground water.

rs indicates ground water occurs at depths greater than 150 feet. Fugro National, Inc.
ed wells indicate depth to ground water generally in excess of 400 feet throughout
(see Volume I, Section 3.0).

ock and basin-fill.

rth and west).

xposed rock.

xposed rock too small for shading.

r resources (WR) or published water , see Volume II, Table 2-1.	Year of water level measurement.
et).	Depth of well (feet).

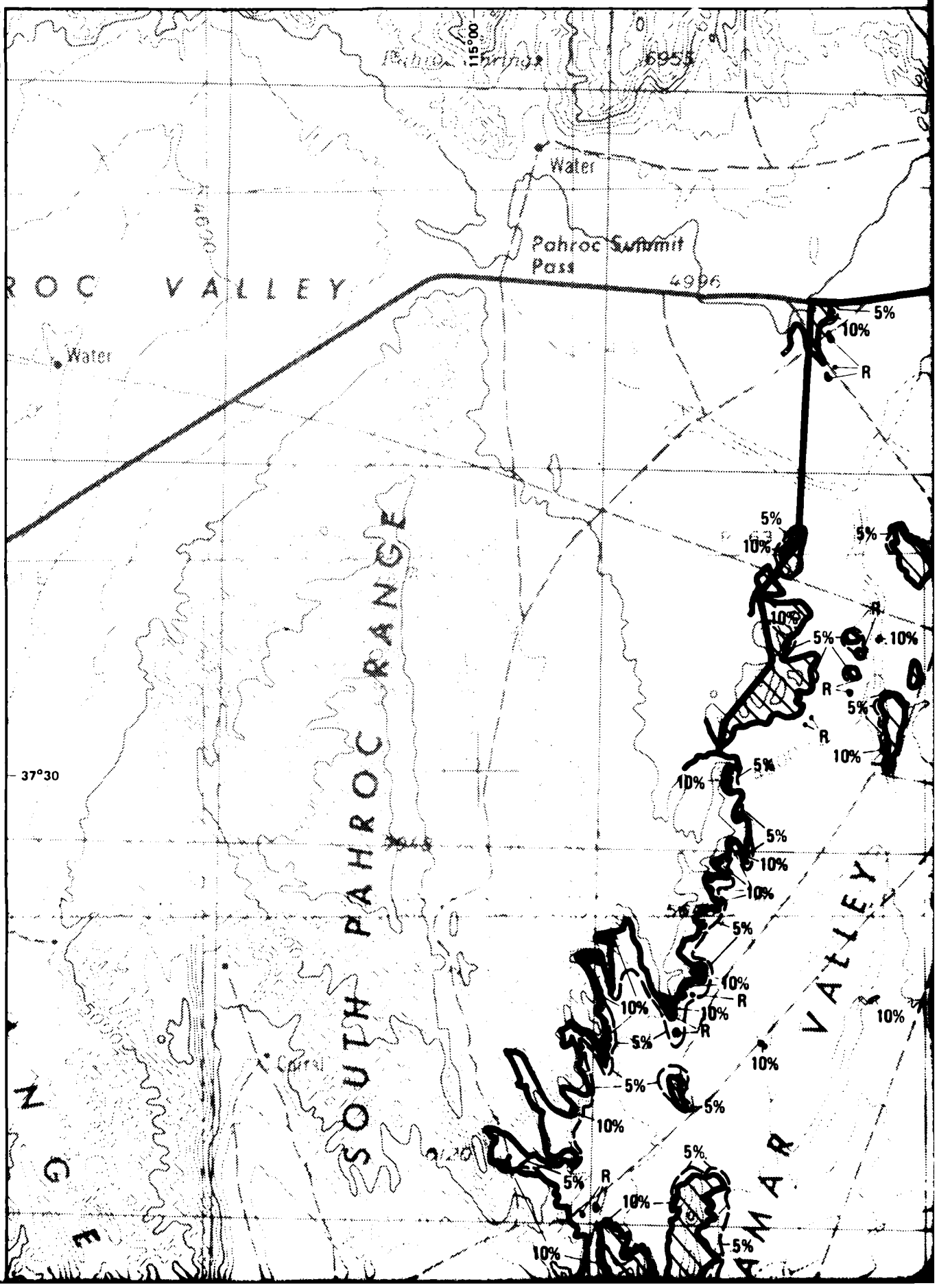
NORTH

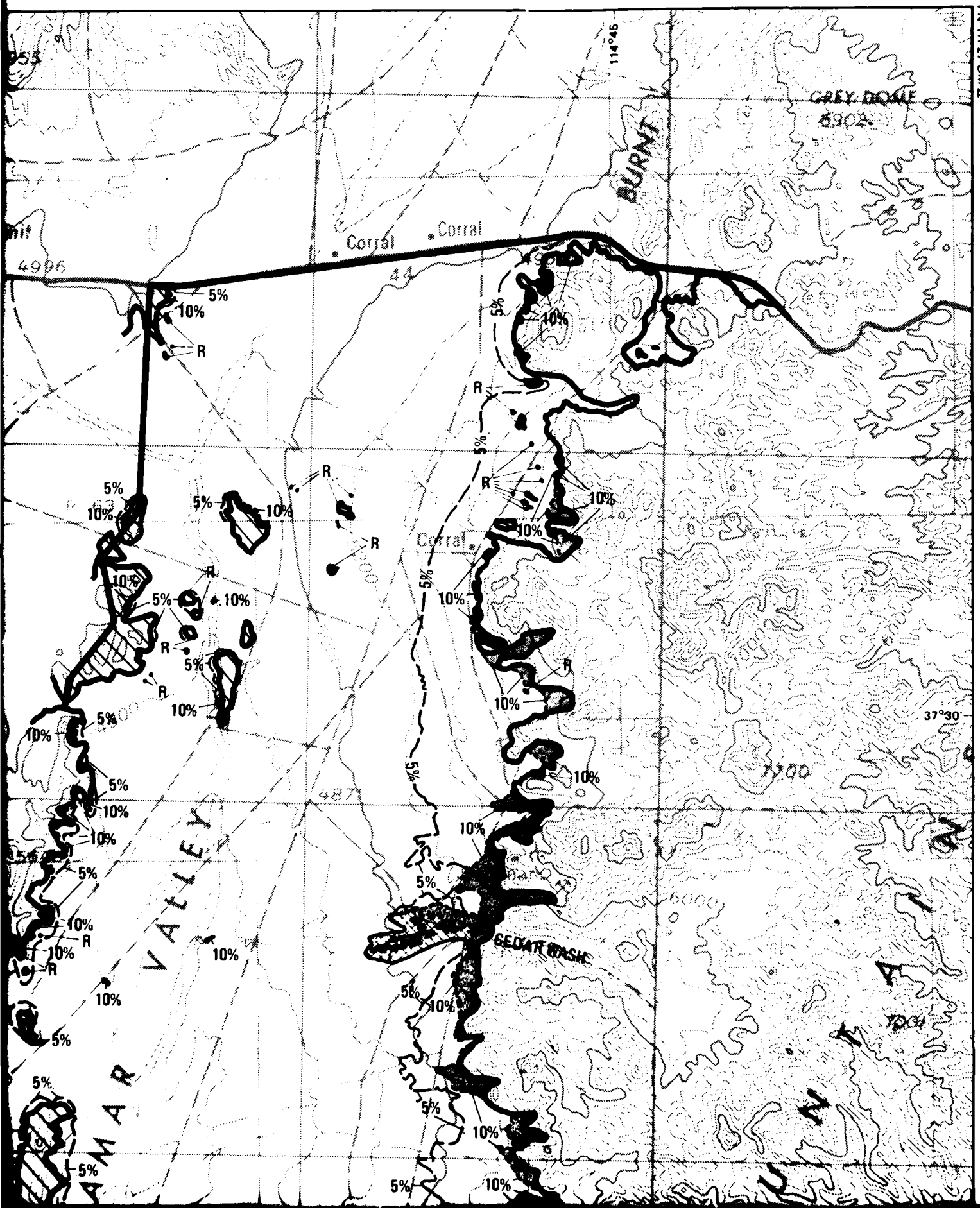
SCALE 1: 125,000

0 2 4
STATUTE MILES

0 2 4
KILOMETERS

24 MAR 81


115°00'
6955
Water
Pahroc Summit
Pass
4996
ROC VALLEY
Water
SOUTH PAHROC RANGE
37°30
AMAR VALLEY
5%
10%
R


114°45'
GREY DOME
BURNT
Corral
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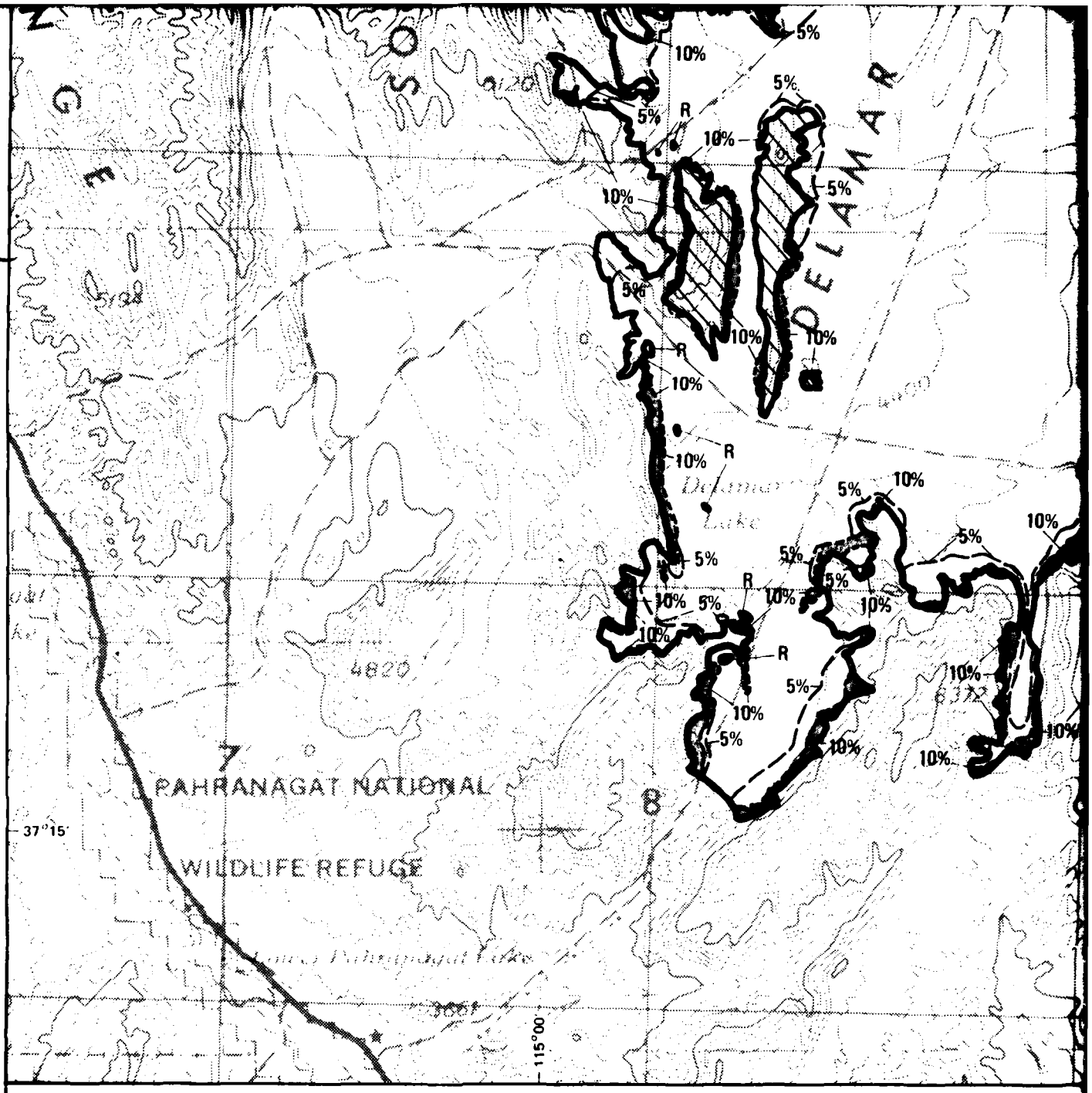
Corral
4996
44
5%
10%
R
37°30'
7700
4871
CEDAR WASH
AMAR VALLEY



EXPLANATION

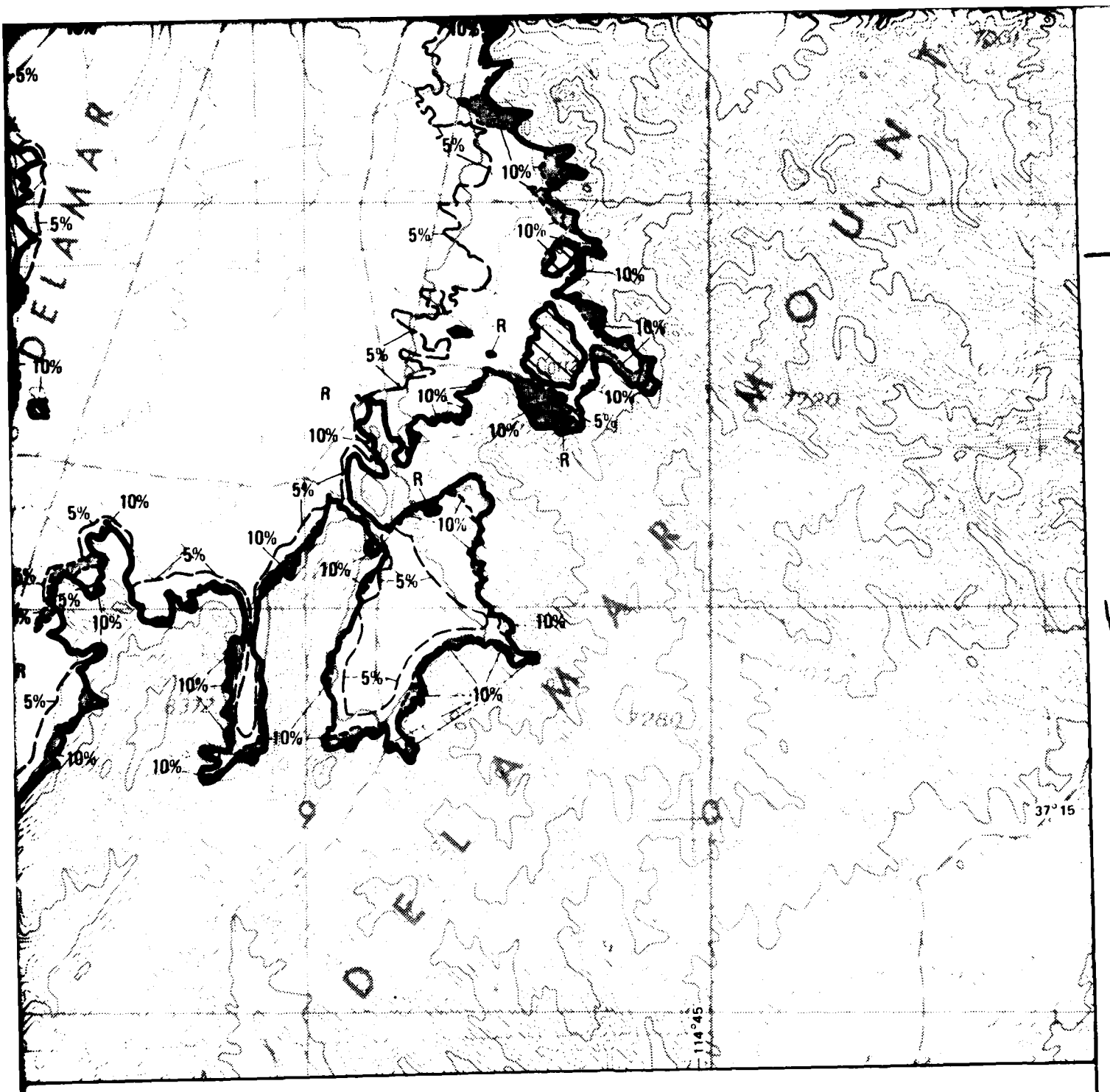
Contact between rock and basin fill

5% Slope line.

10% Slope line.

Valley borders (north and west).

Area excluded, on basis of 10% slo



EXPLANATION

Contact between rock and basin fill.

5% Slope line.

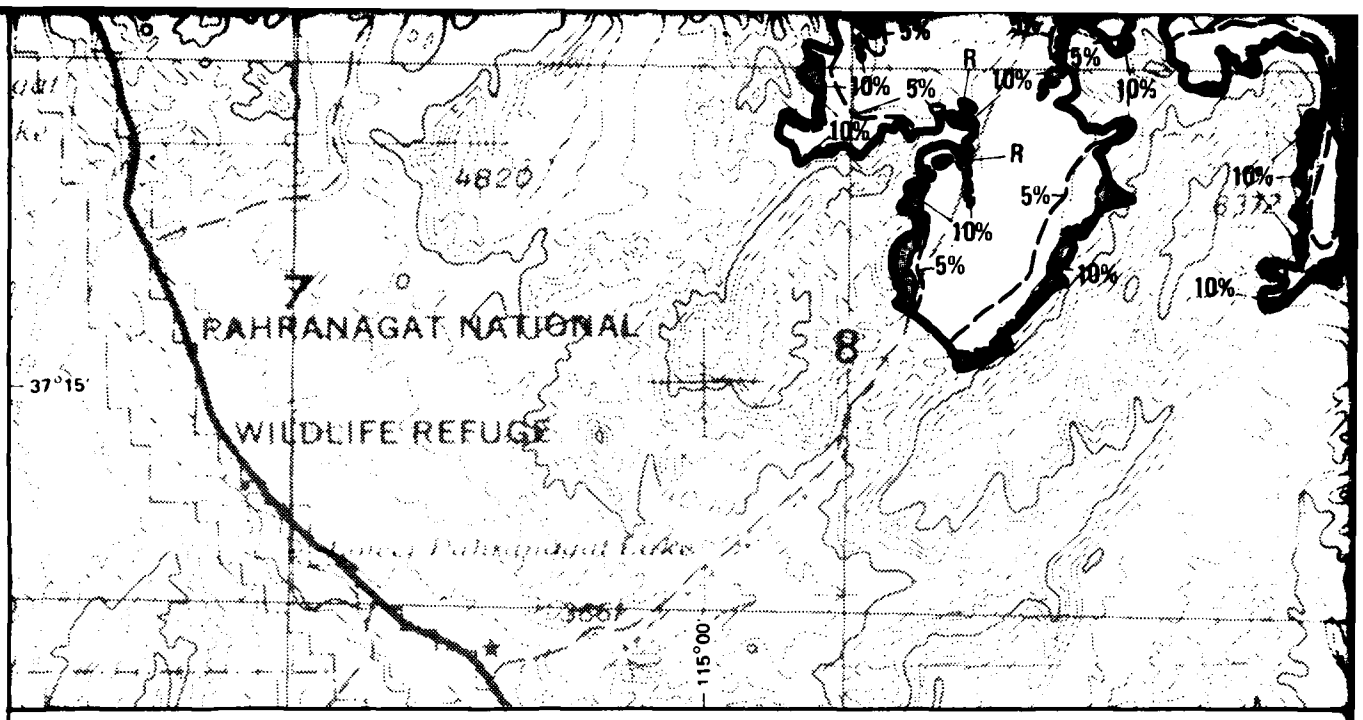
10% Slope line.

Valley borders (north and west).

NORTH

Area excluded, on basis of 10% slopes.

SCALE 1:125,000



EXPLANATIO

Contact between rock and ba

5% Slope line.

10% Slope line.

Valley borders (north and we

Area excluded, on basis of

Terrain exclusion area.

Areas of isolated exposed roc

R Areas of isolated exposed roc

NOTE: Data used in constructing this map are from (2) 1:62,500 USGS topographic maps, and (2 aerial photographs. Due to scale of presen terrain conditions, this map is generalized.

TERRAIN
DELAMAR VALLEY, NEVADA

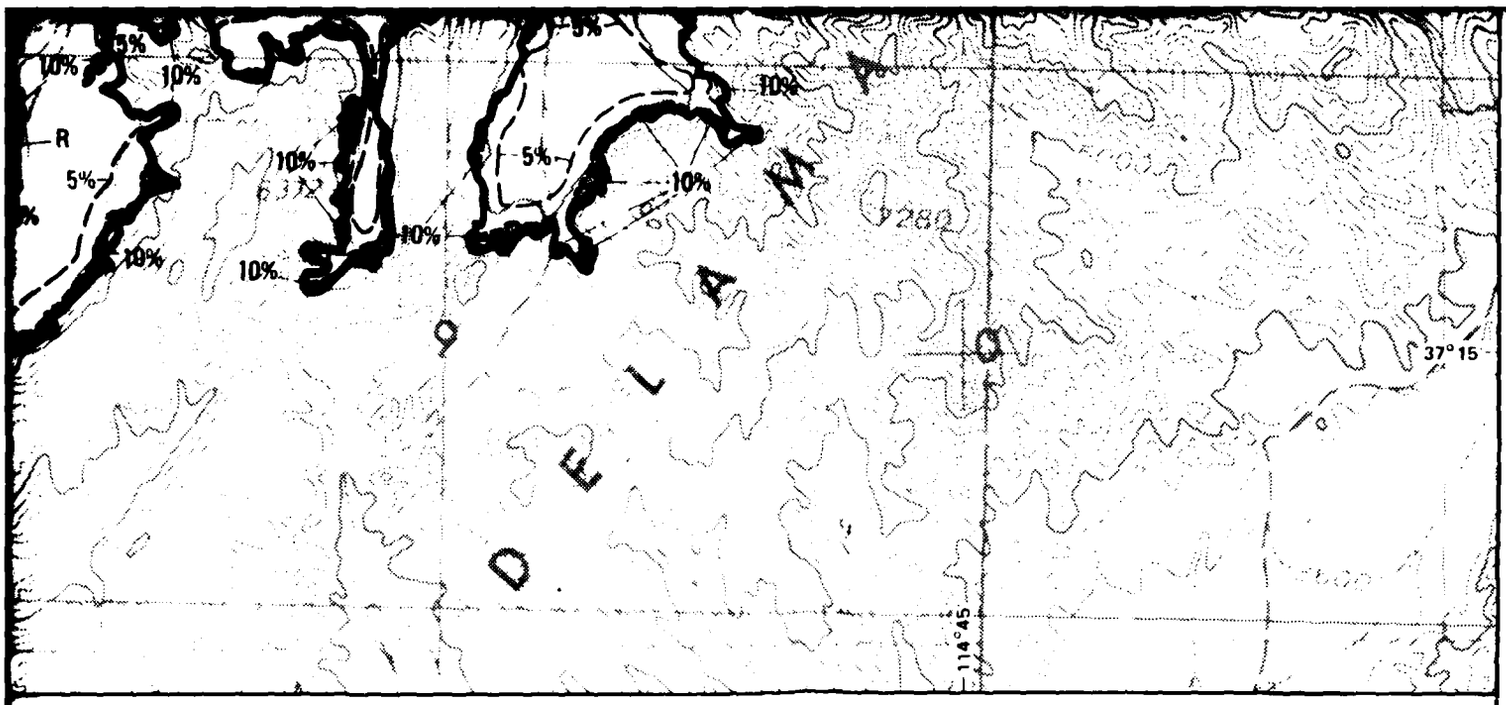
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

DRAWING 3-5

FUGRO NATIONAL, INC.

3

5



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.

Terrain exclusion area.

Areas of isolated exposed rock.

Areas of isolated exposed rock too small for shading.

NORTH

SCALE 1: 125,000

0 2 4

STATUTE MILES

0 2 4

KILOMETERS

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

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Tschanz, C. M., and Pampeyan, E. H., 1970, Geology and mineral deposits of Lincoln County, Nevada Bureau of Mines and Geology Bulletin 73, 187 p.

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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 nor 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 contents 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 seismometer, jug, or pickup.

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 (Ø) - 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 No. 4 (4.75 mm) sieve and retained on 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 <u>S-Wave</u> or <u>transverse wave</u>.

SHEET FLOW - A process in which stormborne 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 colluvialand 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 evaluaton of excavation wall stability.

TRIAXIAL COMPRESSION TEST - A type of test to measure the shear strength of an undisturbed soil sample (ASTM D2850-70). 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.

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.

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	Quantity/Distance:	Eighteen nautical mile exclusion arcs from cities having populations (1970) of 25,000 or more.
		Three nautical mile exclusion arcs from cities having populations (1970) of between 5,000 and 25,000.
	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.
	Economic:	High potential economic resource areas including oil and gas fields, strippable coal, oil shale, uranium deposits, and known geothermal resource areas (KGRA) of sufficient density so as to prohibit use as a siting area.
		Industrial complexes such as active mining areas, tank farms and pipeline complexes of sufficient density so as to prohibit use as a siting area.

EXCLUSION CRITERIA
VERIFICATION STUDIES, NEVADA–UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

TABLE A2-1

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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 shotpoint 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 shotpoints 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.

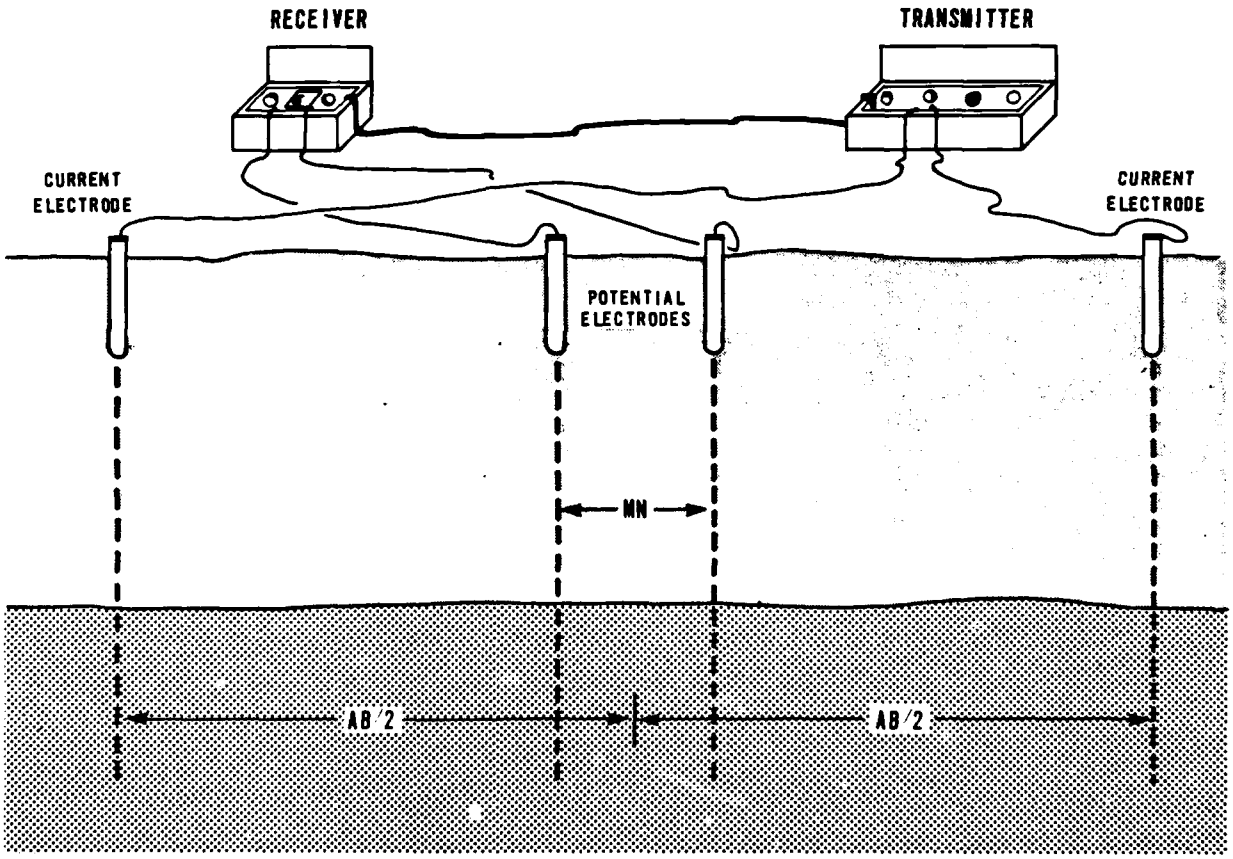
A4.2.2 Field Procedures

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
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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
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 feet (30 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 100' (9.1 to 30.5 m)	-	Pitcher or drive - samples at 10' 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), 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.

A5.1.3 Logging

All soils were classified in the field by the procedures outlined in Section A5.4, "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 A5.4, "Field Visual Soil Classification," and the description was entered on the logs. Section A5.4 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, 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 14 feet (4.2 m), and lengths ranged from 10 to 16 feet (3.0 to 4.9 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 practicable.

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, 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 km) 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) friction cone (cone end resistance capacity of 15 tons [13,608 kg] and 4-1/2-ton [4082 kg] limit on the friction sleeve). All operating controls, recorder, cables, and ancillary 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 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 in/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.

A5.4 FIELD VISUAL SOIL CLASSIFICATION

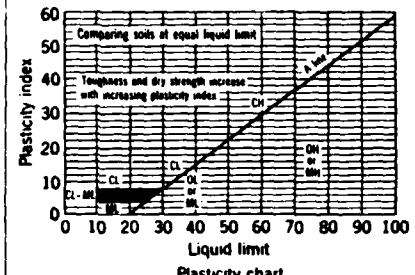
A5.4.1 General

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 procedures of ASTM D 2488-69, Description of Soils (Visual-Manual Procedure). The ASTM procedure is based on the Unified Soil Classification System (see Table A5-1). It describes several visual and/or 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.

A5.4.2 Soil Description

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

Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)				Group Symbols[b]	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[a] (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	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. Use grain size curve in identifying the fractions as given under field identification
			Predominantly one size or a range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
		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. Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	Not meeting all gradation requirements for *GW*
			Plastic fines (for identification procedures, see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures		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; 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		$C_U = \frac{D_{60}}{D_{10}}$ 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; Atterberg limits below "A" line with *PI* greater than 7
			Plastic fines (for identification procedures, see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures		
Fine-grained soils More than half of material is *smaller* than No. 200 sieve size (The No. 200 sieve size is about the smallest particle visible to naked eye)	Identification Procedures on Fraction Smaller than No. 40 Sieve Size						
		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)			
	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	
		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	
	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	
		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
DELAMAR VALLEY, NEVADA

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TABLE A5-1

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Coarse-Grained Soils	Fine-Grained Soils
USCS Name and Symbol	USCS Name and Symbol
Color	Color

Coarse-Grained Soils	Fine-Grained Soils
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 inches (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 number 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

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

Consistency	Shear Strength (ksf)	Shear Strength (KN/m^2)	Field Guide
Very Soft	<0.25	<12.0	Sample with height equal to twice the diameter, sags under own weight

Consistency	Shear Strength (ksf)	Shear Strength (KN/m^2)	Field Guide
Soft	0.25-0.50	12.0-23.9	Can be squeezed between thumb and forefinger
Firm	0.50-1.00	23.0-42.9	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	9.58-191.5	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

Stage	Gravelly Soils	Nongravelly Soils
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.

A5.5 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

A5.6 DATA ANALYSIS AND INTERPRETATION

A5.6.1 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.

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 strength 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 - 4.0
Trench and Test Pit Logs	Section II - 5.0
Surficial Sample Logs	Section II - 6.0
Laboratory Test Results	Section II - 7.0
Cone Penetrometer Test Results	Section II - 8.0

A5.6.2 Soil Characteristics

A5.6.2.1 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, A5.6.2.2 and A5.6.2.3, explain the data analyses and interpretation used in preparing the above tables.

A5.6.2.2 Surface Soils

In order to define the characteristics of the surficial soils, data from trenches, test pits, borings, surficial soil samples, cone penetrometer tests, 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 System, 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 for the vertical shelter basing mode. 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.

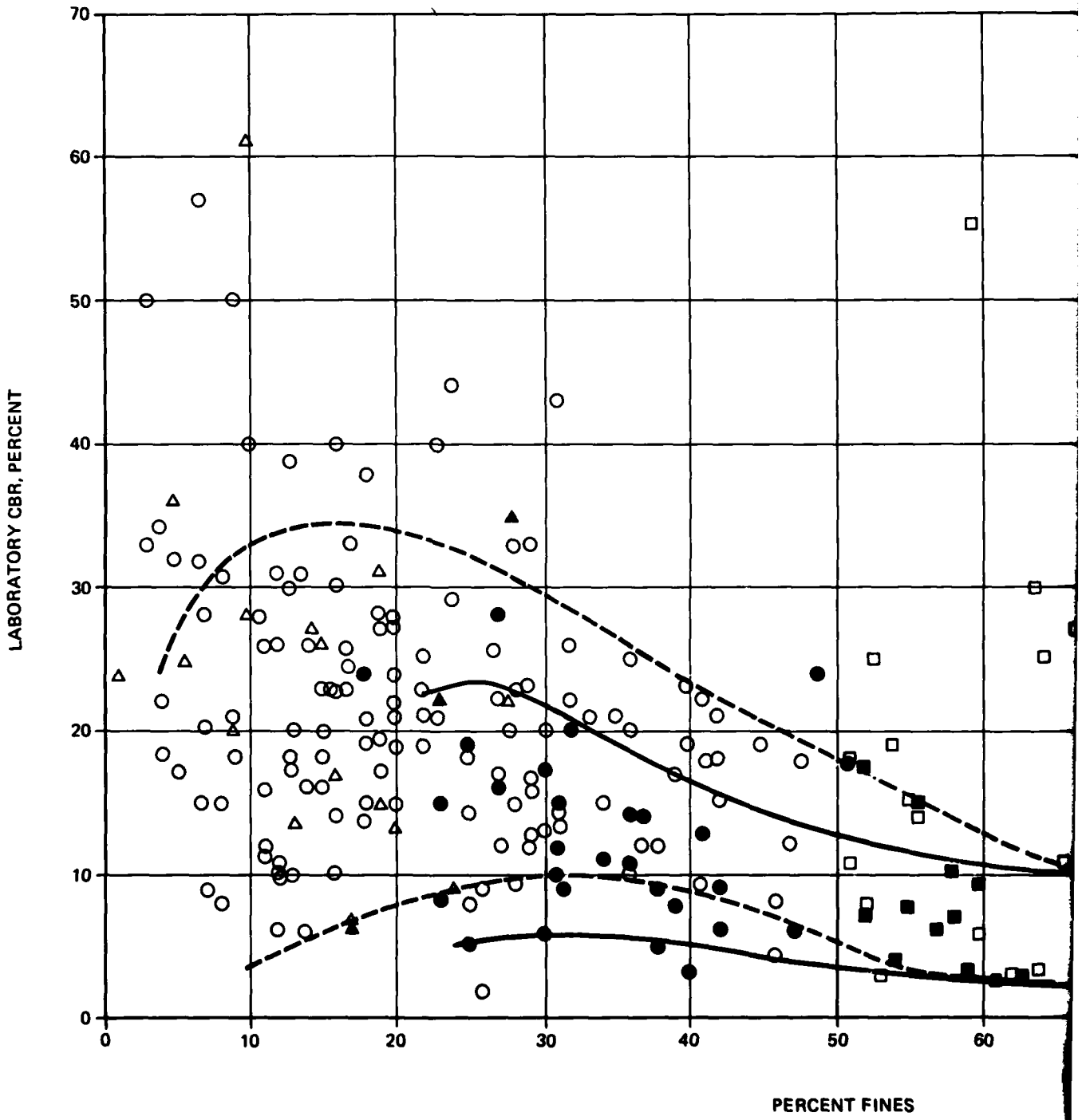
i. CBR Characteristics: California Bearing Ratio, which is commonly used for road design, is dependent on soil type. During Verification studies, a limited number of CBR tests were performed on several soil types which were representative of the surficial soils in the various Verification sites. Based 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.

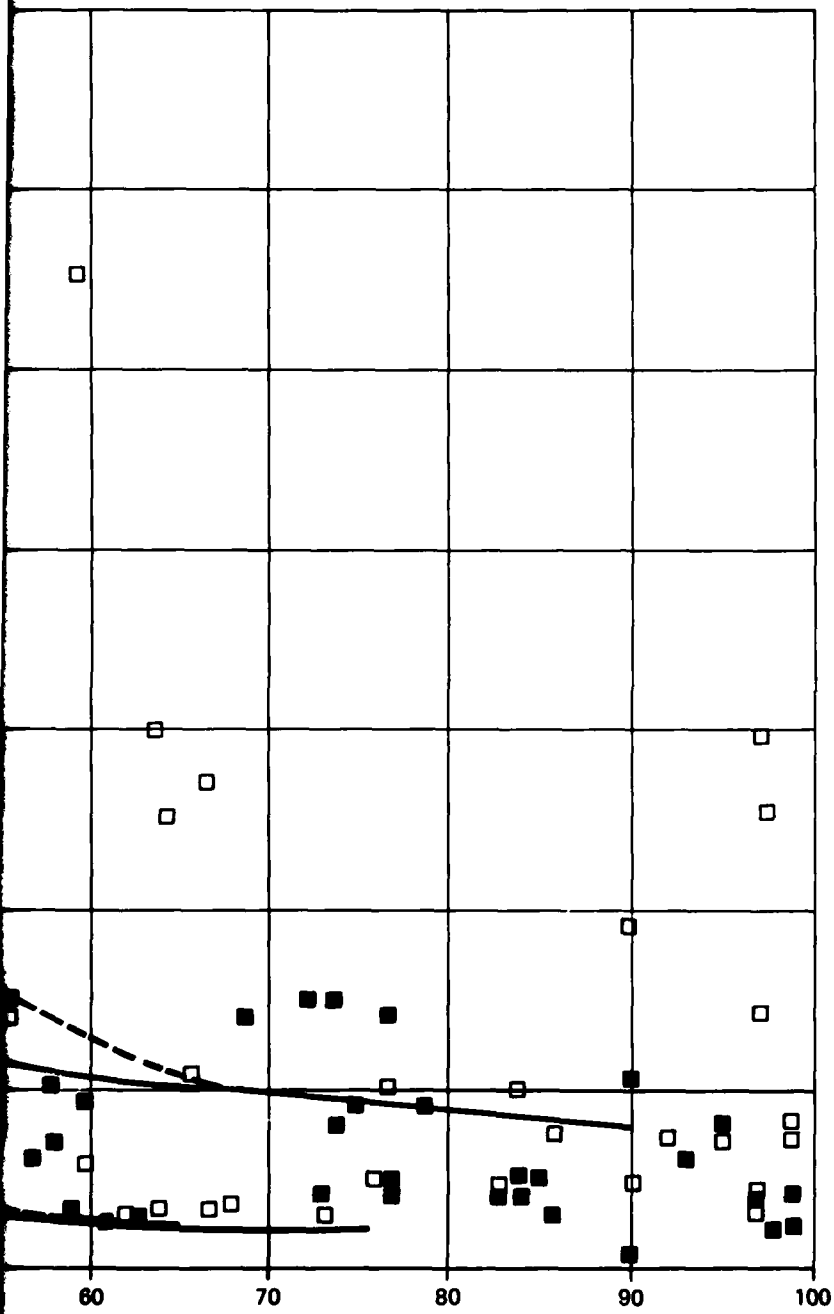
ii. Other Characteristics: These characteristics pertain to frost susceptibility, drainage, and volume change potential. They were estimated based on the physical properties of the soils, results of consolidation tests (for volume change potential), published literature, and our experience. Following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

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.


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

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

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

FIGURE
A5-1

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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 corresponds 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 judgment, 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 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, (SPT = 10 to 30 blows per foot) 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. In this case, an upper limit of cone resistance, equivalent to midrange of "medium dense" category (relative compaction), 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, 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.

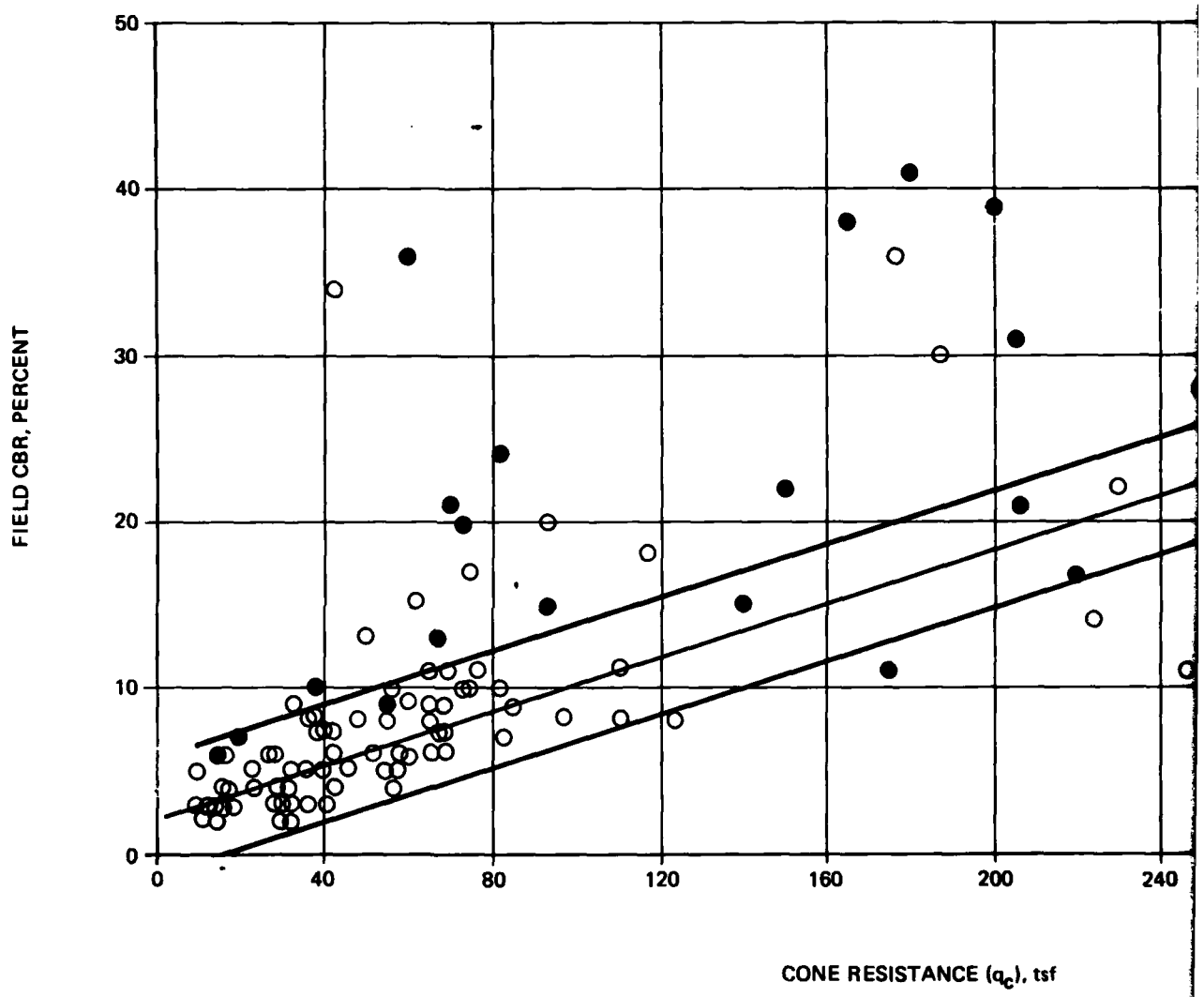
As a result of the preceding four approaches, the following criteria for defining low-strength surficial soil were established:

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."

A5.6.2.3 Subsurface Soils

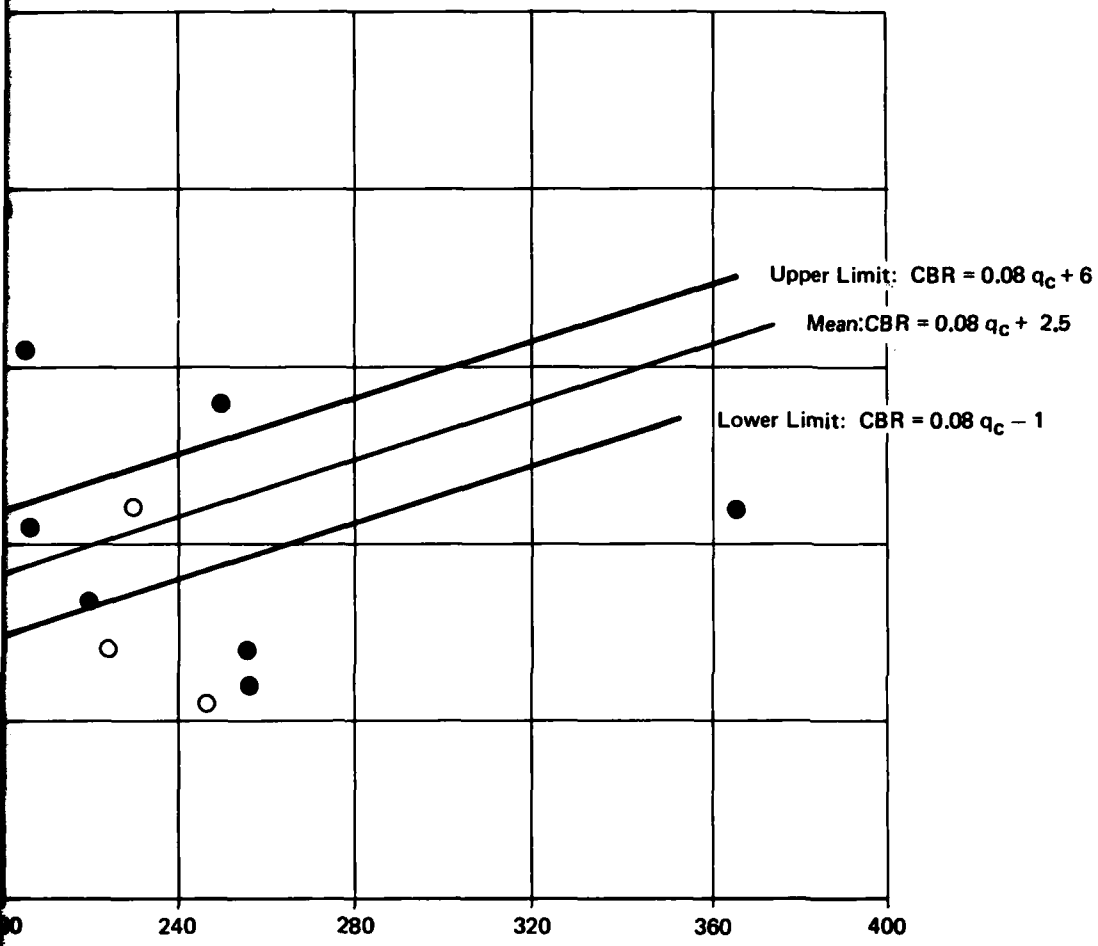
Characteristics of the subsurface soils were developed using data from seismic refraction surveys, borings, trenches, test pits, and laboratory tests.



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.



q_c), tsf

g, Lake, Stone Cabin,

d includes 85% non-

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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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 tests: dry density, moisture content, grain-size distribution, liquid limit, plasticity index, 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.

DAT
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