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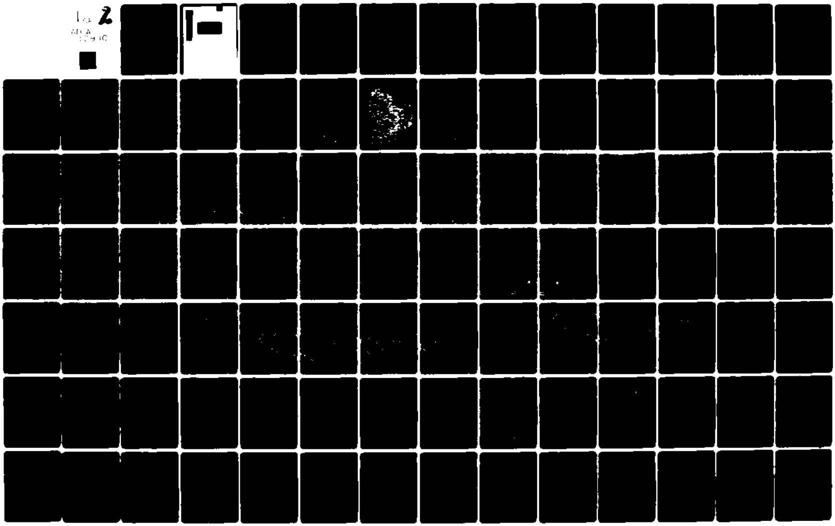

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MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

VERIFICATION STUDY - CAVE 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:

Ertec Western, Inc.
3777 Long Beach Boulevard
Long Beach, California 90807

26 October 1981

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

This report presents the results of the geotechnical studies which were conducted in Cave Valley Nevada. Included are basin-fill characteristics, construction considerations, geologic setting, soils, terrain, and water.

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FOREWORD

This report was prepared for the U.S. Department of the Air Force, Ballistic Missile Office (BMO), in compliance with Contract No. F04704-80-C-0006, CDRL Item 004A6. It contains an evaluation of the suitability of Cave 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 conducted in Cave Valley, Nevada, during 1979 and 1980. The work was done as part of Ertec Western, Inc.'s (formerly Fugro National, Inc.) Verification studies which have two major objectives:

1. Verify and refine boundaries of areas which are geotechnically suitable for the 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 is composed of 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 type of activity in Volume II.

The Verification program is one of the final phases of a site-selection process which started in 1977. The objective of the site-selection process, which includes Screening, Characterization, Ranking, and Verification, 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. 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. Characterization used field studies as well as published information to evaluate the geotechnical suitability of the various regions.

Characterization studies emphasized collection of information to describe geologic units with respect to construction of the MX basing options. Following Screening and Characterization, Ranking, using geotechnical data, classified the seven regions based on relative construction costs for the various basing modes. 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.

The Verification program, while using the results of previous investigations and published information relies mainly on field investigative techniques. The investigative techniques being employed during Verification studies are summarized in Table 1-1.

During these investigations, information on construction properties of the geologic units was obtained. However, special emphasis is given to refining the boundaries of the geotechnically suitable areas which were originally drawn during the Screening studies.

Follow-up studies, such as Layout, will then superimpose cultural, environmental, and site-specific geotechnical constraints on the suitable areas to determine the final sites of the various system components.

OBJECTIVES →	**VERIFICATION OF SUITABLE A**	
DATA FOR EVALUATIONS →	TERRAIN PARAMETERS	GEOLOGIC HAZARD
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

SUITABLE AREA FOR MX DEPLOYMENT

ZARD

ing

lts and

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
- Monitoring wells
- 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

GEO PR

Seismic re

- Compressio
- Layering of

Electri

- Electrical o
- Layering of

2

CHARACTERISTICS OF BASIN FILL

PRELIMINARY
CONSIDER
RECOMM

F

GEOPHYSICAL PROPERTIES

<u>Seismic refraction surveys</u>

- Compressional wave velocities
- Layering of soil

<u>Electrical resistivity surveys</u>

- Electrical conductivity of soils
- Layering of soil

ROAD DESIGN DATA

<u>Trenches and test pits</u>

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

<u>Cone penetrometer tests</u>

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

<u>Laboratory tests</u>

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

<u>Existing data</u>

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

EXCAVATABILITY AND STABILITY

<u>Borings</u>

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

<u>Trenches and test pits</u>

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

<u>Laboratory tests</u>

- Physical properties
- Engineering properties

<u>Geologic mapping</u>

- Distribution of geologic units

<u>Seismic refraction surveys</u>

- Excavatability

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ASIN FILL

PRELIMINARY GEOTECHNICAL CONSIDERATIONS AND RECOMMENDATIONS

AD DESIGN DATA

EXCAVATABILITY AND STABILITY

Trenches and test pits

- tification of soil types
- itu soil density and moisture

ne penetrometer tests

- itu soil strength
- ckness of low strength ficial soil

Laboratory tests

- sical properties
- paction and CBR data
- tability of soils for use oad subgrade, subbase base

Existing data

- tability of soils for use oad subgrade, subbase, base
- avior of compacted soils

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

4

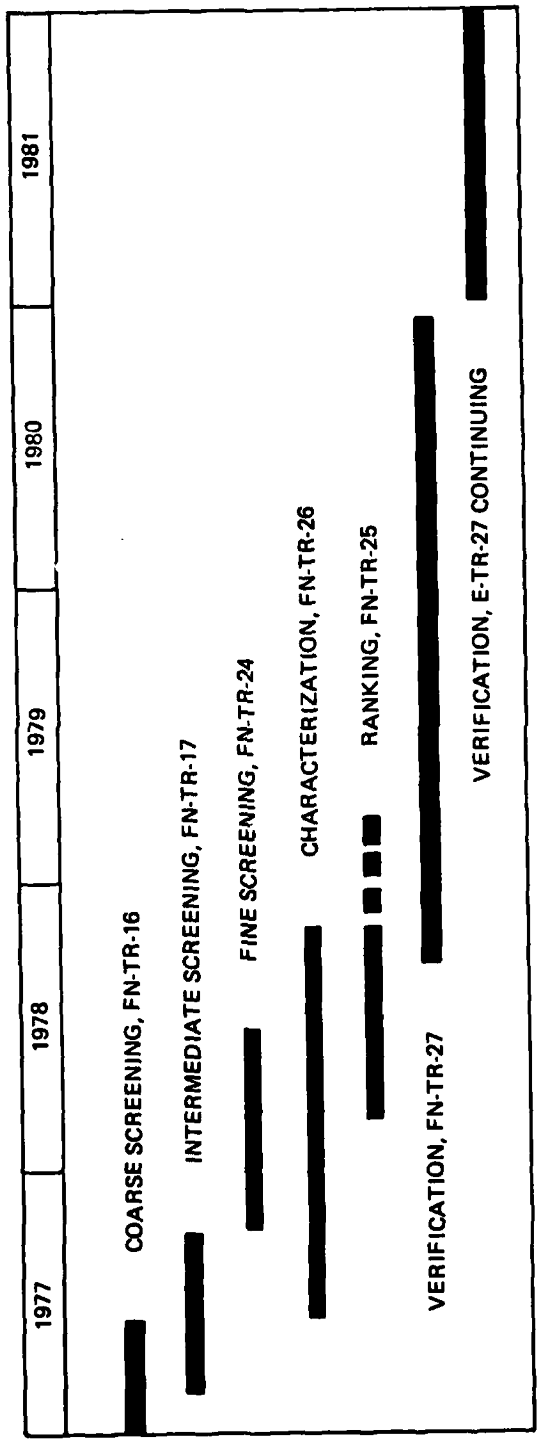
Figure 1-1 shows the site-selection schedule through Verification and identifies the technical report for each element in the process. The areas for which reports have been issued on the Verification studies are shown in Figure 1-2, and the presently defined geotechnically suitable areas for the Nevada-Utah siting region are shown in Drawing 1-1.

1.2 SCOPE OF STUDY

The field work in Cave Valley was completed in 1980. Table 1-2 lists the types and number of field activities that were performed in Cave Valley. Investigation techniques are discussed in the Appendix.

Access to public lands in Cave Valley was arranged through the Ely, Nevada, district office of the Bureau of Land Management (BLM). At their request, all field activities were performed along existing roads or trails to minimize site disturbance. Archaeological and environmental surveys were performed at each proposed activity location. Activity locations were relocated where potential environmental or archaeological conflicts were identified. In some cases, these restrictions prevented distributing activities in an optimum pattern for analysis of geotechnical conditions.

The number of field activities performed during this investigation established a relatively small data base for evaluating such a large area, especially in view of its complex geology and frequent soil variations. Nevertheless, care has been taken to



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SUMMARY OF SITE–
SELECTION SCHEDULE

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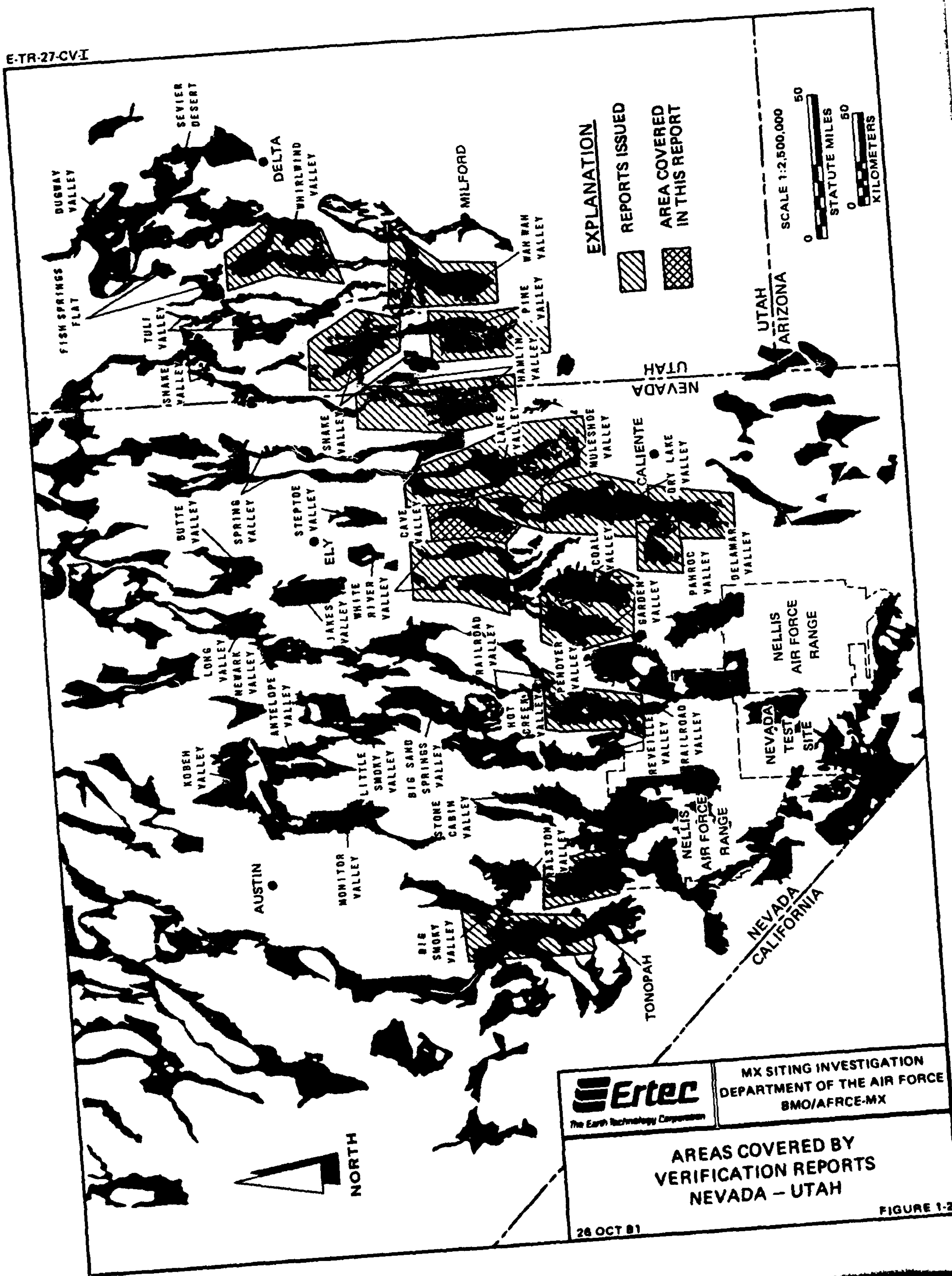
FIGURE 1-1



AREAS COVERED BY VERIFICATION REPORTS NEVADA – UTAH

FIGURE 1-2

GEOLOGY AND GEOPHYSICS–FIELD ACTIVITIES

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geologic mapping stations	56
Shallow refraction	10
Electrical Resistivity	10

ENGINEERING–FIELD ACTIVITIES

ACTIVITY	NO.	NOMINAL DEPTH - FEET (METERS)
Borings	4	95-102 (29-31)
Trenches	6	14 (4)
	1	2 (1)
Test pits	7	5 (2)
	2	2-3 (1)
Surficial soil samples	5	2 (1)
CPT Soundings	20	3-71 (1-22)

ENGINEERING–LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	61
Specific gravity	5
Sieve analysis	47
Hydrometer	2
Atterberg limits	23
Consolidation	1
Unconfined compression	3
Triaxial compression	3
Direct shear	2
Compaction	4
CBR	4
Chemical analysis	5

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DEPARTMENT OF THE AIR FORCE
BMO/AFRCE-MX

SCOPE OF ACTIVITIES
CAVE VALLEY, NEVADA

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TABLE 1-2

optimize the information that could be obtained within specified cost and time constraints of the project.

1.3 DISCUSSION OF ANALYSIS TECHNIQUES

1.3.1 Determination of Suitable Area

The determination of suitable area is based on the exclusion criteria given in Appendix Section 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, those areas where the depth to rock is estimated to be less than 50 and 150 feet (15 and 46 m) below the surface are outlined by contours (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 data from wells listed in Table II-3-1 (Volume II). Data compiled in Table II-3-1 came from ground-water monitoring wells constructed specifically for the Verification program, 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 a well represents the depth to the first, shallow, water-bearing zone, not the static water level. Static levels can be higher than first-encountered water depths since many valleys contain artesian aquifers for which the static water level is above the aquifer. The well data are plotted on a map and used to define the 50- and 150-foot (15- and 46-m) depth-to-water contours.

c. Terrain: The terrain map (Drawing 3-5) was compiled to show areas unsuitable for either vertical or horizontal shelters due to either high surface slopes or frequent deep drainage incisions (criteria are described in Appendix Table A2-1). The interpretation of terrain exclusions is based on a combination of field- and office-derived data. Field data include measurements of typical drainage incision depths. On-site investigations frequently result in the 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 consist 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 by photogeologic interpretation (1:25,000 scale photos) and field reconnaissance. These faults are primarily Quaternary age but some late Tertiary faults may also be included. Generally, those within alluvial deposits are of Quaternary age. The faults shown within rocks in the mountain blocks or at the mountain-valley contact are of unknown age but are most certainly of late Tertiary and/or Quaternary age and have been active under the present tectonic regime. The state geologic maps show numerous other faults within the rocks of the mountain blocks and some of these also may have been active under the present tectonic regime. Since they are not within the siting areas, they have not been studied. The published maps also show numerous inferred faults buried under the alluvium along the mountain-valley contacts. These faults are commonly verified by geophysical studies and may represent earthquake hazards. Since they have no surface expression, they cannot be verified by the reconnaissance methods employed in this study nor are they shown on the geology map.

1.3.2 Determination of Basin-Fill Characteristics

In addition to the primary objective of refining the boundaries of the suitable area, 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 photographs, field mapping, and information from trenches, test pits, and surficial soil samples.

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

The results of laboratory tests on samples from borings, trenches, and test pits and data from seismic refraction lines were used to estimate physical and engineering properties of the soils to a depth of 20 feet (6 m). The data are limited since only four borings, seven trenches, nine test pits, and 10 seismic refraction lines were available. One of the seven trenches and two of the nine test pits were less than 3 feet (1 m) deep because the backhoe excavation capacity was exceeded when hard cementation and/or cobbles were encountered. There may be soil conditions in the upper 20 feet (6 m) that were not encountered by these 30 data points. The number of data points available for description of the surficial soils was increased to 55 by using five surficial soil samples and 20 Cone Penetrometer Test (CPT) soundings, which were located at common locations.

The soil parameters between a depth of 20 and 160 feet (6 and 49 m) are based on data obtained from only four borings. The spacing between borings ranged from 4 to 10 miles (6 to 16 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 a depth of at least 150 feet (46 m), which is the depth of interest for the vertical shelter basing mode.

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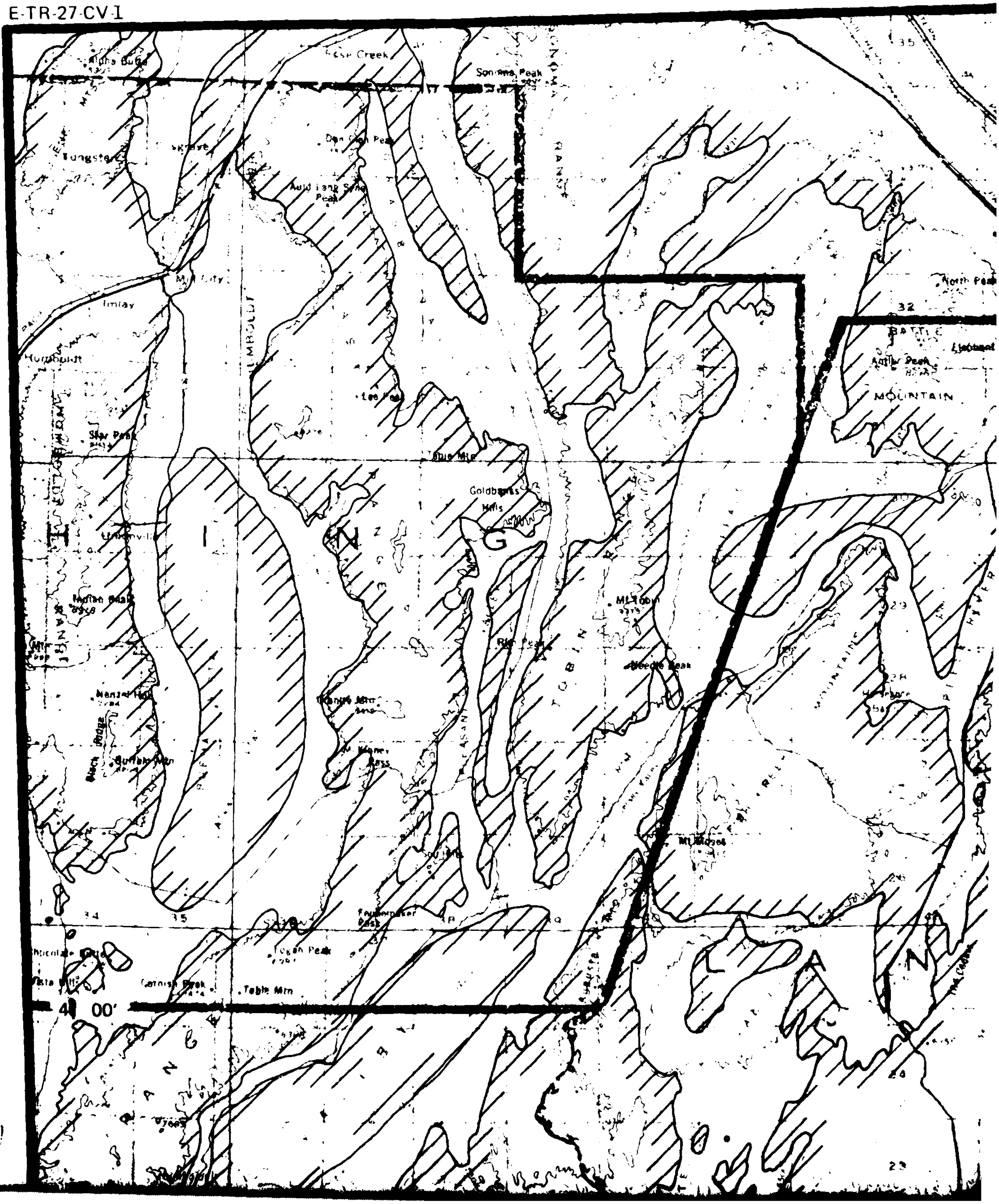

Rose Creek
Sonoma Peak
Tungsten
Imlay
Humboldt
Star Peak
Unionville
Indian Peak
Buffalo Mtn
Auld Lang Syne Peak
Lee Peak
Table Mtn
Goldbanks Hills
Mt Tobin
Needle Peak
Mt Moses
North Peak
Antler Peak
MOUNTAIN
TOBIN
Table Mtn
Tobin Peak
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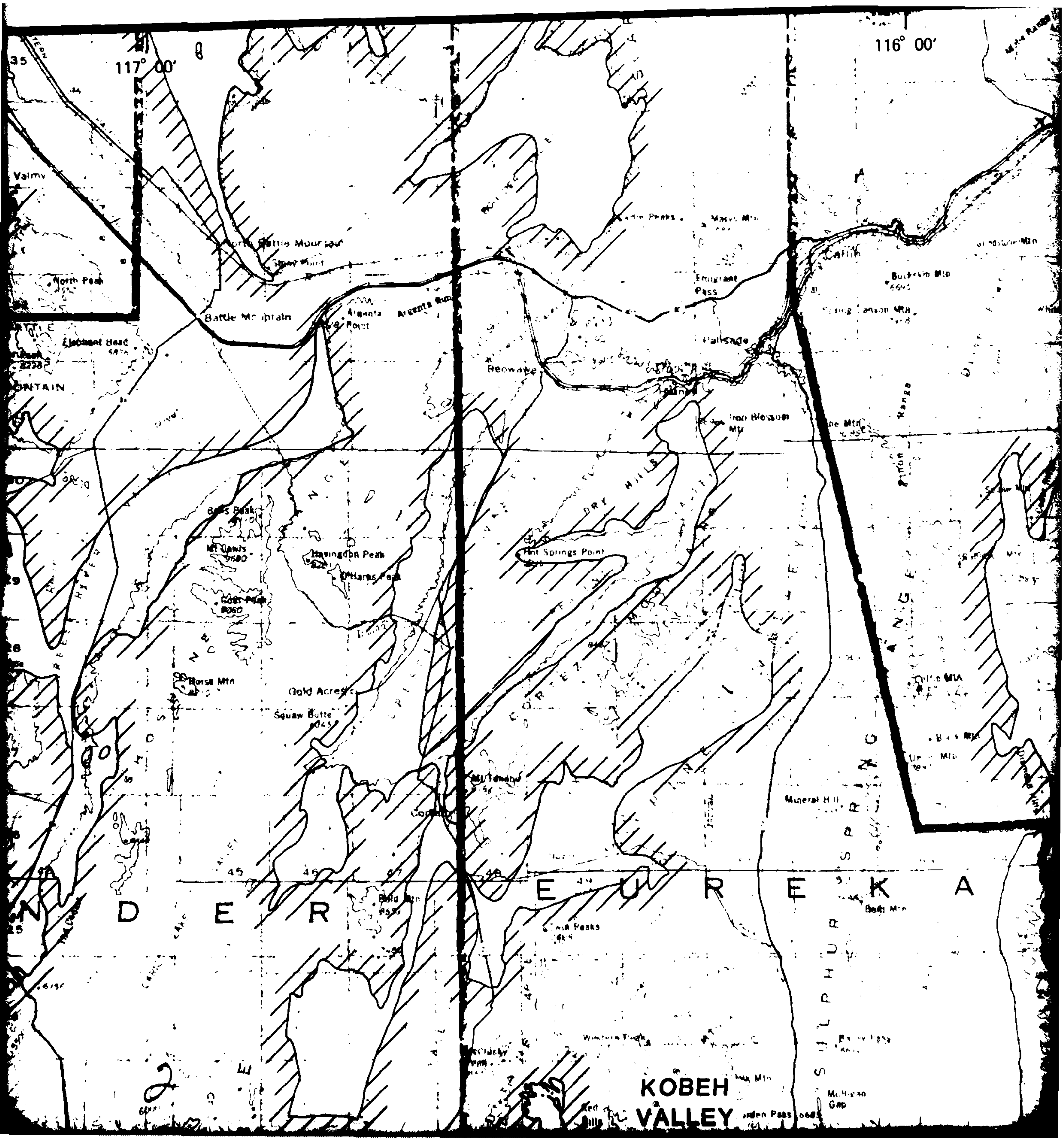

117° 00'
116° 00'
Valmy
North Peak
North Battle Mountain
Stony Point
Battle Mountain
Argenta
Argenta Point
Elephant Head
Emigrant Pass
Palisade
Beowawe
Carlin
Buckskin Mtn
Spring Canyon Mtn
Iron Blossom Mtn
DRY HILLS
Hot Springs Point
Bells Peak
Mt Lewis
9680
Harrington Peak
O'Haras Peak
Granite Peak
8060
Horse Mtn
Gold Acres
Squaw Butte
Mt Tenabo
Cortez
CORTEZ
Mineral Hill
Coffee Mtn
Black Mtn
Union Mtn
Bald Mtn
Twin Peaks
Roberts Creek Mtn
Willow Mtn
Red Hills
Garden Pass
Mulligan Gap
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45
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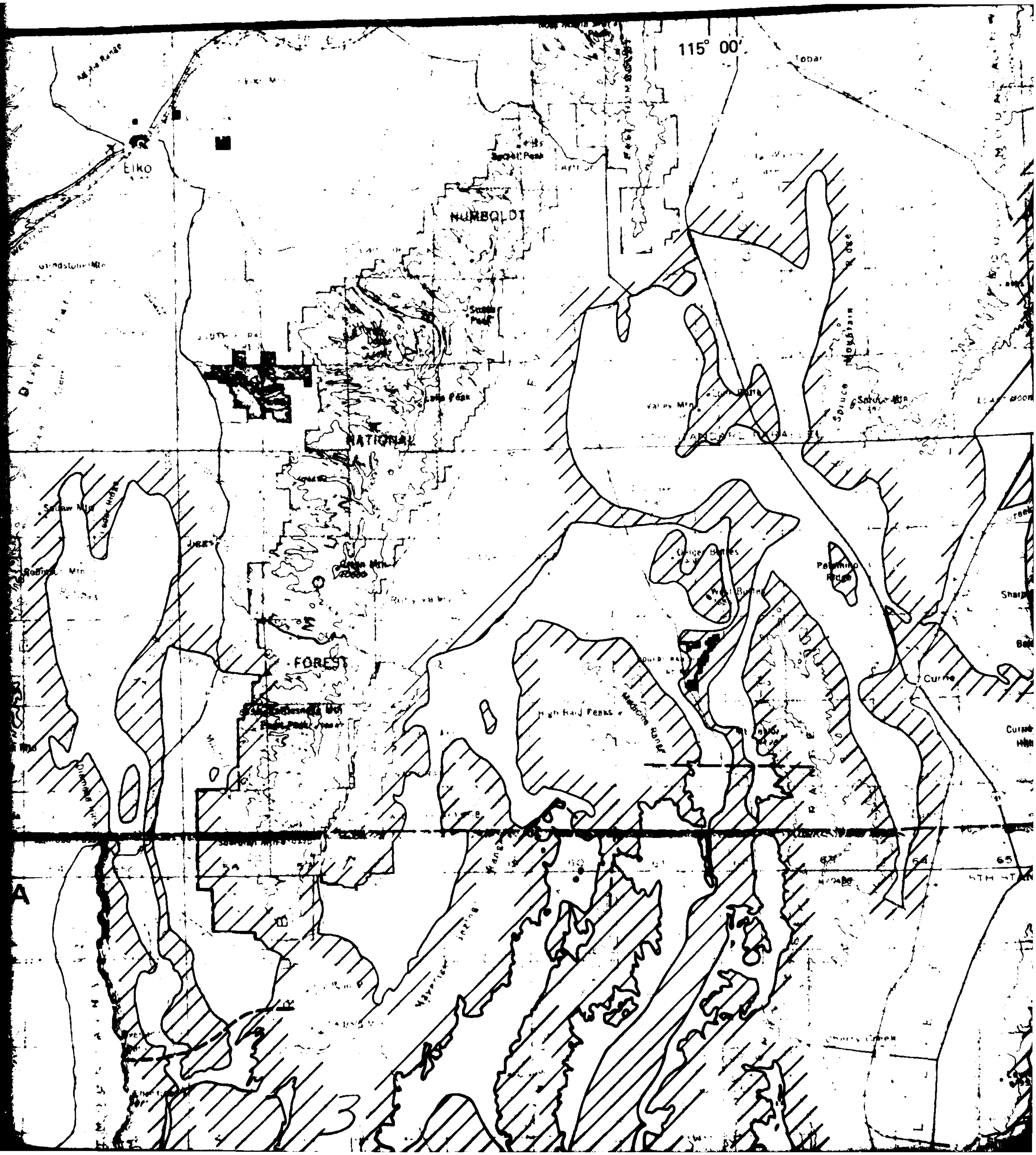
48
49
SULPHUR SPRING



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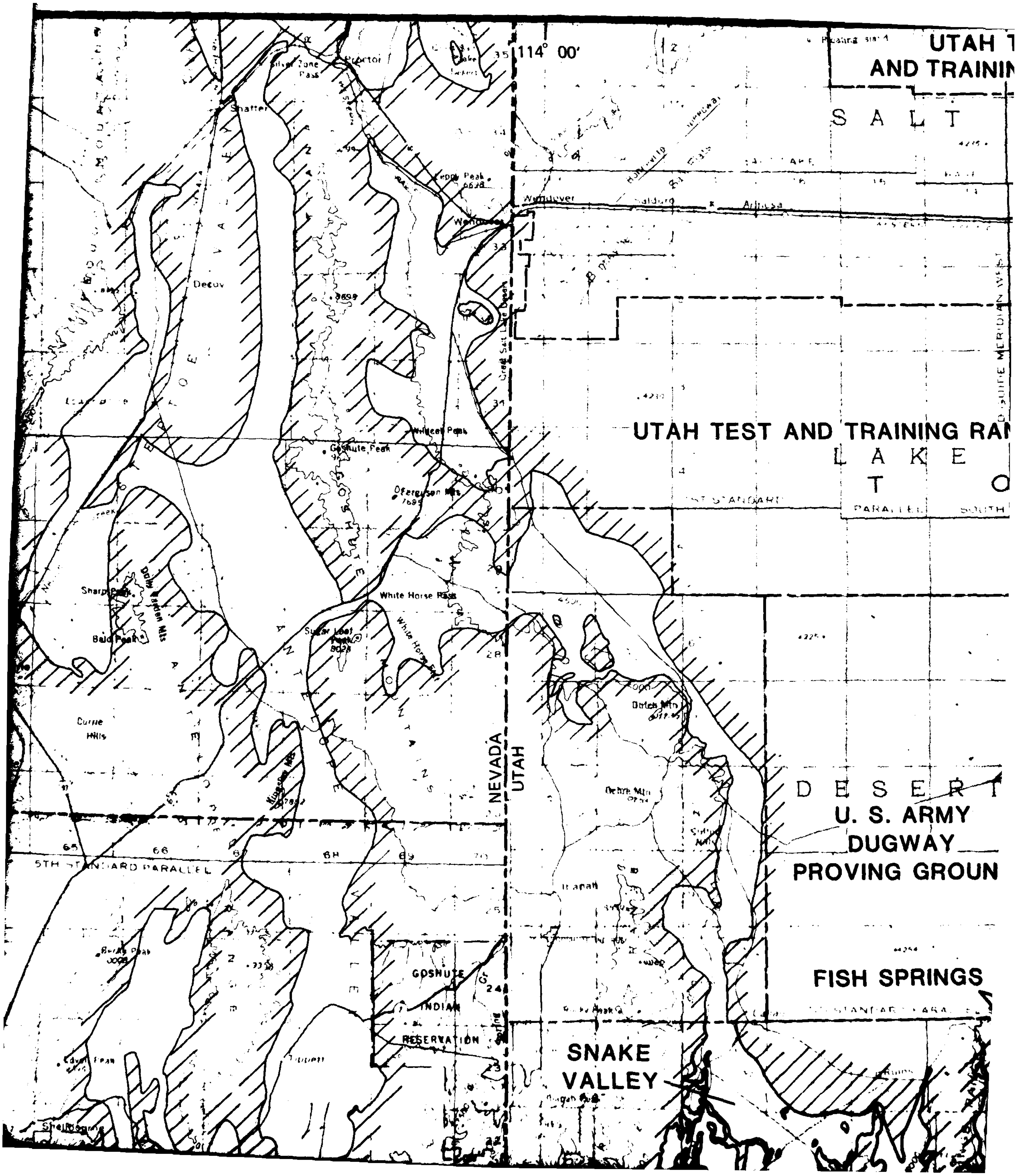
Elko
HUMBOLDT
NATIONAL
FOREST
Valley Mtn
Spruce Mountain Ridge
Currie



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LAKE
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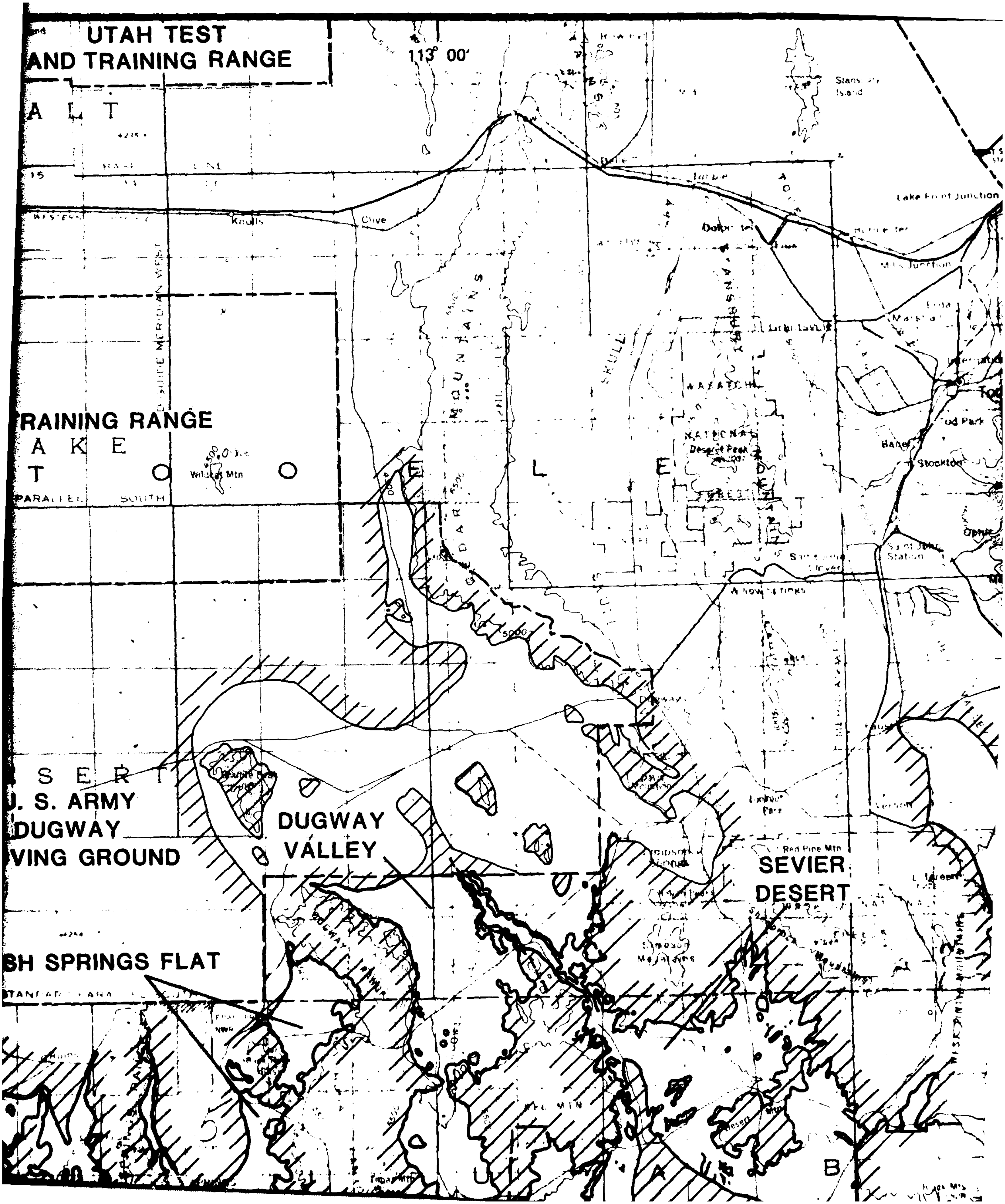
Wendover
UTAH TEST AND TRAINING RAN
NEVADA
UTAH
U. S. ARMY
DUGWAY
PROVING GROUN
FISH SPRINGS
SNAKE
VALLEY
GOSHUTE
INDIAN
RESERVATION
White Horse Pass
Goshute Peak
Sharp Peak
Bald Peak
Currie
Hills
Decoy
Shafter
Pilot Peak
Dutch Mtn
Ochre Mtn
Ibapah
5TH STANDARD PARALLEL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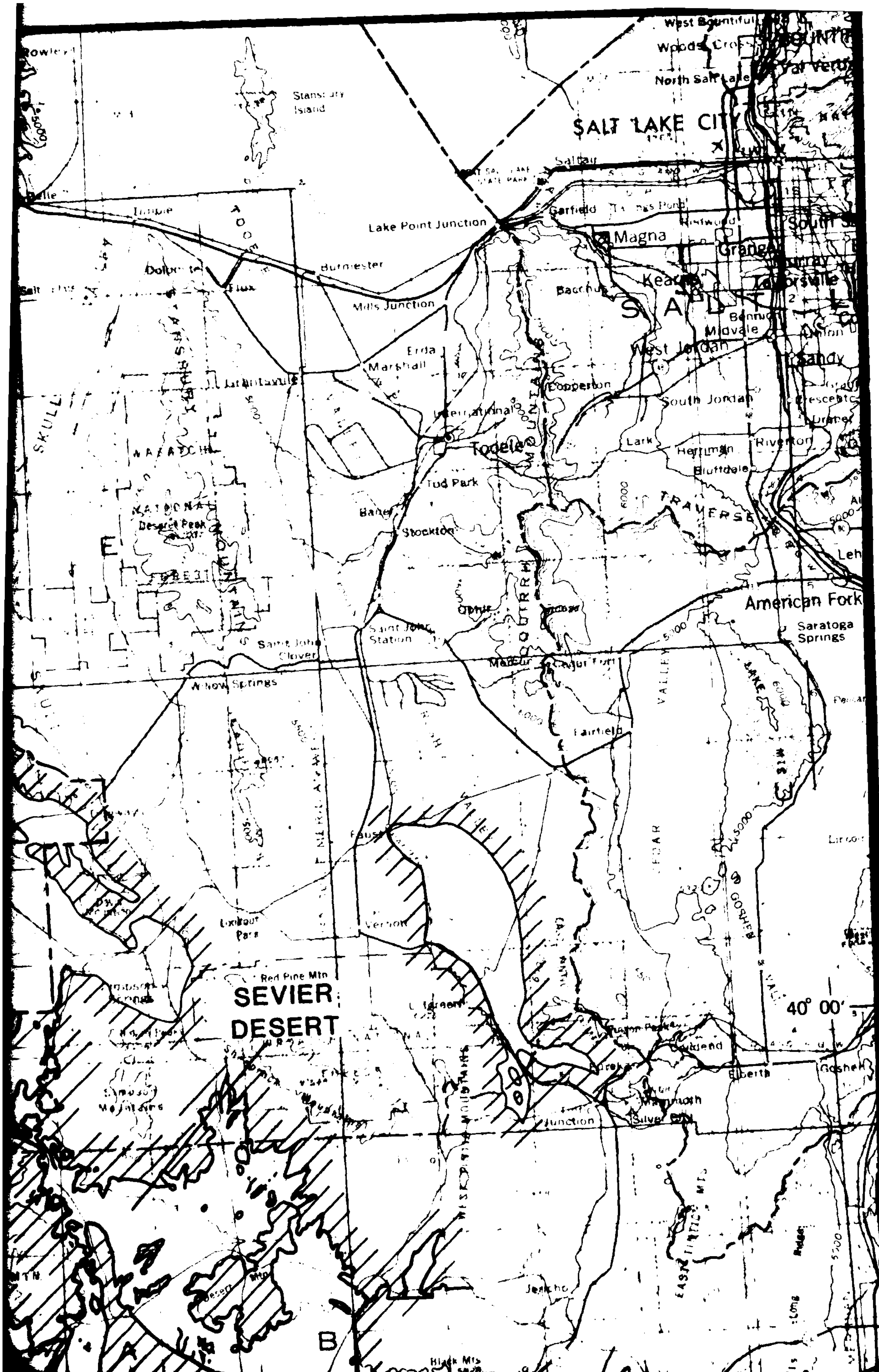
113° 00'
TRAINING RANGE
U. S. ARMY DUGWAY PROVING GROUND
DUGWAY VALLEY
SEVIER DESERT
SH SPRINGS FLAT
Wildcat Mtn
Knolls
Clive
Lake Point Junction
Stockton
Dugway
Red Pine Mtn
Simpson Mountains
CEDAR MOUNTAINS
SKULL VALLEY



West Bountiful
Woods Cross
North Salt Lake
SALT LAKE CITY
Stansbury Island
Saltair
Garfield
Lake Point Junction
Magna
Granger
Burmiester
Mills Junction
Bacchus
Kearns
Taylorsville
Midvale
West Jordan
Sandy
Erda
Marshall
Copperton
South Jordan
Grantsville
International
Tooele
Lark
Herriman
Riverton
Bluffdale
Tod Park
Bauer
Stockton
TRAVERSE
Deseret Peak
American Fork
Saratoga Springs
Ophir
Saint John Station
Clover
Cedar Fort
Willow Springs
Fairfield
Faust
Vernon
Red Pine Mtn
SEVIER DESERT
40° 00′
Goshen
Elberta
Mammoth
Junction
Jericho
Black Mts
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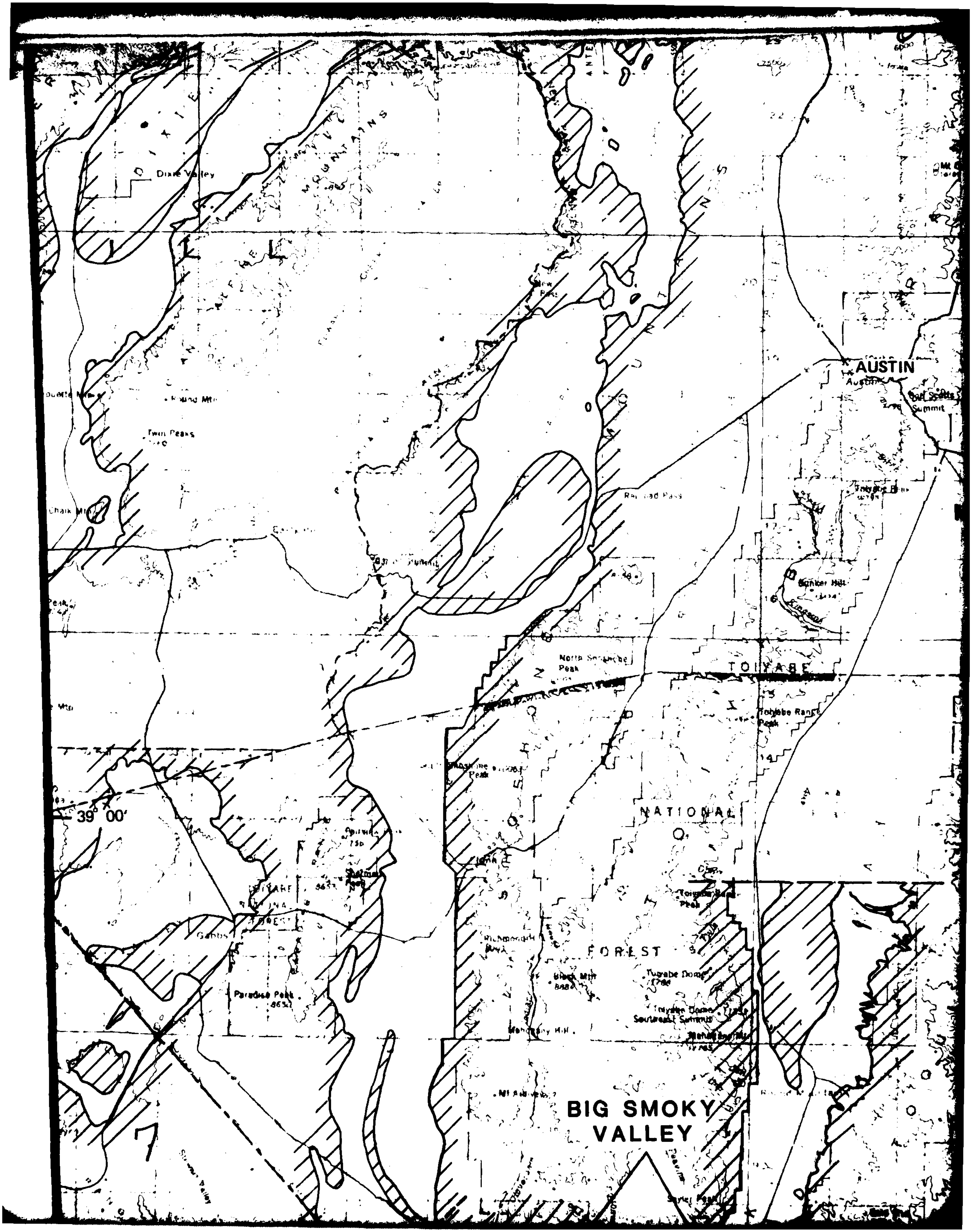
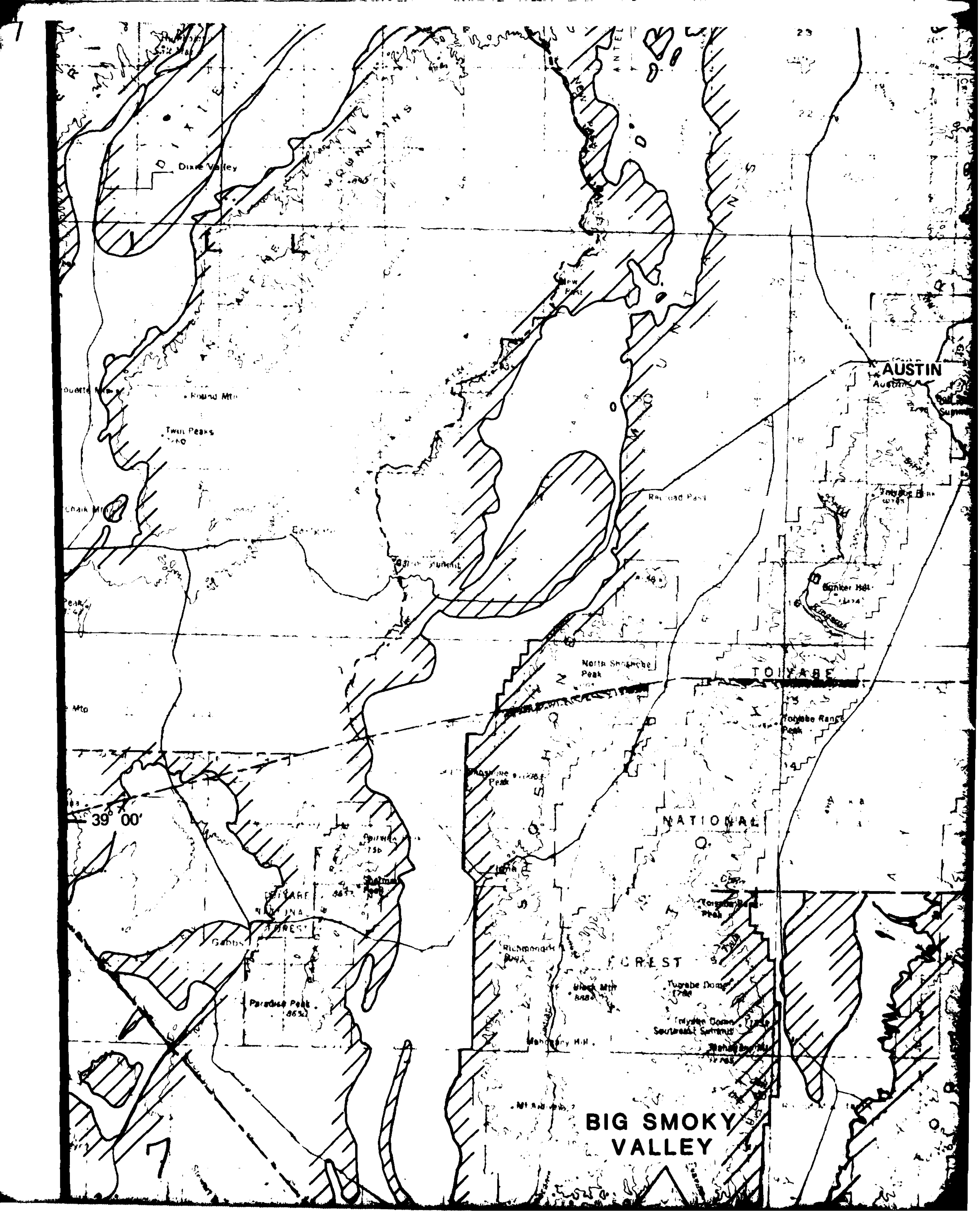


Dixie Valley
MOUNTAINS
Twin Peaks
Round Mtn
Chalk Mtn
New Pass
AUSTIN
Austin
Bob Scotts Summit
Railroad Pass
Toiyabe Peak
Bunker Hill
North Shoshone Peak
TOIYABE
Toiyabe Range Peak
39° 00′
NATIONAL
FOREST
Shoshone Peak
Ione
Gabbs
Paradise Peak
Richmond Mtn
Black Mtn
Toiyabe Dome
Toiyabe Dome Southeast Summit
Mahogany Hill
BIG SMOKY VALLEY
Sayler Peak



Dixie Valley
MOUNTAINS
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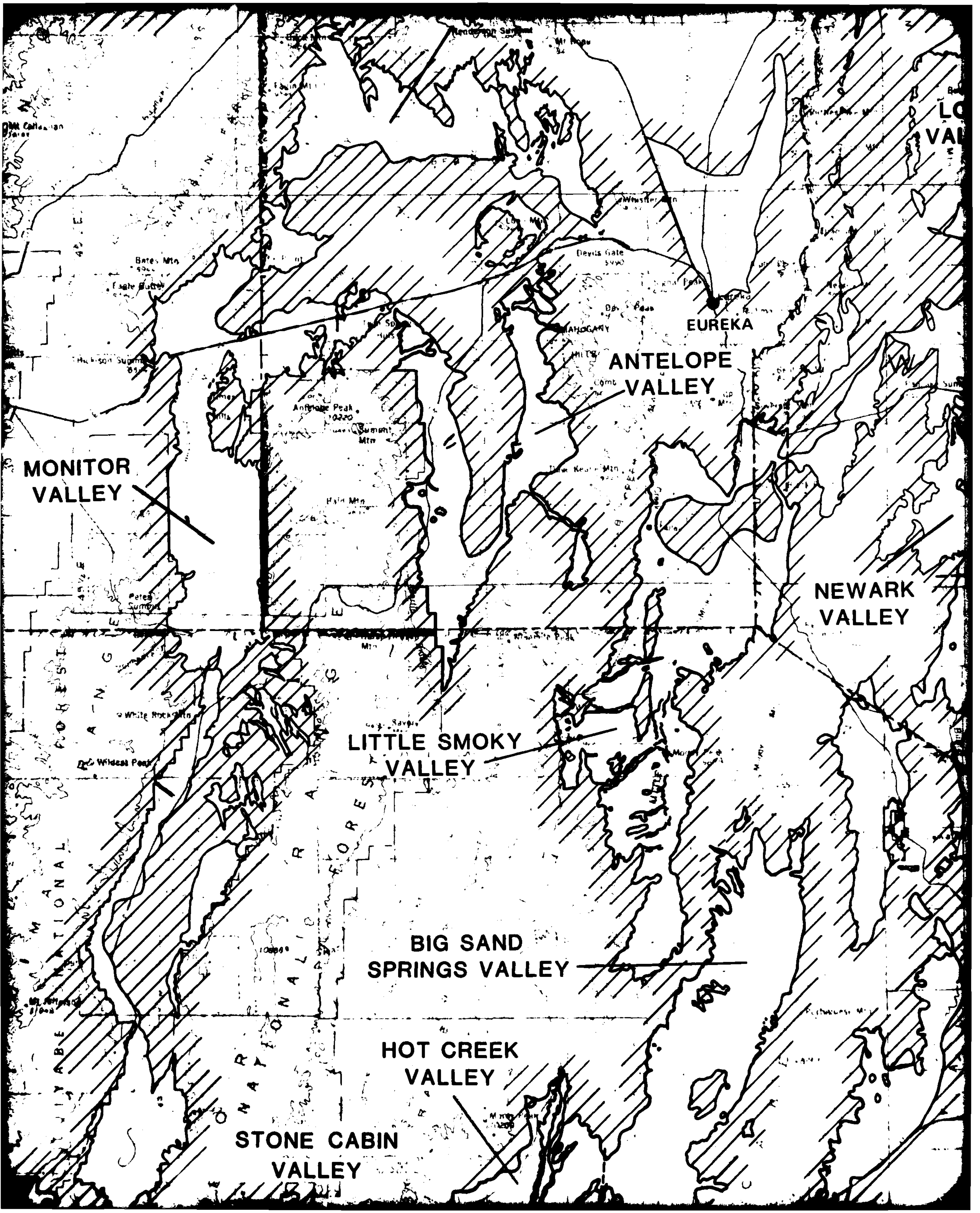
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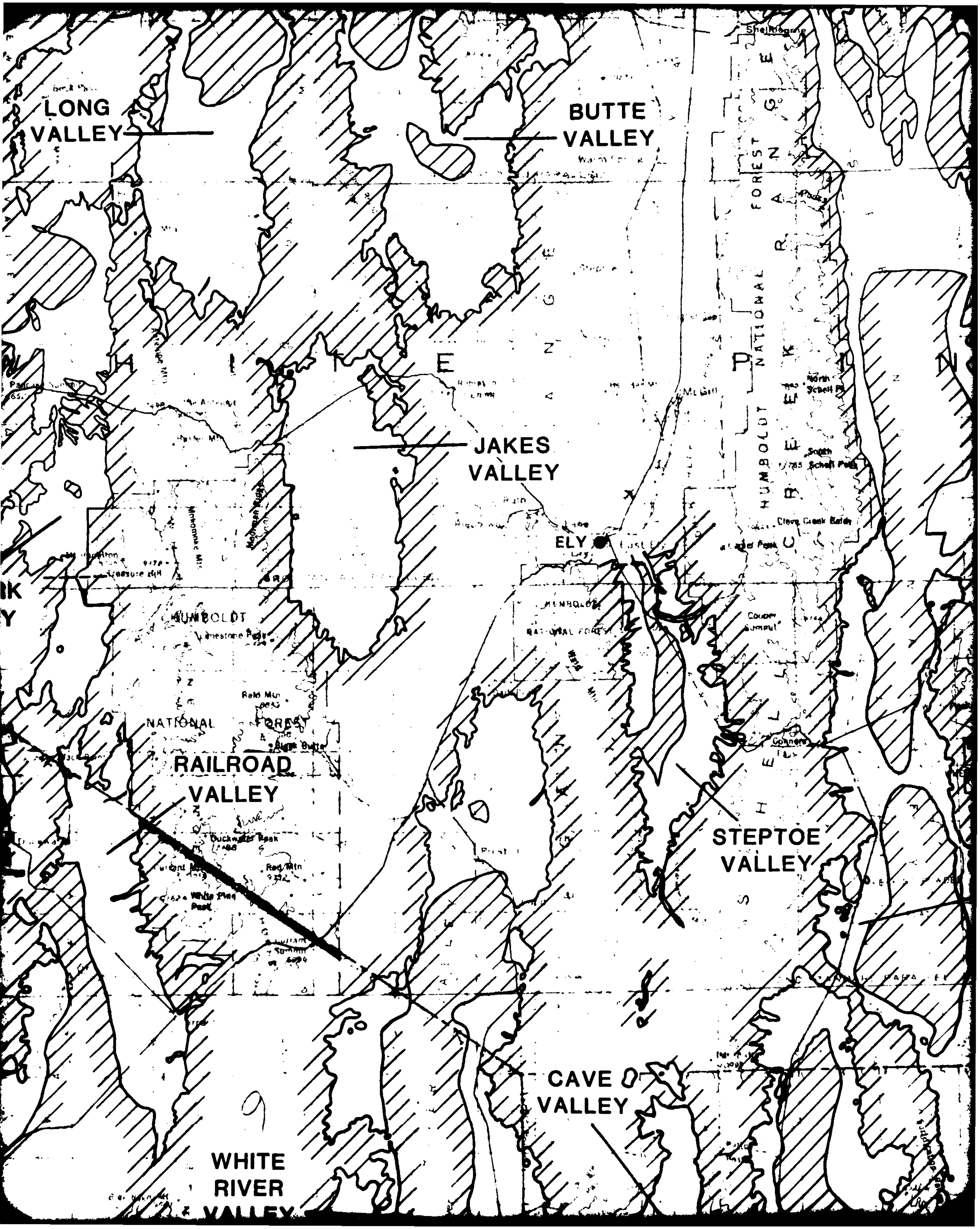
BIG SAND SPRINGS VALLEY
HOT CREEK VALLEY
STONE CABIN VALLEY
Devils Gate
Antelope Peak
Bates Mtn
Hickison Summit
Pete's Summit
White Rock Mtn
Wildcat Peak
Bald Mtn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BUTTE VALLEY
JAKES VALLEY
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RAILROAD VALLEY
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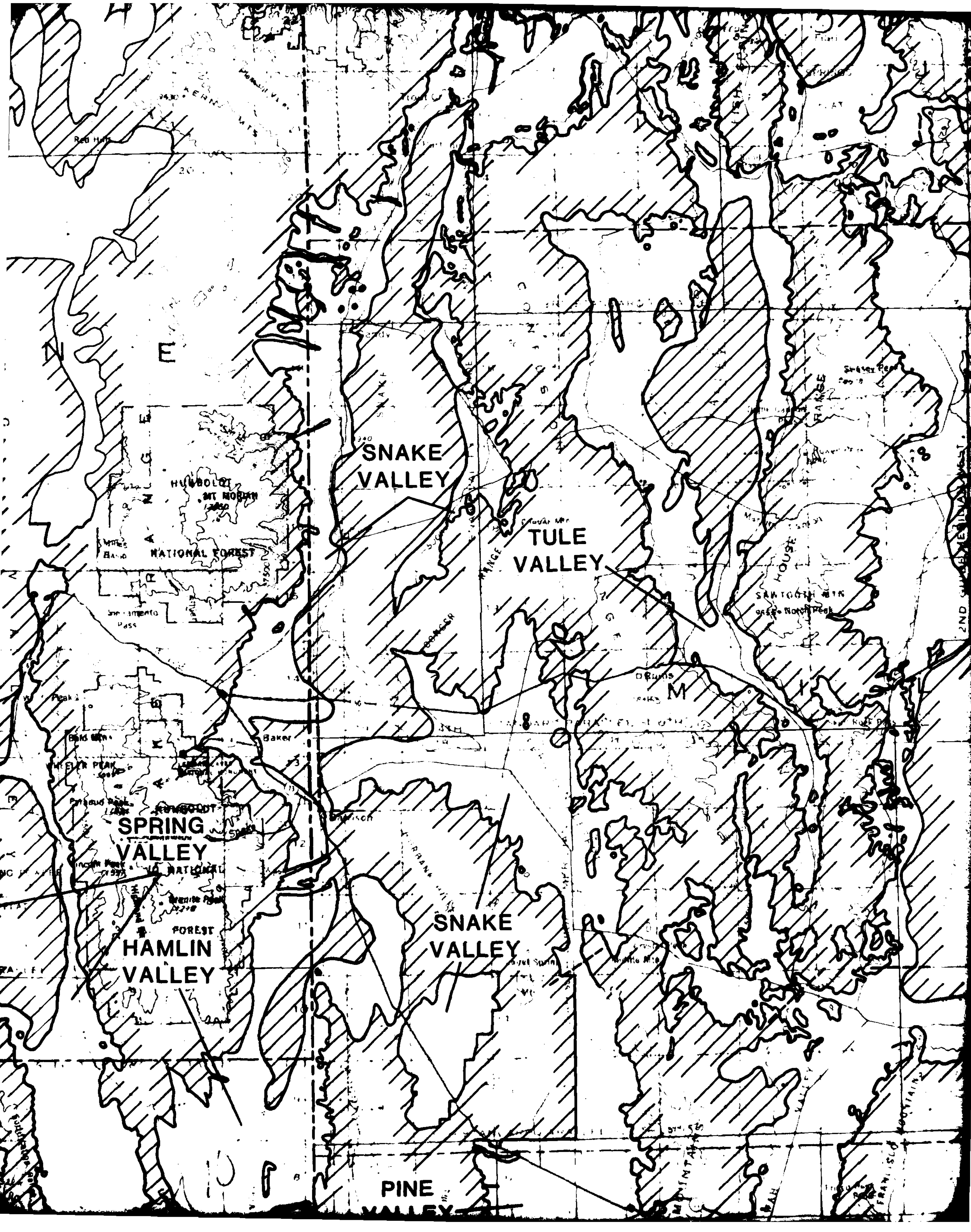
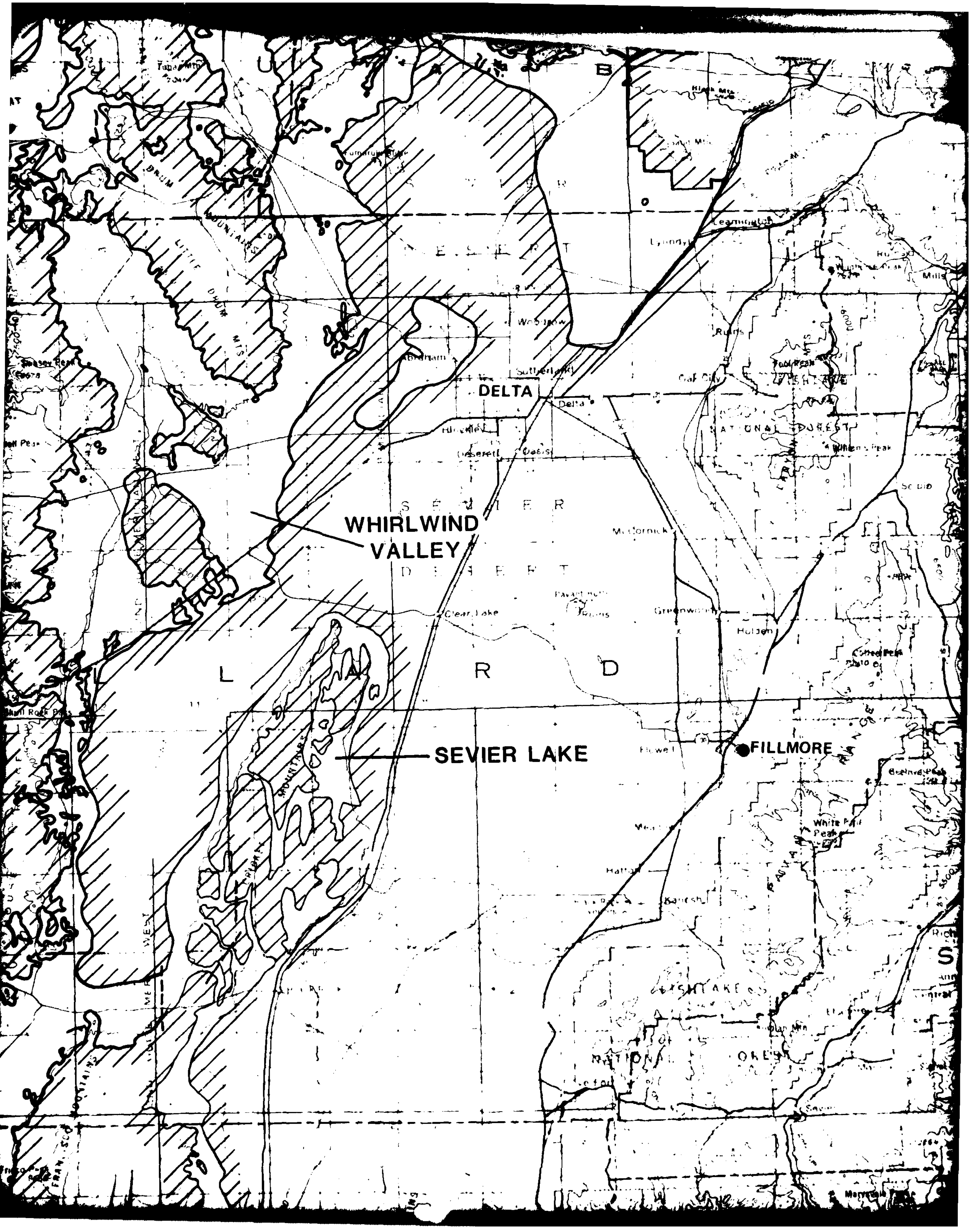
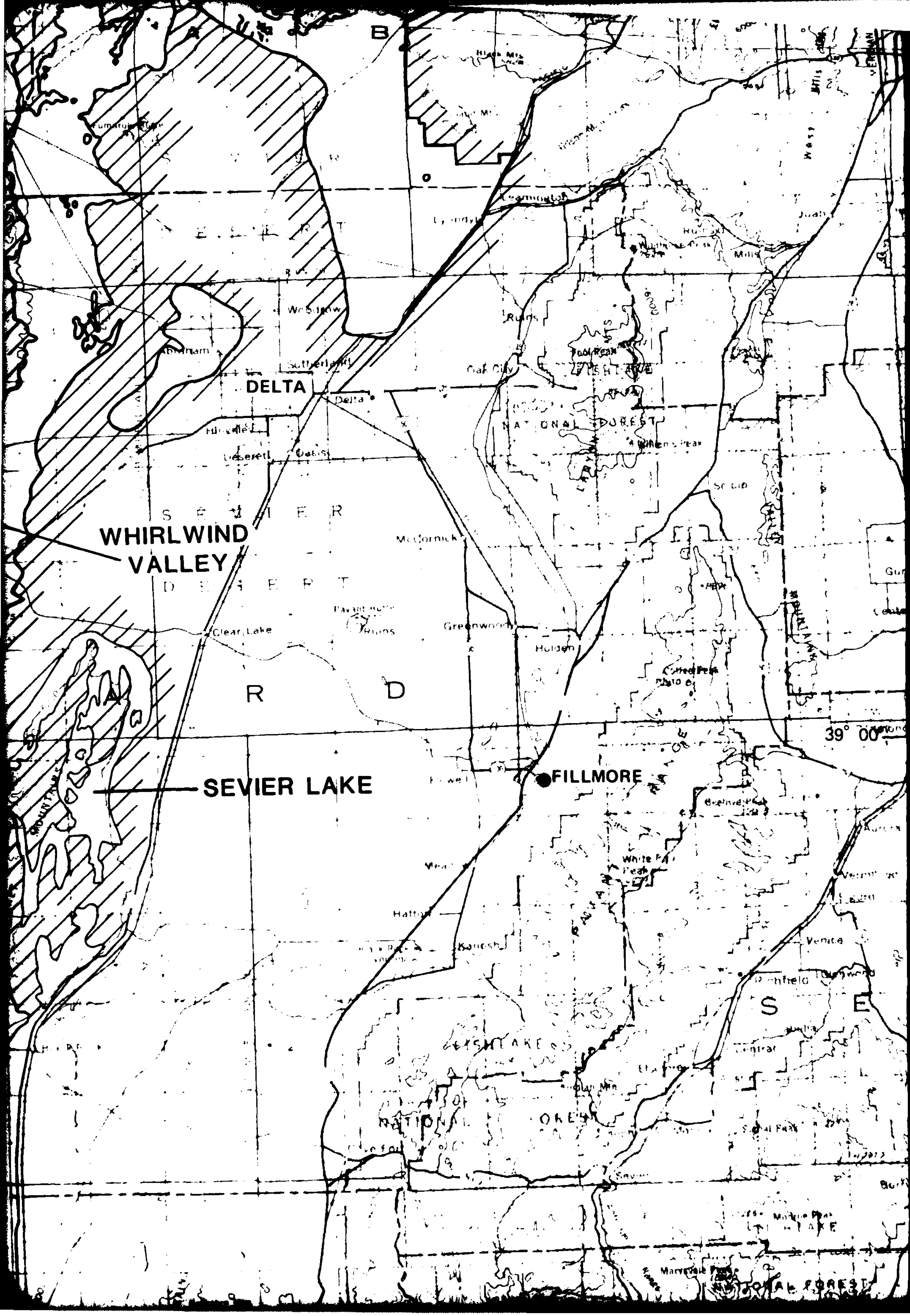
CAVE VALLEY
WHITE RIVER VALLEY
HUMBOLDT NATIONAL FOREST
HUMBOLDT
NATIONAL FOREST

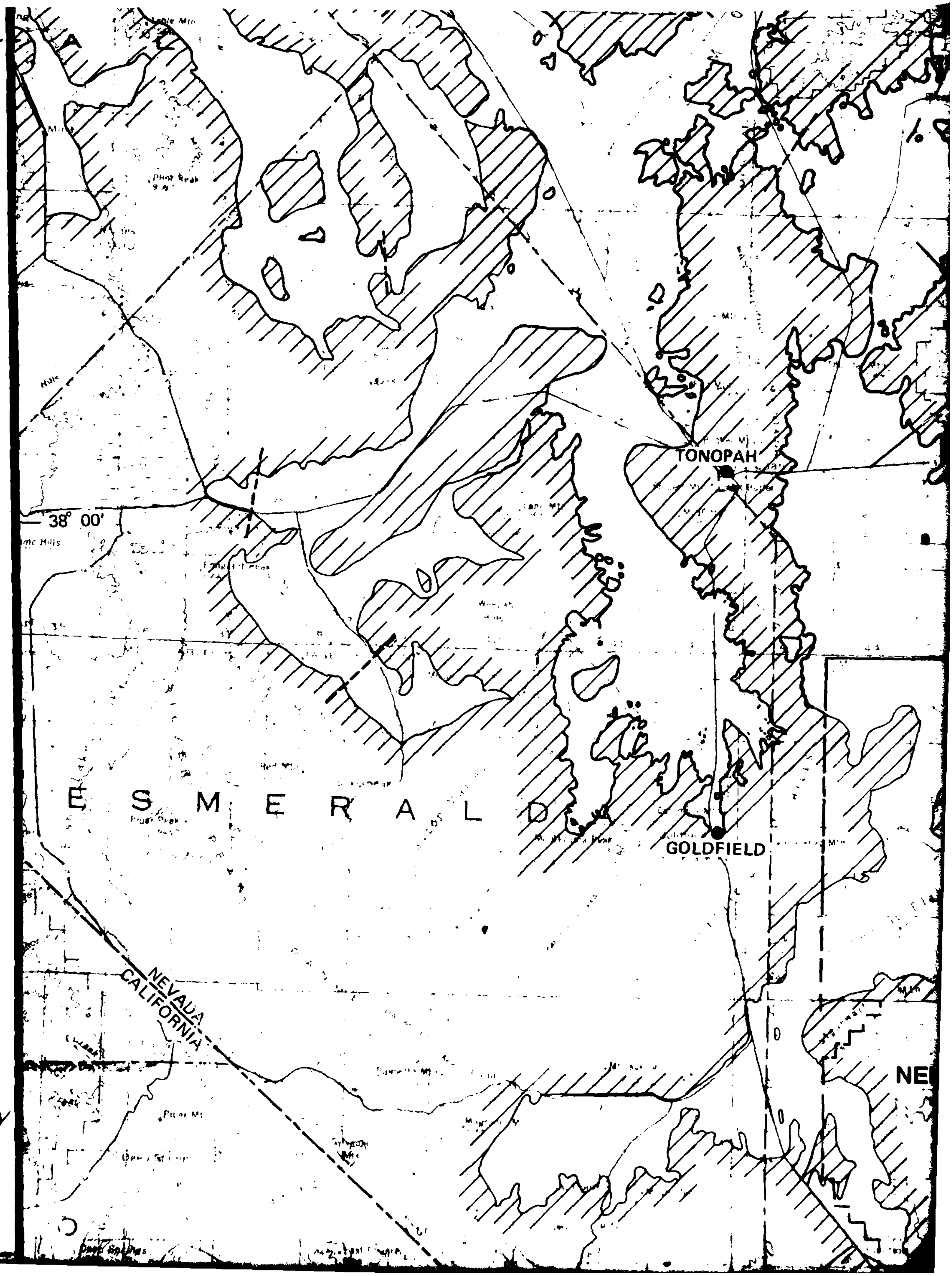

SNAKE VALLEY
TULE VALLEY
SPRING VALLEY
HAMLIN VALLEY
SNAKE VALLEY
PINE VALLEY
HUMBOLDT
MT MORIAH
NATIONAL FOREST
WHEELER PEAK
Baker
SAWTOOTH MTN
HOUSE RANGE
Red Hills
Sacramento Pass



DELTA
WHIRLWIND
VALLEY
SEVIER LAKE
FILLMORE
Delta
Sutherland
Hinckley
Deseret
Oasis
Clear Lake
Greenwood
Holden
Flowell
Meadow
Hatton
Kanosh
Leamington
Lynndyl
Oak City
McCornick
Woodrow
Abraham
NATIONAL FOREST
S E V I E R
D E S E R T
L A R D

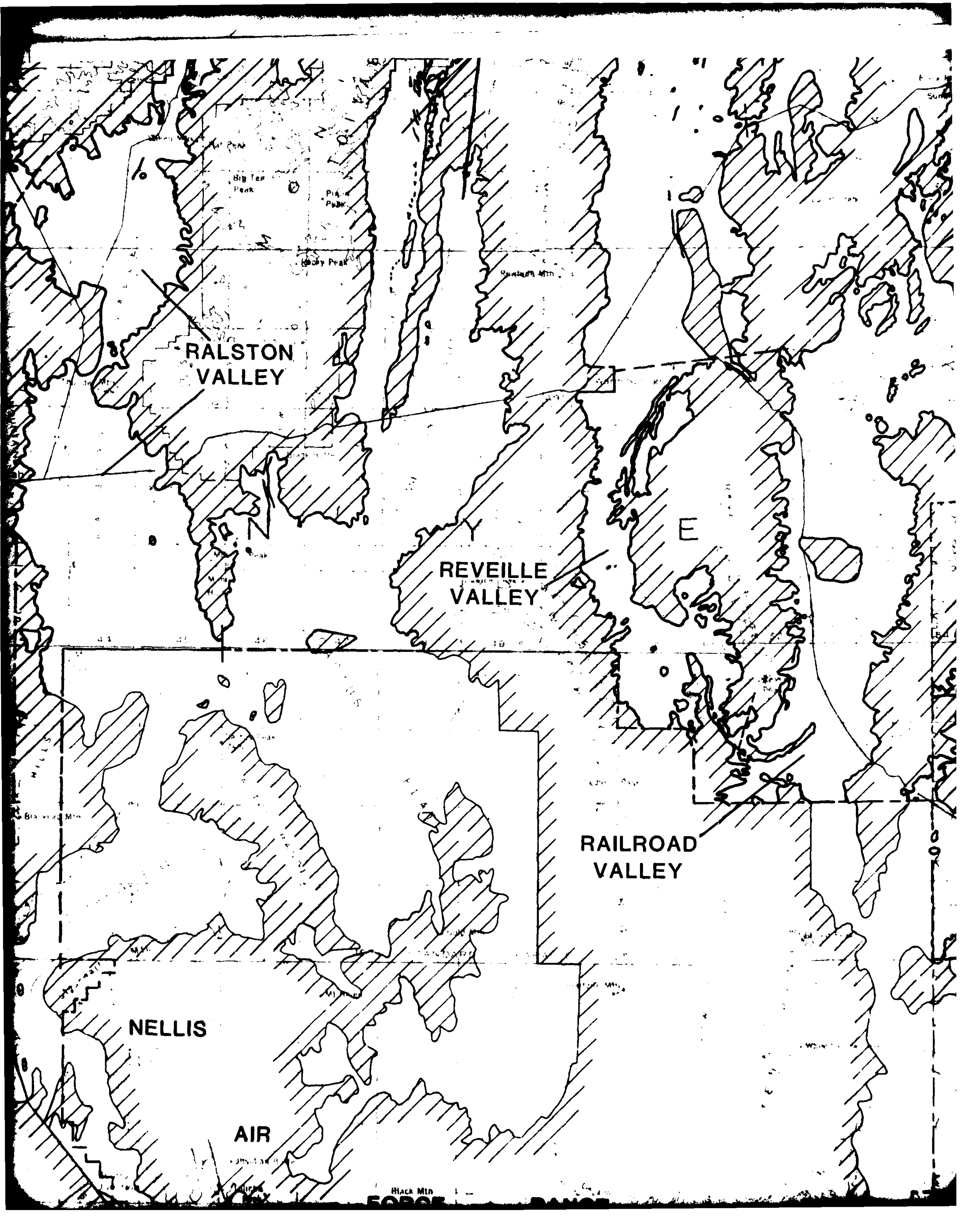


WHIRLWIND VALLEY
DELTA
SEVIER LAKE
FILLMORE
39° 00'
Leamington
Lynndyl
Woodrow
Abraham
Sutherland
Delta
Hinckley
Deseret
Oasis
Oak City
NATIONAL FOREST
McCornick
Greenwood
Holden
Clear Lake
Ruins
Flowell
Hatton
Kanosh
Venice
Sevier



TONOPAH
GOLDFIELD
38° 00'
E S M E R A L D
NEVADA
CALIFORNIA
NE
Pilot Peak
Deep Springs

13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REVEILLE VALLEY
RAILROAD VALLEY
NELLIS
AIR
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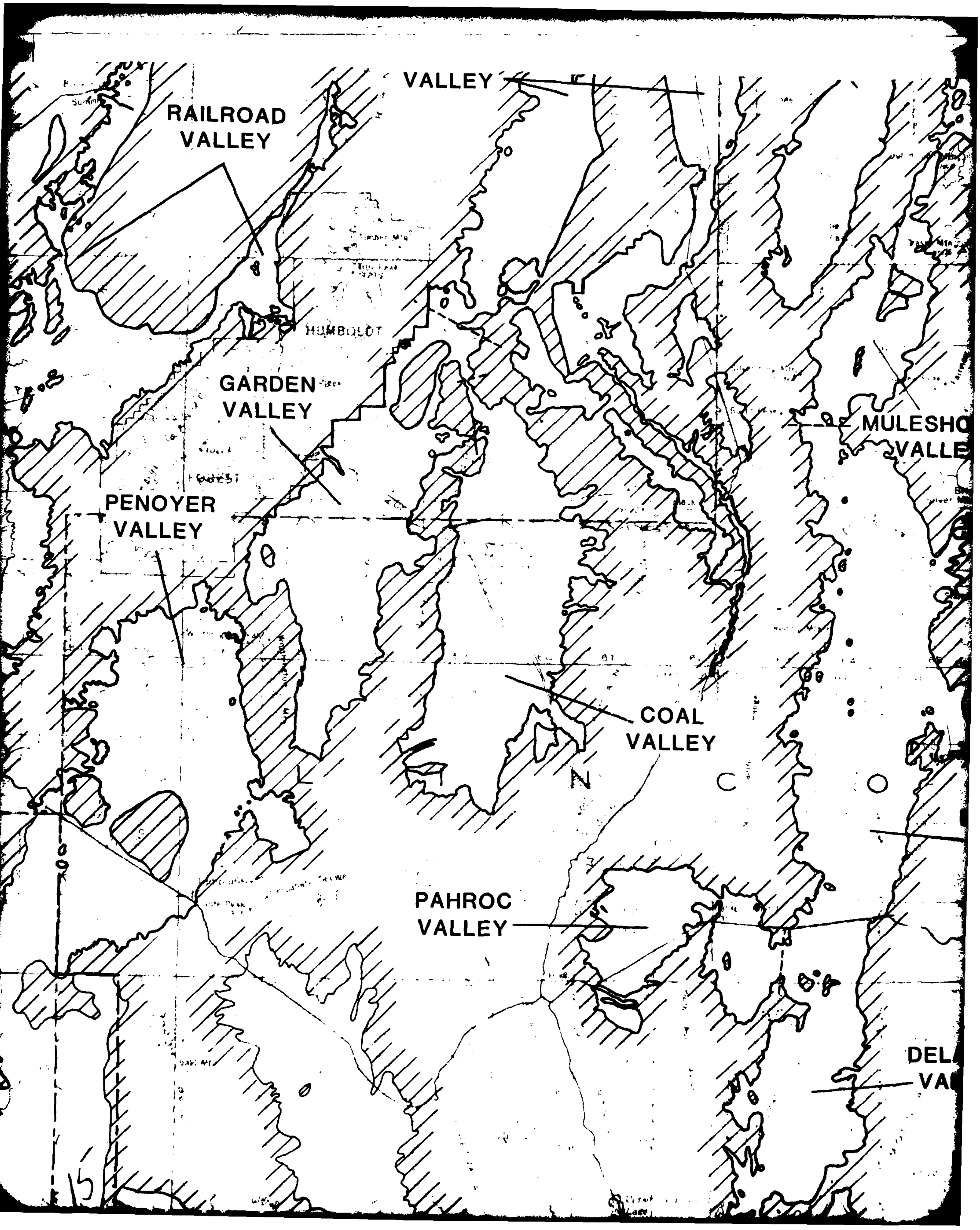
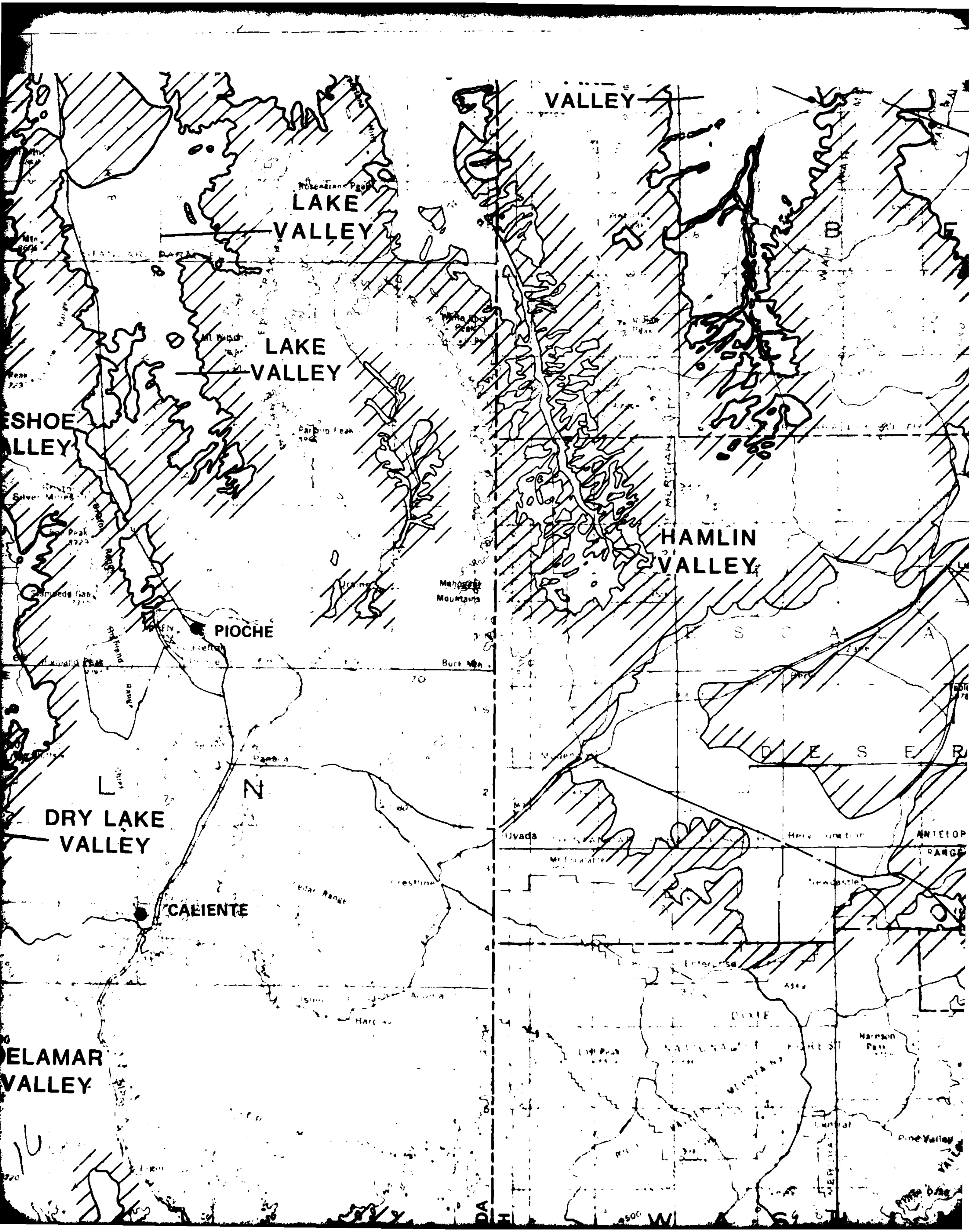
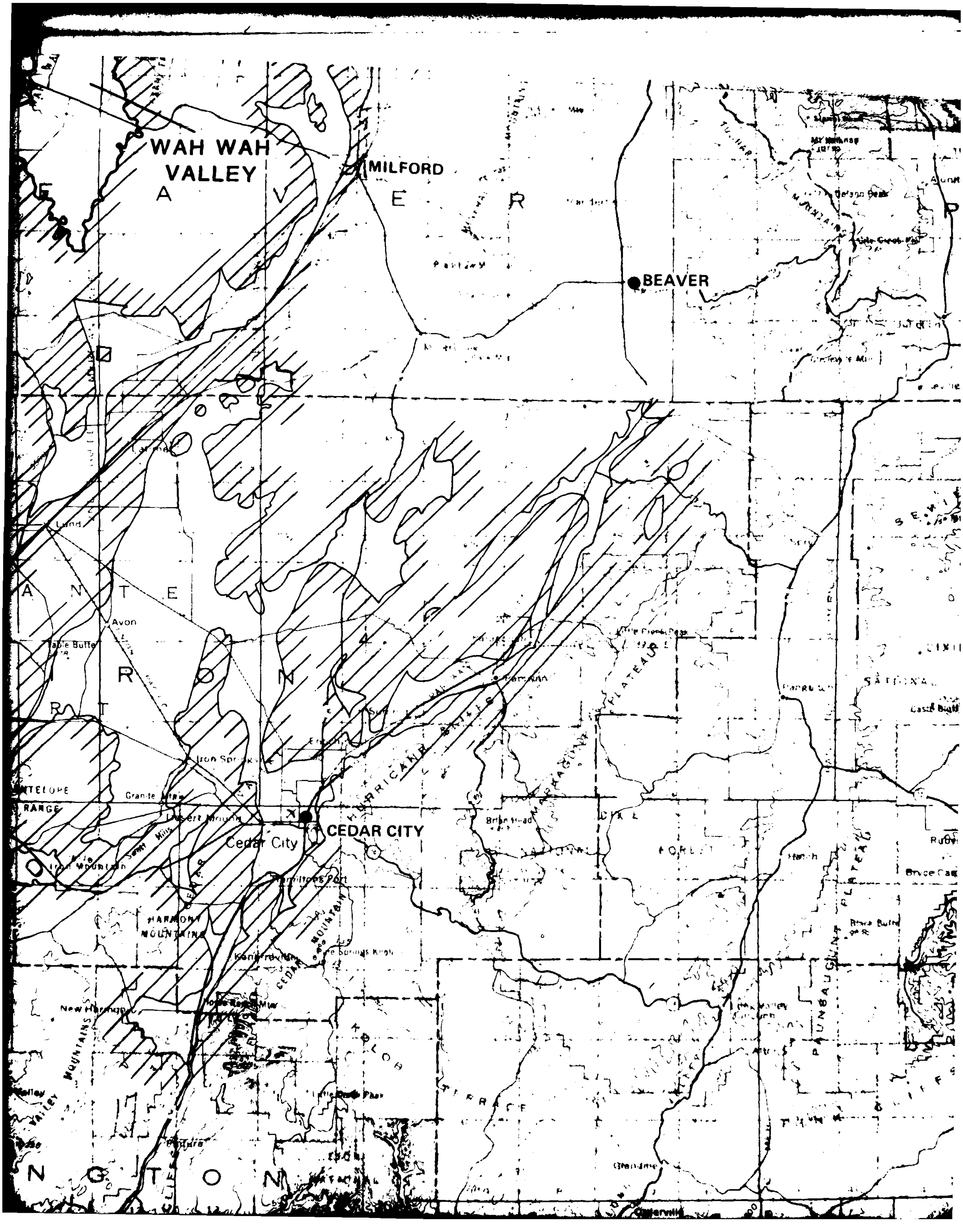
E

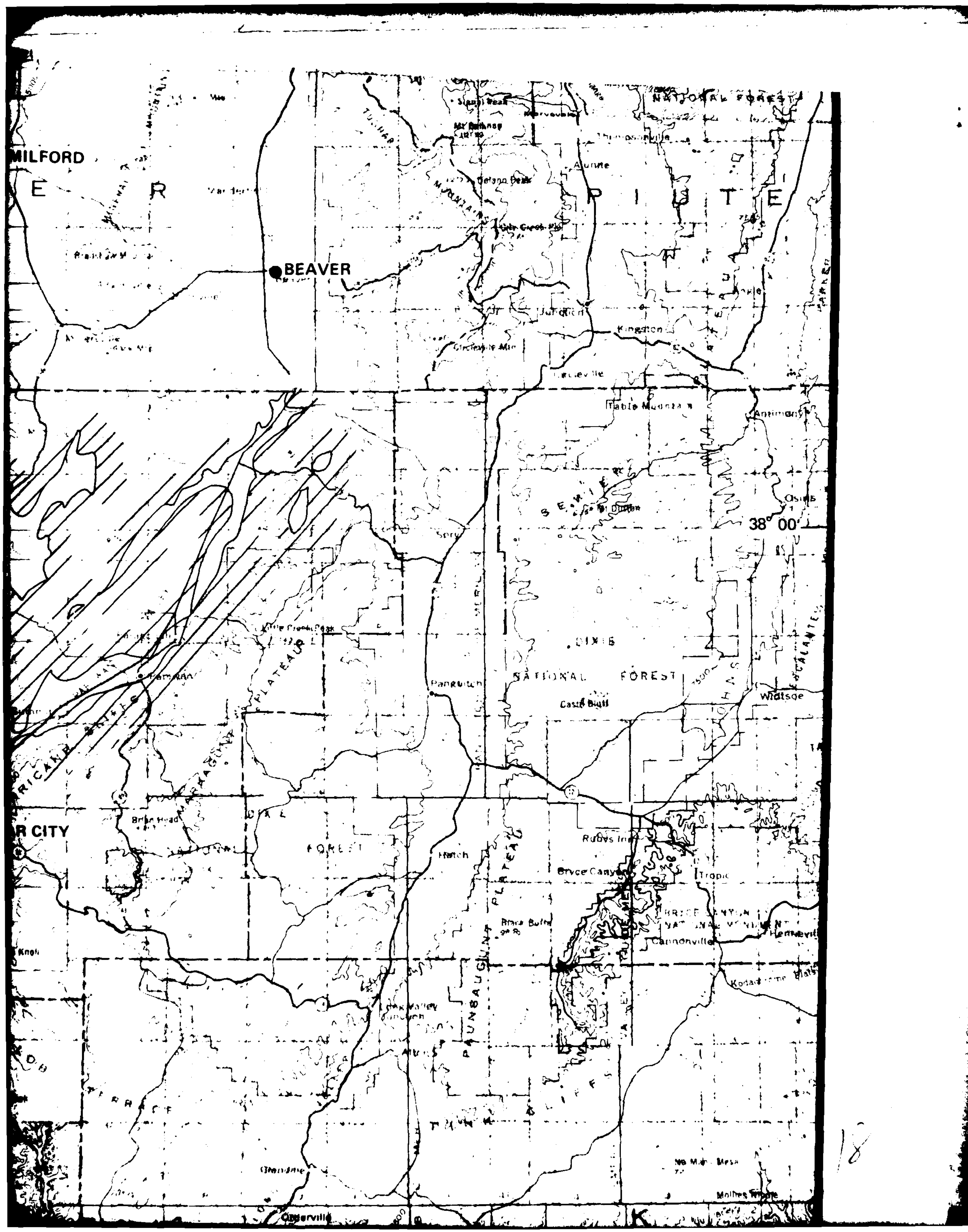


VALLEY
RAILROAD VALLEY
HUMBOLDT
GARDEN VALLEY
PENOYER VALLEY
MULESHO VALLE
COAL VALLEY
N
PAHROC VALLEY
DELA VA
15



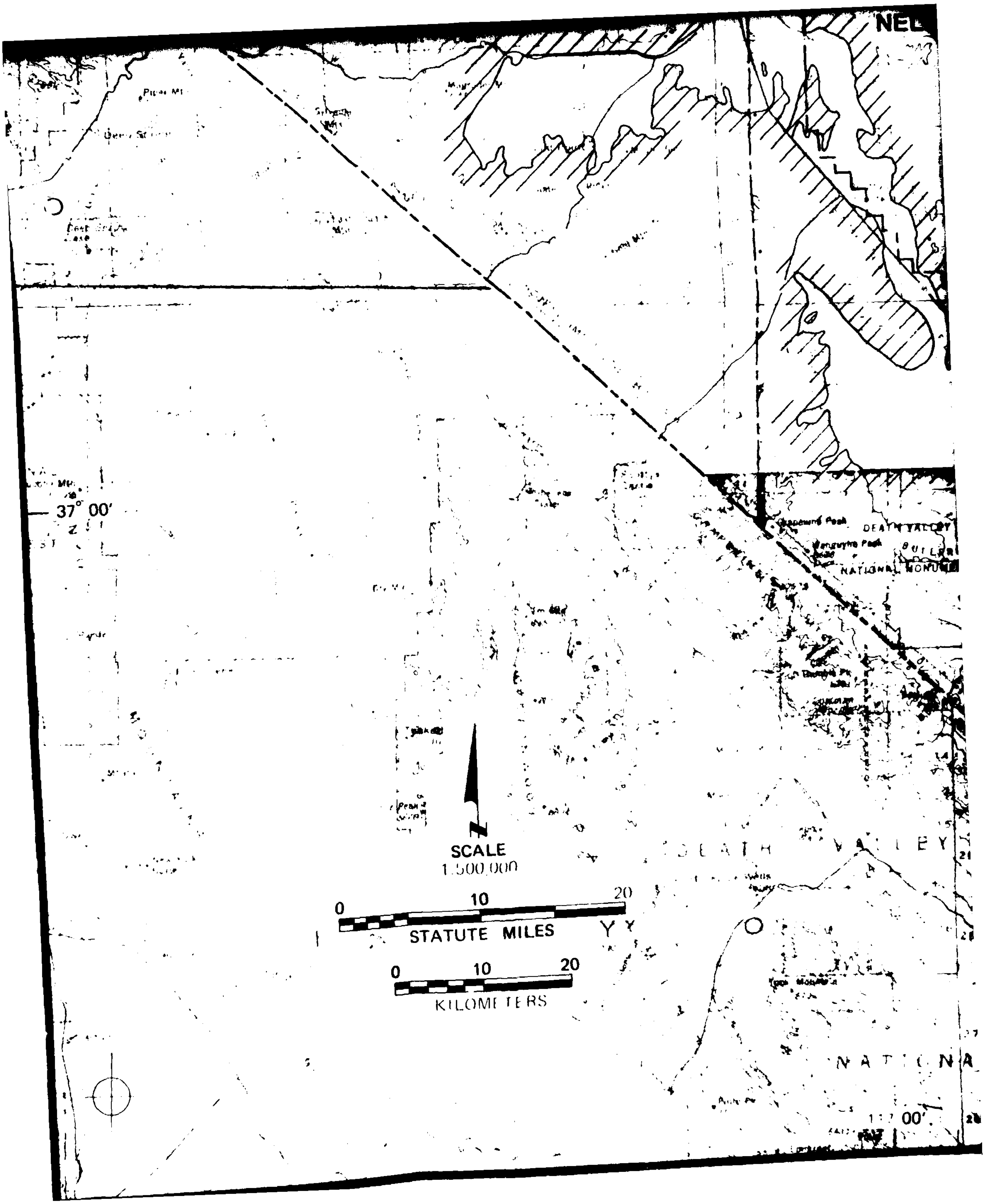
VALLEY
LAKE
VALLEY
LAKE
VALLEY
ESHOE
LLEY
HAMLIN
VALLEY
PIOCHE
DRY LAKE
VALLEY
CALIENTE
ELAMAR
VALLEY
Mahogany
Mountains
Rosencrans Peak
Parsnip Peak
Uvada
Modena
Newcastle
Enterprise
Pine Valley
Caselton
Buck Mtn
ANTELOPE
RANGE
Cedar Range
Crestline


WAH WAH
VALLEY
MILFORD
BEAVER
CEDAR CITY
Cedar City
Lund
Avon
Iron Springs
Granite Mtn
Hamiltons Fort
Kanarraville
New Harmony
HARMONY
MOUNTAINS
HURRICANE CLIFFS
MARKAGUNT
PLATEAU
PAUNSAUGUNT
PLATEAU
KOLOB
TERRACE
Brian Head
Hatch
Panguitch
Parowan
Summit
Enoch
Desert Mound
Iron Mountain
Table Butte
ANTELOPE
RANGE
Glendale
Orderville

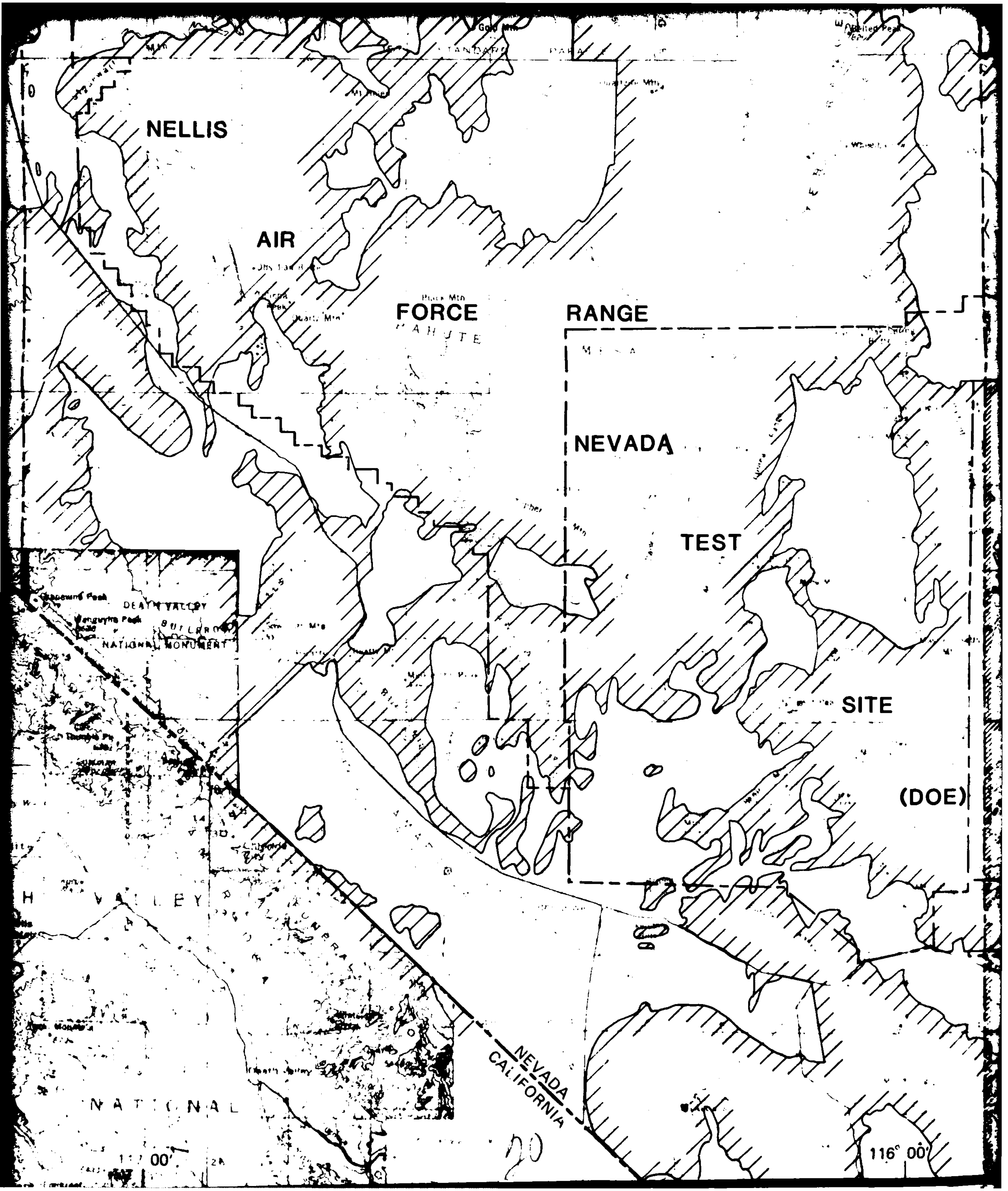


MILFORD
BEAVER
R CITY
38° 00'
NATIONAL FOREST
Thompsonville
Alunite
Delano Peak
Junction
Kingston
Circleville
Table Mountain
Antimony
Osiris
DIXIE
NATIONAL FOREST
Panguitch
Castle Bluff
Widtsoe
Rubys Inn
Bryce Canyon
Tropic
Cannonville
Hatch
PAUNSAUGUNT PLATEAU
Alton
Glendale
Orderville
Little Creek Peak
PLATEAU
FOREST
Brian Head
TERRACE
CLIFFS
No Mans Mesa
Kodachrome Flats

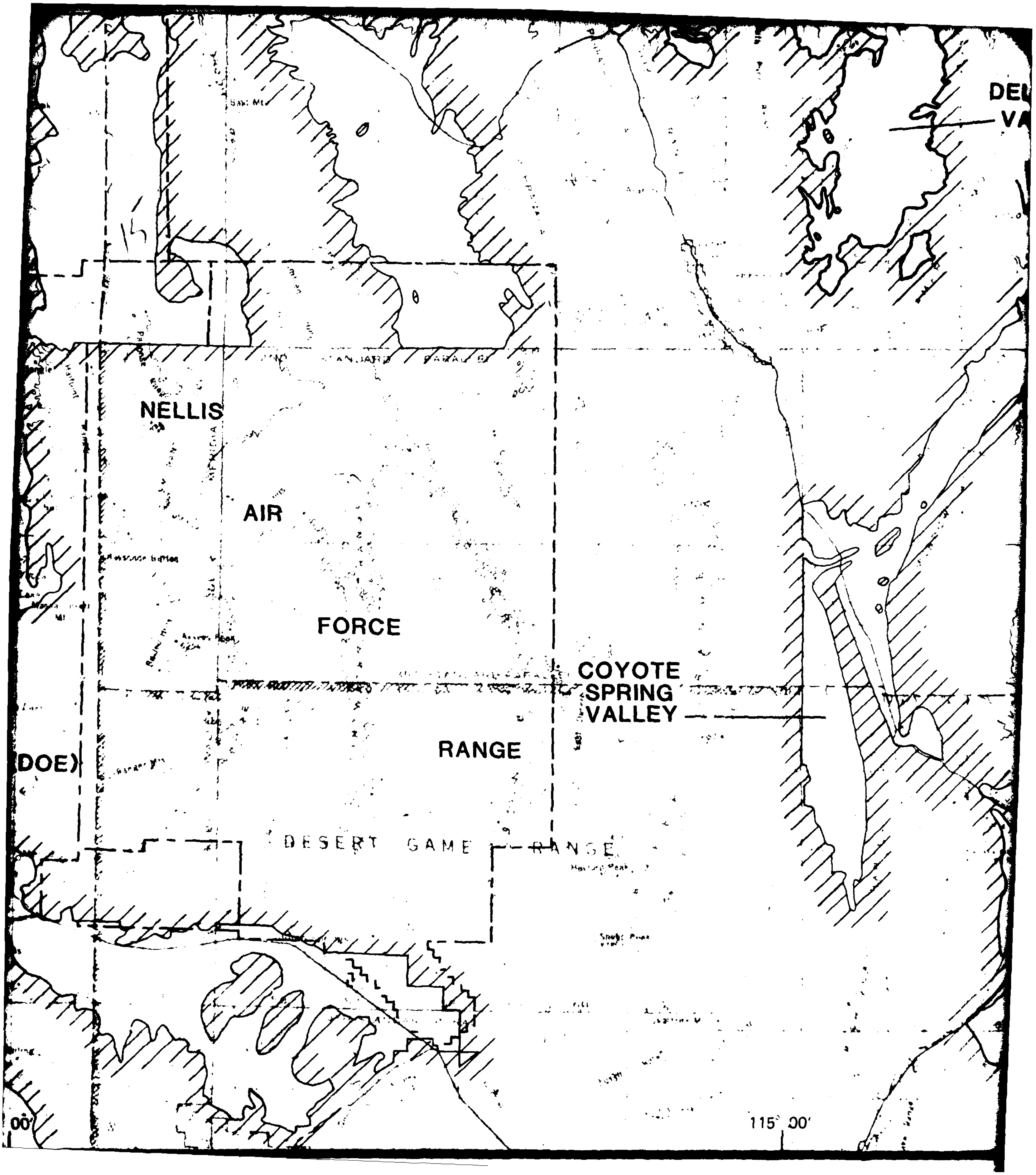
18



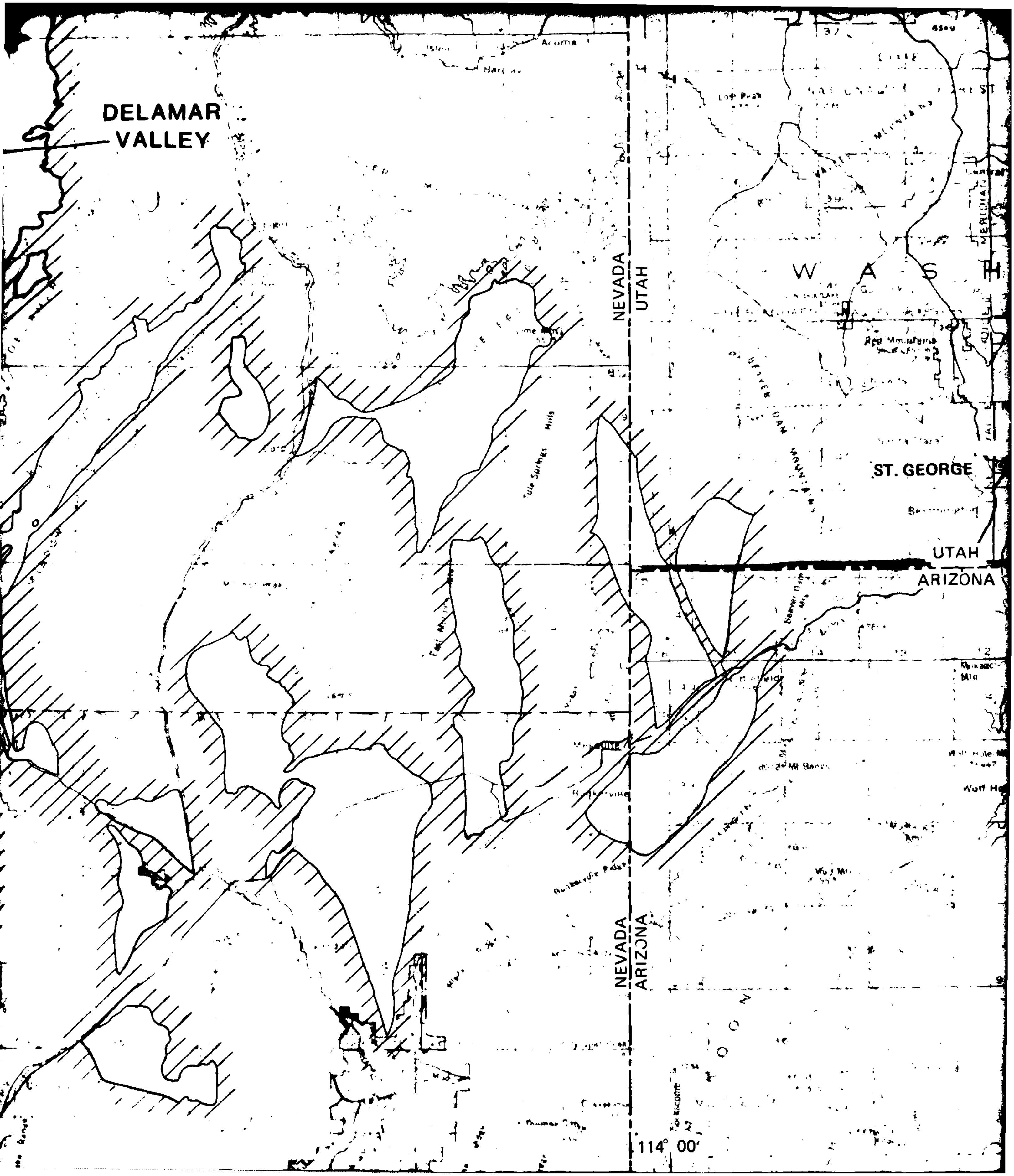
NEL
37° 00'
DEATH VALLEY
NATIONAL MONUMENT
SCALE
1:500,000
0
10
20
STATUTE MILES
0
10
20
KILOMETERS
DEATH VALLEY
NATIONA


NELLIS
AIR
FORCE
RANGE
NEVADA
TEST
SITE
(DOE)
DEATH VALLEY
NATIONAL MONUMENT
NEVADA
CALIFORNIA
116° 00'
117° 00'
NATIONAL

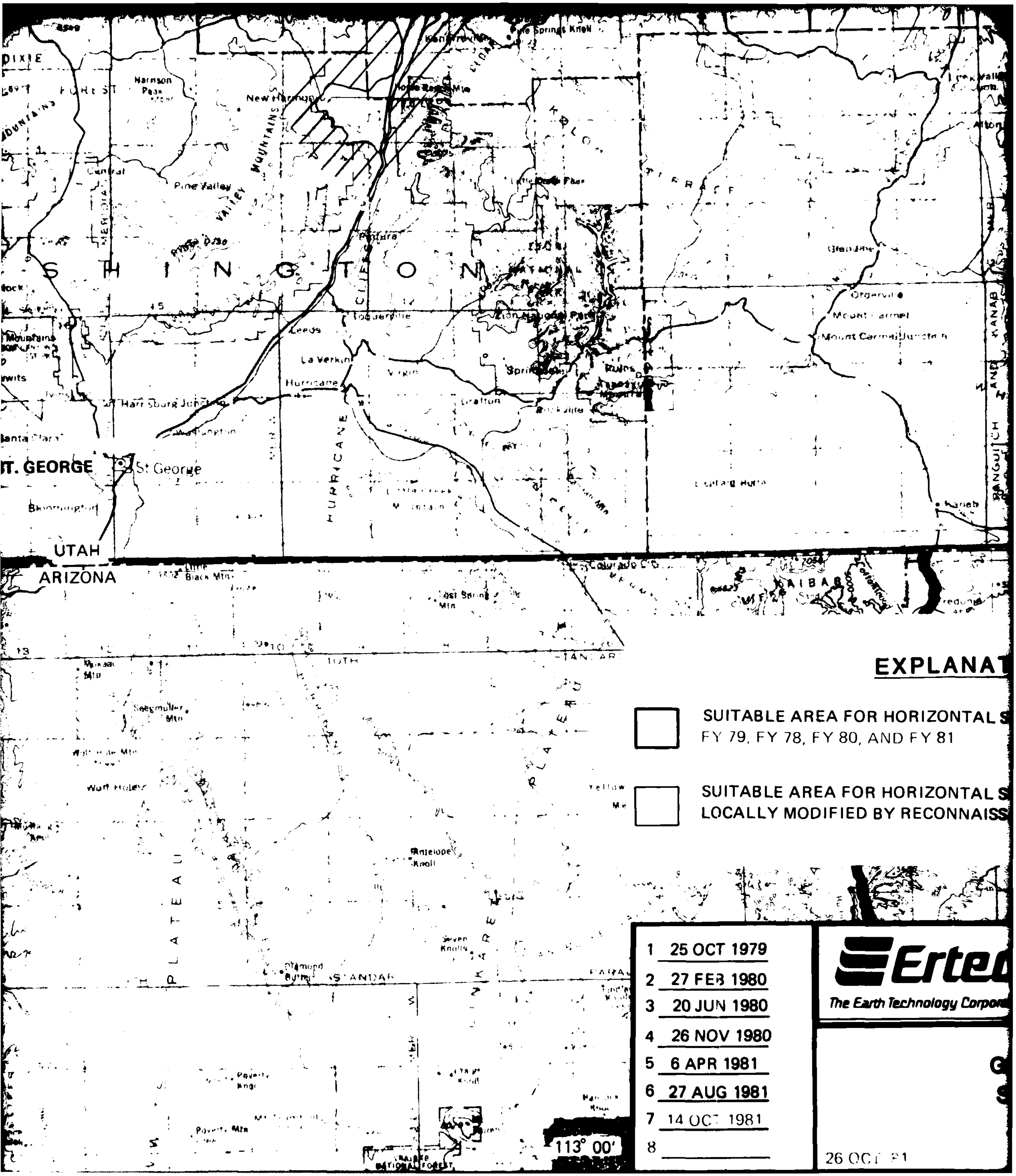
20



NELLIS
AIR
FORCE
RANGE
(DOE)
COYOTE
SPRING
VALLEY
DESERT GAME RANGE
115° 00'



DELAMAR VALLEY
NEVADA
UTAH
ST. GEORGE
UTAH
ARIZONA
NEVADA
ARIZONA
114° 00′



DIXIE
FOREST
Harrison Peak
New Harmony
MOUNTAINS
Pine Valley
VALLEY
Central
KOLOB
TERRACE
CLIFF
Pintura
Toquerville
Leeds
La Verkin
Hurricane
Virgin
Grafton
Rockville
Springdale
Zion National Park
Harrisburg Junction
Washington
Santa Clara
ST. GEORGE
St George
Bloomington
HURRICANE
Orderville
Mount Carmel
Mount Carmel Junction
Glendale
KANAB
Kanab
UTAH
ARIZONA
Black Mtn
Colorado City
KAIBAB
Seegmuller Mtn
Wolf Hole
Antelope Knoll
Seven Knolls
Diamond Butte
PLATEAU
Poverty Knoll
Poverty Mtn
NATIONAL FOREST
113° 00'
EXPLANAT
SUITABLE AREA FOR HORIZONTAL S
FY 79, FY 78, FY 80, AND FY 81
SUITABLE AREA FOR HORIZONTAL S
LOCALLY MODIFIED BY RECONNAISS
1 25 OCT 1979
2 27 FEB 1980
3 20 JUN 1980
4 26 NOV 1980
5 6 APR 1981
6 27 AUG 1981
7 14 OCT 1981
8
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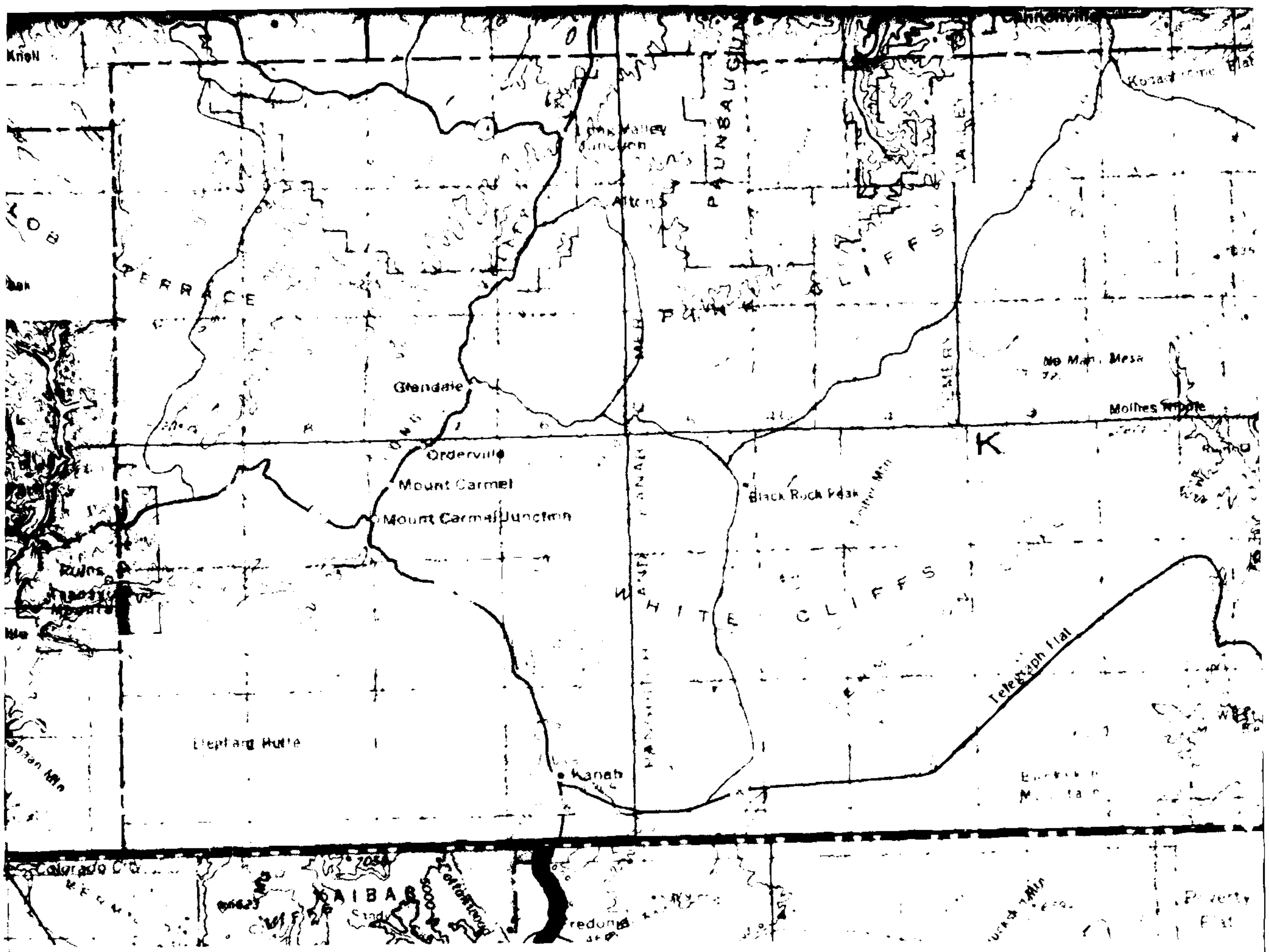

EXPLANATION

SUITABLE AREA FOR HORIZONTAL SHELTER BASED ON VERIFICATION STUDIES FY 79, FY 78, FY 80, AND FY 81

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

1 25 OCT 1979
2 27 FEB 1980
3 20 JUN 1980
4 26 NOV 1980
5 6 APR 1981
6 27 AUG 1981
7

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BMO/AFRCE-MX

GEOTECHNICALLY
SUITABLE AREAS

2.0 RESULTS AND CONCLUSIONS

2.1 SUITABLE AREA

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

The total area of basin-fill materials in Cave Valley is 204 mi^2 (528 km^2). Approximately 45 percent of this area is excluded for the horizontal shelter basing mode, leaving a suitable area of 112 mi^2 (292 km^2). For the vertical shelter basing mode, approximately 49 percent of the total area is excluded, leaving a suitable area of 104 mi^2 (268 km^2).

Detailed shelter layout studies indicate that, with 5200 feet (1585 m) between shelters in a two-thirds filled hexagonal layout, three MX clusters (23 shelters/cluster) can be placed in Cave Valley.

2.2 BASIN-FILL CHARACTERISTICS

This section contains brief descriptions of the soils in the suitable area of Cave 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 60 percent or more of the suitable area. They consist of sandy and/or silty gravels and silty

VERIFICATION VALLEY	STATE	AREA MI ^{2} (KM^2) *		
		BEGINNING AREA	SUITABLE AREA	
			HORIZONTAL	VERTICAL
CAVE	NEVADA	204 (528)	112 (292)	104 (268)

EXCLUSIONS	AREA MI ^{2} (KM^2)	PERCENT REDUCTION **
< 50 FEET (15M) TO ROCK	39 (102)	19
< 150 FEET (46M) TO ROCK	20 (51)	10
< 50 FEET (15M) TO WATER	6 (16)	3
150 FEET (46M) TO WATER	9 (22)	4
TERRAIN ***	77 (198)	38

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

** PERCENT REDUCTIONS, BASED ON BEGINNING AREA, ARE ROUNDED OFF TO NEAREST WHOLE PERCENT. GROUND-WATER DATA FROM FUGRO NATIONAL, INC. (1979).

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

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ESTIMATED SUITABLE AREA
CAVE VALLEY, NEVADA

26 OCT 81

TABLE 2-1

sands. Gravelly soils commonly occur along the northeastern and southern mountain fronts. In general, surficial soils grade to silty sands going downslope from the valley flanks toward the valley axis. The sands and gravels are generally poorly graded. Calcium-carbonate cementation of variable degrees occurs sporadically throughout the valley in the coarse-grained soils.

Fine-grained soils cover approximately 40 percent of the geotechnically suitable area. They consist of sandy silts, sandy clays, and clays. In the suitable area, the fine-grained soils are widespread in the south and along the valley axis in the northern portion of the valley. Their plasticity ranges from nonplastic to highly plastic.

2.2.2 Subsurface Soils

Soils in the subsurface are also predominantly coarse-grained consisting of sandy gravels, 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 dense to very dense below 3 to 4 feet (0.9 to 1.2 m), are poorly to well graded, contain coarse to fine sand and/or gravel, exhibit low compressibilities, and possess moderate to high shear strengths. Fine-grained soils (silts and clays) are anticipated to occur in greater than 25 percent of the subsurface in the suitable area. They are mainly in the central and southern portions of the valley. The fine-grained soils are nonplastic to highly plastic with low to moderate compressibilities and shear strengths.

Calcium-carbonate cementation of variable degrees 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 are between five and nine percent in about 15 percent of the suitable area. The other 85 percent of suitable area has surface gradients less than or equal to five percent. Therefore, preconstruction grading will be minimal for most of the valley. More extensive grading will be necessary along the northeastern valley margin where surface slopes generally range from five to nine percent.

The maximum grade at any shelter location in the layout proposed for the valley would be between five and nine percent. For approximately 95 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 exhibit low strength to an average depth of 4.1 feet (1.2 m). The subgrade supporting properties of these low-strength, coarse-grained soils are inadequate but they can be improved by mechanical compaction. Compaction to a depth greater than 3.5 feet (1.1 m) may be required in approximately 60 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 fair to very good subgrade support for roads.

Based on limited testing, the fine-grained surficial soils exhibit low strength in the suitable area to an average depth of 15.9 feet (4.8 m). Supporting qualities of these soils in their natural state 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 direct support of the base course, but a select granular subbase layer over the compacted fine-grained surficial soils will give the required support.

Aggregates suitable for use as a road base-course material are present in Cave Valley. Studies indicate that potentially suitable road base-course aggregate sources are available in sufficient quantity to meet construction requirements of the MX system in Cave Valley.

The overall cost of drainage structures will be low since the drainage incision depths are generally less than 6 feet (1.8 m) within 85 percent of the suitable area; however, costs of the drainage structures will be higher along the northern valley margins because drainage incision depths are larger.

2.3.3 Excavatability and Stability

The soils in the construction zone are generally dense to very dense and possess various degrees of calcium-carbonate cementation.

Horizontal Shelter: Excavation for the horizontal shelter can be done using conventional equipment such as scrapers, backhoes, and bulldozers. Excavation will be easy to moderately difficult in approximately 85 to 90 percent of the suitable area; however, excavation will be 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. In addition, localized areas of non-rippable materials may be encountered throughout the northwestern portion of the valley. Laboratory test results and field observations indicate that excavations for construction of shelters should generally be cut back to slopes ranging from 1/2:1 to 2:1 (horizontal:vertical) for stability. Variations in density and shear strength, which depend on soil composition and the degree of cementation, cause the wide variation in slope angle. Due to low-strength surficial soil, the top 3 to 4 feet (0.9 to 1.2 m) will generally require a flatter slope than the deeper sections of the excavations.

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 in some cases will probably require the use of slurry or other stabilizing techniques.

R 62 E R 63 E R 64 E 114°45'

EXPLANATION

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

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

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

Areas of isolated exposed rock.

R Areas of isolated exposed rock too small for shading.

Contact between rock and basin-fill.

Valley borders.

SCAL
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STAT
0
KIL

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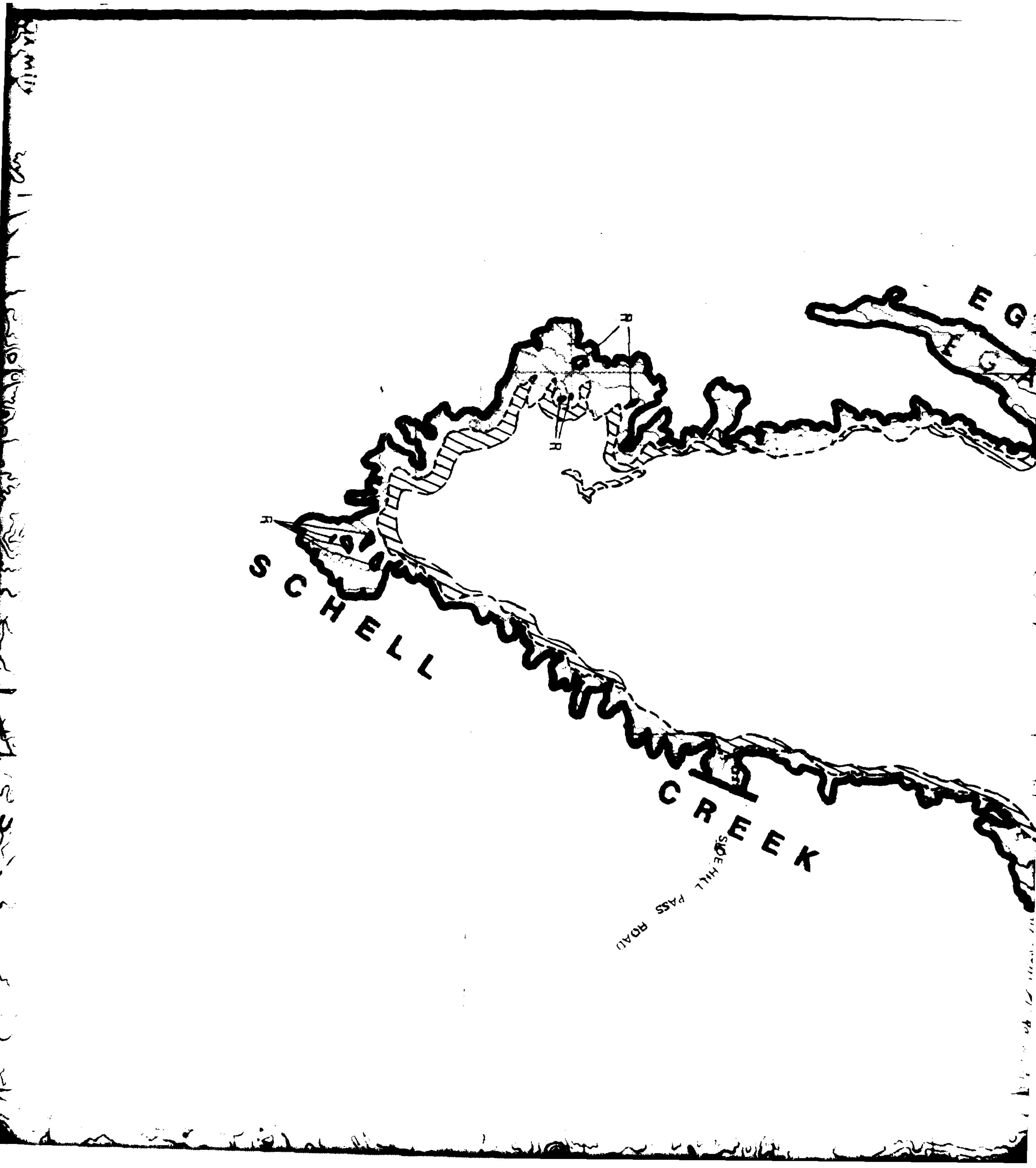
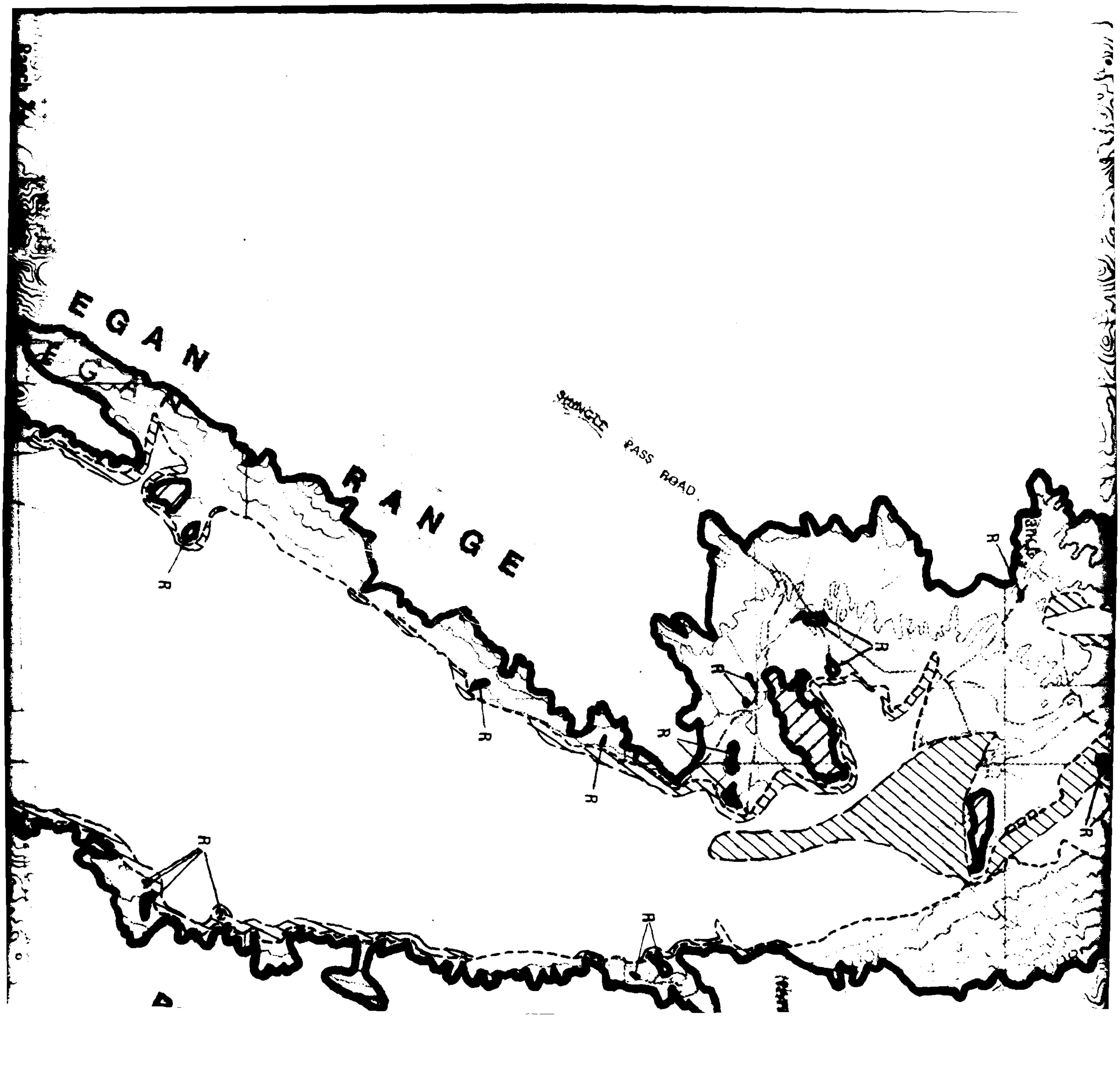
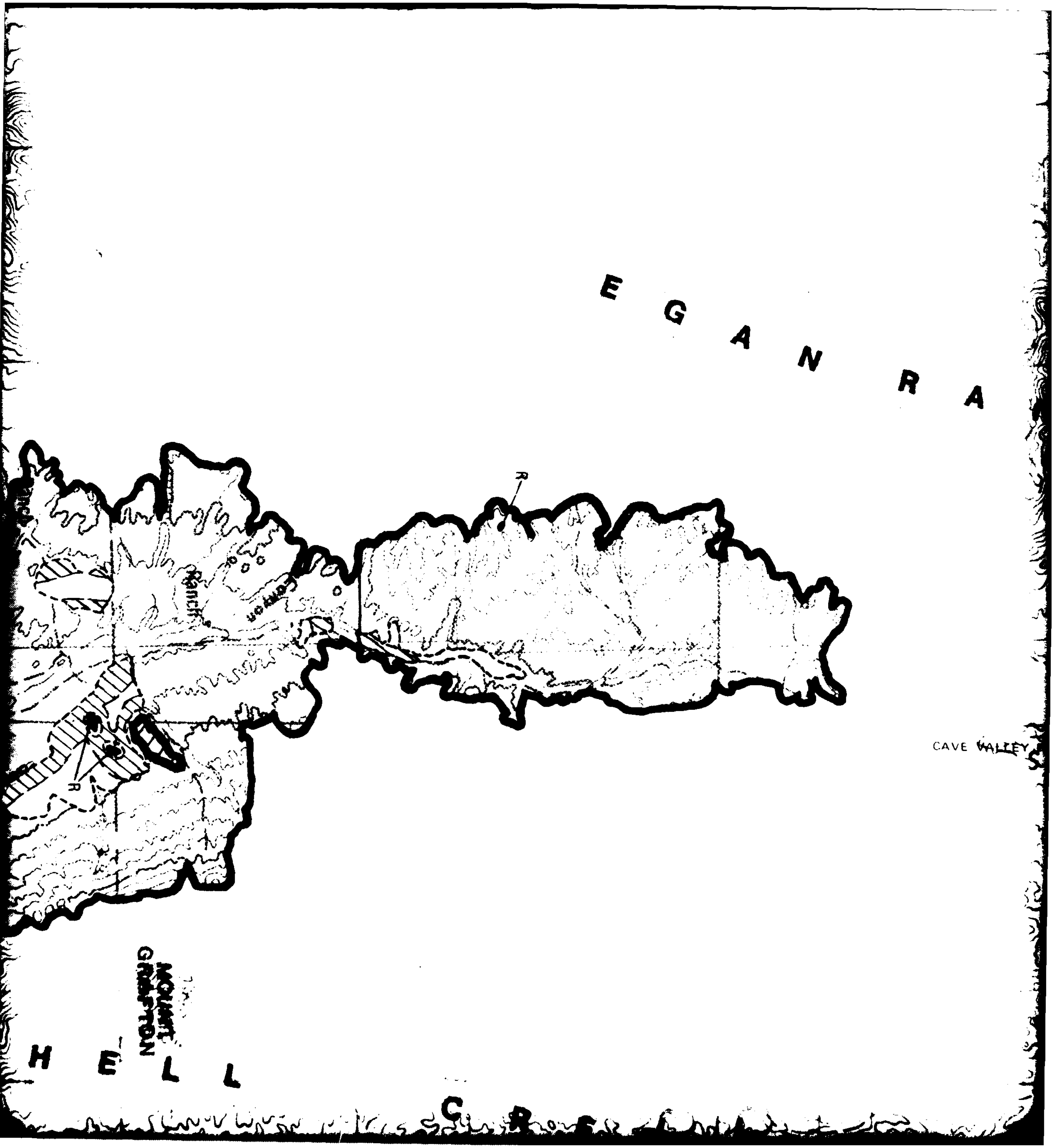
SUITABLE AREA FOR HORIZONTAL
AND VERTICAL SHELTERS
CAVE VALLEY, NEVADA

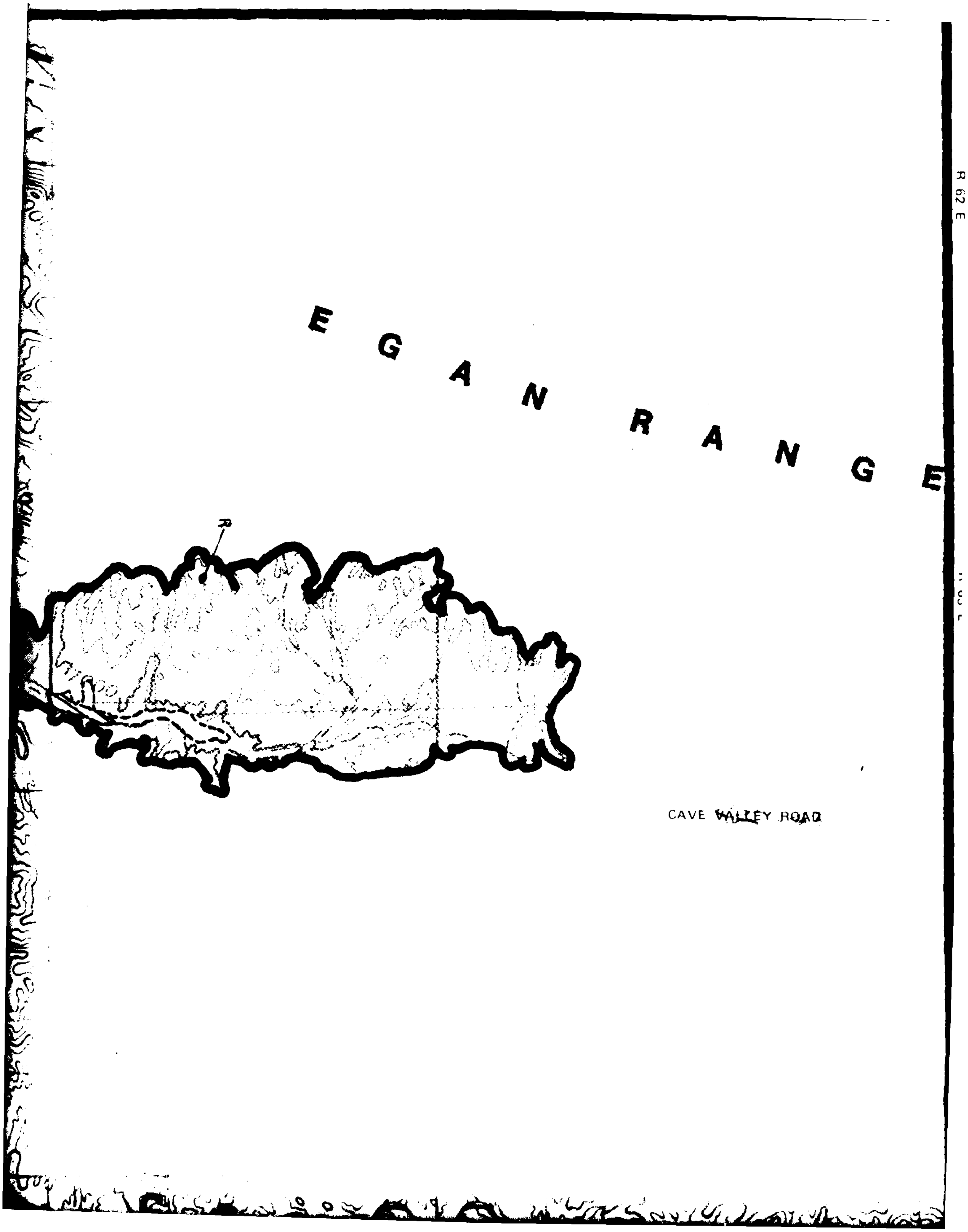
26 OCT 81

DRAWING 2-1


SCHELL
CREEK
EG
SCHELL PASS ROAD


EGAN RANGE
PASS ROAD
R


E G A N R A
R
Ranch
Canyon
R
CAVE VALLEY
MOUNT GRAFTON
H E L L
C R


R 62 E
E G A N R A N G E
CAVE VALLEY ROAD

R 63 E   R 64 E   114°45'   R 65 E

EXPLANATION

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

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

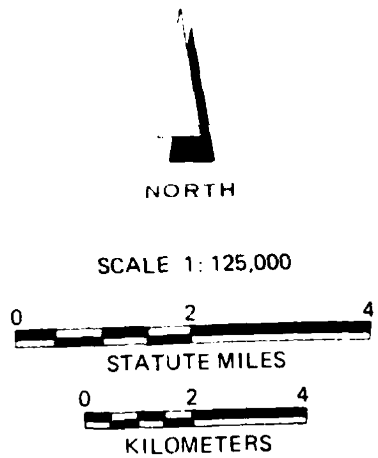
Area unsuitable for both horizontal and vertical shelter basing modes determined from application of depth to rock and water criteria, topography/terrain and cultural exclusions.

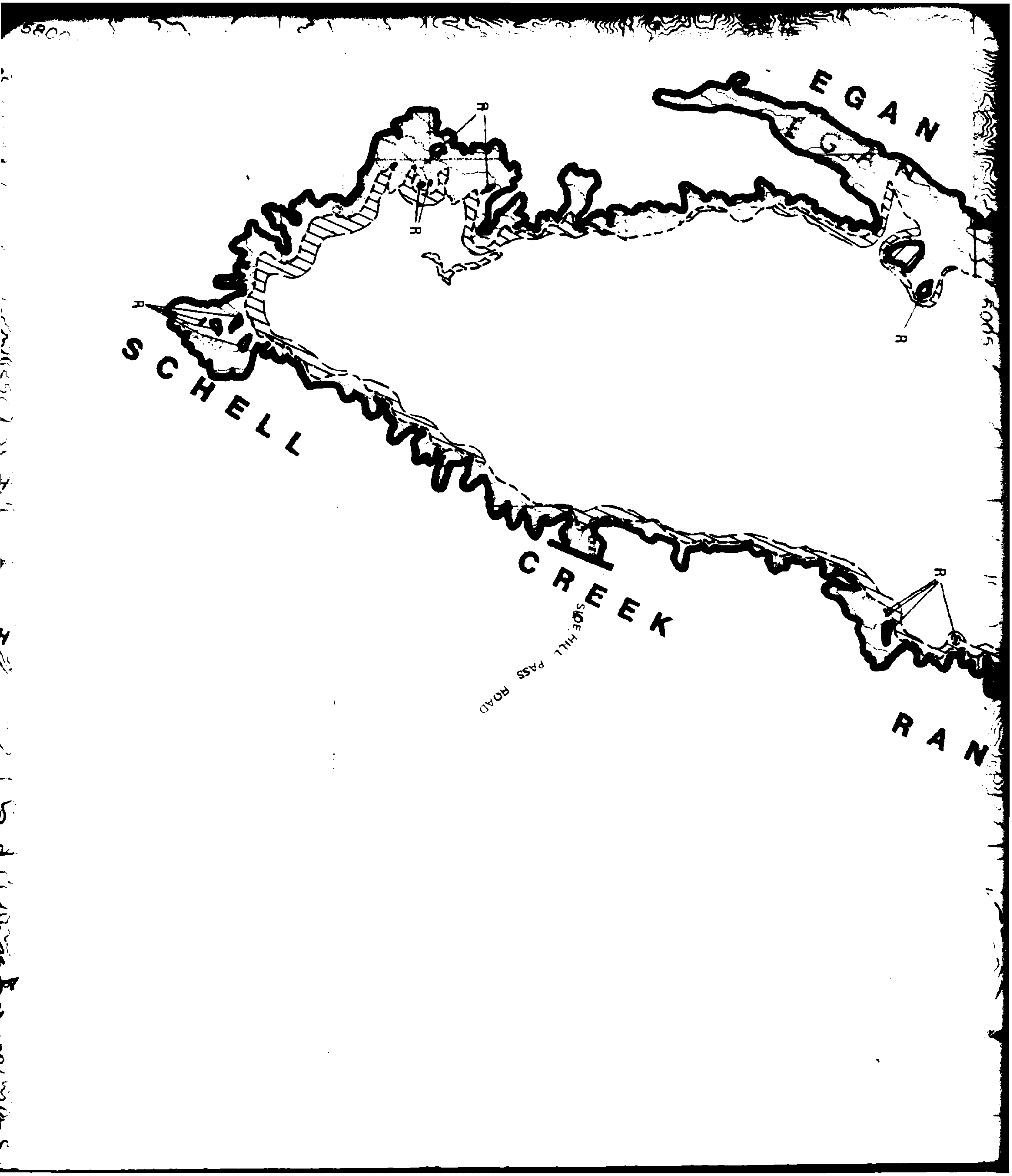
Areas of isolated exposed rock.

R Areas of isolated exposed rock too small for shading.

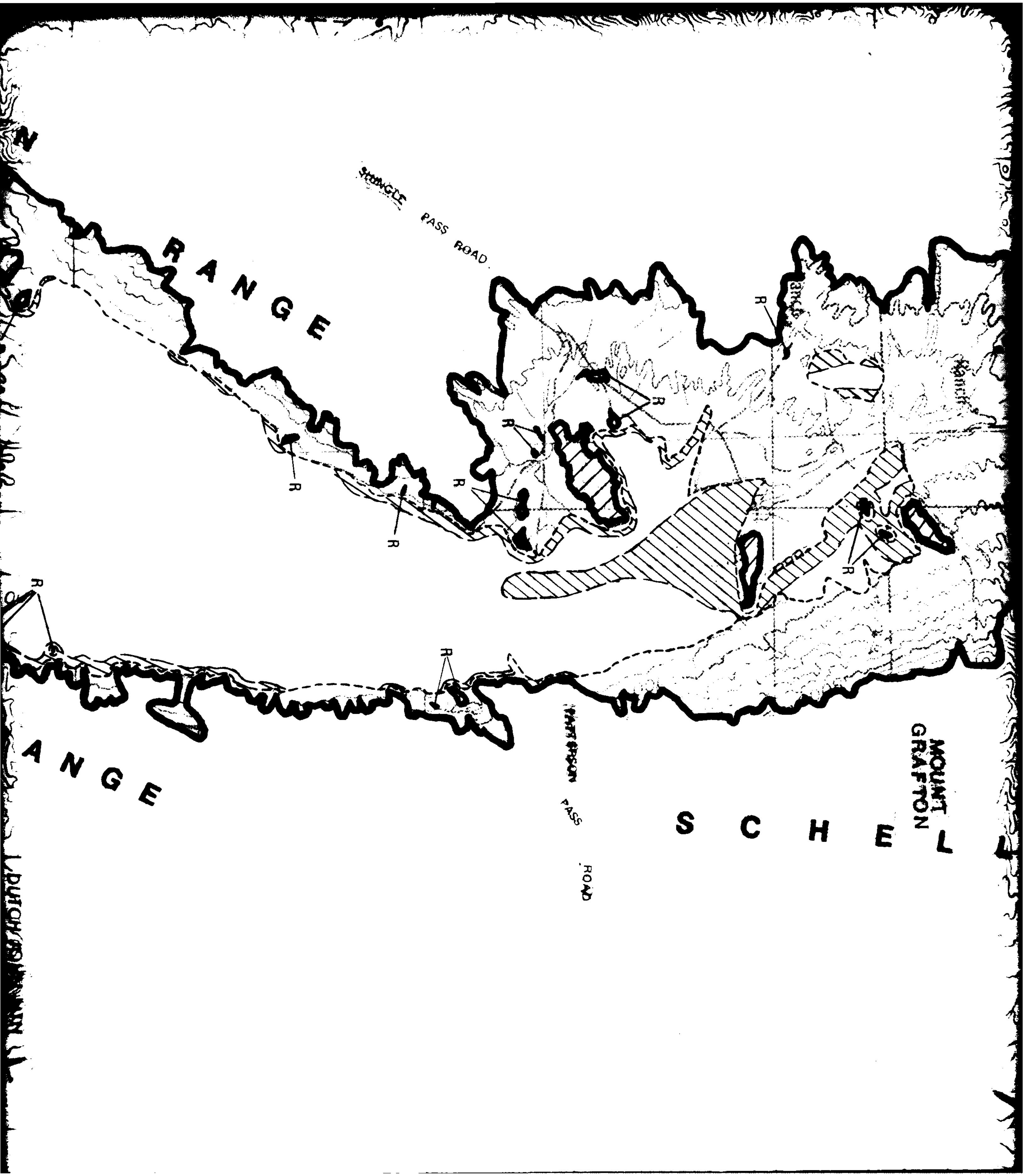
Contact between rock and basin-fill.

Valley borders.

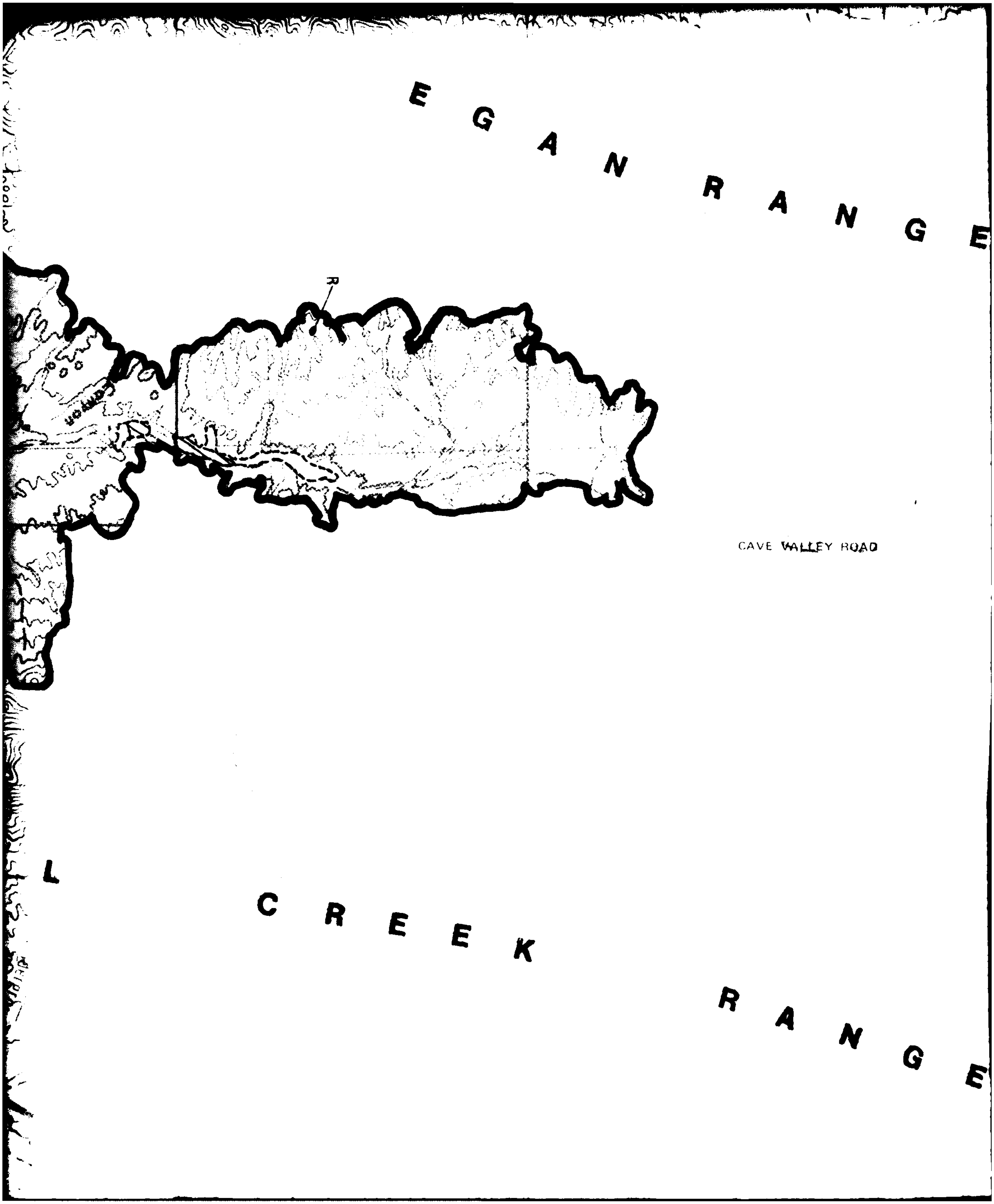




5800
EGAN
R
R
R
R
R
SCHELL
CREEK
SIDE HILL PASS ROAD
RAN



N
RANGE
SHINGLE PASS ROAD
R
ANGE
PASS ROAD
MOUNT GRAFTON
SCHELL

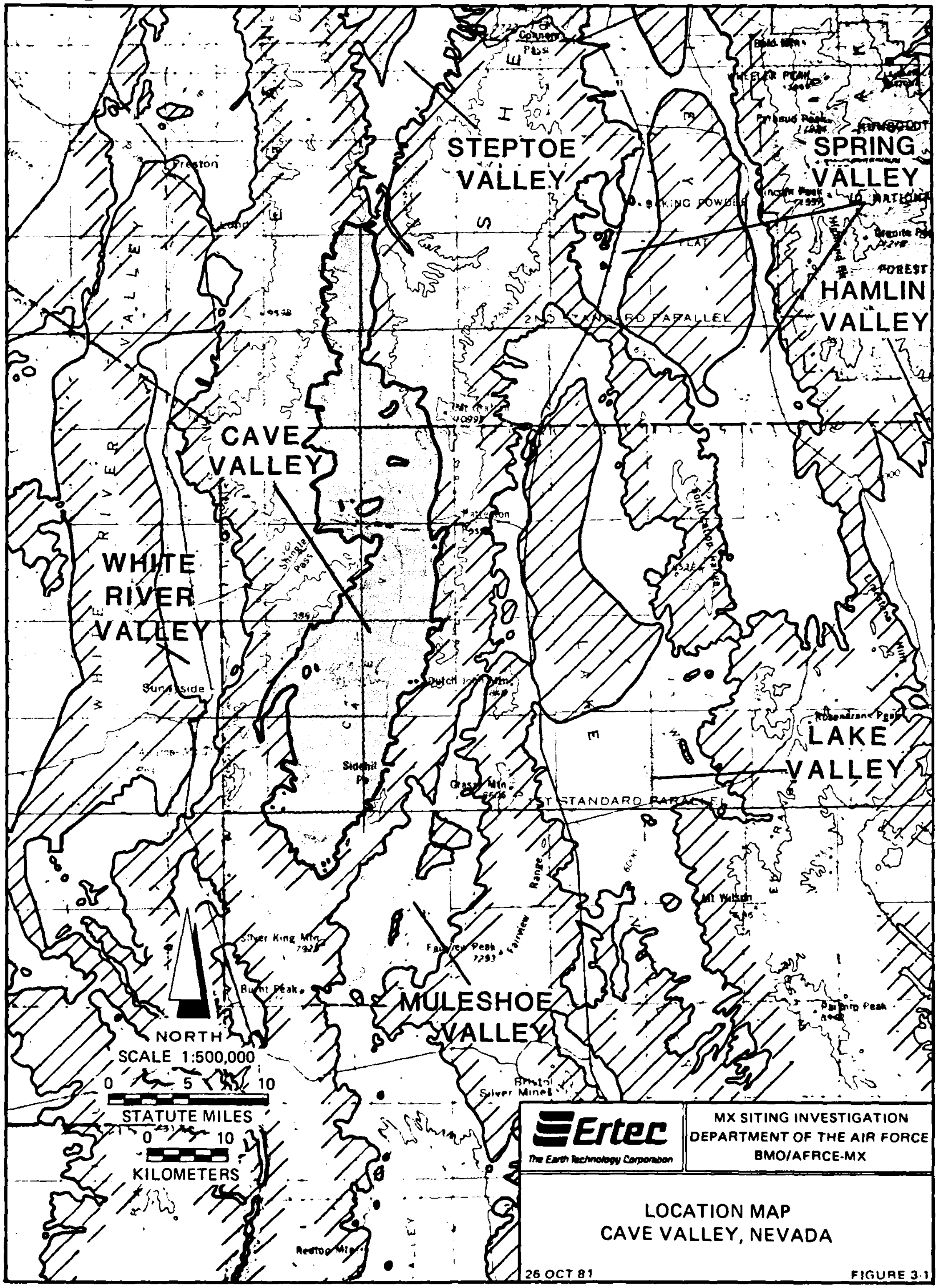

E G A N R A N G E
R
CAVE VALLEY ROAD
L C R E E K R A N G E

3.0 GEOTECHNICAL SUMMARY

3.1 GEOGRAPHIC SETTING

Cave Valley is a northerly trending valley in southeastern Nevada about 50 miles (80 km) northwest of the town of Pioche. It lies between northern Lake and White River valleys on the east and west, respectively (Figure 3-1). The valley is bounded on the east by the Schell Creek Range and on the west by the Egan Range. These ranges merge to form the southern boundary of the valley. The northern boundary is formed by an alluvial divide approximately 7200 feet (219 m) in elevation (Drawing 3-1). Cave Wash is located in the north and central axial portions of the valley and drains southward, termina..ng in a playa in the southern portion of the valley.

A network of well maintained dirt roads provides access to Cave Valley. Cave Valley Road, from Ely, Nevada, enters from the north and traverses north-south through the valley (Drawing 3-1). Patterson Pass Road and Sidehill Pass Road enter the east-central and southeast portions of the valley, respectively, and connect with State Highway 93 in Lake Valley. Shingle Pass Road enters the west-central portion of the valley from the west where it connects with State Highway 38 in White River Valley. A network of graded roads and jeep trails provides access to the remaining portions of the valley. The land consists of undeveloped desert rangeland with scattered corrals, fencing, and water tanks.



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LOCATION MAP
CAVE VALLEY, NEVADA

26 OCT 81

FIGURE 3-1

3.2 GEOLOGIC SETTING

3.2.1 Rock Types

Cave Valley is an elongate, northerly trending alluvial basin bordered by mountains composed of sedimentary, metasedimentary, and volcanic rocks. The Schell Creek Range consists primarily of Cambrian to Permian (?) sedimentary rocks (quartzite, limestone, dolomite, and shale) overlain unconformably by limited exposures of middle Tertiary volcanic rocks (welded tuff and dacite). The Egan Range is composed primarily of early Ordovician to late Pennsylvanian (?) sedimentary rocks (limestone, dolomite, quartzite, and shale) overlain unconformably by middle Tertiary volcanic rocks (welded tuff and dacite).

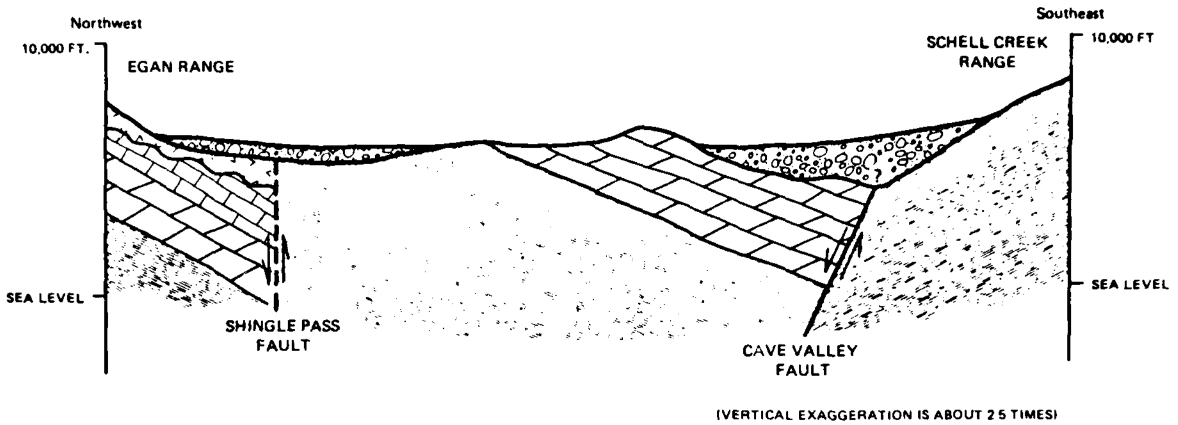
3.2.2 Structure

Cave Valley is within the Great Basin section of the Basin and Range physiographic province. The north-south alignment of valleys and mountains within this region is a direct result of late Cenozoic block faulting caused by east-west or northwest-southeast crustal extension. The physiography of Cave Valley as a north-south trending, flat-floored, topographically enclosed basin lying between two north-south trending mountain ranges is characteristic of this block-faulted tectonic terrane.

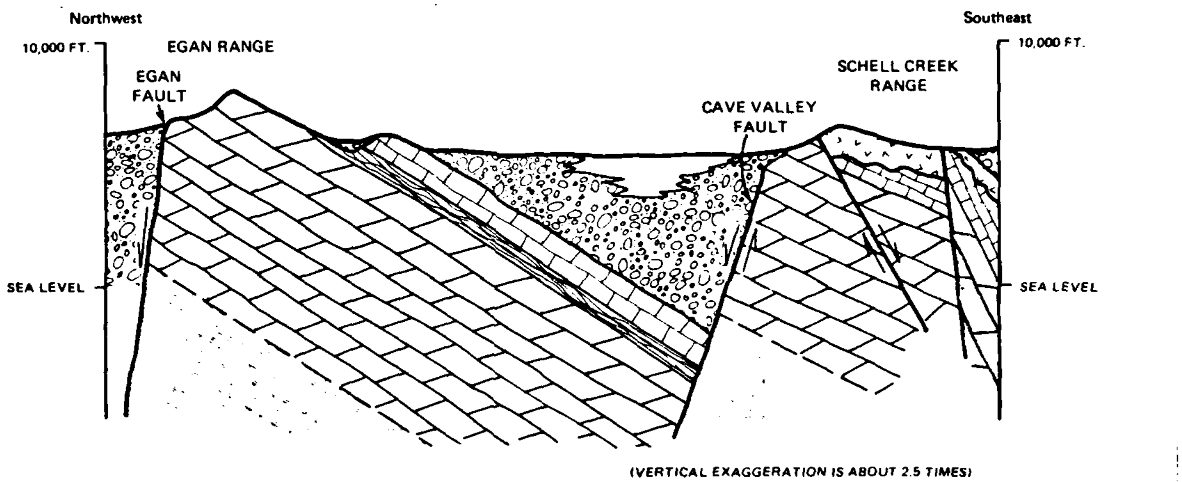
The valley is separated into northern and southern portions by a spur-ridge of Paleozoic rocks which extends northeasterly into Cave Valley from southeast of Shingle Pass in the Egan Range (Drawing 3-2). Scattered small outcrops of Paleozoic strata and gravity data (Ertec Western, Inc., 1981) indicate that this ridge continues below the surface toward Mt. Grafton in the Schell Creek Range.

There are no major surficial Quaternary faults in Cave Valley, but its structural configuration can be postulated from surface geologic and gravity data. The easterly dipping Paleozoic and overlying Tertiary volcanic rocks suggest that both the Egan Range and the Schell Creek Range are down-to-the-east tilted blocks (Figure 3-2). Repetition of the stratigraphic section in both of the mountain ranges indicates a major normal fault underlying Cave Valley. Gravity data (Ertec Western, Inc., 1981) suggest that such a fault lies along the eastern margin of southern Cave Valley. This fault coincides with the Cave Valley fault postulated from stratigraphic data by Kellogg (1960). The depth of the southern Cave Valley basin, estimated from gravity data, suggests stratigraphic separation on this fault on the order of 10,000 feet (3000 m). Although there are no surface scarps along this fault, the presence of northerly striking lineaments (Drawing 3-2) within the alluvial fans along the eastern valley margin support the existence of this fault. These lineaments are primarily alignments of vegetation but numerous sinkholes at their northern end suggest dissolution of shallow carbonate bedrock by ground-water seepage along a subsurface bedrock fault.

Stratigraphic relationships and gravity data suggest that alluvial basin fill is thinner in northern Cave Valley than in southern Cave Valley and that the geologic structure is more



A. CROSS SECTION THROUGH NORTHERN CAVE VALLEY



B. CROSS SECTION THROUGH SOUTHERN CAVE VALLEY

- QUATERNARY PLAYA DEPOSITS
- QUATERNARY AND LATE TERTIARY (?) ALLUVIUM
- TERTIARY VOLCANIC ROCKS
- UPPER PALEOZOIC CARBONATES (PREDOMINANTLY LIMESTONE AND QUARTZITE)
- UPPER PALEOZOIC SHALES
- LOWER PALEOZOIC CARBONATES (PREDOMINANTLY DOLOMITE)
- CAMBRIAN AND PRECAMBRIAN CLASTIC SEDIMENTARY ROCKS
- FAULT (ARROWS INDICATE RELATIVE DIRECTION OF MOVEMENT)
- INFERRED FAULT

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SCHEMATIC GEOLOGIC
CROSS-SECTIONS
CAVE VALLEY, NEVADA

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FIGURE 3-2

complex in the north (Figure 3-2). Two major fault zones are suggested in northern Cave Valley; the northern continuation of the Cave Valley fault on the east and the Shingle Pass fault on the west. The nature and location of the Shingle Pass Fault is poorly known, but based on gravity data, it appears to strike northeasterly between the spur-ridge and the main Egan Range. The southwesterly connection of this fault to a fault in Shingle Pass as shown by Kellogg (1960) cannot be substantiated based on the present data. The northeasterly extent of the Shingle Pass fault and its relationship to the Cave Valley fault are unknown, but based on the amounts of relative stratigraphic separation, the Cave Valley fault appears to be the major basin-bounding fault separating the Egan and Schell Creek fault blocks.

3.2.3 Surficial Geologic Units

Geologic and engineering data collected in the field (Drawing 3-1) were used to verify the interpretations of surficial geologic units made from aerial photographs. Three major geologic units cover approximately 77 percent of Cave Valley. Pleistocene pluvial lake deposits (A4o) are the predominant surficial geologic unit. These sediments are located in the southern portion of the valley and range from silty sands and clays near the valley axis to sands and gravels near the old lake margins (Drawing 3-2). Plio-Pleistocene sediments (A6) are the second most prevalent unit. These sediments are exposed in the northern and northwestern portions of the valley and locally consist of a highly cemented, basal, boulder to pebble conglomerate with overlying interbedded conglomerate, sandstone, and siltstone (Kellogg, 1964). Intermediate-age alluvial fans (A5i) are the third most prevalent surficial unit. These fans occur along the mountain fronts in the east, southeast, and southwest portions of the valley and are composed of silty sand and sandy to silty gravels.

The following geologic units were mapped in Cave Valley (Drawing 3-2):

- Plio-Pleistocene Sediments (A6) - In northern and northwestern Cave Valley, morphologically distinctive units of the Plio-Pleistocene "Cave Valley Formation" occupy approximately 23 percent of the valley area. In general, these deposits strike to the northwest and have a shallow northeasterly dip. Locally, these sediments are highly cemented and consist of a basal boulder to pebble conglomerate with overlying interbedded conglomerate, sandstone, and siltstone. Clasts from the basal conglomerate suggest they were derived locally from lower Paleozoic limestones, while pebbles from the upper interbedded conglomerates indicate local derivation from all of the exposed Paleozoic formations (Kellogg, 1964).

- Old-age Alluvial Fan Deposits (A5o) - These Pleistocene age units occupy approximately five percent of the total valley area. The fans consist of silty sands (A5os) with moderate gravel concentrations and sandy gravels (A5og) generally occurring adjacent to the mountain fronts along the northeastern and southwestern sides of the valley. Cementation ranges from none (gravels) to moderate (sands). Caliche development varies from Stage III for the silty sands to Stage II for the sandy gravels.

- Intermediate-age Alluvial Fan Deposits (A5i) - These Pleistocene age fan deposits occupy approximately 22 percent of the total valley area. The majority are composed primarily of gravelly to silty sands (A5is) and range from silty gravels (A5ig) to clayey sands. The fans occur along the mountain fronts in the southwest and southeast portions of the valley and basinward of the old-age alluvial fan exposures. Cementation in the A5i deposits ranges from none to strong but is generally weak. Caliche development varies from Stage I to Stage IV but is predominantly Stage II.

- Young-age Alluvial Fan Deposits (A5y) - These Holocene age sediments occupy approximately 14 percent of the total valley area. The majority of these fans consist of silty to gravelly sands (A5ys) but range from sandy silts (A5yf) to poorly sorted silty and sandy gravels (A5yg). These units predominantly occur as fans around the margin of the old pluvial lake and are locally interfingered with recent fluvial deposits (A1) along the axial drainage of the valley. Cementation is generally absent. Caliche development ranges from absent to Stage II but is predominantly Stage I.

- Young Fluvial and Associated Floodplain Deposits (A1) - These Holocene age deposits cover five percent of the total valley area. The deposits occur along the axial drainage (Cave Wash) and its tributary system in the north and central portions of the valley. The fluvial deposits within Cave Valley are sandy silts to silty clays (A1f) and are uncemented.

- Lacustrine Deposits (A4, A4o) - A4 represents Holocene playas and A4o designates Tertiary-Quaternary lacustrine sediments. Together, these deposits occur exclusively in the southern portion of the valley and occupy approximately 31 percent of the total valley area. The only A4 deposit (playa) lies on the west side of the valley where it covers approximately 1 mi^2 (2.5 km^2) and is composed of silty sand (A4s). The A4o sediments are remnants of a Pleistocene age pluvial lake (Cave Lake). The composition of the lakebed ranges from silty sand (A4os) to clayey silt and sandy to silty clay (A4of). Cementation is weak to absent in these units. The margin of the lakebed contains abundant shoreline features which indicate a maximum elevation for the lake of 6060 feet (1848 m). These shoreline features are represented by sandy to silty gravel bars (A4og). Cementation in these sediments is weak and exhibits Stage I caliche development.

3.3 SURFICIAL SOILS

Surficial soils of Cave Valley are predominantly coarse-grained. They range from gravels with trace to some fines to sands with some fines. Fine-grained soils (silts and clays) cover widespread areas in the southern and north-central portions of the valley. Soils and their associated predominant surficial geologic units (those estimated to cover at least five percent of the total area) can be categorized in three groups based on their physical and engineering characteristics.

1. Sandy gravels and silty gravels (geologic unit A5ys, A5ig, A5is, and A6);
2. Silty sands (geologic units A4os, A5ys, A5is, and A6); and
3. Sandy silts, sandy clays, and clays (geologic unit A4).

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 3-3.

Approximately 20 to 30 percent of the total area is covered by sandy and silty gravels. Gravelly soils commonly occur in the fans in the eastern portion of the valley. In general, grav l content increases toward the mountain fronts. Sandy and silty gravels have a wide range of particle sizes, but most are poorly graded. Occasionally, cobbles and boulders to 12 inches (305 mm) and larger in diameter are encountered at or near the ground surface in these gravelly deposits throughout the valley. Gravelly deposits also have weak to strong calcium-carbonate cementation.

Silty sands are the predominant surficial soils, covering approximately 50 to 60 percent of the total area. They are widely distributed, being the major component in all areas except the southern portion of the valley. The sands are coarse to fine and poorly graded. Generally, they contain some nonplastic fines. The fines content is highest along the central axis and decreases toward the valley margin. Gravel content increases

SOIL DESCRIPTION	Sandy Gravels and Silty Gravels	Silty Sands
USCS SYMBOLS	GP-GM,	SM
PREDOMINANT SURFICIAL GEOLOGIC UNITS	A5ig, A6	A4os, A5ys, A5is, A
ESTIMATED AREAL EXTENT %	20 - 30	50 - 60
PHYSICAL PROPERTIES		
COBBLES 3 – 12 inches (8 – 30 cm) %	0 - 20	0 - 5
GRAVEL %	43 - 59 [5]	1 - 11
SAND %	19 - 45 [5]	56 - 68
SILT AND CLAY %	7 - 22 [5]	29 - 41
LIQUID LIMIT	NDA	NDA
PLASTICITY INDEX	NDA	NP
ROAD DESIGN DATA		
MAXIMUM DRY DENSITY pcf (kg/m^3)	NDA	112.5 - 128.6 (1802 - 2060)
OPTIMUM MOISTURE CONTENT %	NDA	9.0 - 14.0
CBR AT 90% RELATIVE COMPACTION %	NDA	17 - 18
SUITABILITY AS ROAD SUBGRADE (1)	good to very good	fair to good
SUITABILITY AS ROAD SUBBASE OR BASE (1)	fair to good	poor to fair
THICKNESS OF LOW STRENGTH SURFICIAL SOIL (2) — RANGE ft (m)	0.7 - 3.0 (0.2 - 0.9) [6]	1.8 - 11.2 (0.5 - 3.4)
THICKNESS OF LOW STRENGTH SURFICIAL SOIL (2) — AVERAGE ft (m)	1.6 (0.5) [6]	6.3 (1.9)

(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 for details.

NOTES:
- [ ] –
- NDA – No
  not

y Sands	Sandy Silts, Sandy Clays and Clays	
	ML, CL, CH	
s, A5ys, A5is, A6	A4of	
60	15 - 20	
5	0	
11 [3]	0 [4]	
68 [3]	1 - 34 [4]	
41 [3]	66 - 99 [4]	
A	35 - 69 [3]	
[2]	NP - 47 [4]	
.5 - 128.6 02 - 2060) [2]	103.0 - 106.0 (1650 - 1698) [2]	
- 14.0 [2]	20.0 - 22.2 [2]	
18 [2]	2 - 9 [2]	
to good	poor to fair	
r to fair	not suitable	
- 11.2 - 3.4) [7]	2.5 - >33.0 (0.8 - >10.1) [7]	
[7]	15.9 (4.8) [7]	

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

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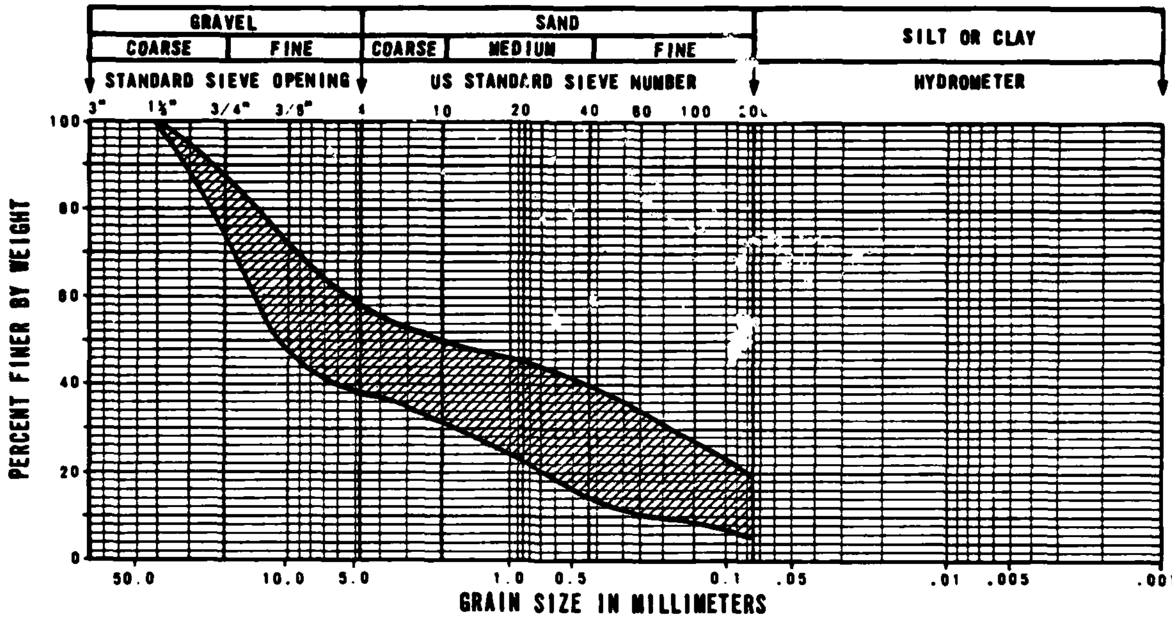
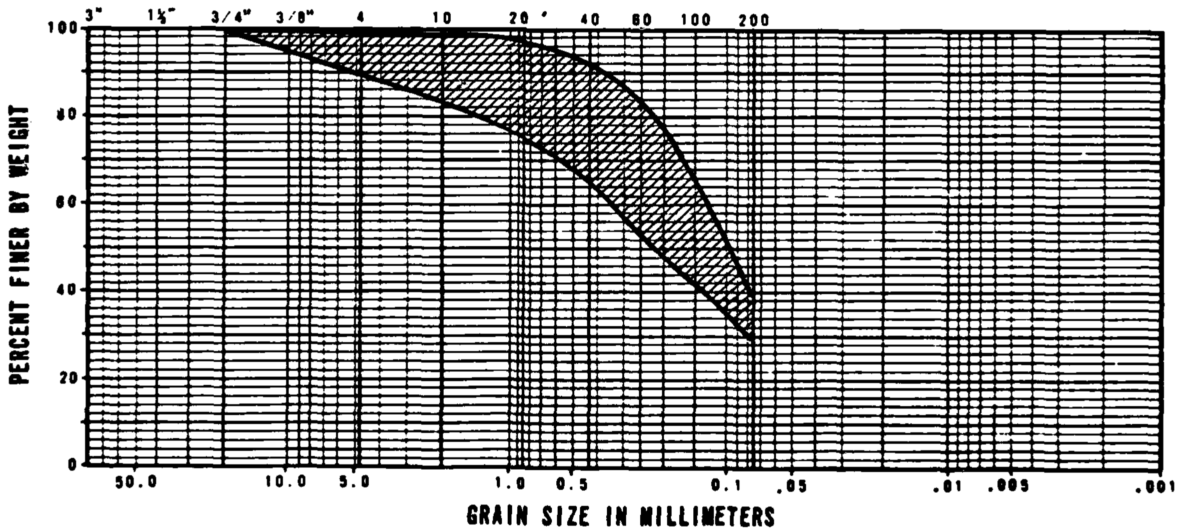
CHARACTERISTICS OF SURFICIAL SOILS
CAVE VALLEY, NEVADA

26 OCT 81 TABLE 3-1

2



SOIL DESCRIPTION: Sandy Gravels and Silty Gravels
from 0 to 2 feet (0.0 to 0.6m)



SOIL DESCRIPTION: Silty Sands
from 0 to 2 feet (0.0 to 0.6m)

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RANGE OF GRADATION OF
SURFICIAL SOILS
CAVE VALLEY, NEVADA
PAGE 1 OF 2

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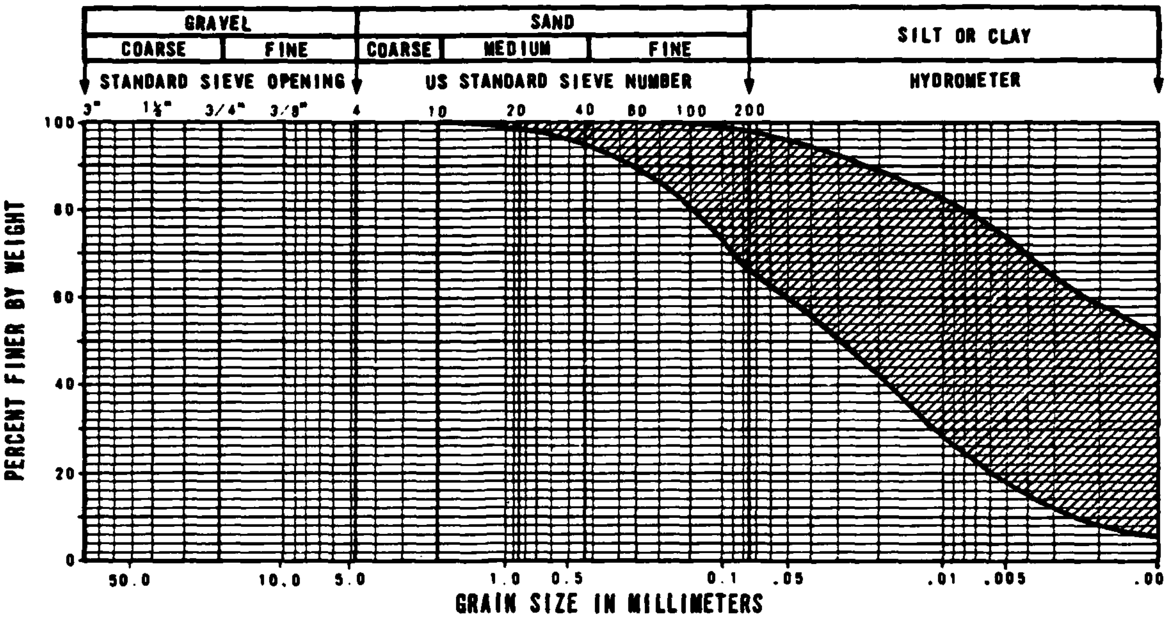
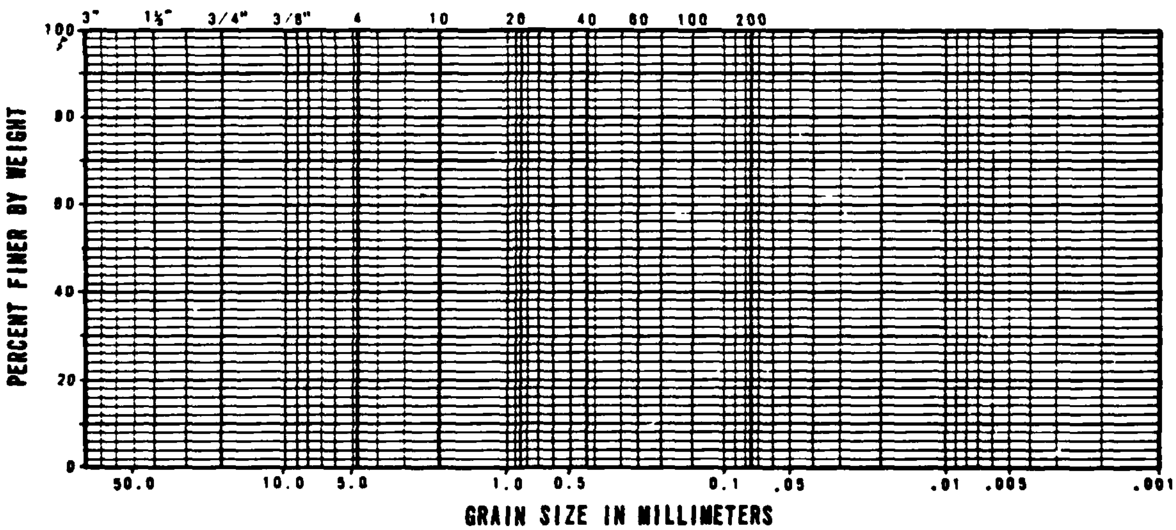
FIGURE 3-3



SOIL DESCRIPTION: Sandy Silts, Sandy Clays, and Clays from 0 to 2 feet (0.0 to 0.6m)



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RANGE OF GRADATION OF
SURFICIAL SOILS
CAVE VALLEY, NEVADA
PAGE 2 OF 2

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FIGURE 3-3

toward the mountain fronts. Weak to strong calcium-carbonate cementation is encountered occasionally in the surficial sands throughout the valley.

Silts and clays cover 15 to 20 percent of the total valley area. The sandy silts, sandy clays, and clays occur predominantly in older lacustrine deposits in the southern and north-central portions of the valley. These soils contain traces to some medium to fine sand. Their plasticity ranges from nonplastic to highly plastic.

3.3.2 Low-Strength Surficial Soil

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

Summaries of the range and mean thickness of the low-strength surficial soil for the three soil categories are included in Table 3-1. Sandy and silty gravels exhibit low strength to depths ranging from 0.7 to 3.0 feet (0.2 to 0.9 m), with an average of 1.6 feet (0.5 m). Silty sands exhibit low strengths to depths ranging from 1.8 to 11.2 feet (0.5 to 3.4 m), with an average of 6.3 feet (1.9 m). The range of depths of low-strength, granular soils is due to variations in the in-situ density and calcium-carbonate cementation. Silts and clays exhibit low strength to depths ranging from 2.5 to greater than 33.0 feet (0.8 to greater than 10.1 m), with an average of 15.9 feet (4.8 m). The deep, low-strength, fine-grained soils are concentrated mainly in southern Cave Valley. The variation in

CONE PENETROMETER TEST NUMBER[1]	THICKNESS OF LOW STRENGTH SURFICIAL SOIL,[2]		SOIL TYPE[3]
	FEET	METERS	
C-1	2.3	0.7	GM
C-2	> 33.0	10.1	CH
C-3	28.3	8.6	CL
C-4	25.2	7.7	CH/SM
C-5	1.8	0.5	SM
C-6	11.2	3.4	SM
C-7	8.0	2.4	CL
C-8	6.1	1.9	ML/CL
C-9	2.5	0.8	CL
C-10	1.9	0.6	GP-GM
C-11	6.0	1.8	SM/SP
C-12	6.3	1.9	SM
C-13	3.9	1.2	SM/SP
C-14	3.0	0.9	GP-GM
C-15	0.7	0.2	GP-GM
C-16	4.2	1.3	SM
C-17	1.0	0.3	SM/GM
C-18	10.4	3.2	ML/SM
C-19	0.9	0.3	SW-SM
C-20	13.7	4.2	SM

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

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

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

where q_c is cone resistance.

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

CONE PENETROMETER TEST NUMBER[1]	THICKNESS OF LOW STRENGT SURFICIAL SOIL,[2]	
	FEET	METERS

NOTES:
- For fine gr strength su of the soil
- SM/GM – ind
- NDA – No d

...SS OF LOW STRENGTH ...RFICIAL SOIL,[2]		SOIL TYPE [3]
	METERS	

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

...: • 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

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THICKNESS OF LOW STRENGTH
SURFICIAL SOILS
CAVE VALLEY, NEVADA

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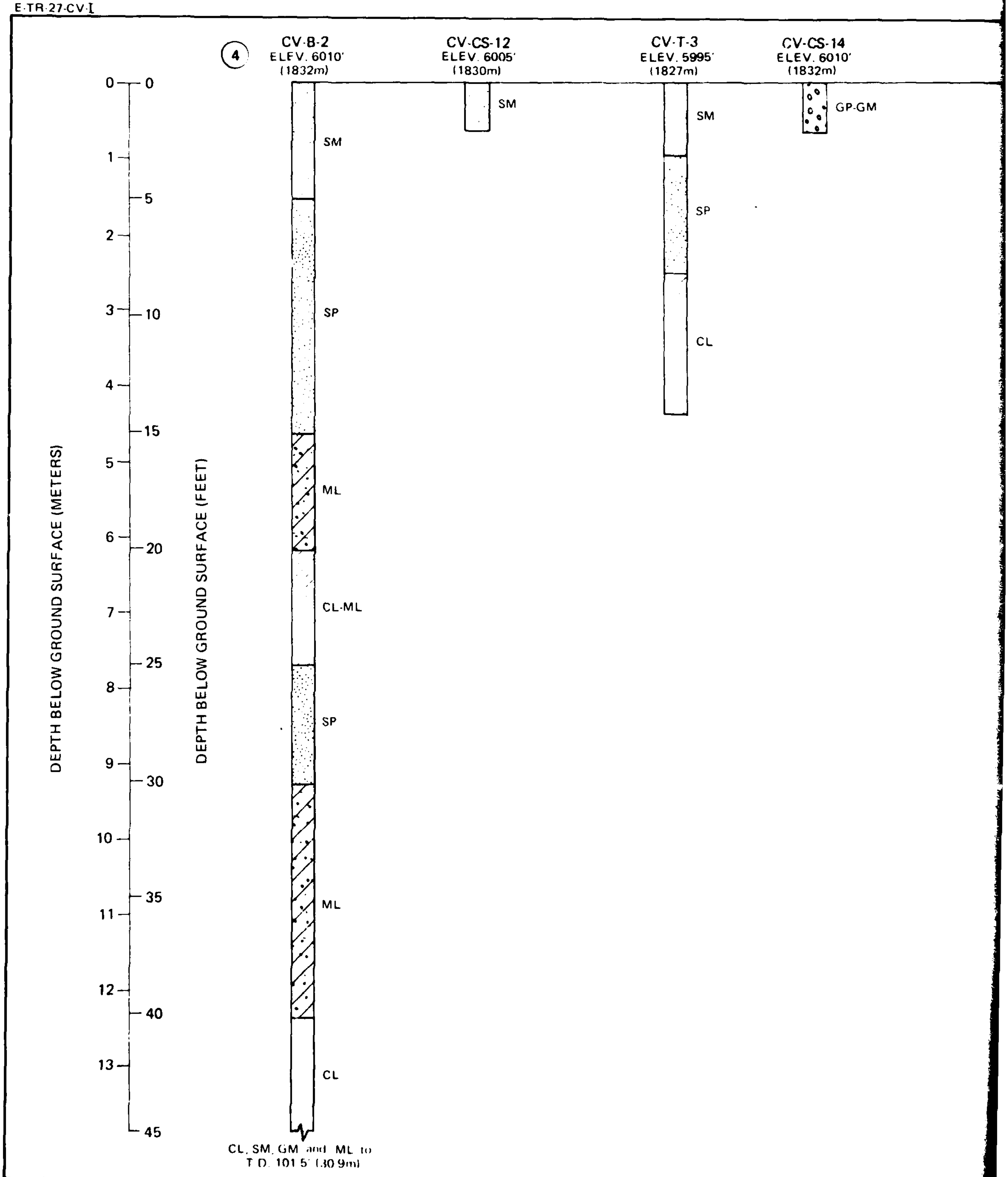
the thickness of low-strength, fine-grained soils is due to changes in the in-situ density, the amount of fine sand, and calcium-carbonate cementation.

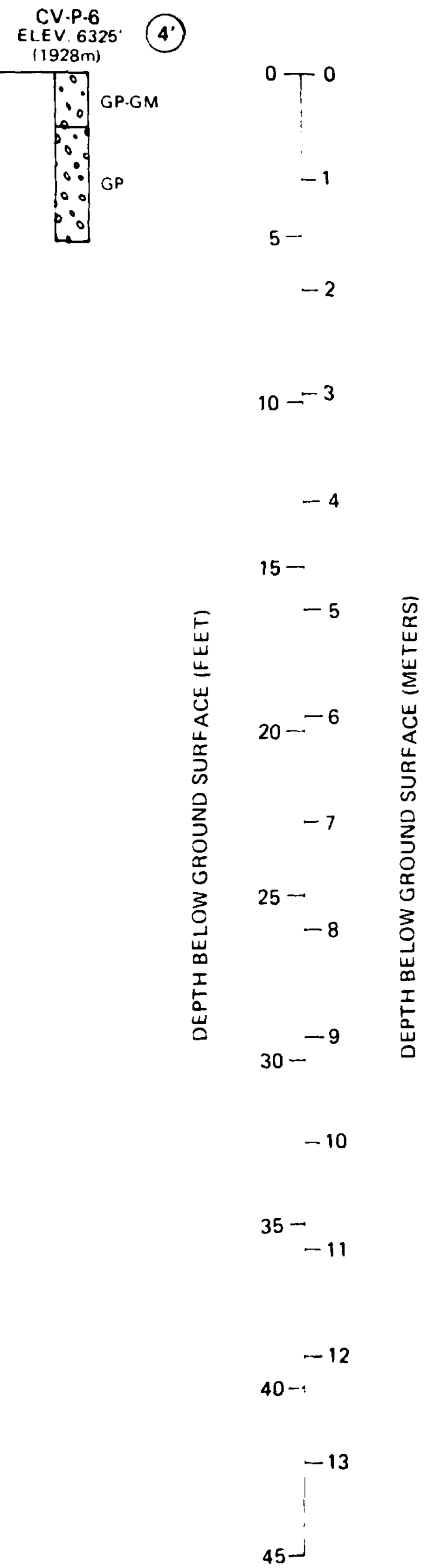
3.4 SUBSURFACE SOILS

Subsurface soils are predominantly coarse-grained and are estimated to compose 70 to 80 percent of the subsurface deposits within the total area. These soils consist of sandy gravels, gravels, gravelly sands, sands, and silty sands. The fine-grained soils consist of sandy silts, silts, sandy clays, silty clays, and clays with plasticity ranging from nonplastic to highly plastic. Fine-grained soils are estimated to compose 20 to 30 percent of the subsurface deposits within the total area boundaries.

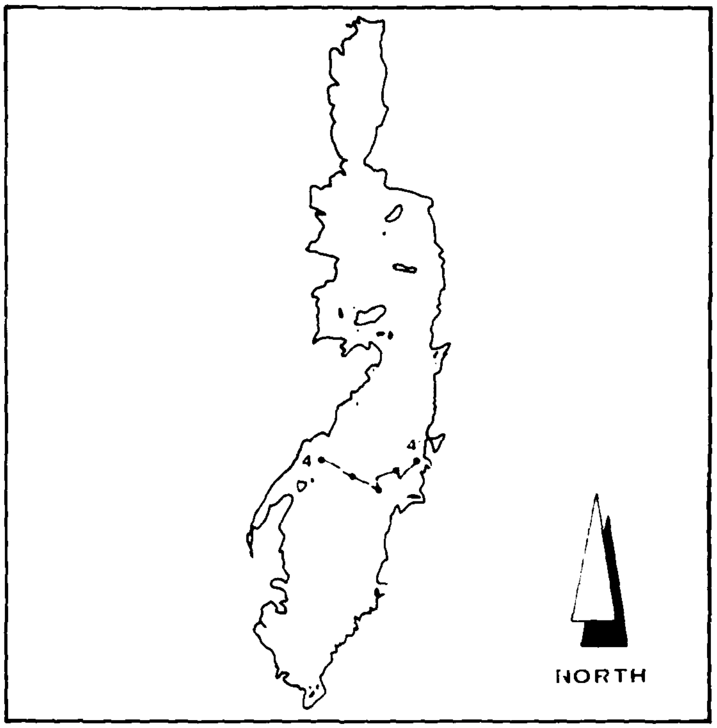
The composition of subsurface soils with depth, as determined from borings, trenches, and test pits, is illustrated in the soil profiles presented in Figures 3-4 through 3-6. Results of seismic and electrical surveys are summarized in Table 3-3. The characteristics of subsurface soils, determined from field and laboratory tests, are presented in Table 3-4. Ranges of gradation of the subsurface soils are shown in Figure 3-7.

Coarse-grained subsurface soils are poorly to well-graded, contain coarse to fine sands and gravels, and are dense to very dense below 3 to 4 feet (0.9 to 1.2 m). Variable cementation occurs intermittently, but well-developed, continuous cementation was not encountered. These soils exhibit low compressibilities and moderate to high shear strengths.


4
CV-B-2
ELEV. 6010'
(1832m)
CV-CS-12
ELEV. 6005'
(1830m)
CV-T-3
ELEV. 5995'
(1827m)
CV-CS-14
ELEV. 6010'
(1832m)
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
SM
SP
ML
CL-ML
SP
ML
CL
SM
SM
SP
CL
GP-GM
CL, SM, GM and ML to
T.D. 101.5' (30.9m)



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

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SOIL PROFILE 4 – 4'
CAVE VALLEY, NEVADA

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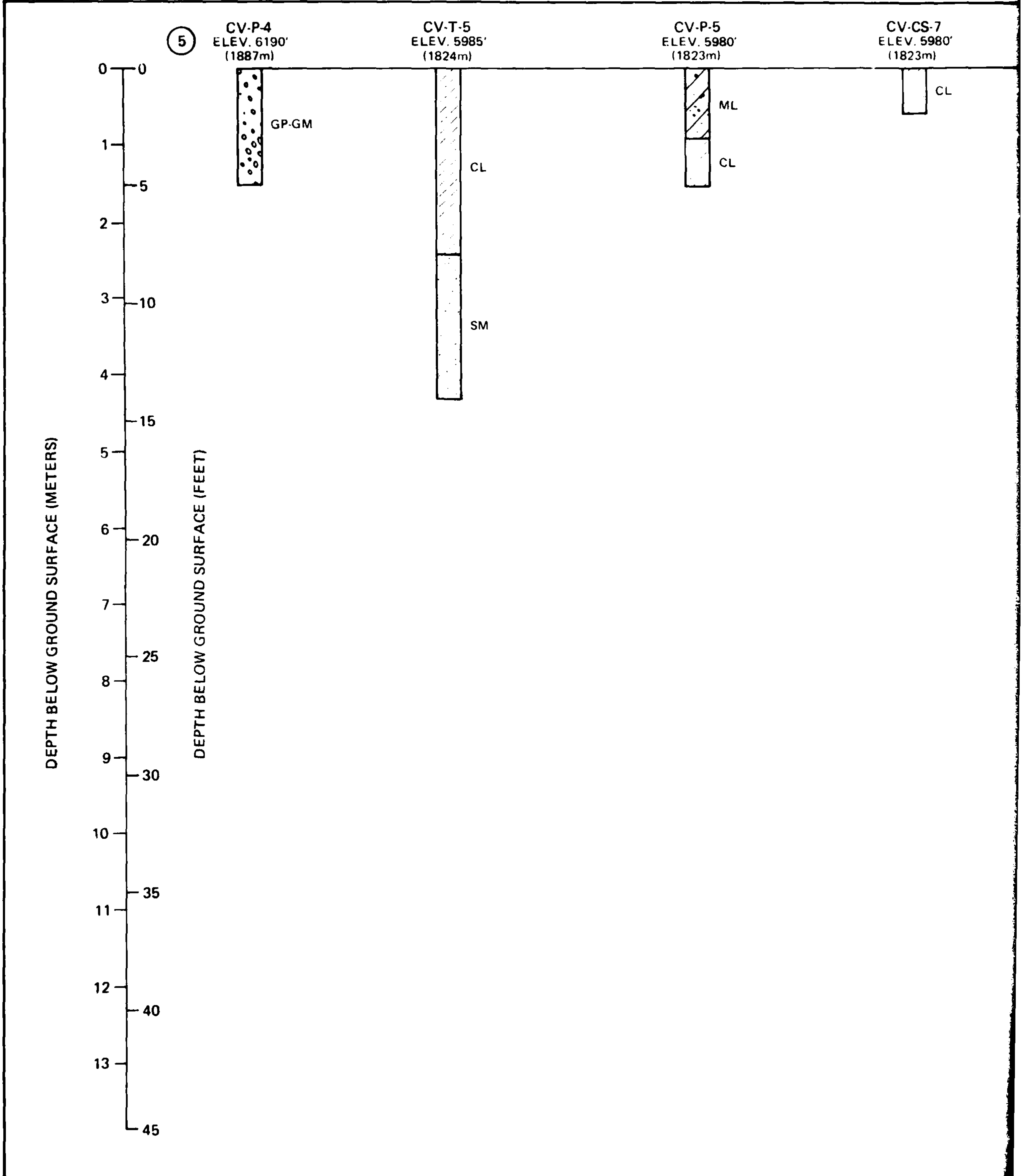
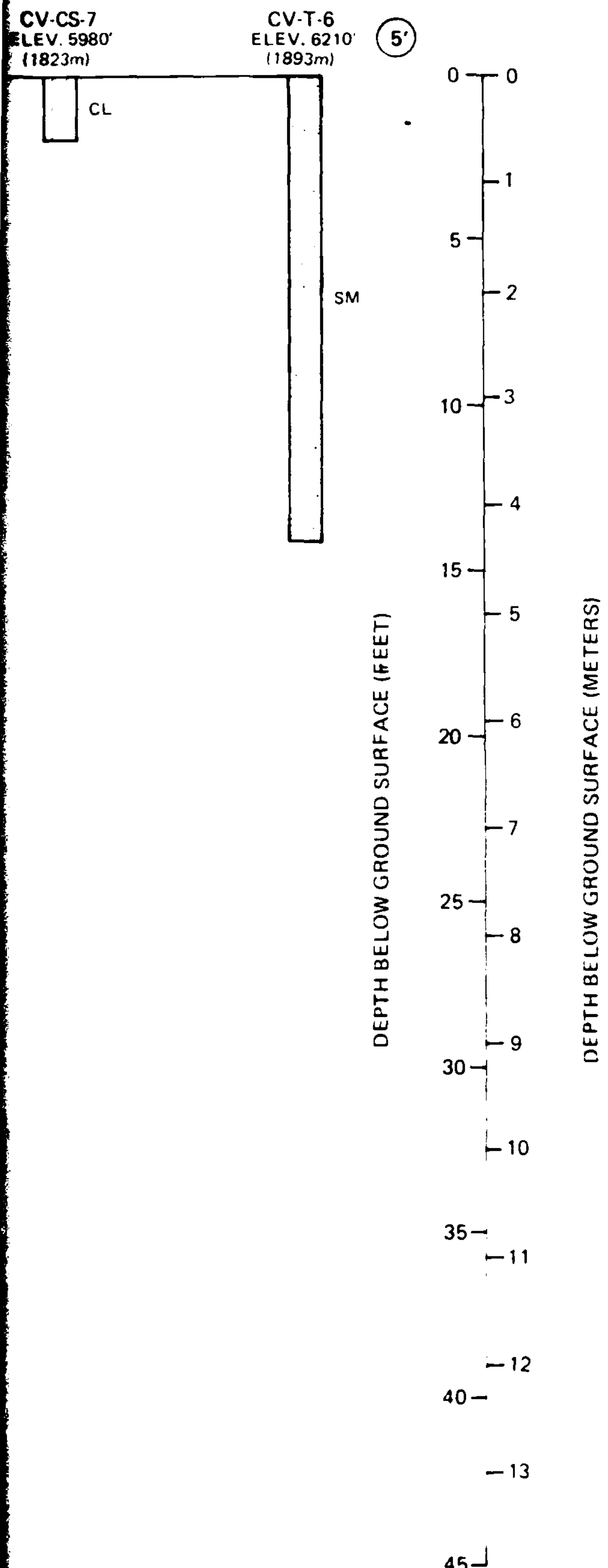
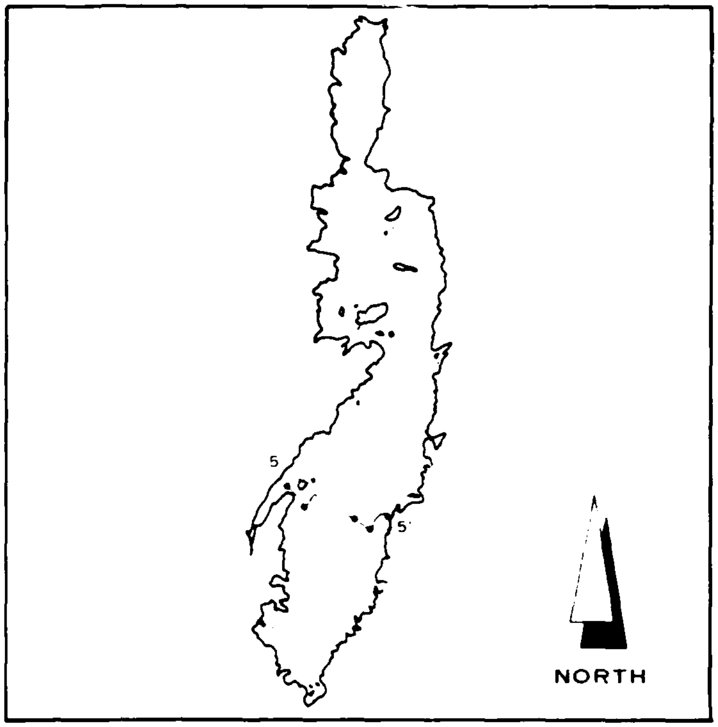
FIGURE 3-4


5
CV-P-4
ELEV. 6190'
(1887m)
GP-GM
CV-T-5
ELEV. 5985'
(1824m)
CL
SM
CV-P-5
ELEV. 5980'
(1823m)
ML
CL
CV-CS-7
ELEV. 5980'
(1823m)
CL
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0
5
10
15
20
25
30
35
40
45



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

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SOIL PROFILE 5 - 5'
CAVE VALLEY, NEVADA

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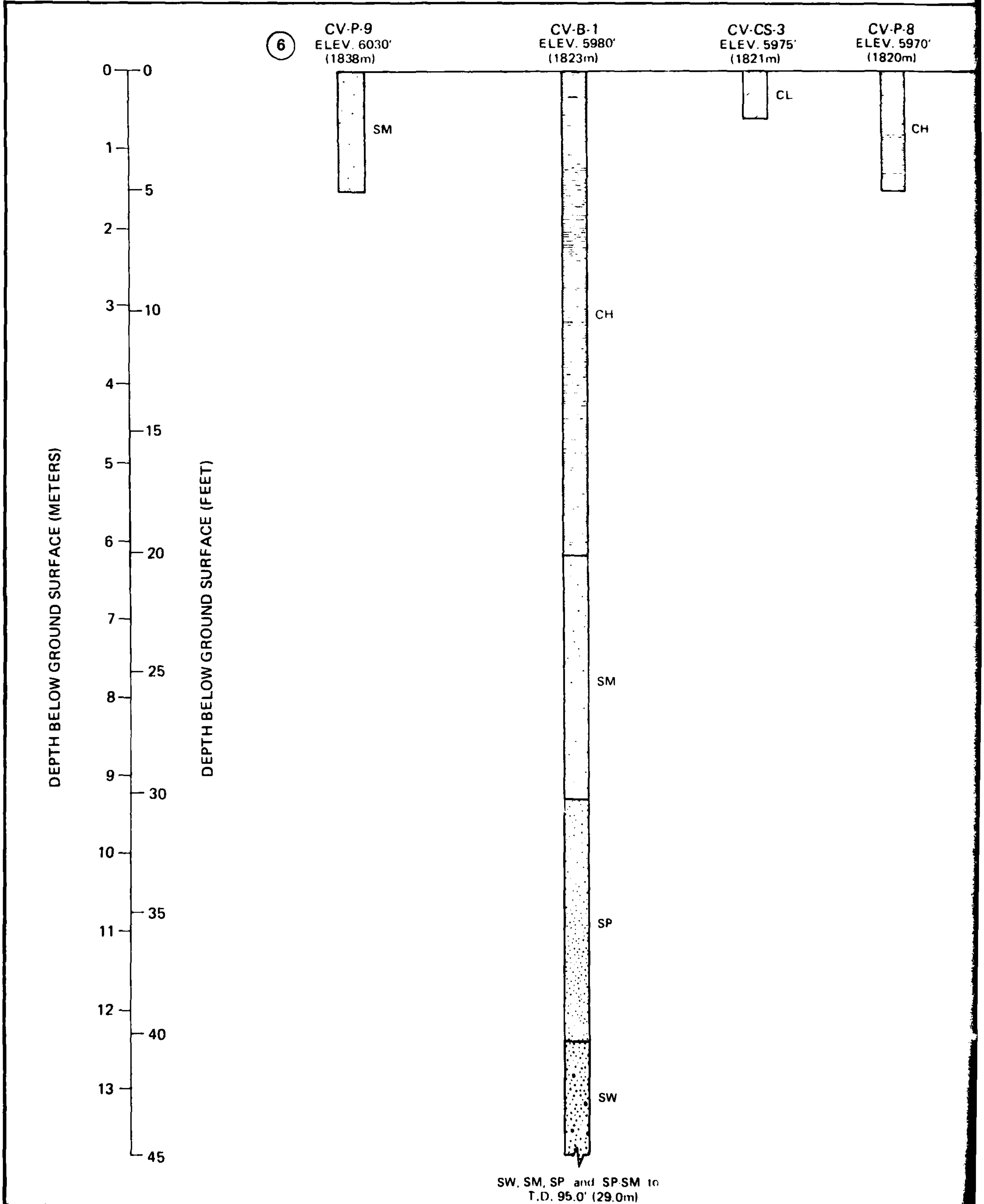
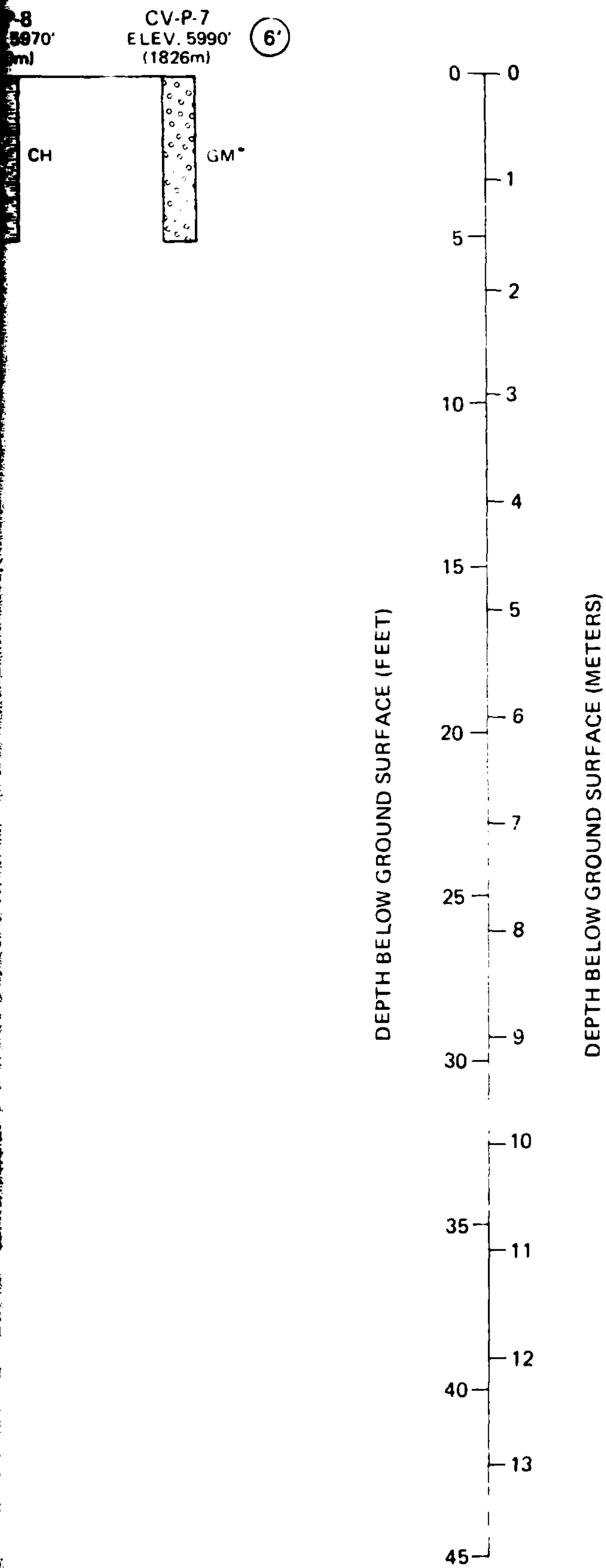
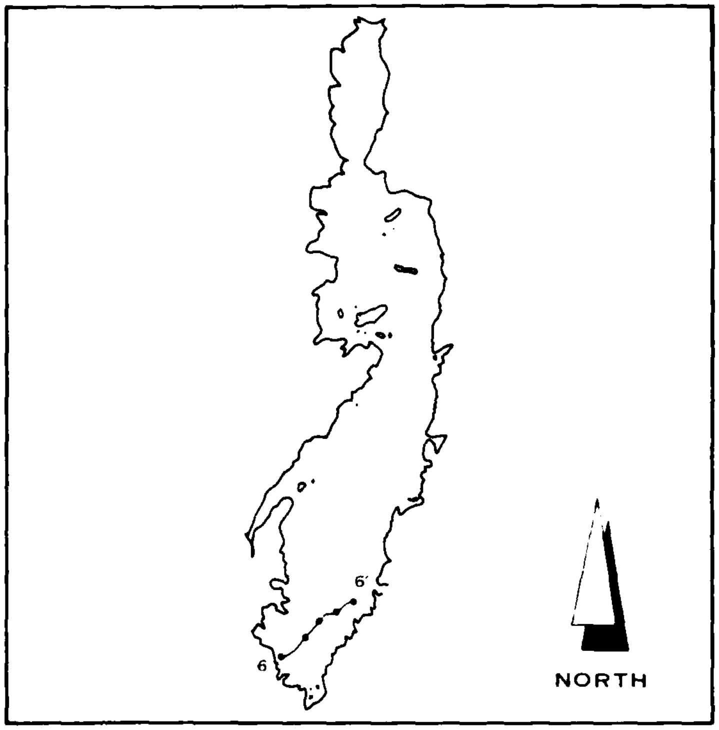
FIGURE 35


6
CV-P-9
ELEV. 6030'
(1838m)
CV-B-1
ELEV. 5980'
(1823m)
CV-CS-3
ELEV. 5975'
(1821m)
CV-P-8
ELEV. 5970'
(1820m)
SM
CL
CH
CH
SM
SP
SW
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 5 10 15 20 25 30 35 40 45
SW, SM, SP and SP-SM to
T.D. 95.0' (29.0m)



LOCATION MAP



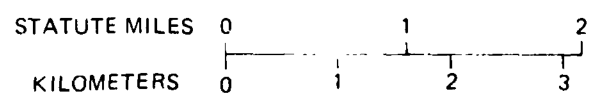
EXPLANATION

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



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SOIL PROFILE 6 - 6'
CAVE VALLEY, NEVADA

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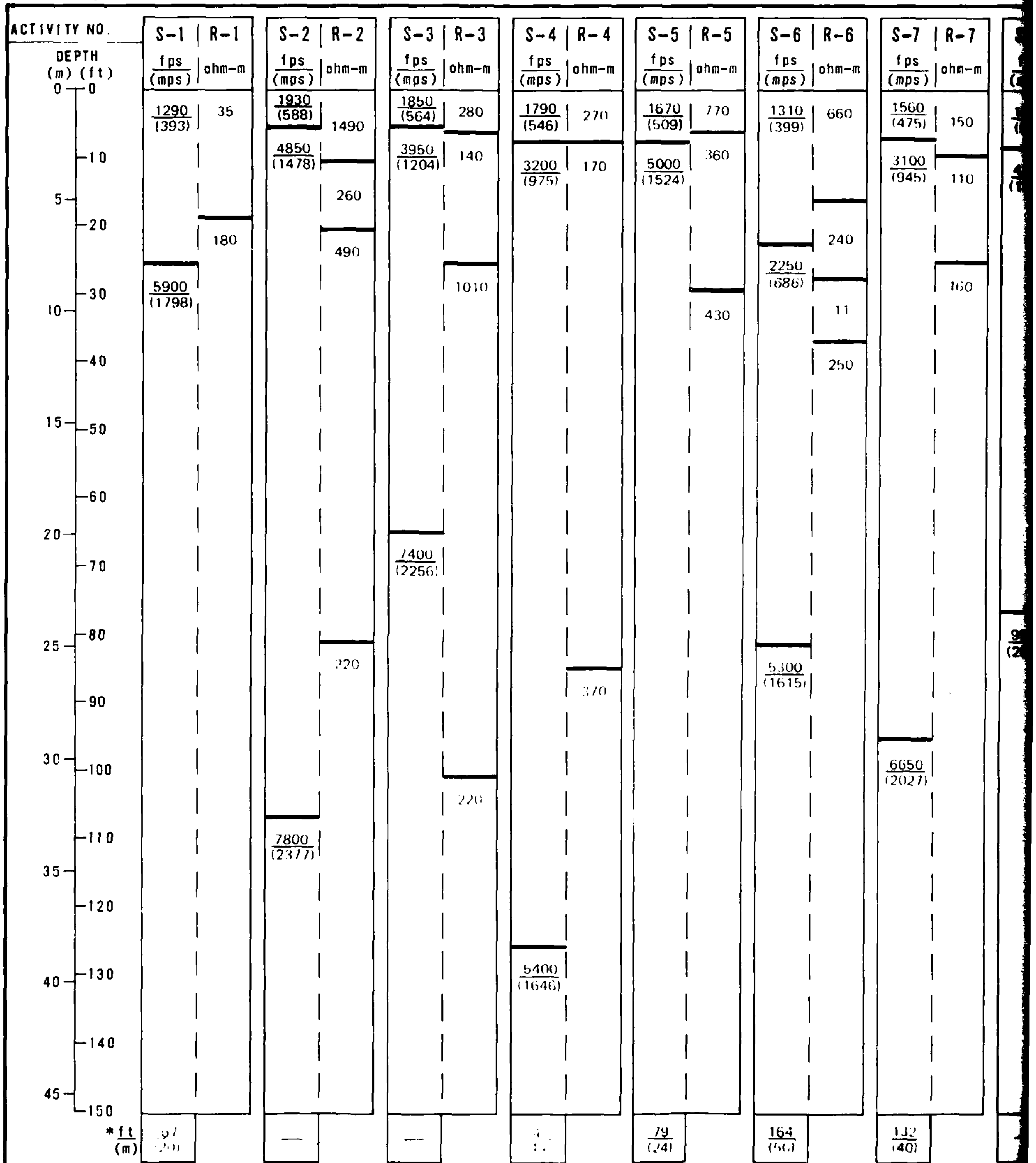
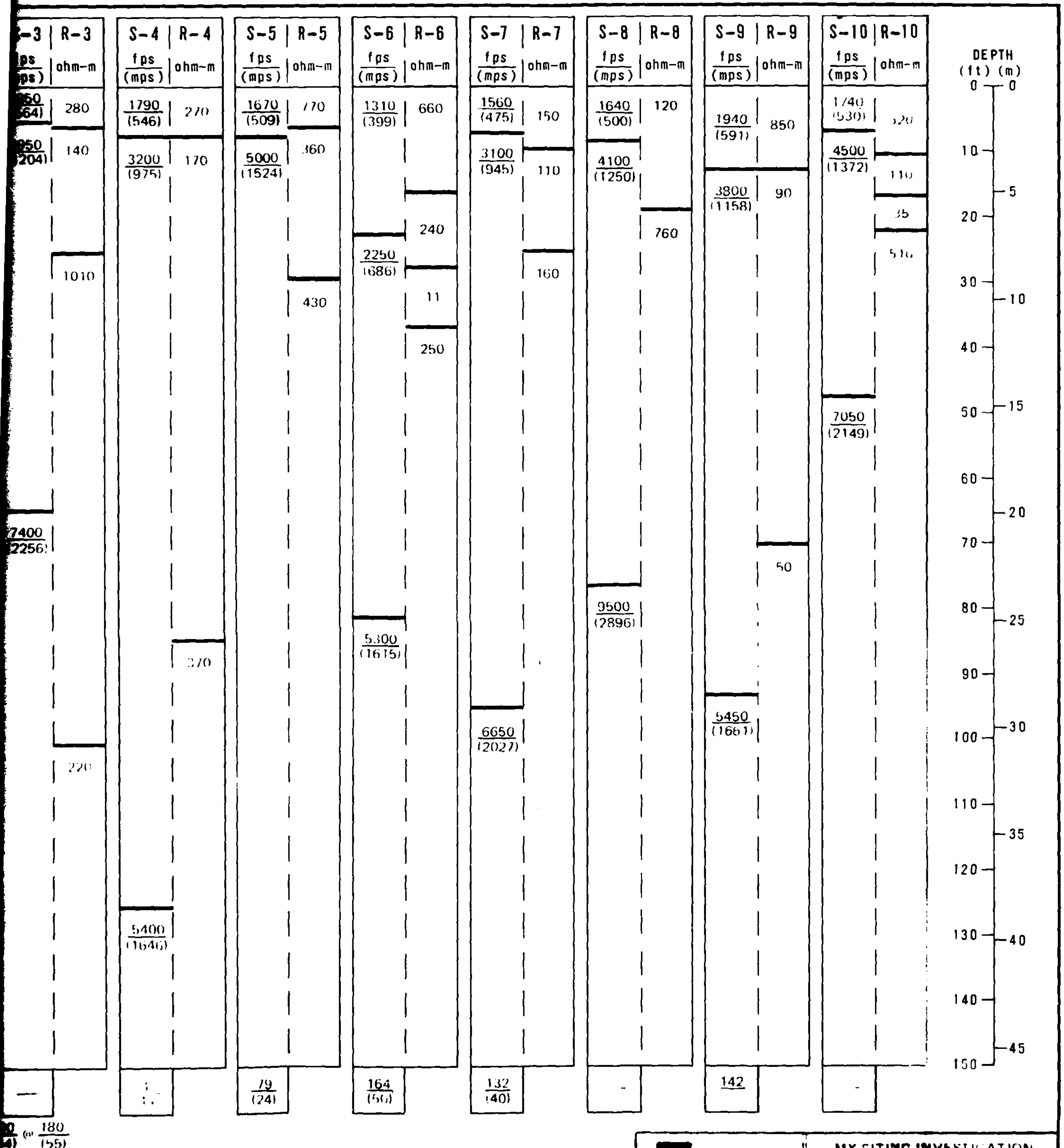
FIGURE 3-6

2



Deeper Results: Velocity Resistivity @ Depth $\frac{13300}{(4054)}$ @ $\frac{180}{(55)}$



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SEISMIC REFRACTION AND
ELECTRICAL RESISTIVITY RESULTS
CAVE VALLEY, NEVADA

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TABLE 3.3

AFV-16

DEPTH RANGE	2' - 20' (0.6 - 6.0m)	
SOIL DESCRIPTION	Coarse-grained soils	Fine-grai
	Gravels, Sandy Gravels, Gravelly Sands, Sands, and Silty Sands	Sandy Silts, Silts, Clays
USCS SYMBOLS	GP, GW-GM, SP, SW-SM, SM	ML, CL, CH
ESTIMATED EXTENT IN SUBSURFACE %	70 - 75	25 - 30
PHYSICAL PROPERTIES		
DRY DENSITY pcf (kg/m^3)	86.5 - 128.6 (1386 - 2060) [12]	69.4 - 95.2 (1112 - 1525)
MOISTURE CONTENT %	2.6 - 15.3 [12]	18.4 - 51.3
DEGREE OF CEMENTATION	none to strong	none to moderate
COBBLES 3 - 12 inches (8 - 30 cm) %	0 - 20	0
GRAVEL %	0 - 83 [10]	0 - 7
SAND %	13 - 85 [10]	3 - 39
SILT AND CLAY %	4 - 40 [10]	54 - 97
LIQUID LIMIT	NDA	29 - 52
PLASTICITY INDEX	NP [3]	NP - 32
COMPRESSIONAL WAVE VELOCITY fps (mps)	1290 - 5000 (393 - 1524) [17]	1640 (500)
SHEAR STRENGTH DATA		
UNCONFINED COMPRESSION S_u - ksf (kN/m^2)	1.3 (62) [1]	0.8 (38)
TRIAXIAL COMPRESSION c - ksf (kN/m^2), $\phi°$	c = 0.1 (5) ϕ = 41 [1]	c = 0.5 (24) ϕ
DIRECT SHEAR c - ksf (kN/m^2), $\phi°$	c = 0.2 (10) ϕ = 33 [1]	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 4 borings, 6 trenches, and 8 test pits, and results of 10 seismic refraction surveys.
- Characteristics of soils below 20 feet (6.0 meters) are based on results of tests on samples from 4 borings and results of 10 seismic refraction surveys.

- [ ] - N
- NDA - No

m)	20' – 160' (6.0 – 49.0m)	
Fine-grained soils	**Coarse-grained soils**	**Fine-grained soils**
Silts, Silts, Silty Clays, and	Sandy Gravels, Gravelly Sands, and Silty Sands	Sandy Silts, Silts, and Sandy Clays
L, CH	GW-GM, GP-GM, GM, GC, SW, SP, SM, SC	ML, CL
0	75 - 80	20 - 25
- 95.2 (- 1525) [10]	77.8 - 128.7 (1246 - 2062) [28]	77.0 - 102.9 (1234 - 1648) [11]
51.3 [10]	4.9 - 22.7 [28]	7.8 - 27.2 [11]
to moderate	*none to strong*	*none to weak*
	0 - 20	0
[3]	0 - 58 [18]	0 - 5 [4]
[3]	30 - 77 [18]	4 - 25 [4]
7 [3]	4 - 49 [18]	74 - 96 [4]
2 [4]	32 - 42 [4]	25 - 28 [3]
2 [5]	NP - 24 [6]	1 - 8 [3]
[1]	1290 - 6650 (393 - 2027) [16]	NDA
[1]	NDA	1.9 (91) [1]
5 ϕ = 22 [1]	NDA	c = 0.2 (10) ϕ = 35 [1]
	NDA	c = 1.1 (53) ϕ = 33 [1]

[ ] – Number of tests performed.

NDA – No data available (insufficient data or tests not performed).

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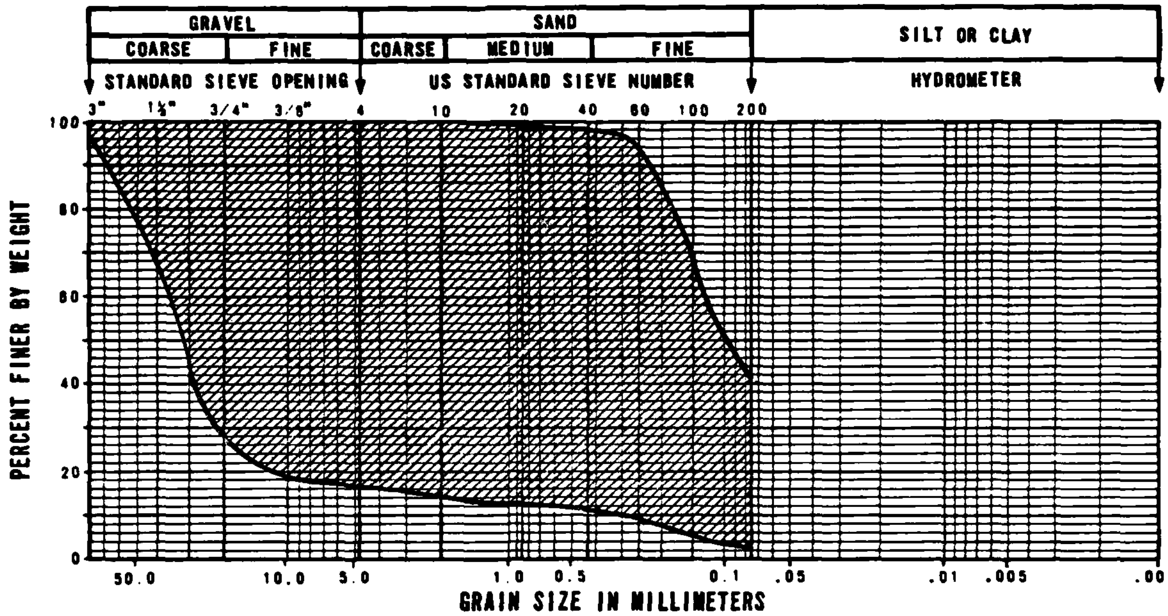
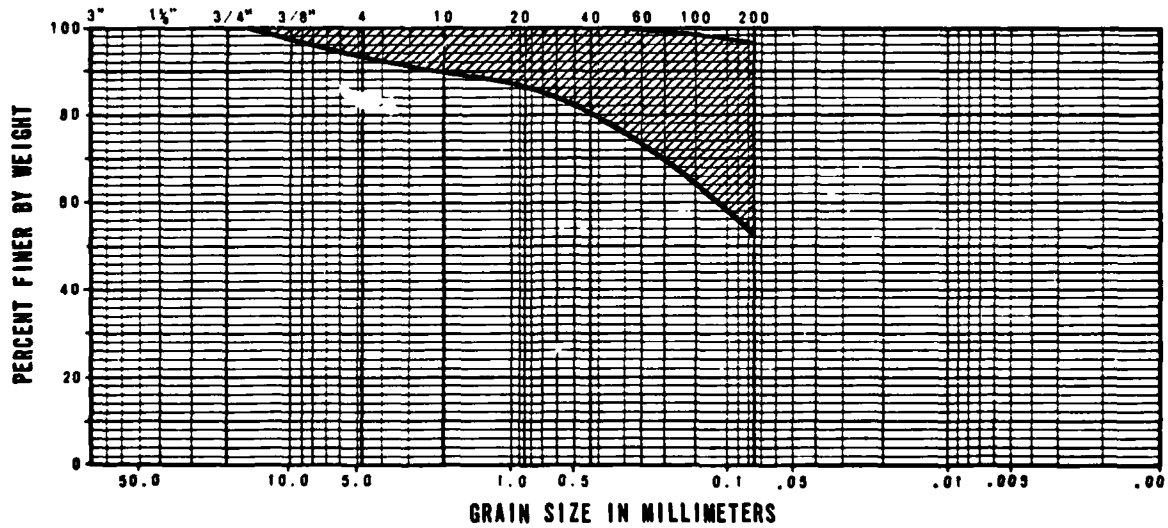
CHARACTERISTICS OF SUBSURFACE SOILS
CAVE VALLEY, NEVADA

26 OCT 81 TABLE 3-4

2



SOIL DESCRIPTION: Coarse-Grained Soils
from 2 to 20 feet (0.6 to 6.1m)



SOIL DESCRIPTION: Fine-Grained Soils
from 2 to 20 feet (0.6 to 6.1m)

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RANGE OF GRADATION OF
SUBSURFACE SOILS
CAVE VALLEY, NEVADA
PAGE 1 OF 2

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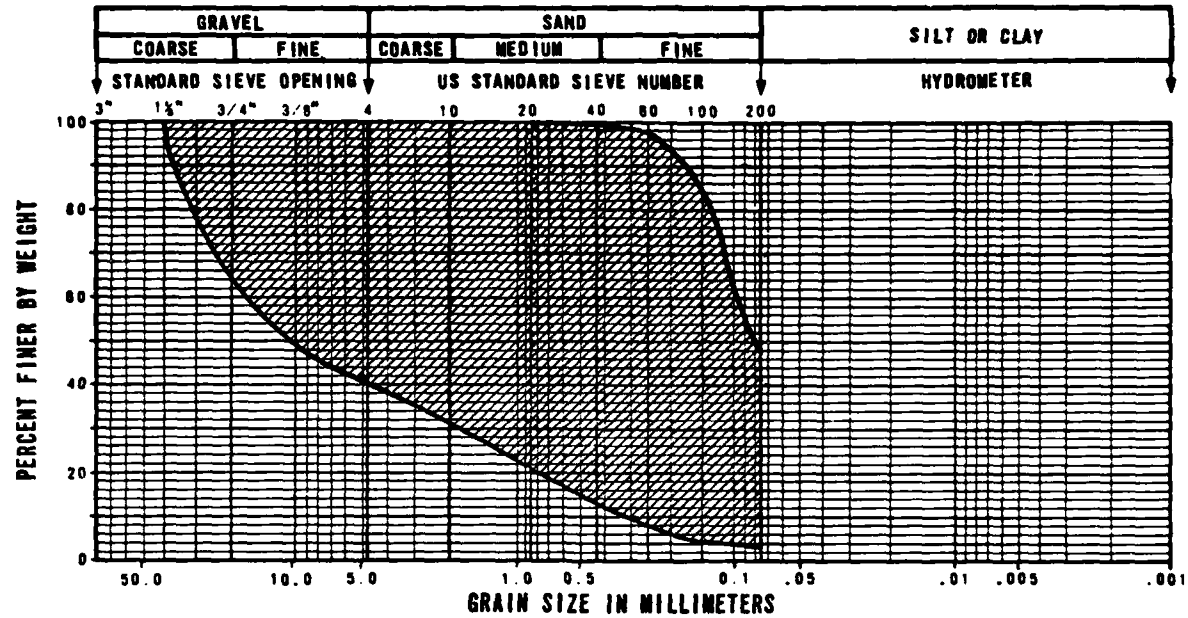
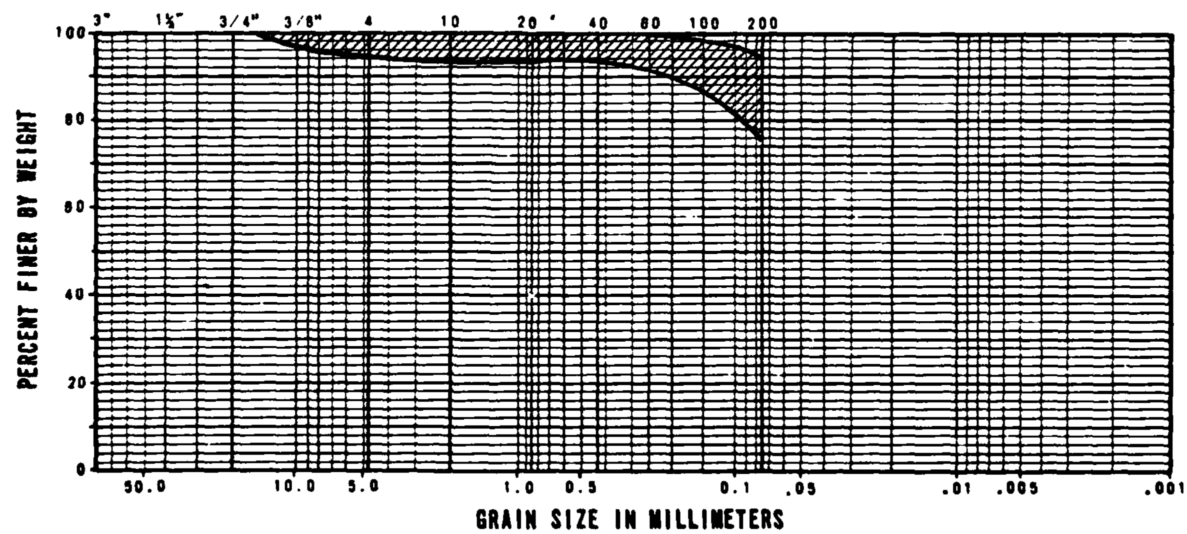
FIGURE 3-7



SOIL DESCRIPTION: Coarse-Grained Soils
from 20 to 160 feet (6.1 to 48.8m)



SOIL DESCRIPTION: Fine-Grained Soils
from 20 to 160 feet (6.1 to 48.8m)

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RANGE OF GRADATION OF
SUBSURFACE SOILS
CAVE VALLEY, NEVADA
PAGE 2 OF 2

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FIGURE 3-7

Fine-grained soils (silts and clays) range in consistency from soft to very stiff and exhibit low to moderate compressibilities and shear strengths. Calcium-carbonate cementation varies from weak to strong depending on the age of the deposit, soil properties, and environmental factors.

The soils in the construction zone (120 feet [37 m]) have a wide range of seismic compressional wave velocities (1290 to 6650 fps [393 to 2027 mps]) depending on their composition, consistency, cementation, and moisture content. Although the data are limited, velocities in fine-grained soils generally are found to be substantially lower than those in coarse-grained soils. Compressional wave velocities for deeper materials are also listed in Table 3-3.

Electrical conductivity measured for the soils in the upper 50 feet (15 m) ranged from 0.0016 to 0.008 mhos per meter (average 0.0036 mhos per meter). At seven of the 10 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 done on five samples obtained from Cave Valley indicate that the potential for sulfate attack for soils on concrete will be "negligible" to "mild."

3.5 DEPTH TO ROCK

Drawing 3-3 shows the 50- and 150-foot (15- and 46-m) depth-to-rock contours in Cave Valley. This interpretation is based on

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UNCLASSIFIED E-TR-27-CV-1 NL

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A
299

limited point data from borings, seismic refraction surveys, site-specific published data, and depths inferred from geologic and geomorphic relationships. Approximately 19 percent of the basin-fill material in the valley is interpreted to be underlain by rock at depths less than 50 feet (15 m). An additional 10 percent of the valley is interpreted to contain shallow rock between depths of 50 and 150 feet (15 and 46 m).

The bedrock/basin-fill contact is irregular within Cave Valley. Sedimentary and volcanic rocks in the northern portion of the valley protrude through the overlying old- to intermediate-age alluvial fans up to 1.5 miles (2.4 km) from the mountain fronts (Drawing 3-2). These areas are interpreted to have rock at depths less than 50 and 150 feet (15 and 46 m) closely surrounding the outcrop exposures. Reentrant canyons throughout the valley are also interpreted to be underlain by shallow rock beneath alluvial fan and active stream deposits.

Plio-Pleistocene sediments (A6) (Drawing 3-2) in the north and northwestern portions of the valley have not been classified as areas of rock. However, this unit may contain isolated areas which are strongly cemented and probably non-rippable at shallow depths, thereby classifying them in this instance as areas of rock and/or shallow rock. When this occurs, these areas may cause localized engineering or construction problems.

3.6 DEPTH TO WATER

Drawing 3-4 shows the location of the 15 wells used to define ground-water conditions in Cave Valley. The sources of these data in addition to Ertec activities are Eakin (1962), Shilling and Garside (1968), Garside (1977), and the Nevada State Engineer's Office (1959 to 1967). Information pertaining to the wells is listed in Table II-3-1 (Volume II).

Approximately three percent of the valley is interpreted to contain water at depths less than 50 feet (15 m). An additional four percent of the valley is interpreted to contain water between depths of 50 and 150 feet (15 and 46 m).

Ground-water conditions along the eastern portion of Cave Valley may be affected by faults and joints as suggested by springs and sinkholes near Gardner Ranch (Drawing 3-4). Similar shallow ground-water conditions are thought to exist along the eastern rock/basin-fill contact where other springs occur. These springs may also be fault related.

3.7 TERRAIN

3.7.1 Terrain Exclusions

Terrain exclusions are shown in Drawing 3-5. Areas designated as terrain exclusions are considered to be unsuitable based on a combination of field-derived and office-derived data which were evaluated under the criteria in Appendix Table A2-1. Field derived exclusions include 1) areas having very steep slopes, such as the sides of major drainages; and 2) areas in which incisions deeper than 10 feet (3 m) are spaced closer than 1000 feet (305 m) apart. Office-derived exclusions consist primarily of areas identified on topographic maps as having slopes greater than 10 percent. In some instances, where road access is inadequate for field inspection, office analysis of aerial photographs was used to define and exclude areas of rugged or adverse terrain. However, preference was given to determining these exclusions in the field. Even though areas where slopes are between five and 10 percent are considered to be suitable, they are identified in Drawing 3-5 because they require special consideration in planning construction and operations.

Approximately 38 percent or 77 mi^2 (198 km^2) of the total area within Cave Valley is excluded due to adverse terrain. Approximately 80 percent (62 mi^2 [161 km^2]) of these field and office derived exclusions are located in the northern portion of the valley. In general, the terrain exclusions are synonymous with the location of Plio-Pleistocene sediments (A6). The remaining terrain exclusion areas consist of approximately 15 mi^2 (39 km^2) topographic slopes that exceed 10 percent and approximately 3 mi^2 (8 km^2) of deeply incised old-age alluvial fans (A5o). These exclusions are generally located near the bedrock/basin-fill contact throughout the remainder of the valley. The exclusion criteria typically exclude small reentrant canyons around the valley.

3.7.2 Incision Depths and Number of Drainages Per Mile

Data on incision depths and number ·ainages encountered per mile within the suitable area were analyzed for Cave Valley. Information on incision depths was obtained from field observations with the number of drainages per mile determined from both field observations and interpretations of aerial photographs.

The results shown in Table 3-5 are average values of the two drainage characteristics (depth and number of drainages per mile). They are listed for each prevalent surficial unit with further breakdowns providing data on 1) characteristics of the geologic unit on each side of the valley axial drainage, and 2) characteristics of the unit where its surface slopes are between five and 10 percent versus areas where its slopes are less than five percent.

The small areal extent of some of the surficial units resulted in limited or insufficient data for analysis (Table 3-5). The available data show that old-age alluvial fan (A5o) units have the deepest incisions throughout the valley where the surface slope is greater than five percent. The alluvial fans of intermediate age (A5i) generally have slightly deeper incisions than younger surficial units especially on the western side of the valley. Incision depths vary within the specific surficial geologic units depending on grain size and percent slope (Table 3-5).

Drainages associated with young fluvial deposits (A1) present a potential for flash-flooding in the north-central portion of the valley. This potential should be considered when planning construction in these areas.

SURFICIAL GEOLOGIC UNIT	AVERAGE NUMBER OF DRAINAGES PER MILE			
	WESTERN SIDE OF VALLEY		EASTERN SIDE OF VALLEY	
	SURFACE SLOPE, %		SURFACE SLOPE, %	
	0 - 5	5 - 10	0 - 5	5 - 10
A1f	1.25 (.79)	–	1.0 (0.10)	–
A4of	0.88 (.99)	–	2.0 (2.24)	–
A4os	3.5 (1.35)	–	2.11 (1.41)	–
A5ys	–	–	3.36 (1.69)	–

NOTE: DRAINAGES WERE COUNTED ALONG A 1-MILE LINE PERPENDICULAR TO THE DRAINAGE DIRECTION

SURFICIAL GEOLOGIC UNIT	AVERAGE DEPTH OF INCISIONS			
	WESTERN SIDE OF VALLEY		EASTERN SIDE OF VALLEY	
	SURFACE SLOPE, %		SURFACE SLOPE, %	
	0 - 5	5 - 10	0 - 5	5 - 10
A1f	5.09 ft (2.84 ft) 1.55 m (0.87 m)	–	3.00 ft 0.91 m	–
A4of	1.00 ft (0.0 ft) 0.30 (0.0 m)	–	1.80 ft (0.86 ft) 0.55 m (0.26 m)	–
A4os	–	–	1.94 ft (1.68 ft) 0.59 m (0.51m)	5.36 ft (3.05 ft) 1.63 m (0.93 m)
A5ys	3.0 ft• (0.91 m)	10.00 ft 3.05 m	3.09 ft (3.2 ft) 0.94 m (0.98m)	2.50 ft (0.76 m)
A5yg	–	–	–	3.00 ft (1.54 ft)
A5is	5.25 ft (3.62 ft) 1.60 m (1.10m)	4.11 ft (1.76 ft) 1.25 m (0.54 m)	4.69 ft (8.56 ft) 1.43 m (2.61 m)	3.71 ft (1.76 ft) 1.13 m (0.54 m)
A5os	–	10.00 ft 3.05 m	–	5.00 ft 1.52m

- • LIMITED DATA (6 < n <10) VALUE IS MEDIAN, NO STANDARD DEVIATION
- – NO DATA OR INSUFFICIENT DATA (n < 6)
- ( ) STANDARD DEVIATION
- A5o OLD-AGE ALLUVIAL FANS
- A5i INTERMEDIATE-AGE ALLUVIAL FANS
- A5y YOUNG-AGE ALLUVIAL FANS
- A4o OLDER LACUSTRINE DEPOSITS
- A4 ACTIVE PLAYAS
- A1 ACTIVE STREAM-CHANNEL DEPOSITS
- g GRAVELS
- s SANDS
- f FINES, CLAYS, SILTS

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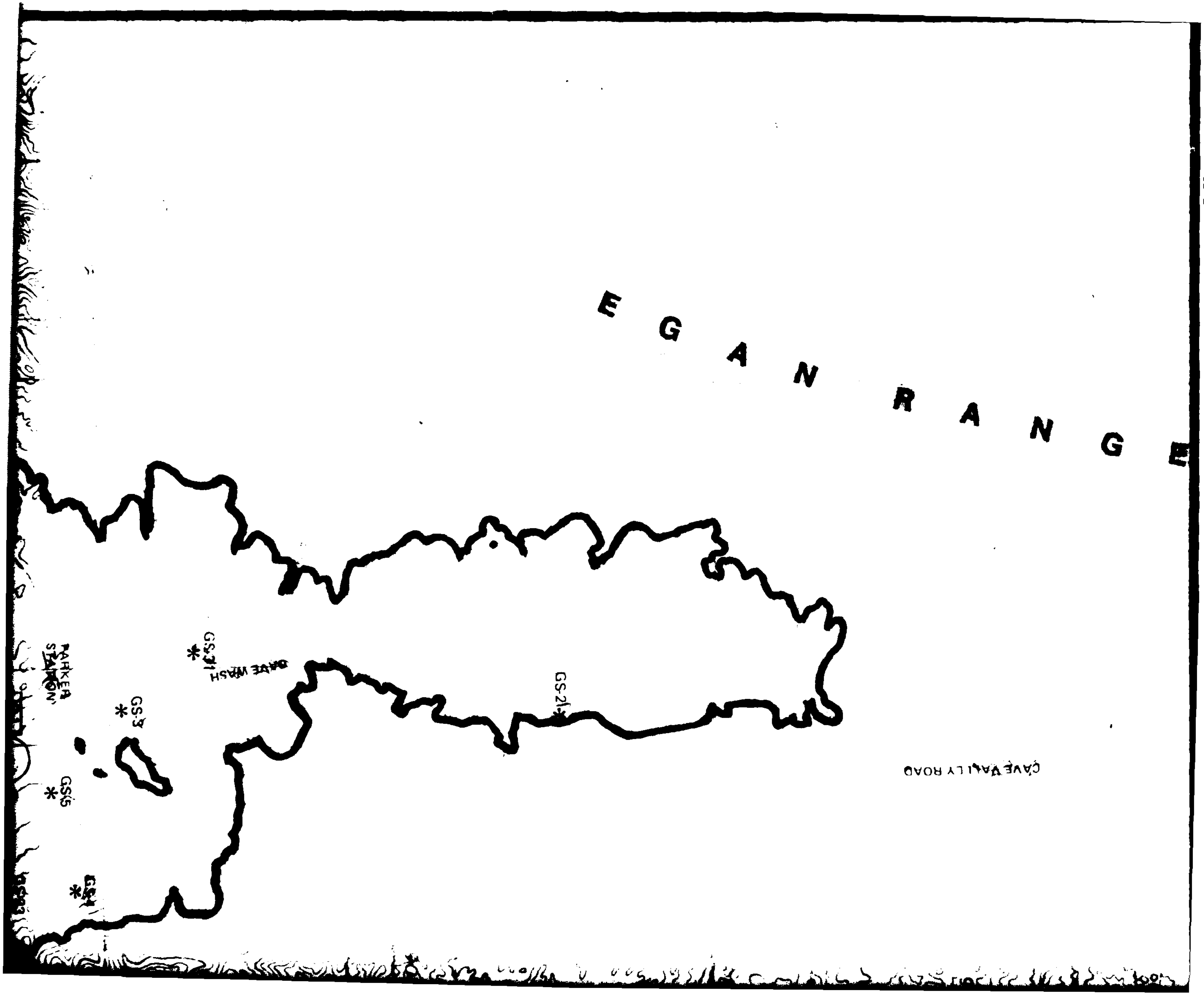
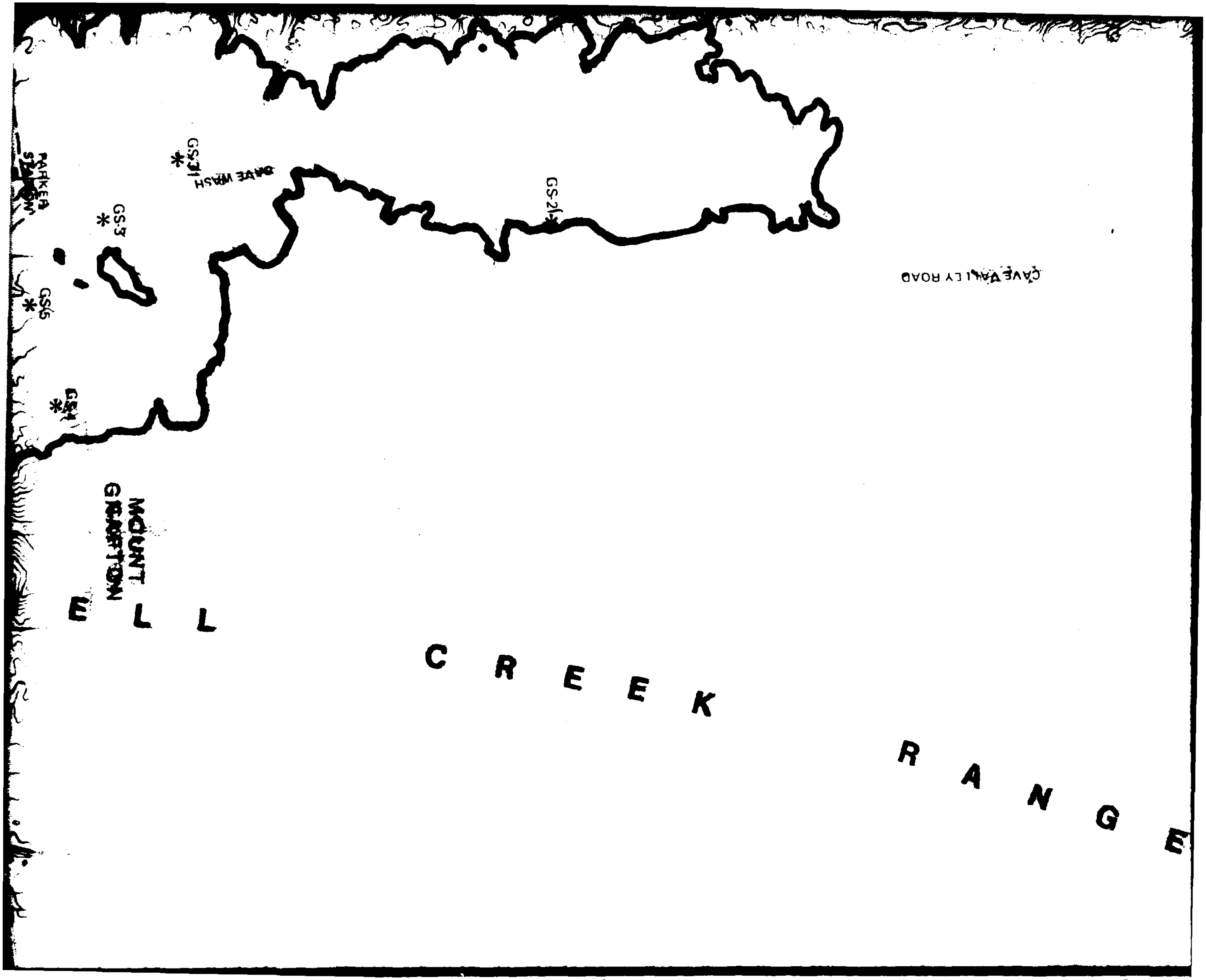
DRAINAGES PER MILE AND DEPTH OF INCISIONS IN SELECTED SURFICIAL GEOLOGIC UNITS
CAVE VALLEY, NEVADA

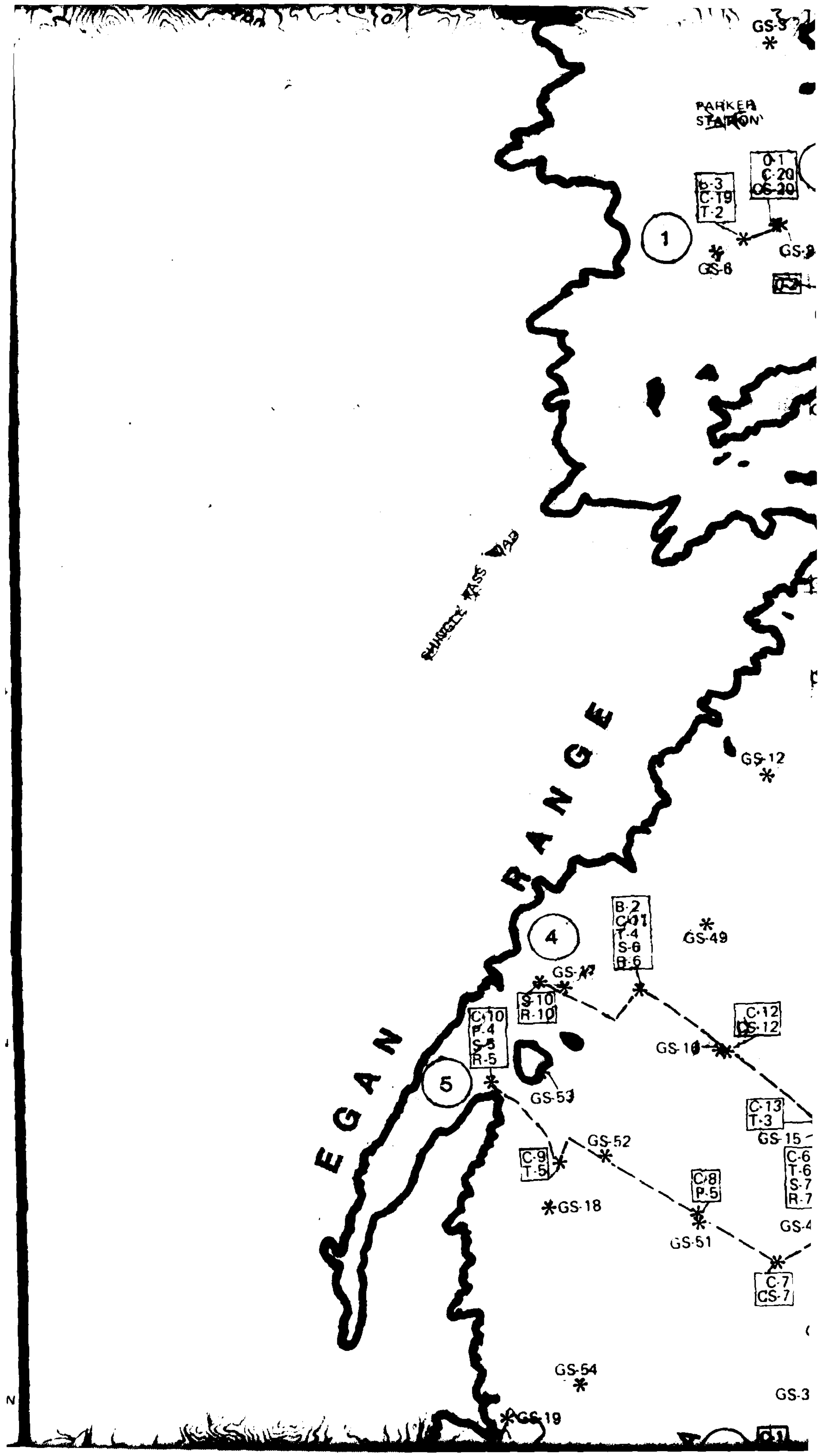
26 OCT 81

TABLE 3-5

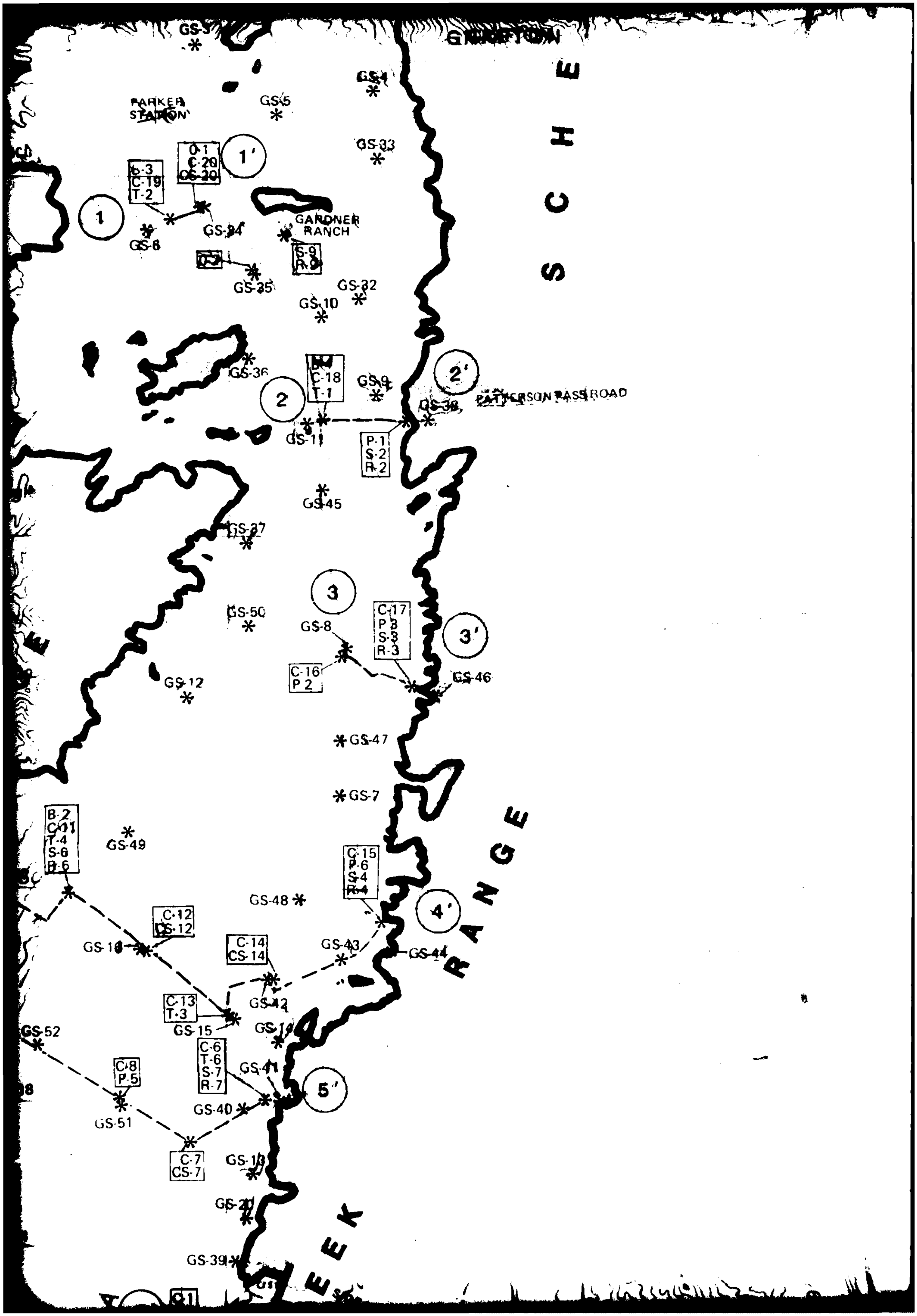


EGAN RANGE
CAVE VALLY ROAD
GS-2
GS-3
GS-5
PARKER STATION

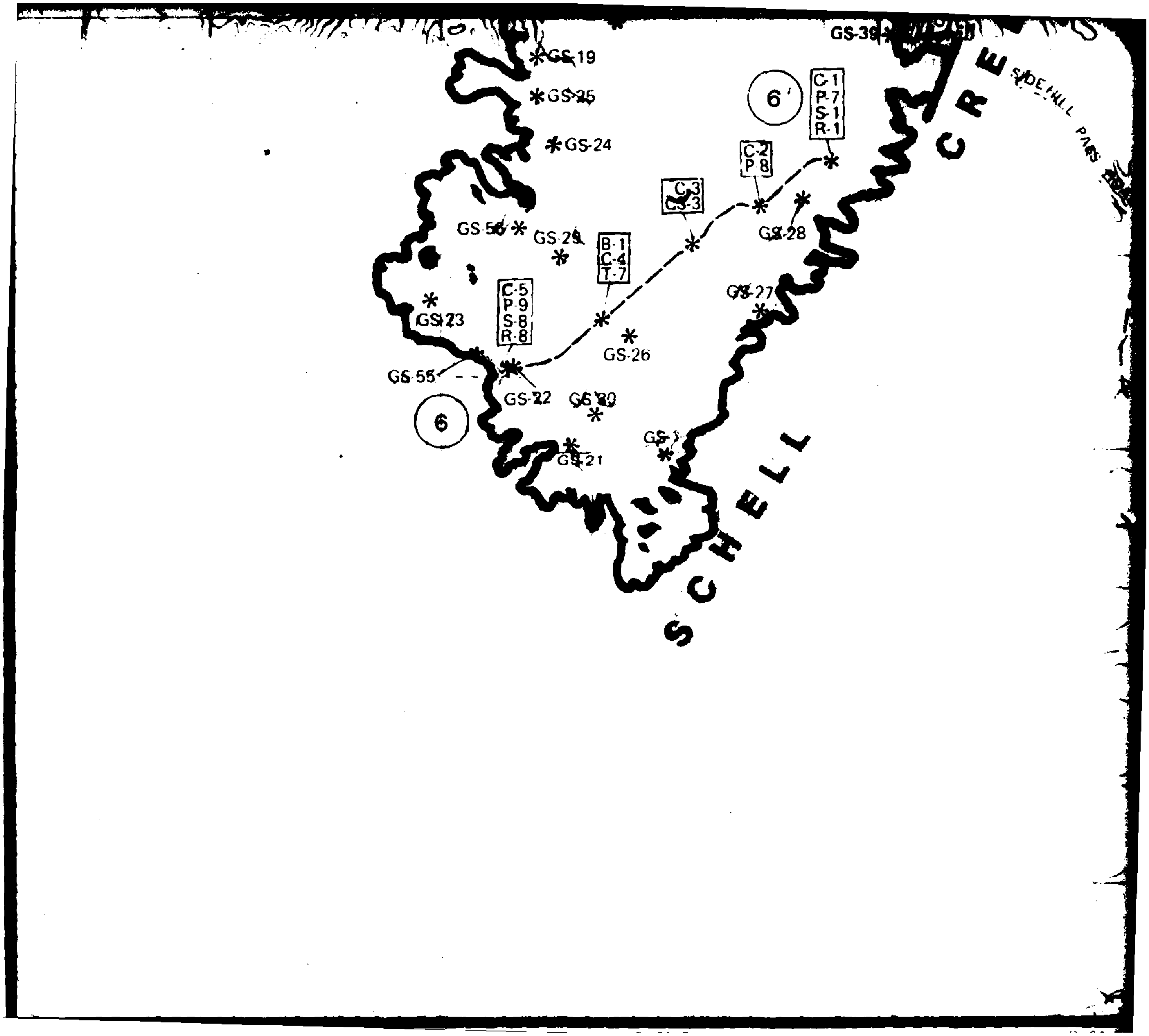

CAVE VALLEY ROAD
GS-2
CAVE WASH
GS-1
GS-3
PARKER STATION
GS-5
GS-4
MOUNT GRAFTON
ELL CREEK RANGE

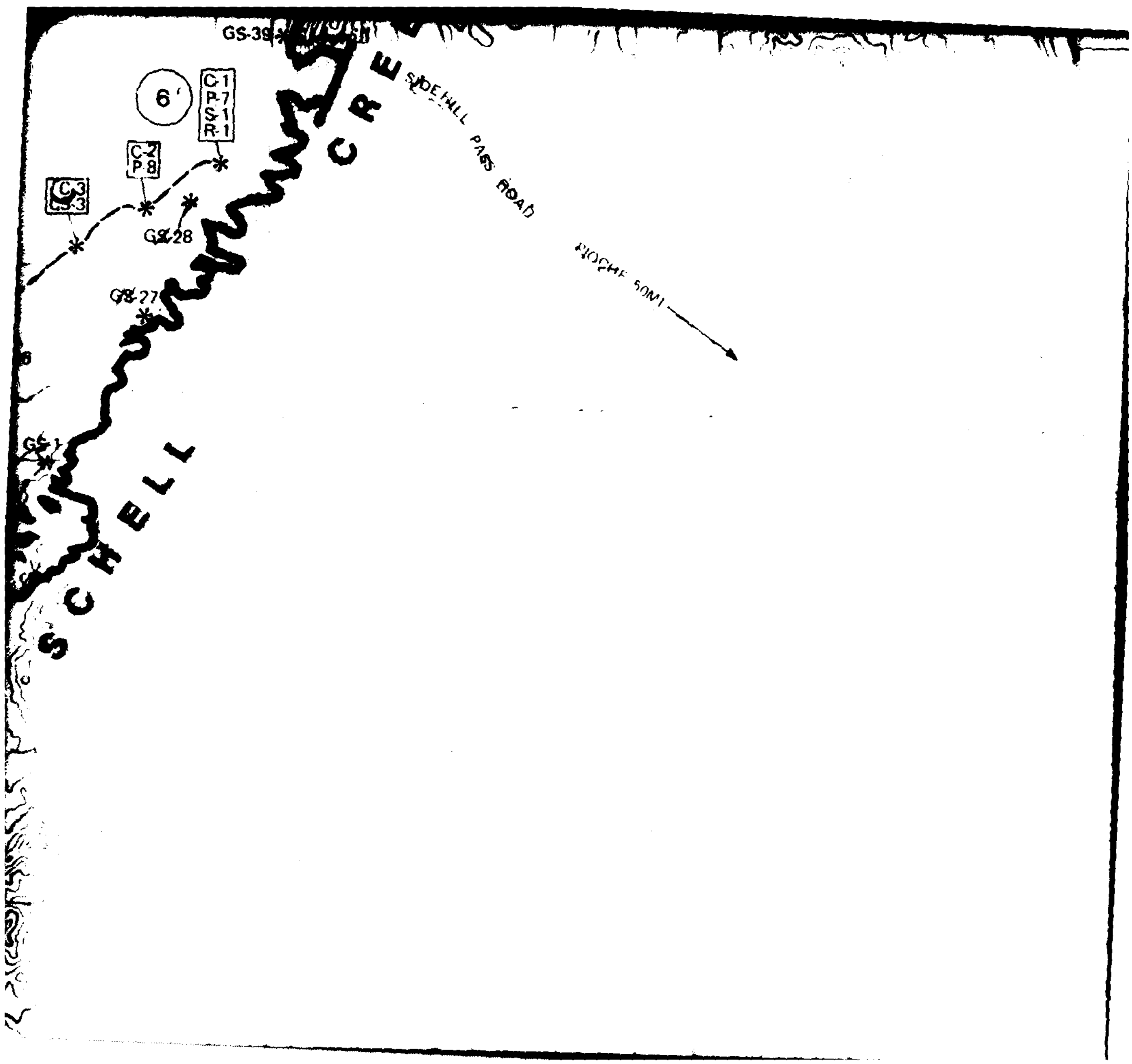


GS-3
PARKER STATION
O-1
C-20
GS-20
B-3
C-19
T-2
1
GS-6
GS-9
EGAN RANGE
GS-12
B-2
C-11
T-4
S-6
R-6
GS-49
4
GS-17
S-10
R-10
C-10
P-4
S-5
R-5
C-12
GS-12
GS-16
5
GS-53
C-13
T-3
GS-15
GS-52
C-9
T-5
C-6
T-6
S-7
R-7
C/8
P-5
GS-18
GS-51
C-7
CS-7
GS-54
GS-3
GS-19



GS-3
GS-4
GS-5
PARKER STATION
GS-33
B-3
C-19
T-2
0-1
C-20
CS-20
1
1'
GARDNER RANCH
GS-34
GS-6
S-9
R-9
GS-35
GS-32
GS-10
S
C
H
E
GS-36
C-18
T-1
GS-9
2
2'
PATTERSON PASS ROAD
GS-38
GS-11
P-1
S-2
R-2
GS-45
GS-37
3
GS-50
GS-8
C-17
P 3
S-3
R-3
3'
C-16
P 2
GS-46
GS-12
GS-47
GS-7
B-2
C-11
T-4
S-6
R-6
GS-49
C-15
P-6
S-4
R-4
GS-48
4'
C-12
CS-12
GS-16
C-14
CS-14
GS-43
GS-44
GS-42
C-13
T-3
GS-15
GS-14
C-6
T-6
S-7
R-7
GS-52
C-8
P-5
GS-41
5'
GS-40
GS-51
C-7
CS-7
GS-13
GS-20
GS-39
RANGE
EEK


GS-39
SIDE HILL PASS
CRE
SCHELL
6'
6
C-1
P-7
S-1
R-1
C-2
P-8
C-3
GS-3
B-1
C-4
T-7
C-5
P-9
S-8
R-8
GS-19
GS-25
GS-24
GS-56
GS-29
GS-28
GS-27
GS-23
GS-26
GS-55
GS-22
GS-20
GS-21


GS-39
6
C-1
P-7
S-1
R-1
C-2
P-8
GS-28
GS-27
GS-1
SCHELL
CRE
SIDEHILL PASS ROAD

R 62 E   R 63 E   R 64

EXPLANATION

*	ACTIVITY LOCATION
GS 1	GEOLOGIC STATION
B 1	BORING
O 1	GROUND-WATER LEVEL MONITORING WELL
C-1	CONE PENETROMETER TEST (CPT)
CS-1	SURFICIAL SOIL SAMPLE
T-1	TRENCH
P-1	TEST PIT
S-1	SEISMIC REFRACTION LINE
R-1	ELECTRICAL RESISTIVITY SOUNDING
1 -- 1'	ACTIVITY LINE
	Contact between rock and basin-fill.
	Valley borders.
	Areas of isolated exposed rock

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ACTIVITY LOCATION MAP
CAVE VALLEY, NEVADA

26 OCT 81

DRAWING 3-1

63 E R 64 E 114°45' R 65 E

EXPLANATION

ACTIVITY LOCATION

GEOLOGIC STATION

BORING

GROUND-WATER LEVEL MONITORING WELL

CONE PENETROMETER TEST (CPT)

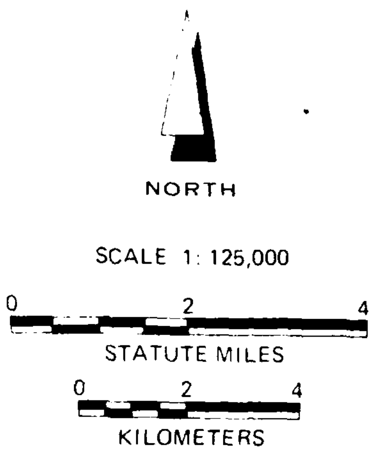
SURFICIAL SOIL SAMPLE

TRENCH

TEST PIT

SEISMIC REFRACTION LINE

ELECTRICAL RESISTIVITY SOUNDING

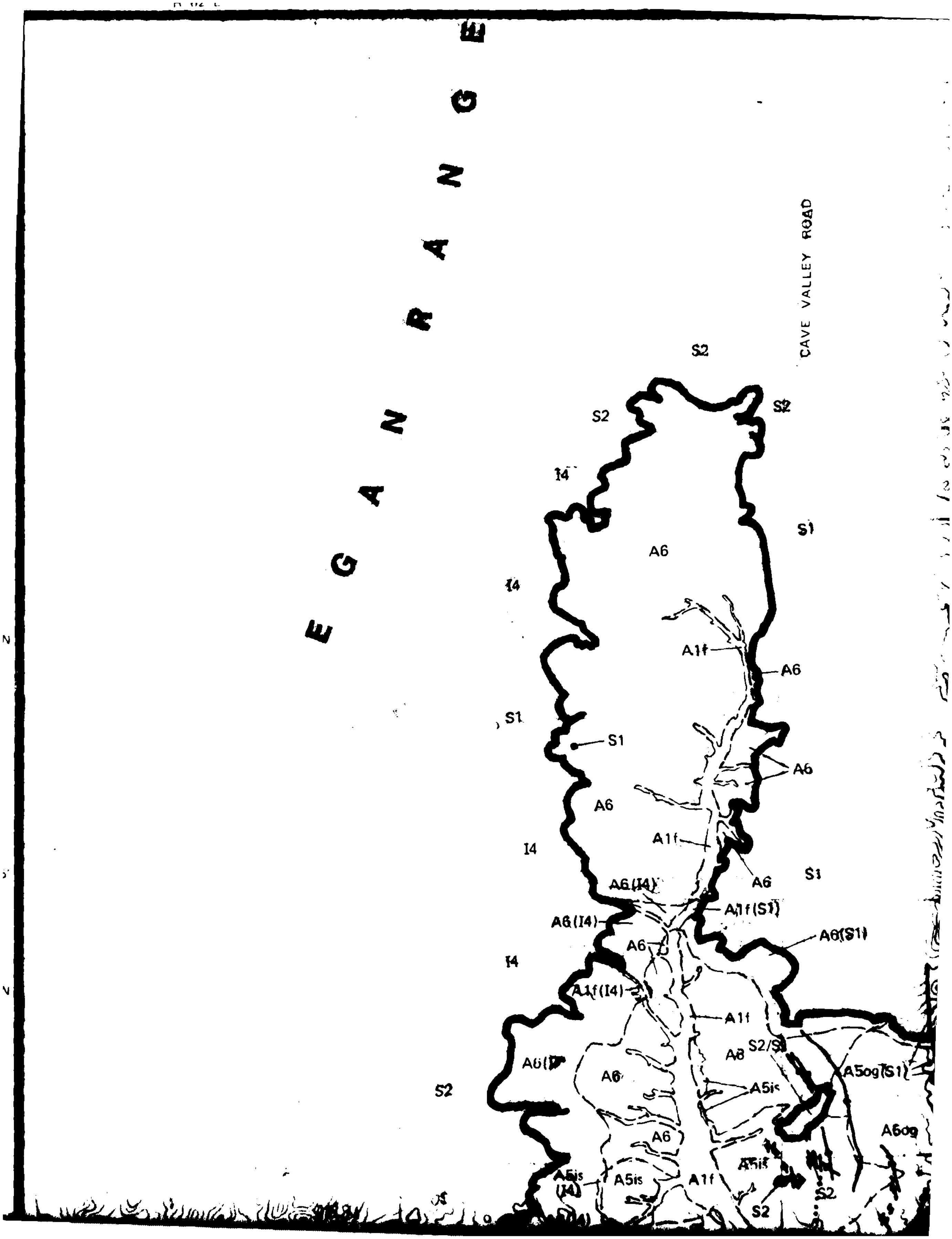


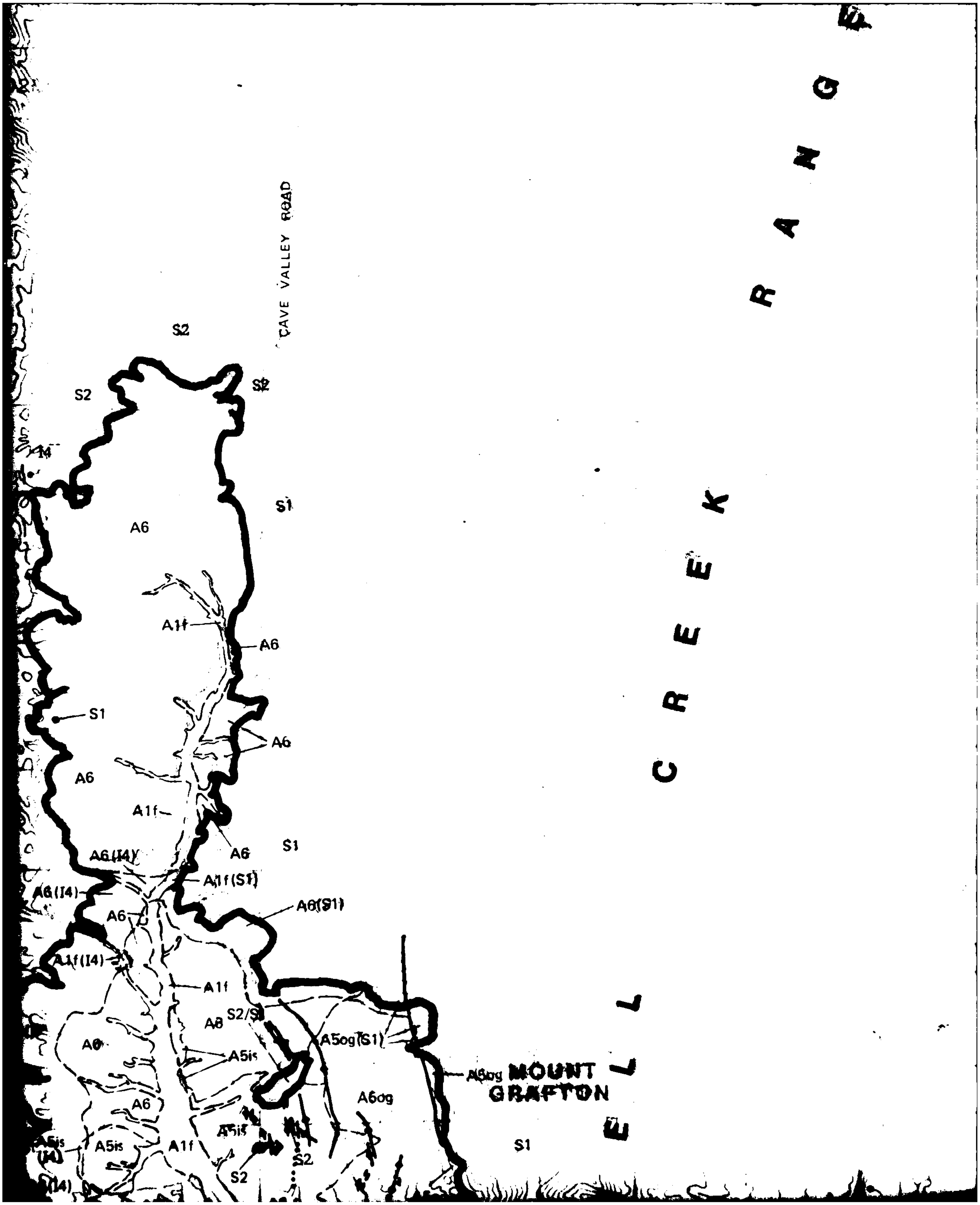
ACTIVITY LINE

Contact between rock and basin-fill.

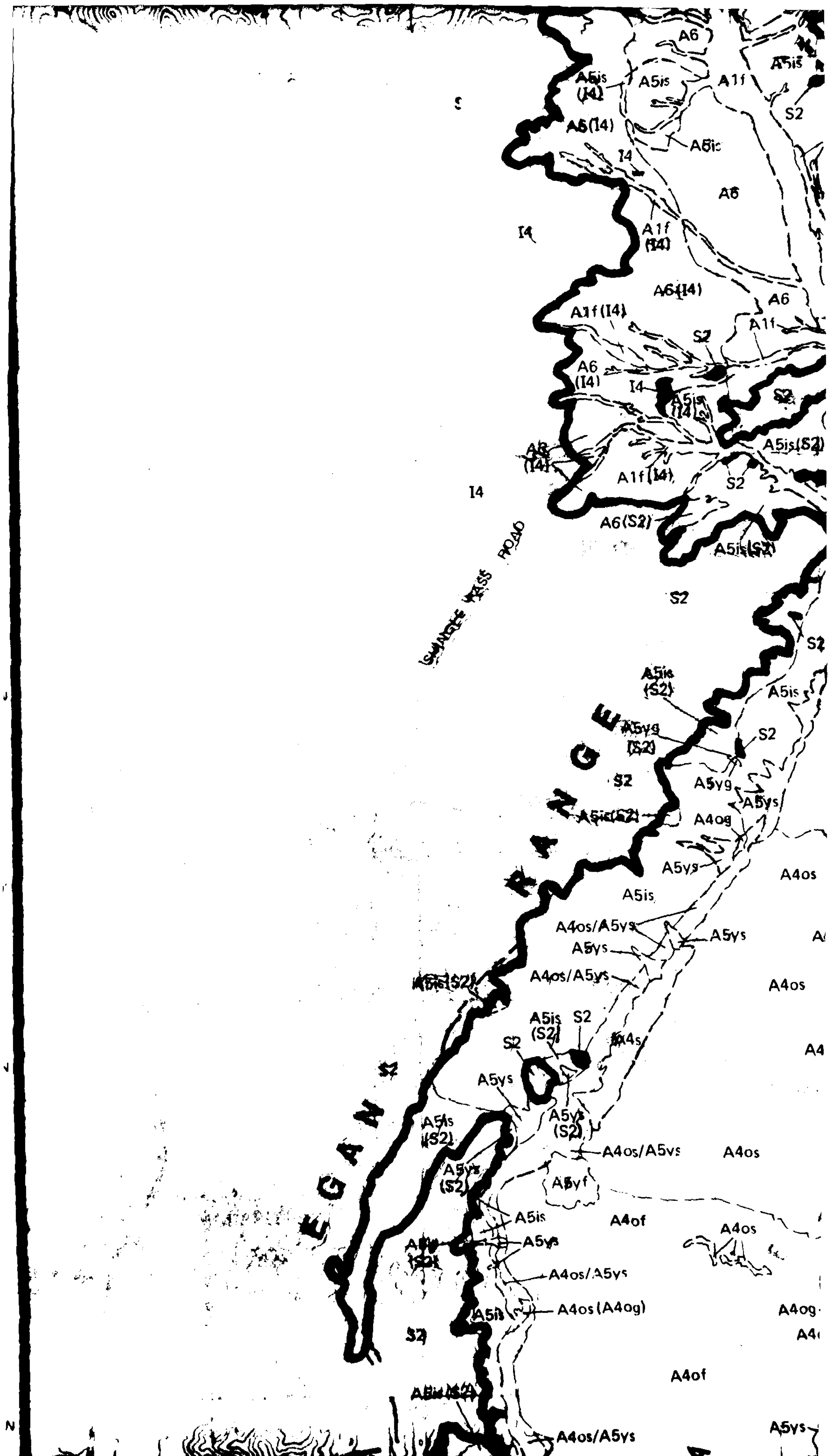
Valley borders.

Areas of isolated exposed rock.

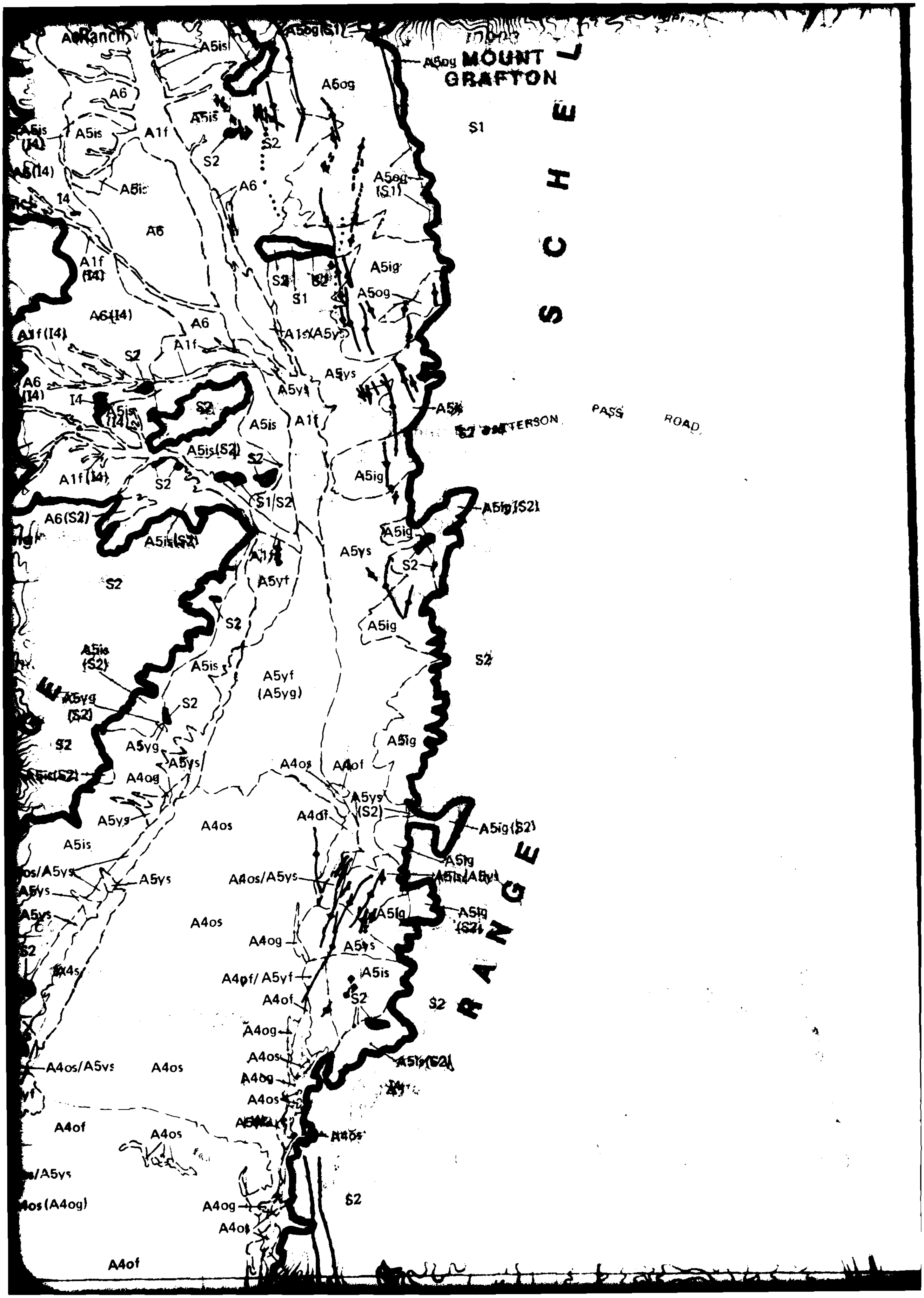

EGAN RANGE
CAVE VALLEY ROAD
S2
S2
S2
I4
S1
A6
I4
A1f
A6
S1
S1
A6
A6
A1f
I4
A6
S1
A6(I4)
A1f(S1)
A6(I4)
A6(S1)
A6
I4
A1f(I4)
A1f
S2/S1
A6
A5og(S1)
A6
S2
A5is
A6og
A6
A5is
A5is (I4)
A5is
A1f
S2
S2



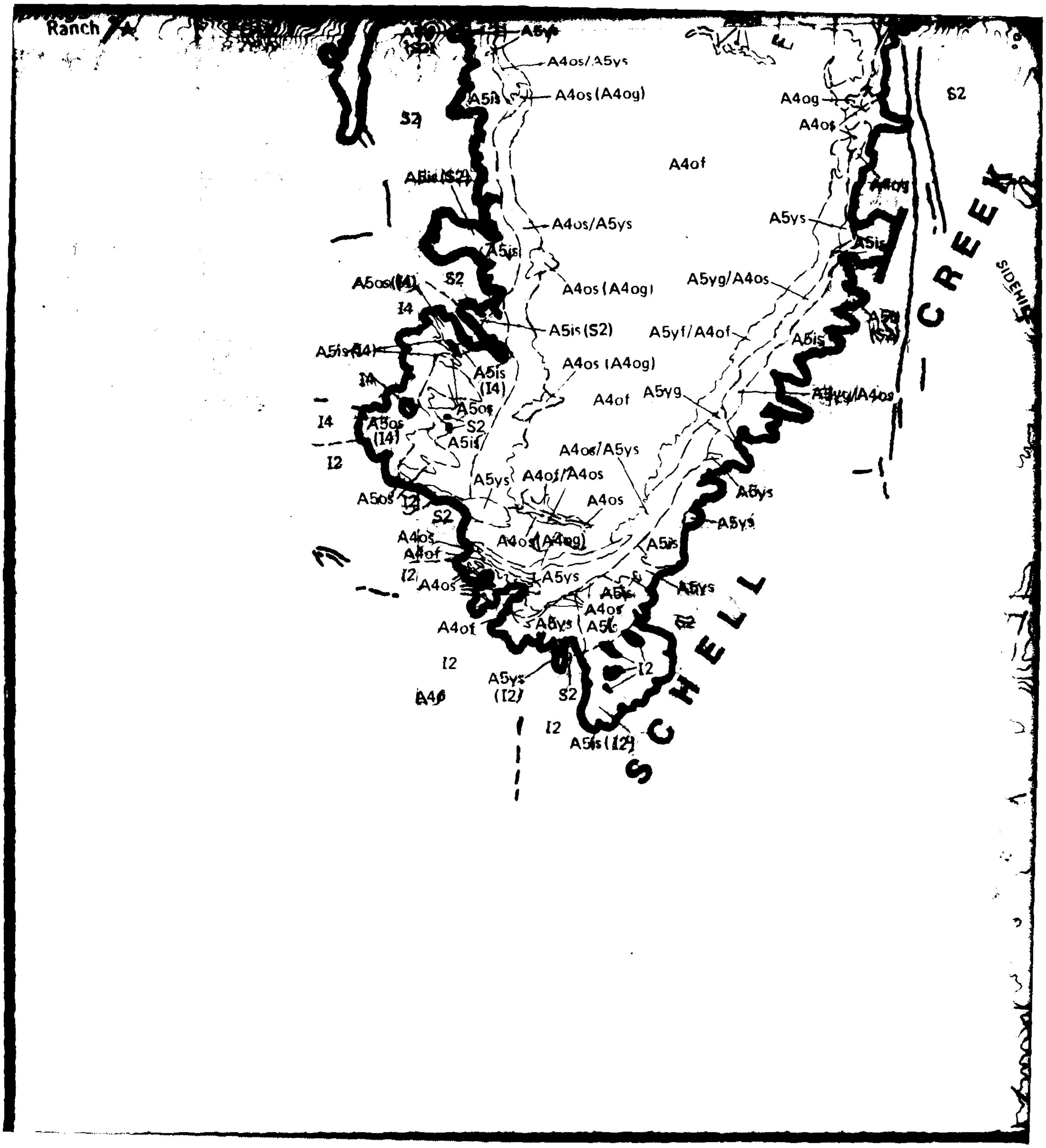
CAVE VALLEY ROAD
ELL CREEK RANGE
MOUNT GRAFTON
S2
S2
S2
I4
S1
A6
A1f
A6
S1
A6
A6
A1f
A6
S1
A6(I4)
A1f(S1)
A6(I4)
A6(S1)
A6
A1f(I4)
A1f
S2/S1
A6
A5og(S1)
A6
A5is
A5og
A5og
A6
A5is
A5is
A1f
S2
S2
S1

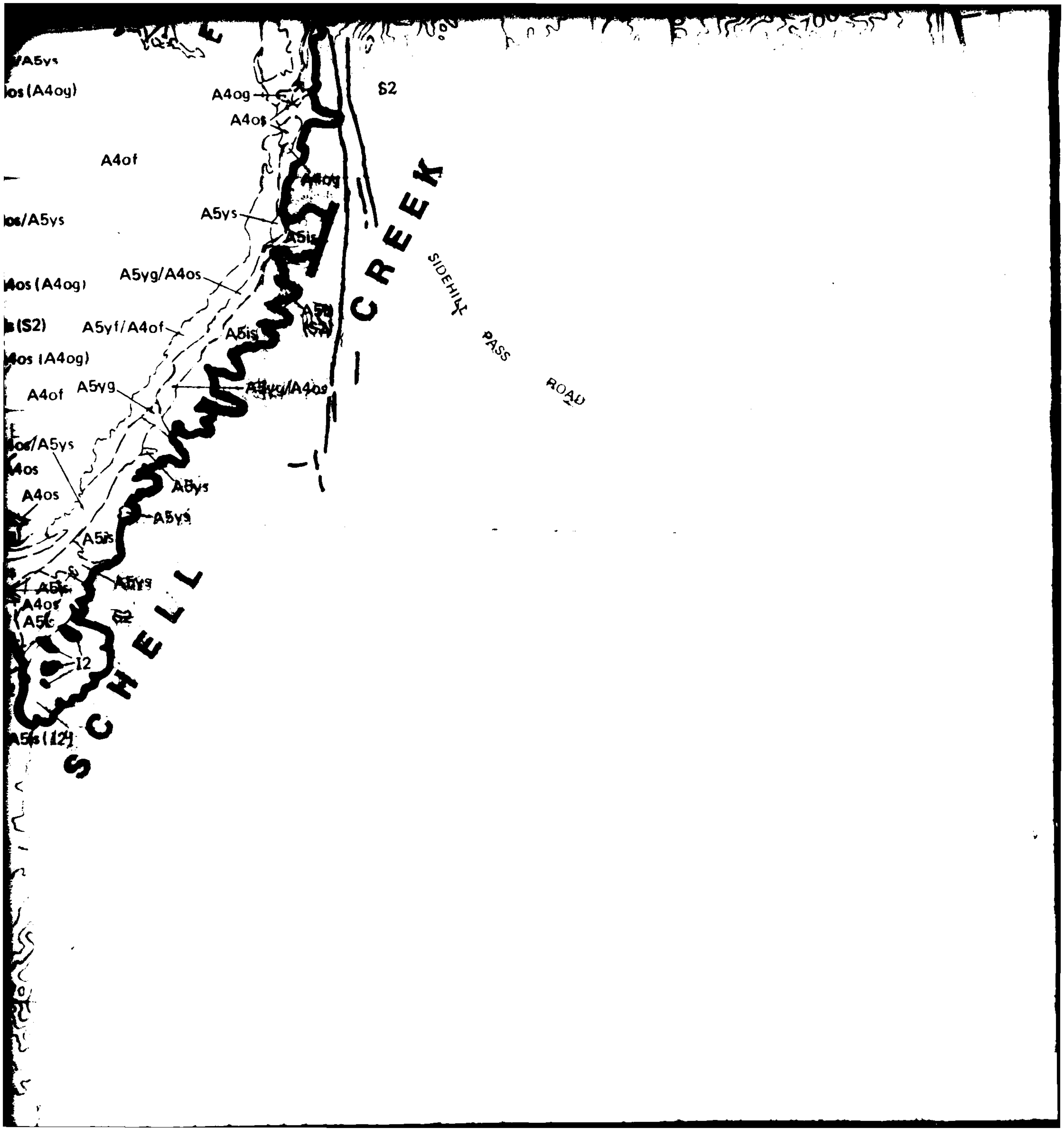


A6
A5is
A5is (I4)
A1f
S2
A5(I4)
A5is
I4
A6
I4
A1f (I4)
A6(I4)
A6
A1f(I4)
A1f
S2
A6 (I4)
I4
A5is (I4)
S2
A5is(S2)
A1f(I4)
S2
I4
A6(S2)
A5is(S2)
SAVAGE PASS ROAD
S2
S2
A5is (S2)
A5is
A5yg (S2)
S2
S2
A5yg
A5ys
A4og
A5ys
A4os
A5is
A4os/A5ys
A5ys
A5ys
A4os/A5ys
A4os
S2
A5is (S2)
S2
S2
A4s
A4
A5ys
A5ys (S2)
A5is (S2)
A4os/A5vs
A4os
A5ys (S2)
A5yf
A5is
A4of
A4os
A5ys
A4os/A5ys
A4os (A4og)
A4og
S2
A4of
A4os/A5ys
A5ys
EGAN RANGE



MOUNT GRAFTON
SCHELL
RANGE
PATTERSON PASS ROAD
Ranch
A5og(S1)
A5og
A5is
A6
A5is
A1f
S2
A6
A5og
(S1)
S1
A6
A1f
(I4)
A5ig
S1
A6(I4)
A1f(I4)
A1s(A5ys)
A5ys
A1f
A5is
A5is(S2)
S1/S2
A1f(I4)
A6(S2)
A5ig
A5ig(S2)
A5yf
A5is
(S2)
A5yf
(A5yg)
A5yg
(S2)
A5ig
A4os
A4of
A4og
A5ys
(S2)
A4df
A5ig(S2)
A4os/A5ys
A5ig
A5is(A5ys)
A4og
A4of/A5yf
A4of
A4os
A5ys(S2)
A4os/A5ys
A4of
A4og
A4os
A4of


Ranch
A5ys
A4os/A5ys
A4os (A4og)
A5is
S2
A4og
A4os
A4of
A4os/A5ys
A5ys
A5is
A4os (A4og)
A5yg/A4os
S2
A5os(I4)
I4
A5is (S2)
A5yf/A4of
A5is
A5is(I4)
A4os (A4og)
A5is
(I4)
A4of
A5yg
A5yg/A4os
A5os
S2
I4
A5os
(I4)
A5is
I2
A4os/A5ys
A5ys
A4of/A4os
A5os
A4os
A5ys
S2
A5ys
A4os
A4of
A4os (A4og)
A5is
I2
A4os
A5ys
A5ys
A4os
A4of
A5ys
I2
I2
A5ys
(I2)
S2
I2
A5is (I2)
S2
SCHELL
CREEK



S2
A4og
A4os
A4of
A5ys
A5is
A5yg/A4os
A5yf/A4of
A5yg
A4os (A4og)
A4os
A5is
A4of
A5is (I2)
I2
SCHELL CREEK
SIDEHILL PASS ROAD

A1f / A1s	Young fluvial deposits in modern stream channels and flood plains. A1f sandy silts and
A4s	Young active playa lacustrine deposits. A4s silty sands.
A4of / A4os / A4og	Old lacustrine sediments deposited during past pluvial periods. A4of -- silts and clays. A4 A4og silty gravels, occurs only on map at margin of lake deposits at bars.
A5yf / A5ys / A5yg	Young-age alluvial fan deposits undergoing active deposition. A5yf - sandy silts and clay sands; A5yg silty gravels.
A5is / A5ig	Intermediate-age alluvial fan deposits undergoing active erosion with no deposition. A5i A5ig-- sandy gravels.
A5os / A5og	Old-age alluvial fan deposits having deep incisions and rounded erosional surfaces. A5os A5og-- sandy to silty gravels.
A6	Tertiary young sediments of the Plio-Pleistocene age Cave Valley formation which con to boulder conglomerate and grades upward into interbedded conglomerates, sandston These sediments exhibit some localized zones of strong cementation.
A5is/A5ys	Combination of geologic unit symbols indicates a mixture of surficial basin-fill deposit The predominant unit is listed first.
A5is(I2)	A designation for a deposit where the unit listed first is underlain at shallow depth by

ROCK UNITS

Igneous (I)

I2	Undifferentiated volcanic rocks consisting of rhyolite, latite, dacite, and andesite.
I4	Undifferentiated volcanic rocks consisting of welded tuffs, ash flows, ignimbrites, and

Sedimentary (S)

S1	Sandstone.
S2	Limestones and dolomites.

dern stream channels and flood plains. A1f sandy silts and clays. A1s silty sands.

e deposits. A4s silty sands.

posited during past pluvial periods. A4of silts and clays. A4os silty to gravelly sands
only on map at margin of lake deposits at bars.

its undergoing active deposition. A5yf sandy silts and clays; A5ys silty and gravelly

deposits undergoing active erosion with no deposition. A5is silty [illegible] vally sands;

having deep incisions and rounded erosional surfaces. A5os gravelly to silty sands.

the Plio-Pleistocene age Cave Valley formation which consists of a basal cobble
grades upward into interbedded conglomerates, sandstones, and siltstones.
e localized zones of strong cementation.

t symbols indicates a mixture of surficial basin-fill deposits inseparable at map scale.
d first.

where the unit listed first is underlain at shallow depth by parenthetic unit.

ROCK UNITS

ks consisting of rhyolite, latite, dacite, and andesite.

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

A6	**Tertiary young sediments of the Plio-Pleistocene age Cave Valley formation which co**[...] to boulder conglomerate and grades upward into interbedded conglomerates, sandstone[...] These sediments exhibit some localized zones of strong cementation.
A5is/A5ys	Combination of geologic unit symbols indicates a mixture of surficial basin-fill deposits [...] The predominant unit is listed first.
A5is(I2)	A designation for a deposit where the unit listed first is underlain at shallow depth by p[...]

ROCK UNITS

Igneous (I)

I2	Undifferentiated volcanic rocks consisting of rhyolite, latite, dacite, and andesite.
I4	Undifferentiated volcanic rocks consisting of welded tuffs, ash flows, ignimbrites, and py[...]

Sedimentary (S)

S1	Sandstone.
S2	Limestones and dolomites.

SYMBOLS

Contact between rock and basin fill.

Contact between surficial basin-fill or rock units.

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

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

Valley borders.

NOTES

1. Surficial basin fill units pertain only to the upper several feet of soi[...] Due to variability of surficial deposits and scale of map presentation units descriptions refer to the predominant soil types. Varying amounts of other soil types can be expected within each geologic unit.
2. The distribution of geologic data stations is presented in Volume II Drawing II 1 1. A tabulation of all station data and generalized descriptions of all geologic units is included in Volume II, Section 1.
3. Geology in areas of exposed rock derived from Ertec Western, Inc (1979, 1980) unpublished data, Tschanz and Pampeyan (1970), and Carlson (1978), and Hose, Blake, and Smith (1976).

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SURFICIAL GEOLOGICAL UNITS
CAVE VALLEY, NEVADA

26 OCT 81

DRAWING 3-2

into interbedded conglomerates, sandstones, and siltstones.
localized zones of strong cementation.

t symbols indicates a mixture of surficial basin-fill deposits inseparable at map scale.
ed first.

where the unit listed first is underlain at shallow depth by parenthetic unit.

ROCK UNITS

ks consisting of rhyolite, latite, dacite, and andesite.

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

SYMBOLS

sin-fill.

in-fill or rock units.

, ball on downthrown side, dashed where approximately
ere inferred in alluvium.

y a fault, generally expressed as a linear vegetational growth

pertain only to the upper several feet of so
ficial deposits and scale of map presentation
o the predominant soil types. Varying amounts
e expected within each geologic unit
gic data stations is presented in Volume II
tion of all station data and generalized descripti
cluded in Volume II, Section 1
sed rock derived from Ertec Western, Inc
d data Tschanz and Pampeyan (1970),
Hose Blake, and Smith (1976)

NORTH

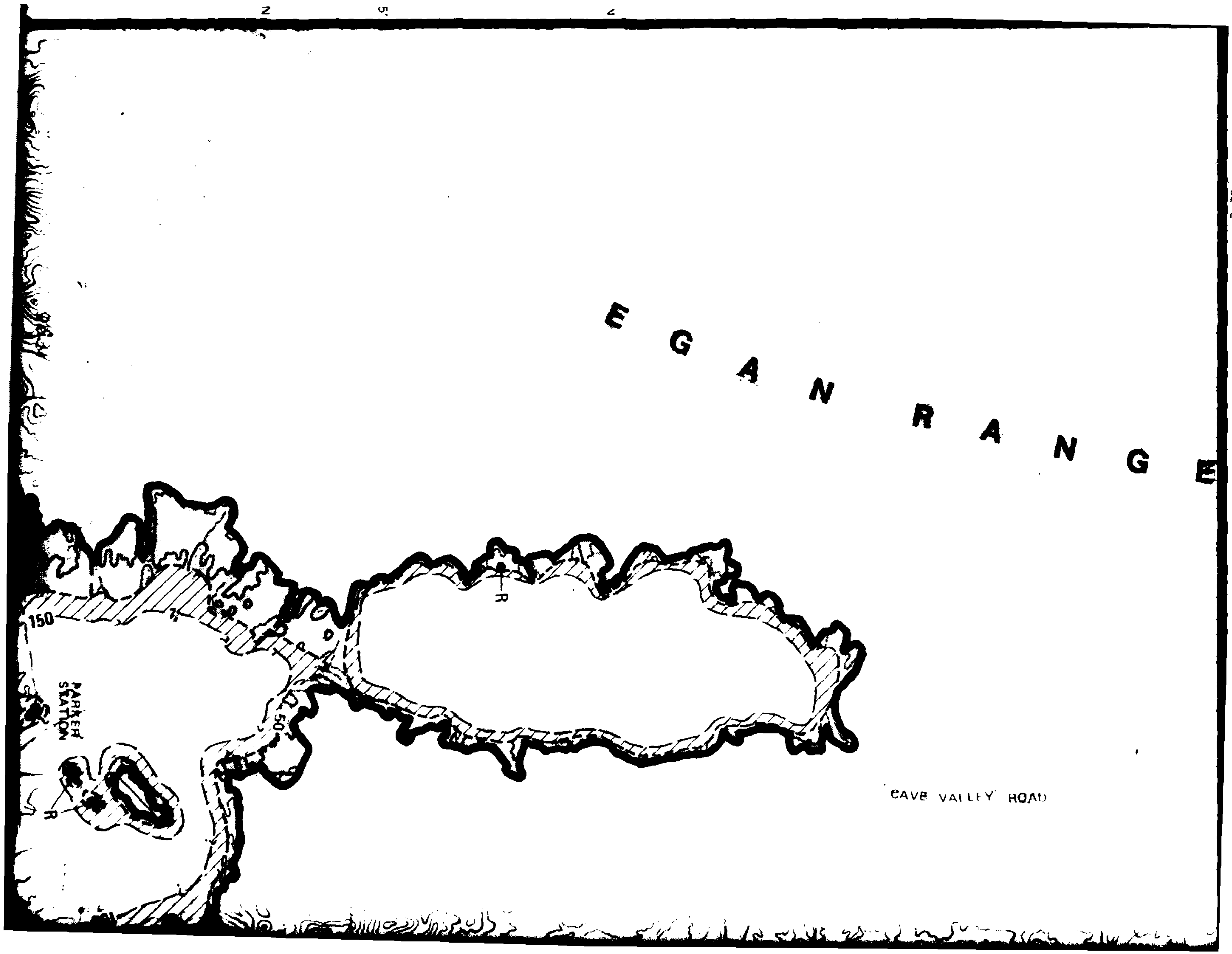
SCALE 1: 125,000

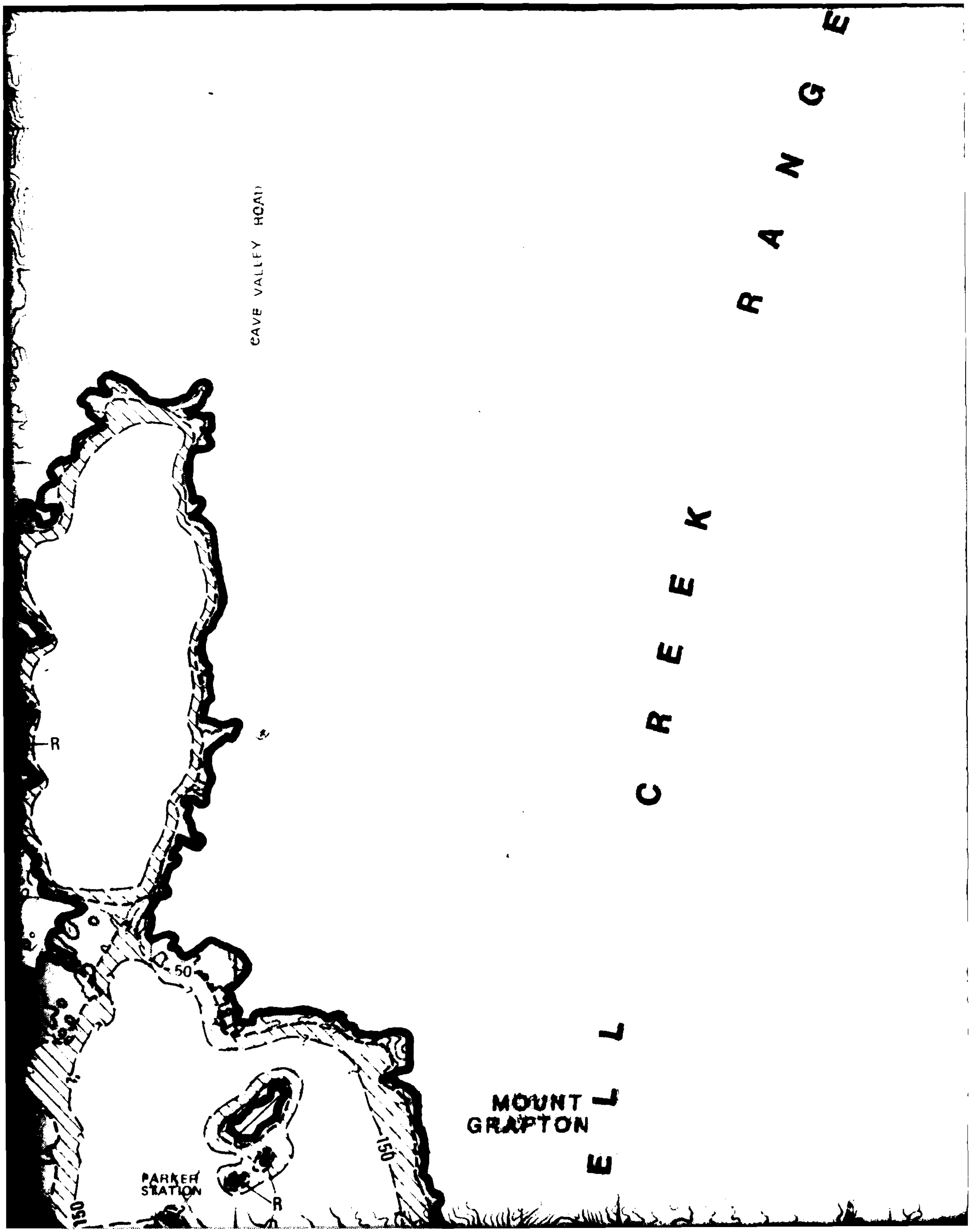
0 2 4

STATUTE MILES

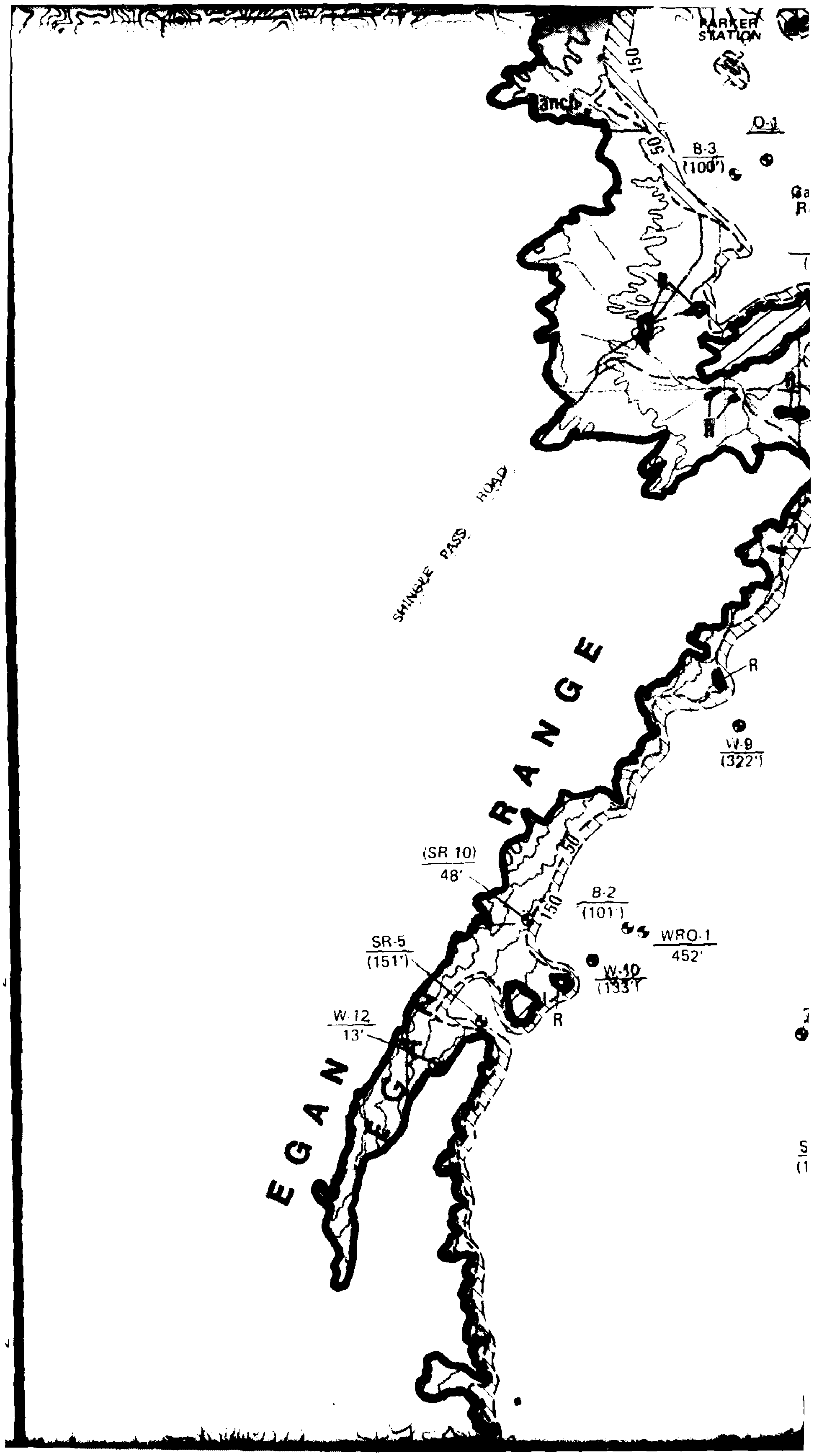
0 2 4

KILOMETERS

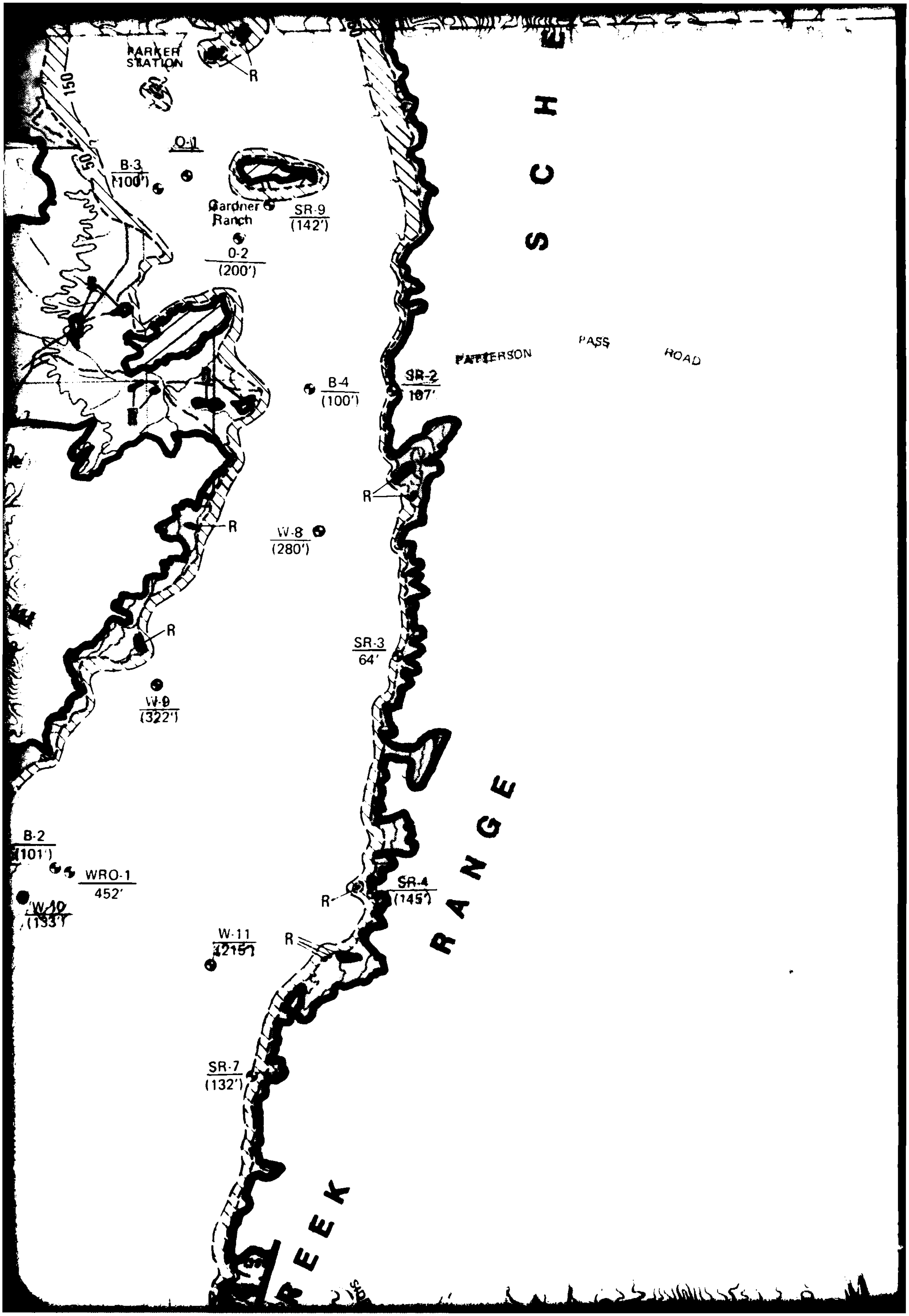

EGAN RANGE
CAVE VALLEY ROAD
PARKER STATION
R
R
150
50

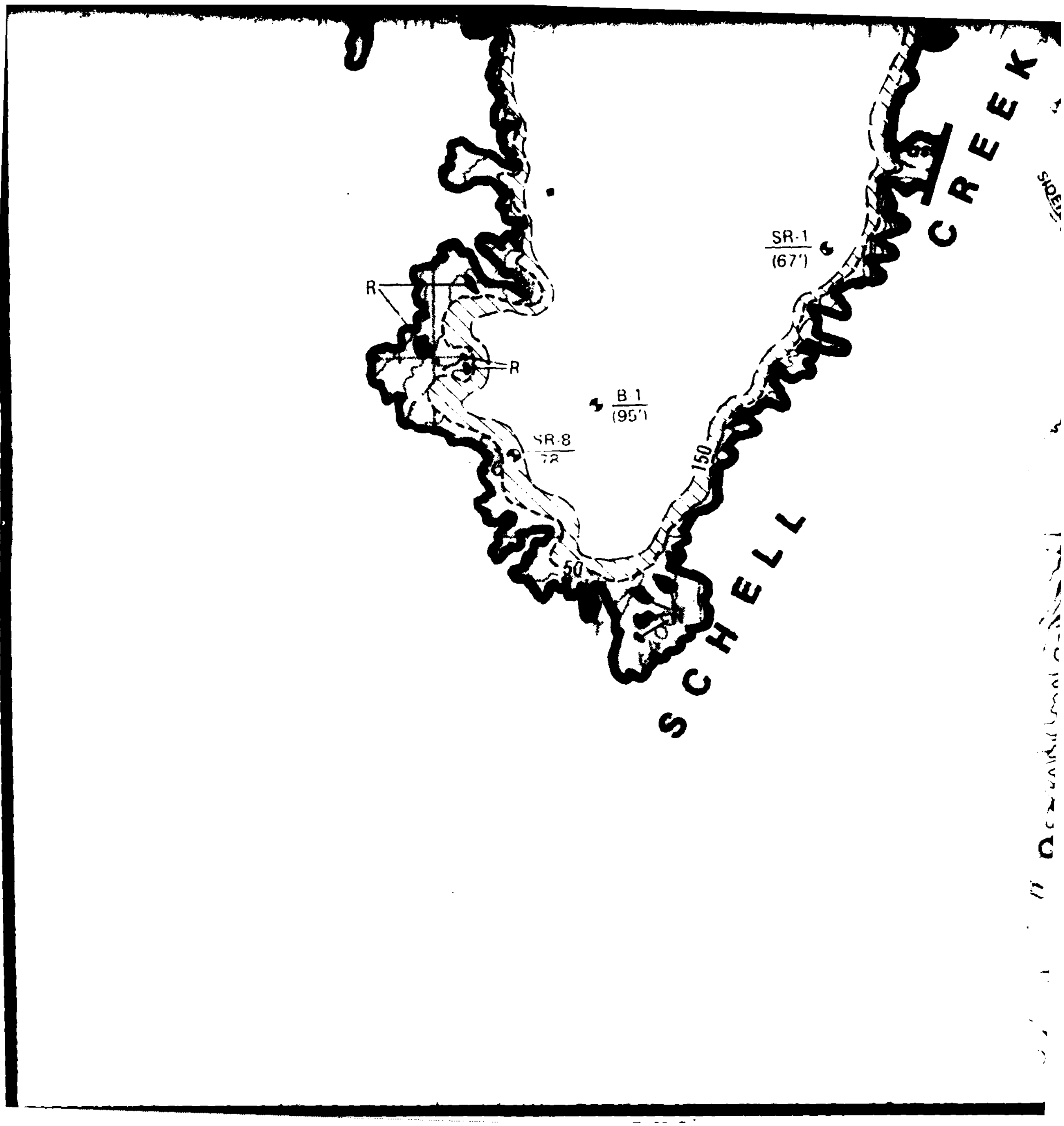


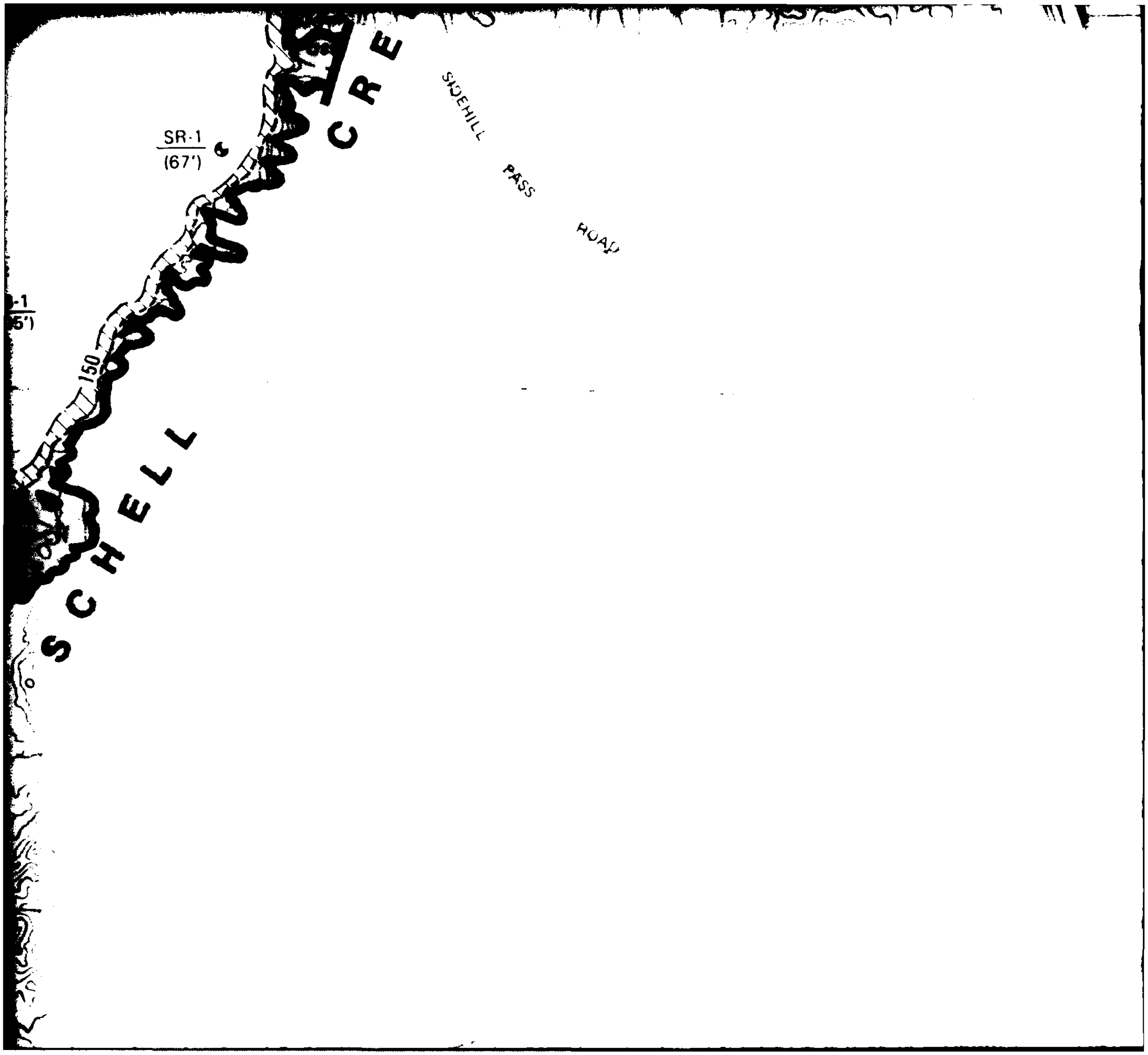
CAVE VALLEY ROAD
ELL CREEK RANGE
MOUNT
GRAPTON
PARKER
STATION
R
R
50
150
150



PARKER STATION
150
ancb
Q-1
50
B-3
(100')
R
SHINGLE PASS ROAD
EGAN RANGE
R
W-9
(322')
(SR 10)
48'
50
B-2
(101')
150
WRQ-1
452'
SR-5
(151')
W-10
(133')
R
W-12
13'


PARKER STATION
R
150
50
O-1
B-3 (100')
Gardner Ranch
SR-9 (142')
0-2 (200')
PATTERSON PASS ROAD
B-4 (100')
SR-2 107'
R
R
W-8 (280')
R
SR-3 64'
W-9 (322')
B-2 (101')
WRO-1 452'
W-10 (133')
R
SR-4 (145')
W-11 (215')
R
SR-7 (132')
S C H
RANGE
EEK


R
R
SR-1
(67')
B-1
(95')
SR-8
72
150
50
SCHELL CREEK



SR-1
(67')
150
SCHELL
CRE
PASS

R 62 E   R 63 E   R

EXPLANATION

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

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

Contact between rock and basin-fill.

Valley borders.

Areas of isolated exposed rock.

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

B-1 / 199′ — Data Source Seismic refraction line and electrical resistivity sounding (S
boring (B), observation well (O), published water well (W), or water
resources observation well (WRO).
Depth to rock or, when in parentheses, total depth at which rock not enc

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

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DEPTH TO ROCK
CAVE VALLEY, NEVADA

26 OCT 81

DRAWING 3-3

83 E R 64 E 114° 45 R 65 E

EXPLANATION

rock at a depth of approximately 50 feet (15m) – shading indicates
ect (15m).

rock at a depth of approximately 150 feet (46m) – shading indicates
eet (15m) and 150 feet (46m).

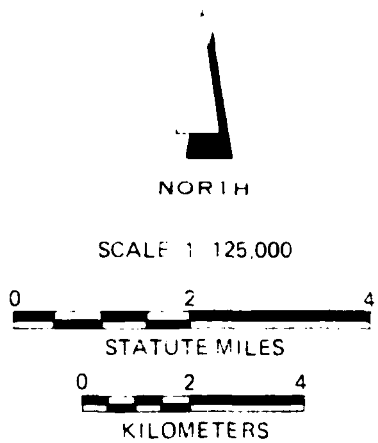
ock and basin-fill.

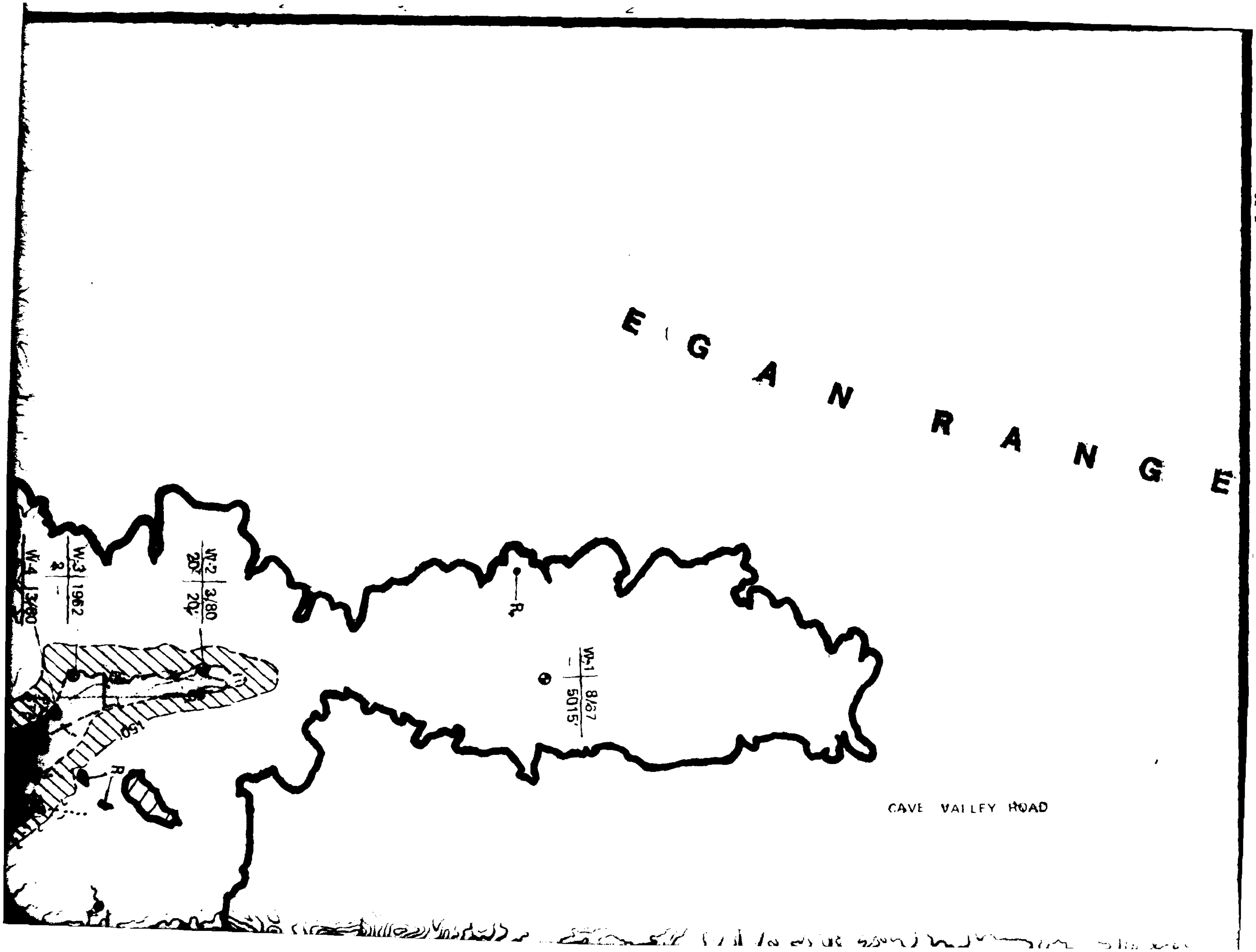
xposed rock.

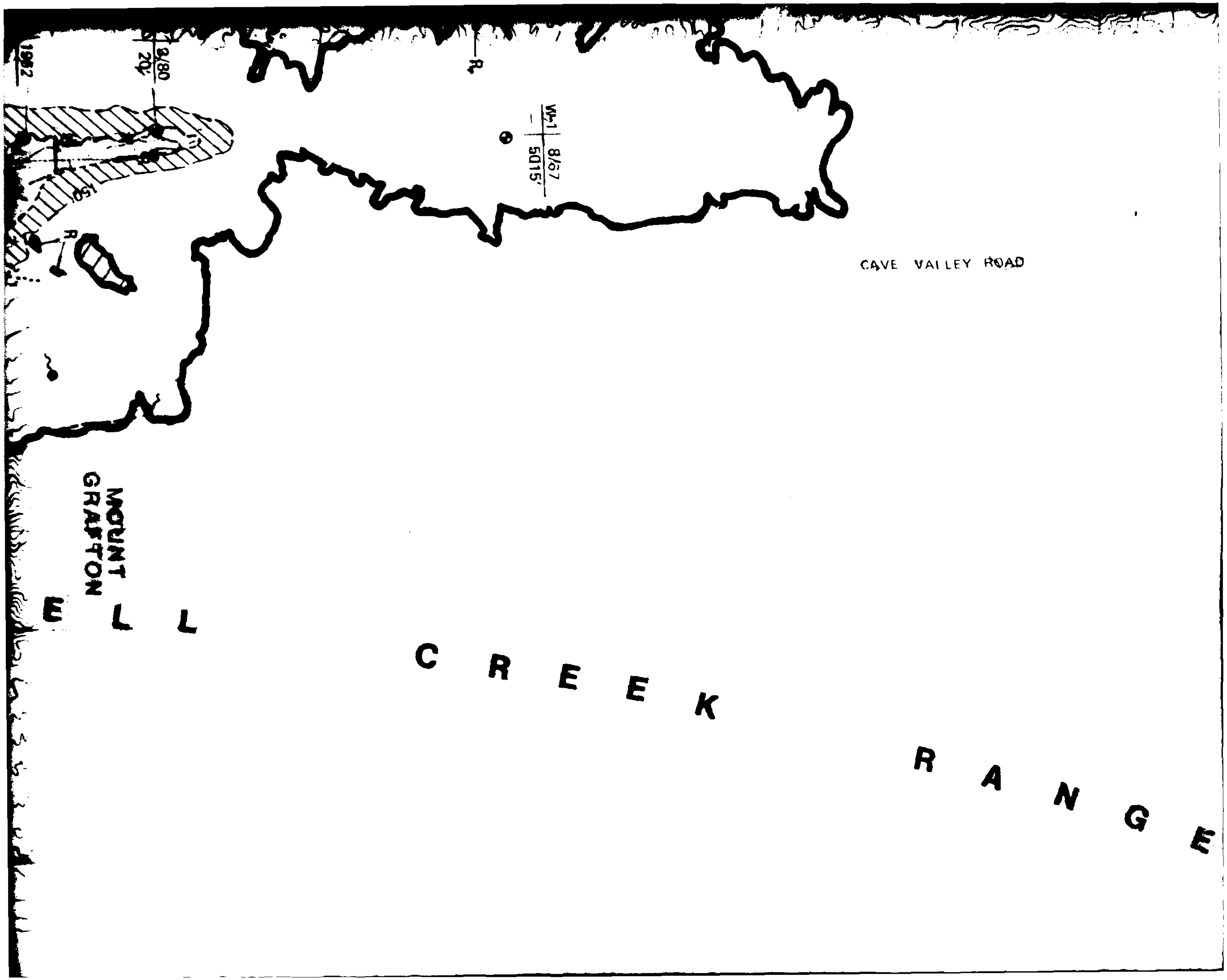
xposed rock too small for shading.

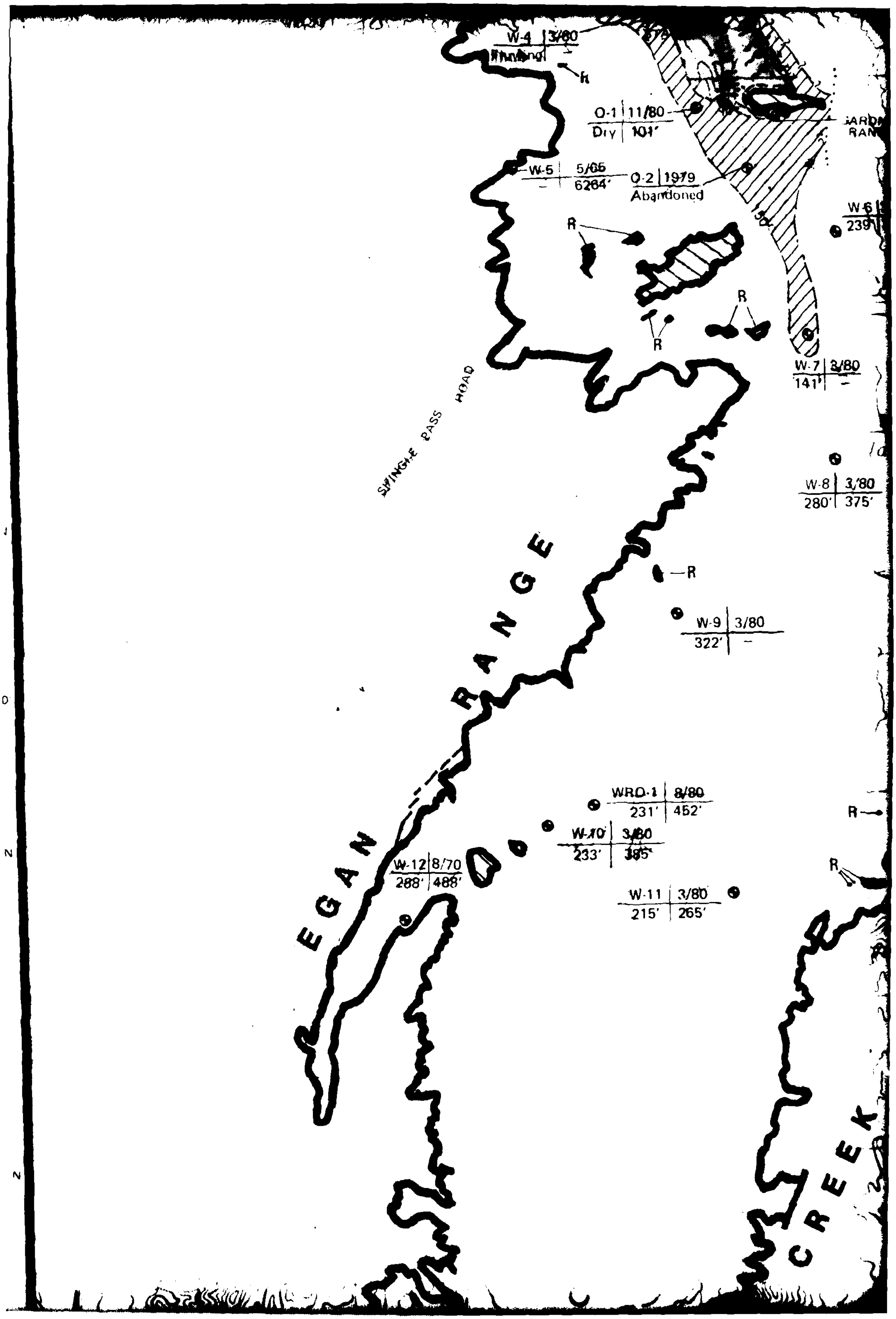
mic refraction line and electrical resistivity sounding (SR),
tion well (O), published water well (W), or water
on well (WRO)
when in parentheses, total depth at which rock not encountered.

s are based on geologic interpretations
d data points shown on the map
ntour locations can be expected as
ta are obtained.

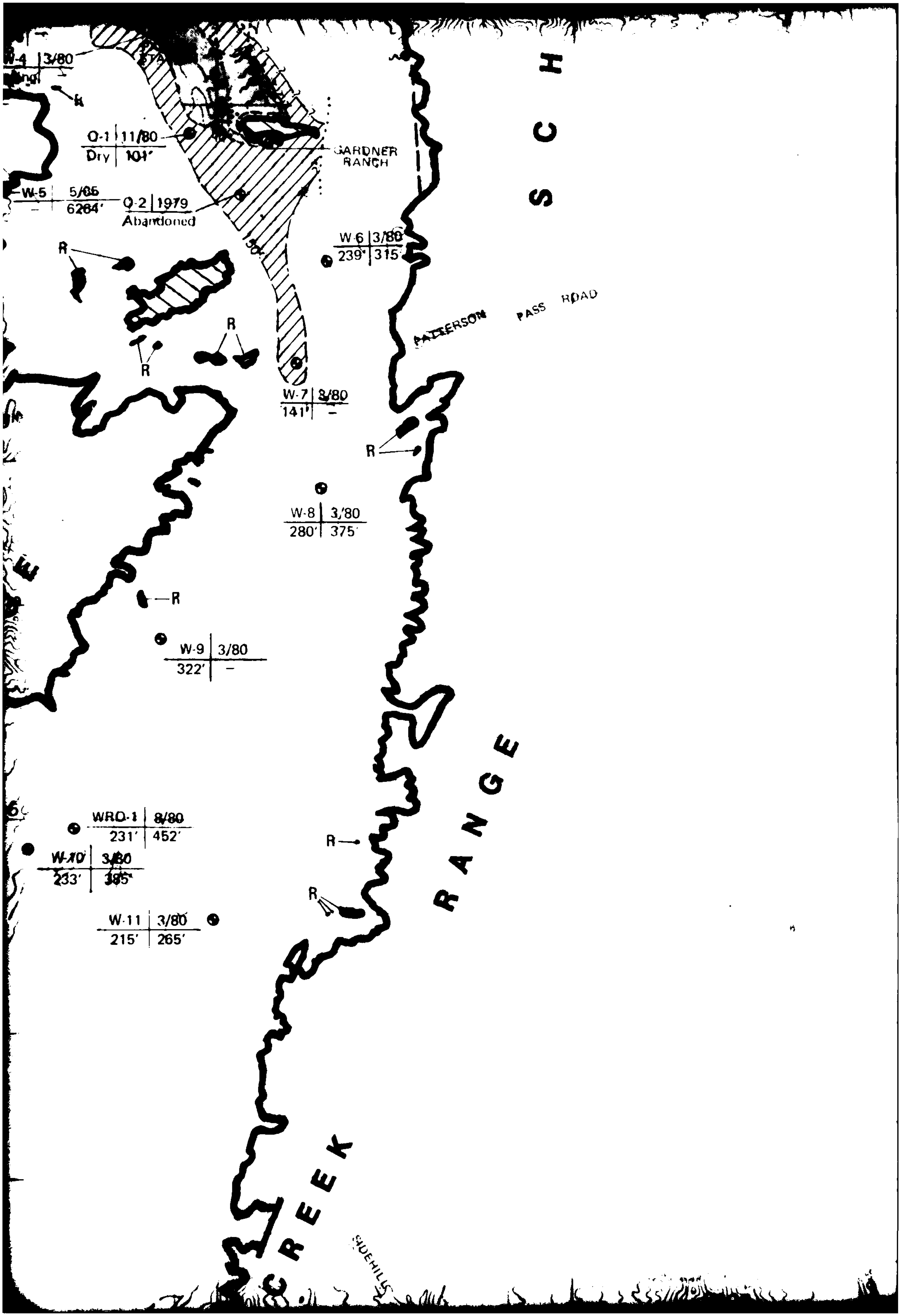



EGAN RANGE
CAVE VALLEY ROAD
W-1 | 8/67
– | 5015'
R
W-2 | 3/80
20' | 20'
W-3 | 1962
8 | –
W-4 | 13/80
150
R

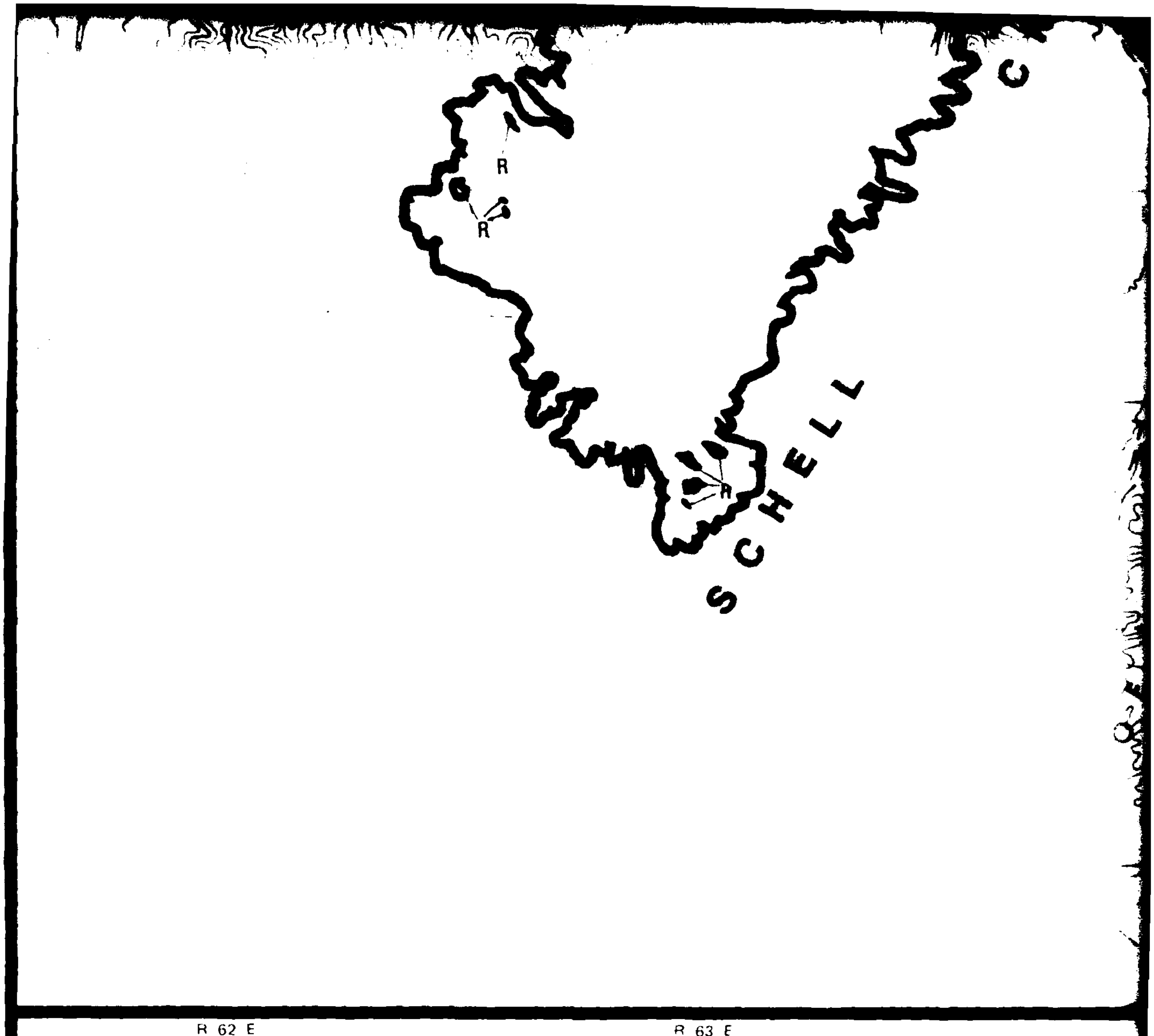

CAVE VALLEY ROAD
MOUNT GRAFTON
E L L C R E E K R A N G E
W-1
8/67
5015'



W-4 3/80
O-1 11/80
Dry 101'
W-5 5/65
6284'
O-2 1979
Abandoned
R
W-6
239
W-7 3/80
141'
SWINGLE PASS ROAD
W-8 3/80
280' 375'
EGAN RANGE
R
W-9 3/80
322'
WRD-1 8/80
231' 452'
W-10 3/80
233' 385'
W-12 8/70
288' 488'
W-11 3/80
215' 265'
CREEK



W-4 3/80
Q-1 11/80
Dry 101'
GARDNER RANCH
W-5 5/65
6264'
Q-2 1979
Abandoned
W-6 3/80
239' 315'
S C H
PATTERSON PASS ROAD
R
W-7 3/80
141' –
W-8 3/80
280' 375'
W-9 3/80
322' –
WRD-1 8/80
231' 452'
W-10 3/80
233' 385'
W-11 3/80
215' 265'
RANGE
CREEK



EXPLANATION

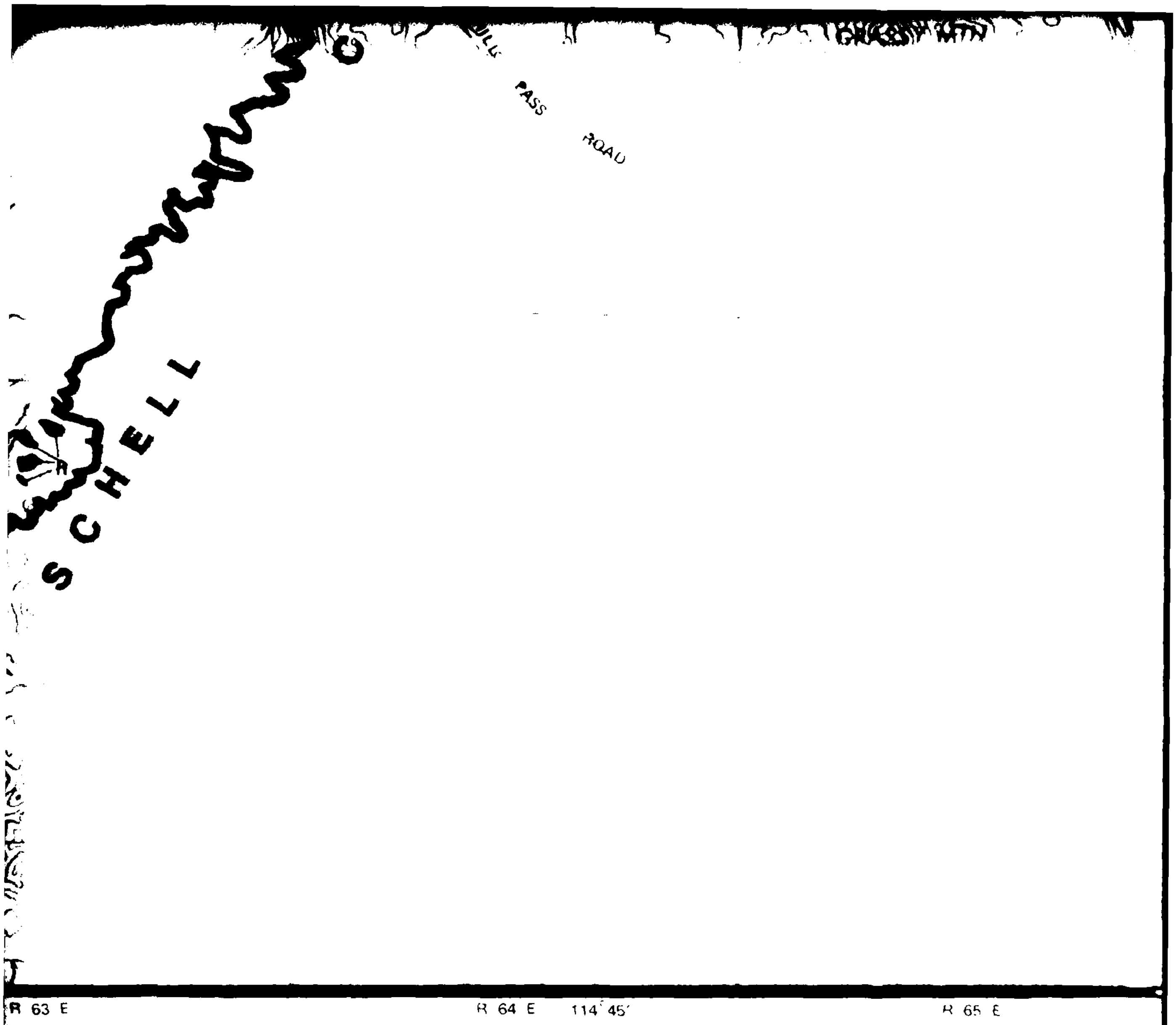
50' — Contour indicates water at a depth of approximately 50 feet (15m) - sha
water less than 50 feet (15m).

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

Absence of contours indicates water occures at depths of greater than 1
borings, and assorted wells indicate depths to ground water generally in
remainder of Cave Valley (see Volume I, Section 3.6).

Contact between rock and basin-fill.

Valley borders.



EXPLANATION

s water at a depth of approximately 50 feet (15m) - shading indicates
0 feet (15m).

s water at a depth of approximately 150 feet (46m) shading indicates
0 feet (15m) and 150 feet (46m).

urs indicates water occures at depths of greater than 150 feet. Ertec Western, Inc.
rted wells indicate depths to ground water generally in excess of 200 feet throughout
e Valley (see Volume I, Section 3.6).

rock and basin-fill.

NORTH

SCALE 1:125,000

0 2 4
STATUTE MILES

0 2 4
KILOMETERS

R 62 E R 63 E R 6

EXPLANATION

50'

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

150

Contour indicates water at a depth of approximately 150 feet (46m) shadi water between 50 feet (15m) and 150 feet (46m).

Absence of contours indicates water occures at depths of greater than 150 f borings, and assorted wells indicate depths to ground water generally in exc remainder of Cave Valley (see Volume I Section 3.6).

Contact between rock and basin-fill.

Valley borders.

Areas of isolated exposed rock.

R Areas of isolated exposed rock too small for shading.

W-1	5-80
340'	394'

Data Source Published water well (W), observation well (O) or water resources observation well (WRO). see Volume II, Table II-3-1.

Depth to water (feet)

Spring

Fault, trace of surface rupture, dashed where approximately located, dott

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DEPTH TO WATER
CAVE VALLEY, NEVADA

26 OCT 81

DRAWING 3-4

R 63 E R 64 E 114° 45' R 65 E

EXPLANATION

cates water at a depth of approximately 50 feet (15m) - shading indicates
n 50 feet (15m).

NORTH

SCALE 1 125,000

ates water at a depth of approximately 150 feet (46m) - shading indicates
n 50 feet (15m) and 150 feet (46m).

0 2 4
STATUTE MILES

0 2 4
KILOMETERS

ontours indicates water occures at depths of greater than 150 feet. Ertec Western, Inc.
ssorted wells indicate depths to ground water generally in excess of 200 feet throughout
Cave Valley (see Volume I, Section 3.6).

een rock and basin-fill.

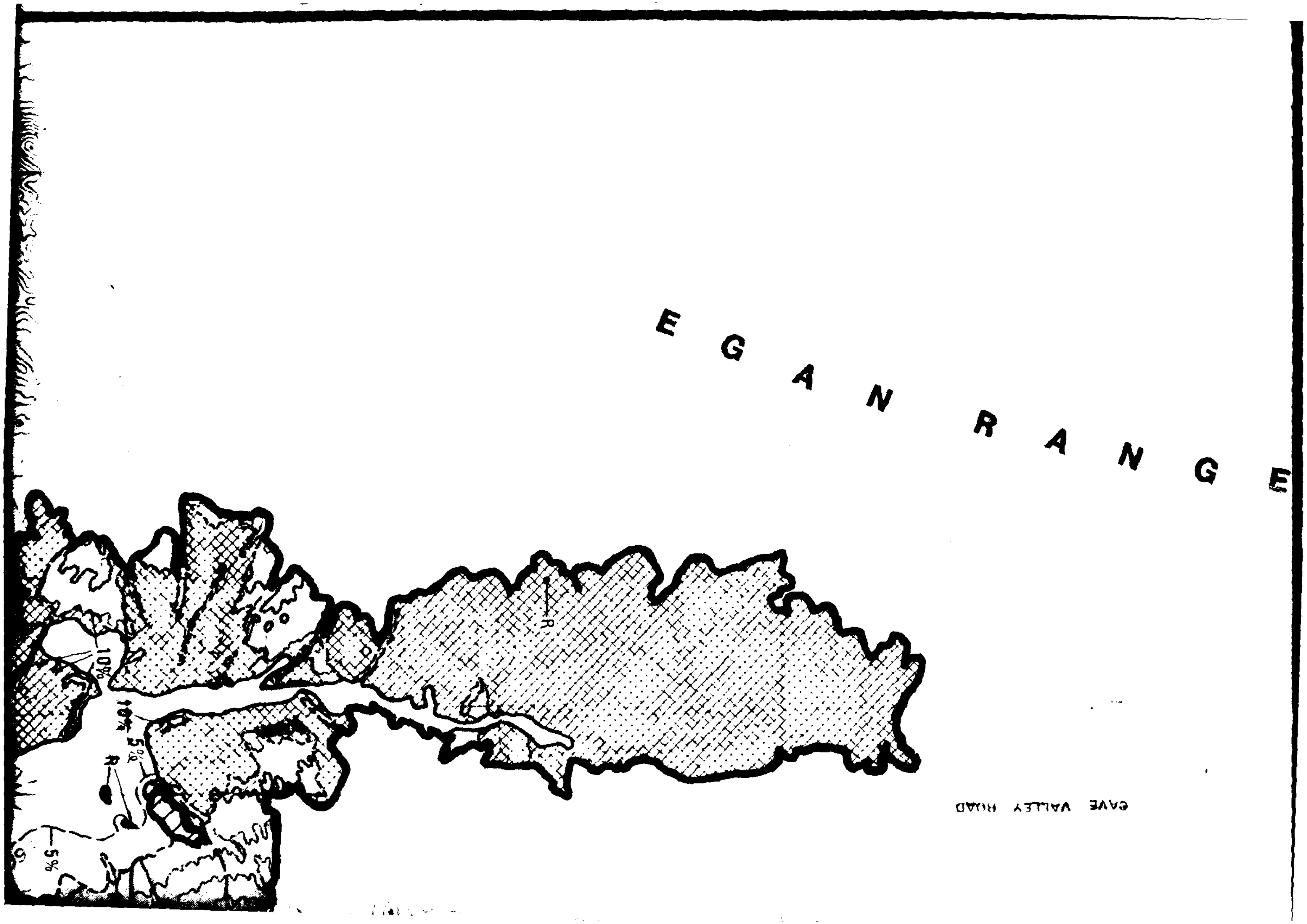
s.

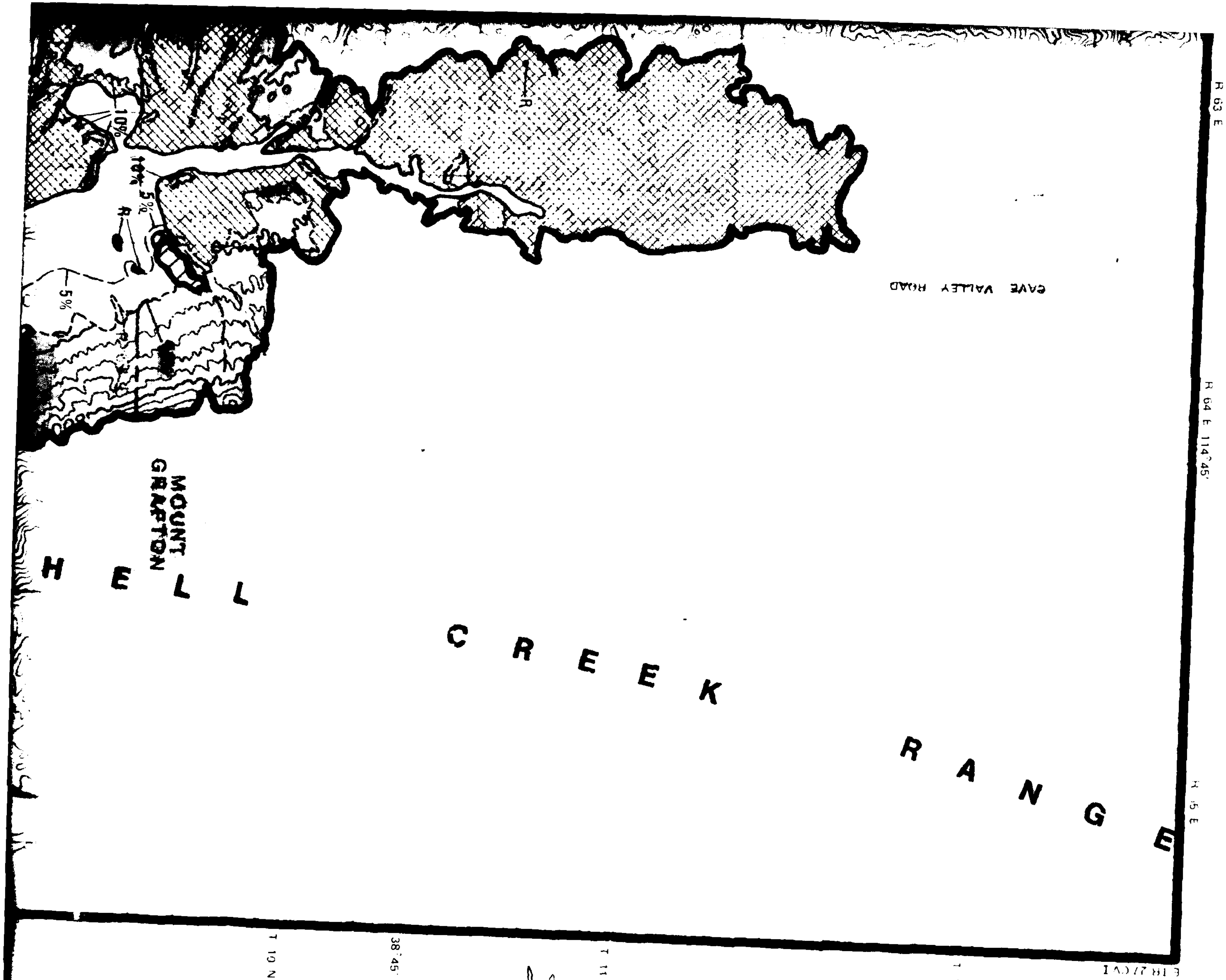
ted exposed rock.

ted exposed rock too small for shading.

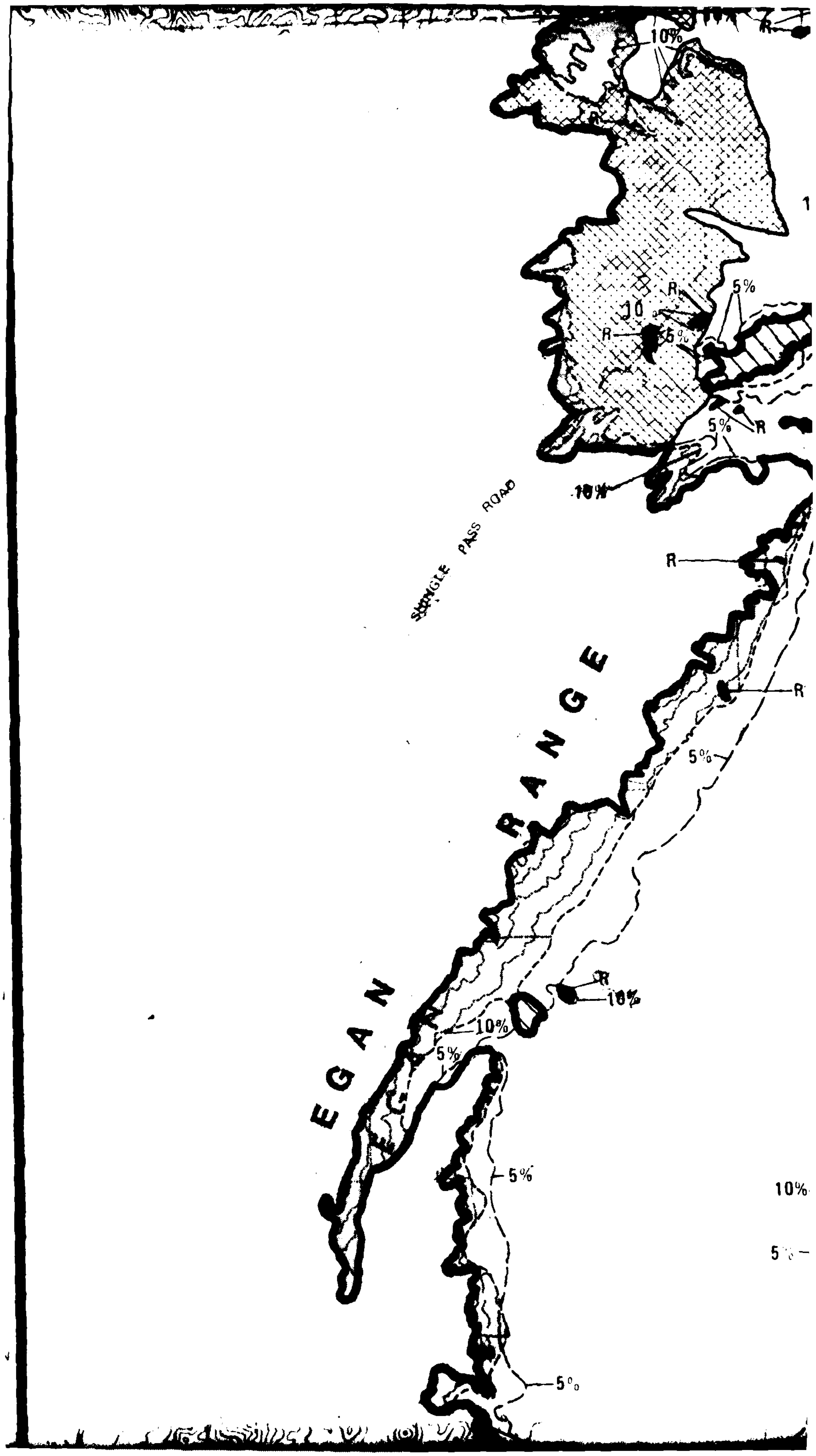
Published water well (W), observation well (O) or water rvation well (WRO), see Volume II, Table II-3 1.	Month-Year of water level measurement, or year when month unknown.
r (feet)	Depth of well (feet)

surface rupture, dashed where approximately located, dotted where inferred.

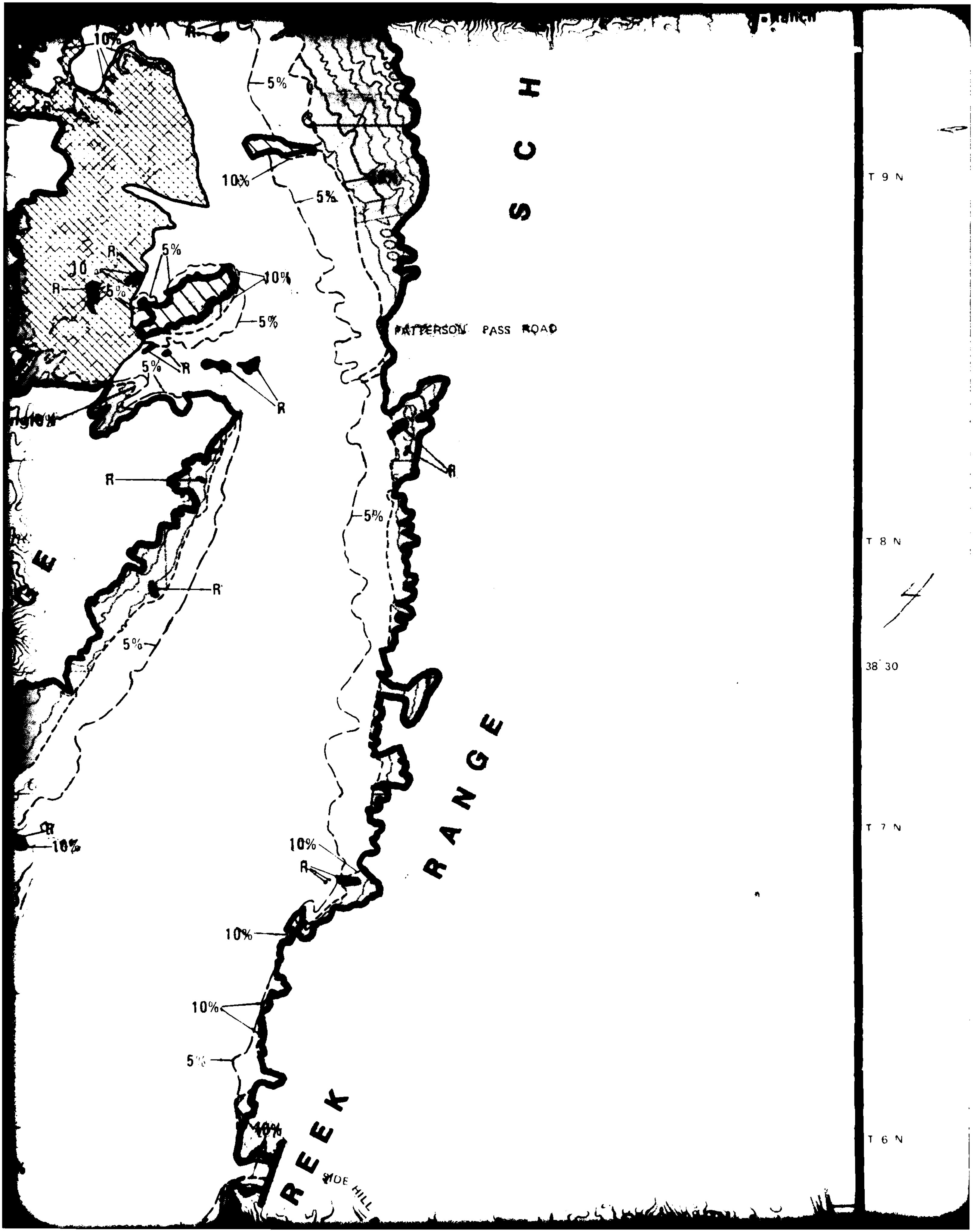

EGAN RANGE
CAVE VALLEY ROAD
R
10%
5%
R
10%
5%



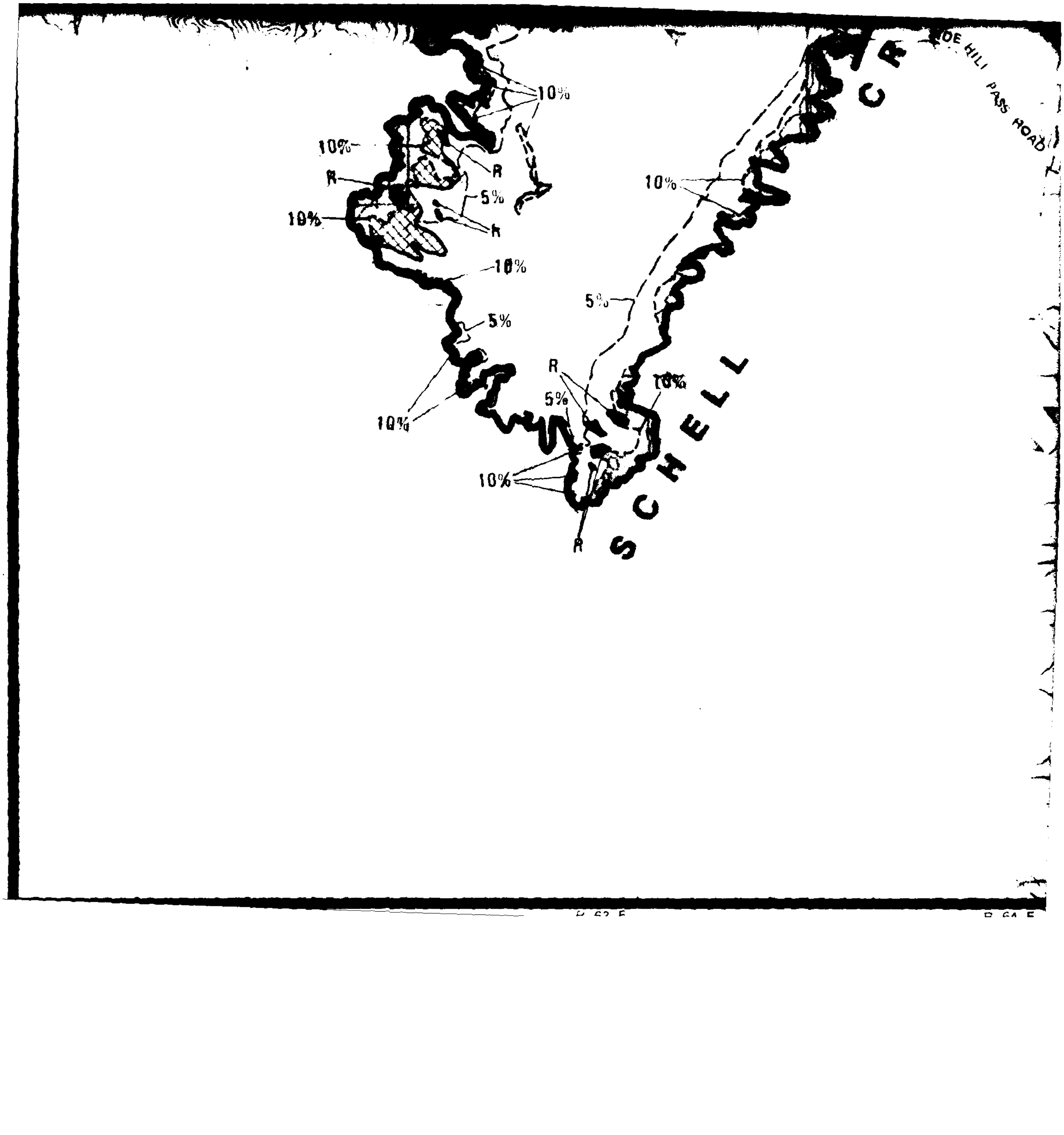
HELL CREEK RANGE
MOUNT GRAFTON
CAVE VALLEY ROAD
R 63 E
R 64 E 114°45'
T 10 N
38°45'
T 11 N
10%
5%
R
2



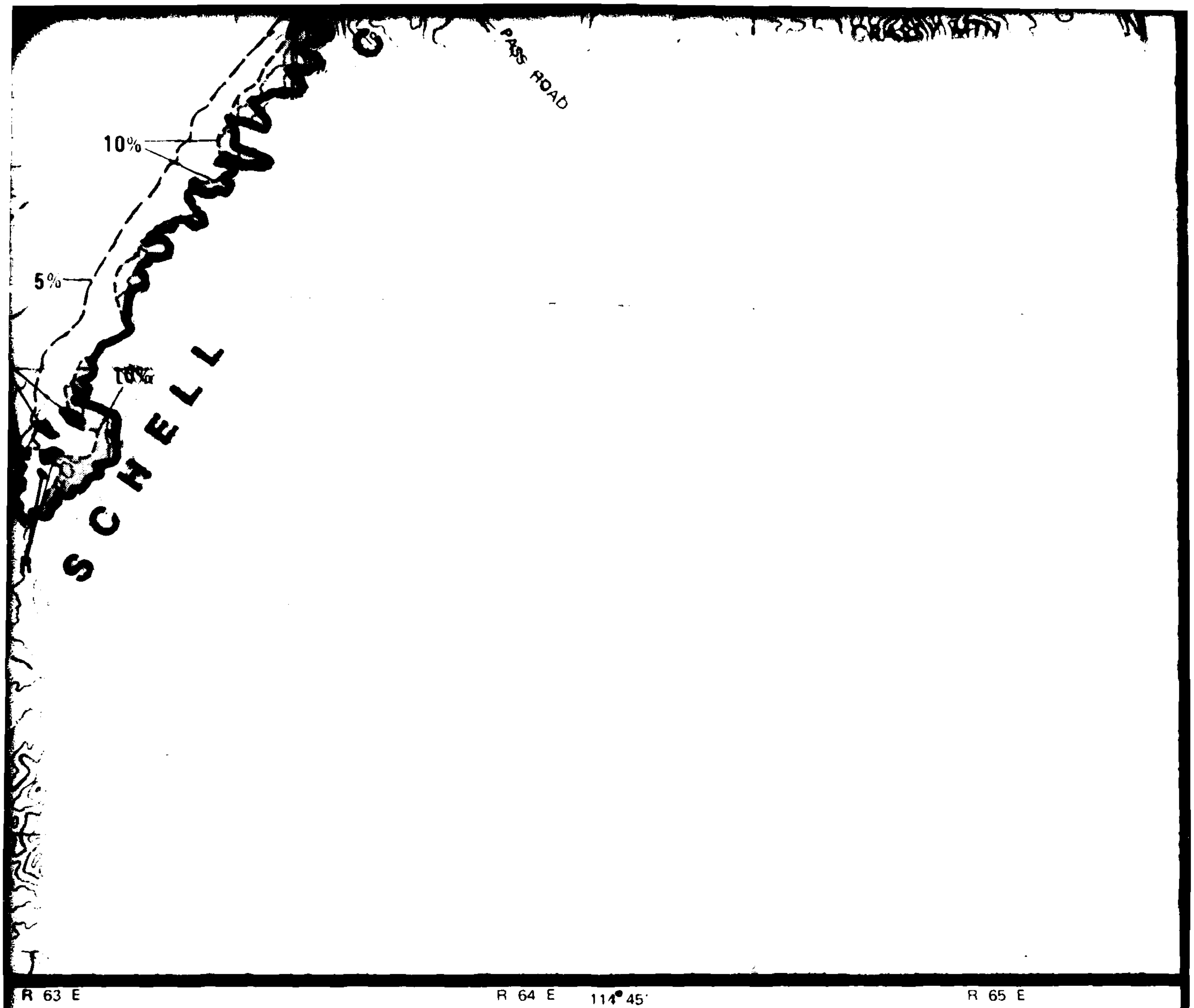
EGAN RANGE
SHINGLE PASS ROAD
10%
5%
R



10%
5%
10%
5%
S C H
5%
10%
5%
R
PATTERSON PASS ROAD
R
R
R
5%
R
5%
R
E
R
5%
T 9 N
T 8 N
38 30
T 7 N
RANGE
10%
R
10%
10%
10%
5%
10%
REEK
SIDE HILL
T 6 N



10%
10%
R
R
10%
5%
R
10%
5%
10%
10%
5%
R
5%
10%
10%
R
SCHELL CR
PASS ROAD



EXPLANATION

Contact between rock and basin-fill.

5% slope line.

10% slope line.

Valley borders.

Areas excluded on basis of 10% slopes.

Terrain exclusion area.

Areas of isolated exposed rock.

NORTH

SCALE 1: 125,000

0 2 4

STATUTE MILES

0 2 4

KILOMETERS

R 62 E R 63 E R 64

EXPLANATION

Contact between rock and basin-fill.

5% slope line.

10% slope line.

Valley borders.

Areas excluded on basis of 10% slopes.

Terrain exclusion area.

Areas of isolated exposed rock.

R Areas of isolated exposed rock too small for shad

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

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TERRAIN
CAVE VALLEY, NEVADA

26 OCT 81

DRAWING 3-6

63 E R 64 E 114°45′ R 65 E

EXPLANATION

Contact between rock and basin-fill.

5% slope line.

10% slope line.

Valley borders.

Areas excluded on basis of 10% slopes.

Terrain exclusion area.

Areas of isolated exposed rock.

Areas of isolated exposed rock too small for shading.

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

NORTH

SCALE 1: 125,000

0 2 4

STATUTE MILES

0 2 4

KILOMETERS

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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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CALIFORNIA BEARING RATIO (CBR) - The ratio (in percent) of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed rock base material (ASTM D 1883-73). During the CBR test, the load is applied on the circular penetration piston (3 in^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.

CAMBRIAN PERIOD - The span of time between 570 and 500 million years ago, a subclassification of the Paleozoic era.

CENOZOIC ERA - The span of time between 65 million years ago to the present.

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.

Page A-3 Blank

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.

ERTEC DRIVE SAMPLE - A 2.50-inch-(6.4-cm) diameter soil sample obtained from a drill hole with an Ertec drive sampler. The Ertec 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.

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 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 deposited 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.

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

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

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

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

GRANULAR - See Coarse-Grained.

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

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

GROUND-WATER MONITORING WELL - A hole drilled in the ground and cased with polyvinyl-chloride (PVC) pipe for the purpose of locating the ground water piezometric surface.

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

HOLOCENE EPOCH - A span of time in the Quaternary period from approximately eight to 10 thousand years ago to the present.

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.

MESOZOIC ERA - The span of time between 225 and 65 million years ago.

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).

ORDOVICIAN PERIOD - The span of time between 500 and 400 million years ago; a subclassification of the Paleozoic era.

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.

PALEOZOIC ERA - The span of time between 570 to about 225 million years ago.

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.

PENNSYLVANIAN PERIOD - The span of time between 320 and 280 million years ago; a subclassification of the Paleozoic era.

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.

PERMIAN PERIOD - The span of time between 280 to about 225 million years ago; a subclassification of the Paleozoic era.

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.

PLEISTOCENE EPOCH - The span of time between two to three million years ago to about eight to 10 thousand years ago; a subclassification of the Quaternary period.

PLIOCENE EPOCH - The span of time between five and two to three million years ago; a subclassification of the Tertiary period.

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).

QUATERNARY PERIOD - The span of time between two to three million years ago to present, a subclassification of the Cenozoic era.

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 S-Wave or transverse wave.

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 colluvial and alluvial deposits occurring on or near the earth's surface.

TERTIARY PERIOD - The span of time between 65 and two to three million years ago; a subclassification of the Cenozoic era.

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 D 2850-70). To conduct the test, a cylindrical specimen of soil is surrounded by a fluid in a pressure chamber and subjected to an isotropic pressure. An additional compressive load is then applied 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 of cuttings 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 coarse-grained soil is identified as well-graded if it has a wide range of grain sizes and substantial amounts of most intermediate sizes.

Definitions were derived from the following references:

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

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

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

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

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

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.

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EXCLUSION CRITERIA
VERIFICATION STUDIES, NEVADA–UTAH

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TABLE A2-1

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.

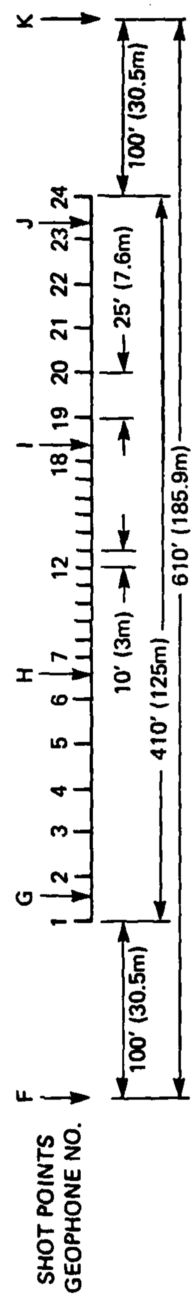
A4.1.2 Field Procedures

Each seismic refraction line consisted of a single spread of 24 geophones with a distance of 410 feet (125 m) between end points (Figure A4-1). 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



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SEISMIC REFRACTION LINE
LAYOUT
VERIFICATION STUDIES, NEVADA–UTAH

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FIGURE A4-1

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 increased by increasing the distance between the current electrodes. The arrangement of electrodes in the Schlumberger method is shown in Figure A4-2. 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.

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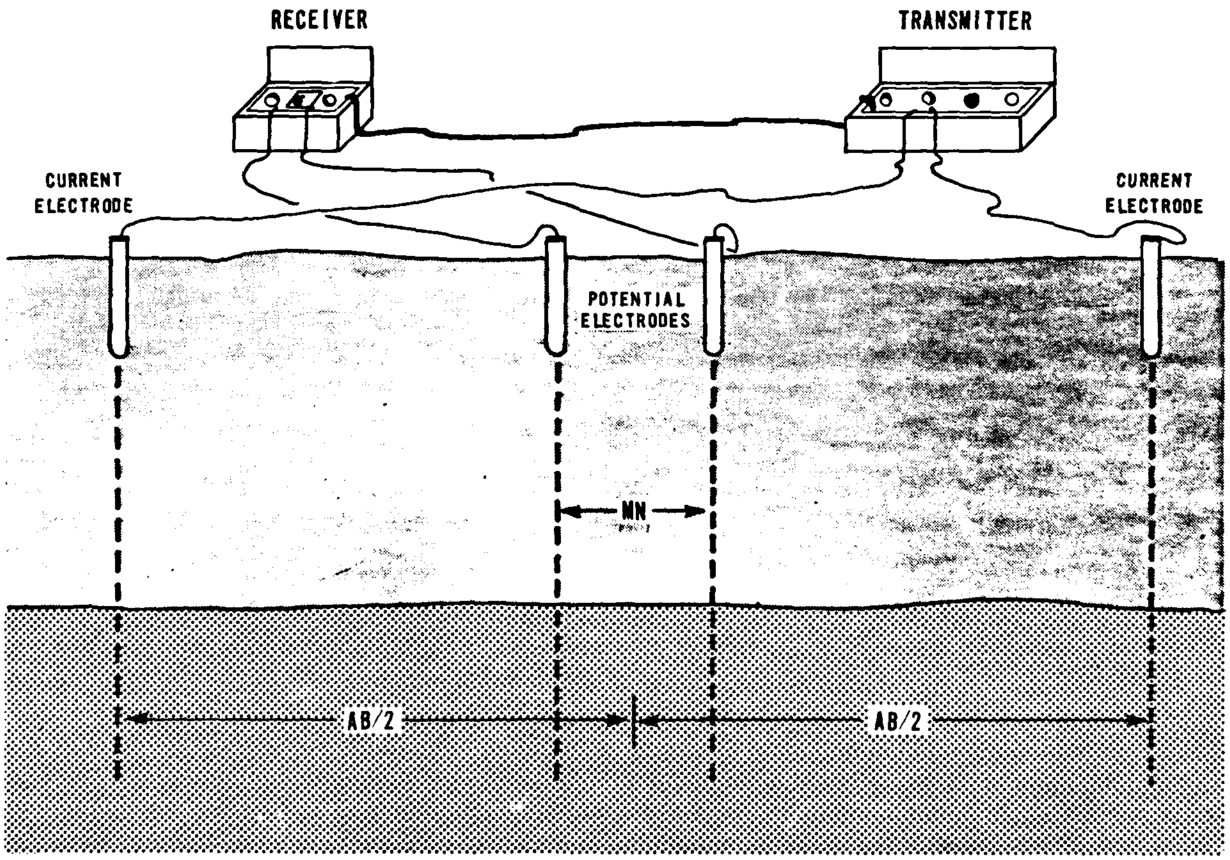

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SCHLUMBERGER ARRAY
ELECTRICAL RESISTIVITY SOUNDING

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FIGURE A4-2

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. An electronic digitizer is used to digitize the field curve for computer program input.

A5.0 ENGINEERING PROCEDURES

Soil engineering activities consisted of the following:

1. Field activities;

- o Borings
- o Trenches
- o Test Pits
- o Surficial Soil Samples
- o Cone Penetrometer Tests
- o Ground Water Monitoring Wells.
- o Field CBR Tests

2. Office activities;

- o Laboratory Tests
- o Data Analyses and Interpretations

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

A5.1 BORINGS

A5.1.1 Drilling Equipment and Methods

A truck-mounted Failing 1500 drill rig with hydraulic pulldown was used to drill borings at designated locations using rotary techniques. To return soil cutting to the surface, a bentonite-water slurry was used. A tricone drill bit was used for drilling in coarse-grained soils and a drag bit in fine-grained soils. The total depth of borings ranged from 100 to 200 feet (30 to 61 m) unless bedrock was encountered at a lesser depth. The borings were nominally 4 7/8 inches (124 mm) in diameter.

A5.1.2 *Methods of Sampling and Testing*

A5.1.2.1 Sampling and Testing Intervals

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

0' tc 10' (0.0 to 3.0 m)	- Pitcher or drive samples at 3 feet (0.9 m) intervals
10' to 30' (3.0 to 9.1 m)	- Pitcher or drive samples at 5 feet (1.5 m) intervals
30' to 120' (9.1 to 36.6 m)	- Pitcher or drive samples at 10 feet (3.0 m) intervals
120' to 200' (36.6 to 61.0 m)	- Pitcher or drive samples at 20 feet (6.1 m) intervals

Adjacent to the completed boring, continuous penetration testing and split-spoon sampling were performed from 0' to 10' (0.0 to 3.0 m).

A5.1.2.2 Sampling Techniques

a. Pitcher Samples: The Pitcher sampler was used to obtain undisturbed soil samples. The primary components of this sampler consist of 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 obtaining Pitcher samples, the sampling tube was inspected for sharpness and protrusions and placed in the core barrel. The Pitcher sampler was then lowered to the bottom of the boring and the thin-walled sampling tube was advanced into the soil by hydraulic pulldown and the weight of the drill rods. 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 and draining of the drilling fluid from the tube, the recovered soil sample was inspected and logged. The tube ends were trimmed and sealed with cap plugs and waxed. When Pitcher samples could not be retrieved without disturbance, they were clearly marked as "disturbed." Each sample was identified with a label indicating job number, boring number, sample number, depth range, Unified Soil Classification Symbol (Table A5-1) and date. The Pitcher samples were placed in foam-lined wooden boxes for transport.

b. Ertec Drive Samples: Ertec drive samplers were used to obtain relatively undisturbed soil samples. The Ertec drive sampler is a ring-lined barrel sampler with an outside diameter of 3.0 inches (76.2 mm) and an inside diameter of 2.50 inches (65.5 mm). It contains 12 individual 1-inch (25.4-mm) long rings and is attached to a 12-inch (30-cm) long waste barrel.

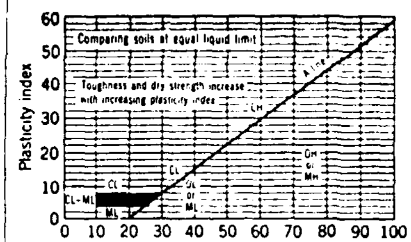
The sampler was lowered to the bottom of the boring and advanced into the soil with a 300 pound (136 kg) downhole hammer dropped 24 inches (61.0 cm). The number of blows required to advance the sampler for each 6-inch (15-cm) interval was recorded. After 12 inches (30 cm) of penetration, the sampler was brought to the surface and the sample, retained in the rings, was extruded from the barrel. Then the sample was placed in a plastic bag and sealed in a plastic sample container. Each sample was labeled as explained under "Pitcher Samples." Drive samples were placed in foam-lined steel boxes for transport.

c. Bulk Samples: Bulk samples were obtained by screening the returning drilling fluid to obtain drill cuttings when Pitcher or drive sampling attempts failed. Recovered samples were placed in plastic bags and labeled as explained previously.

Major divisions			Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)			Group Symbols [a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria
Coarse-grained soils. More than half of material is *larger than No. 200 sieve size*[b] (The No. 200 sieve size is about the smallest particle visible to naked eye)	Gravels. More than half of coarse fraction is larger than No. 4 sieve size (For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size)	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes			GW	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)			GM	Silty gravels, poorly graded gravel-sand-silt mixtures	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics	Atterberg limits below "A" line, or *PI* less than 4 — Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, with *PI* greater than 7
	Sands. More than half of coarse fraction is smaller than No. 4 sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			SW	Well graded sands, gravelly sands, little or no fines	Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles ½-in. *maximum size; rounded* and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing			SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)			SM	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 5 — Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)			SC	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits below "A" line with *PI* greater than 7
Fine-grained soils. More than half of material is *smaller* than No. 200 sieve size	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	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses	
			Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions	
	Silts and clays liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
			High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays	Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)	
			Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity		
Highly Organic Soils			Readily identified by colour, odour, spongy feel and frequently by fibrous texture			Pt	Peat and other highly organic soils		

Use grain size curve in identifying the fractions as given under field identification

Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5% GW, GP, SW, SP; More than 12% GM, GC, SM, SC; 5% to 12% *Borderline* cases requiring use of dual symbols



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 $\frac{1}{64}$ 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.

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UNIFIED SOIL CLASSIFICATION SYSTEM

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TABLE A5-1

d. Rock Cores: Rock cores were obtained with a sampler consisting of an NX double-tube core barrel (core size 2.125 inches [54 mm]) with a diamond cutting bit at its lower end. The bit cut an annular hole in the rock mass creating a cylinder or core of rock which was recovered in the core barrel. When rock was encountered in a boring, approximately 15 feet (4.5 m) of core was obtained before abandoning the hole. The rock cores were removed from the core barrel, examined by a geologist, and placed in core boxes. The core boxes were labeled as explained in "Pitcher Samples."

e. Standard Penetration Tests and Split-Spoon Samples A split-spoon assembly was used to perform penetration tests and obtain representative disturbed soil samples in the top 10.0 feet (3.0 m). The split-spoon assembly consists of a barrel shoe, a split barrel or tube, a solid sleeve, and a sampler head. The sampler shoe is 1.375 inches (35 mm) inside diameter and about 18 inches (45.7 cm) in length. Testing with the split barrel sampler was accomplished by driving the sampler 18 inches (45.7 cm) into the soil with a 140-pound (63.6-kg) hammer dropped 30 inches (76 cm) in accordance with the American Society for Testing and Materials (ASTM) procedure D 1586-67, "Penetration Test and Split-Barrel Sampling of Soils." The number of blows required to drive the assembly the last 12 inches (30.4 cm) was recorded as the Standard Penetration Resistance (N value). The soil samples were recovered, classified, and discarded in the field.

A5.1.3 Ground Water Monitoring Borings

Borings at some locations were used to monitor ground water levels as well as to obtain soil samples. The procedures used to establish a ground water monitoring well are described in Section A5.4.

A5.1.4 Logging

All soils were classified in the field by the procedures outlined in Section A5.6, "Field Visual Soil Classification," of this appendix. All soil descriptions, as well as the following general information, were 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; the method of drilling and sampling; drill bit type and size; and sampler driving weight and average drop as applicable. Rock encountered in the borings was described according to classifications given in Travis (1955) and Folk (1974). Section A5.6 discusses other pertinent data and observations which were entered on the boring logs during drilling.

A5.1.5 Sample Storage and Transportation

Samples were handled with care to avoid disturbance, particularly while traversing rough terrain. Whenever ambient air temperatures fell below 32°F (0°C), samples were stored in heated rooms during the field work and transported to Ertec Western's Long Beach laboratory in heated cabins on pickup trucks.

A5.2 TRENCHES, TEST PITS, AND SURFICIAL SOIL SAMPLES

A5.2.1 Excavation Equipment

The trenches, test pits, and surficial soil samples were excavated with 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, the trench width was nominally 2 feet (0.6 m). Trench depths were typically 10 to 14 feet (3.0 to 4.3 m) with lengths up to 14 feet (4.3 m). Test pits were nominally 2 feet (0.6 m) wide, 5 feet (1.5 m) deep, and ranged from 5 to 10 feet (1.5 to 3.0 m) in length. Surficial soil sample excavations were typically 2 feet (0.6 m) wide, 2 to 3 feet (0.6 to 1.0 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 trench to minimize stress on the walls. The excavations were backfilled with the excavated material and the ground surface was restored to a condition as conformable with the surrounding terrain as practical.

A5.2.3 Sampling

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

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

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

A5.2.4 Logging

The procedures for field visual classification of soil encountered in the trenches, test pits, and surficial samples are outlined in Section A5.6, "Field Visual Soil Classification," of this appendix. For excavations less than 4 feet (1.2 m) in depth, technicians entered the trenches and test pits for logging and sampling. Excavations deeper than 4 feet (1.2 m) were logged from ground level by observing the trench walls and examining the backhoe bucket contents. All trench walls were photographed prior to backfilling. Each field trench, test pit, and surficial sample log included the following: soil descriptions; 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. Section A5.6 discusses other pertinent data which were entered on the logs during excavation.

A5.3 CONE PENETROMETER TESTS

A5.3.1 Test 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 friction sleeve capacity of 4-1/2-ton [4082-kg]). All operating controls, recorder, cables, and ancillary equipment were housed in the specially designed self-contained vehicle. The cone tip had an apex angle of 60° and a base area of 2.3 in^2 (15 cm^2). The friction sleeve, having an area of 31.8 in^2 (205 cm^2), was fitted above the cone base. The resistance to penetration and the local friction was measured by load cells built into the penetrometer and was relayed to the surface recorder via cables in the hollow sounding rods. One end of the penetrometer was threaded to receive the first sounding rod. The hollow sounding 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 the cone into the soil. The hydraulic thrust system was mounted over the center of gravity of the truck permitting use of the full 17.5-ton (15,877-kg) truck weight as load reaction.

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." The tests were conducted by positioning the electronic cone penetrometer truck over the designated test location, stabilizing and leveling the truck by setting and adjusting the outriggers on the ground surface, and 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 hydraulic system) or the desired depth of penetration was reached. As a general rule, the depth of penetration did not exceed 33 feet (10 m). If refusal was reached within the top 2 or 3 feet (0.6 or 0.9 m), the test was repeated again a few feet away from the first location. Details of the test such as penetrometer test number and location, refusal depth and cause, total depth of the test if refusal was not reached, cone serial number, name of logger, date of test, and project name and number were entered on a log sheet.

At least three cone penetrometer tests were performed at each field California Bearing Ratio (CBR) test location.

A5.4 GROUND WATER MONITORING WELLS

A5.4.1 Drilling Equipment and Method

A truck-mounted Failing 1500 rotary drilling rig, or equivalent, was used to drill the monitoring wells at designated locations. A biodegradable polymer drilling fluid was used to return soil cuttings to the surface. A tricone drill bit was used for drilling in coarse-grained soils and a drag bit for fine-grained soils. The wells were nominally 4 7/8 inches (124 mm) in diameter with depths ranging from 100 to 200 feet (30 to 61 m) unless bedrock was encountered at a lesser depth. When rock was encountered approximately 15 feet (4.5 m) of core were obtained before casing the well. The wells were cased with 2-inch diameter (51-mm) polyvinyl chloride (PVC) pipe. Prior to installation, the bottom 20 feet (6 m) of the PVC pipe was slotted. After installation the pipe was flushed until clear water returned to the surface. The annulus between the pipe and the hole was backfilled with pea gravel to approximately 30 feet (9 m) above the bottom of the well.

A5.4.2 Logging

The soil cuttings were classified in the field by the procedures outlined in Section A5.6, "Field Visual Soil Classification," of this appendix. Rock encountered in the wells was described according to classifications given in Travis (1955) and Folk (1974). The following general information was entered on the well logs at the time of drilling: well number and location; project name and number; name of drilling company and driller; name of logger; date logged; method of drilling; and drill bit type and size. Section A5.6 discusses other pertinent data which were entered on the well logs during drilling.

A5.4.3 Monitoring

After the water level reached equilibrium, the water level was measured and recorded at regular time intervals to provide information on the average depth to water and seasonal groundwater level fluctuations.

A5.5 FIELD CALIFORNIA BEARING RATIO (CBR) AND IN-SITU DENSITY TESTS

A5.5.1 Equipment

Field CBR tests were done in selected Verification valleys using equipment as described in the U.S. Army Corps of Engineers' Technical Manual (TM) 5-530. Supplemental equipment for conducting field density and moisture content tests by the sand-cone method (ASTM D 1556-64) "Density of Soil in Place by the Sand-Cone Method" and the "Speedy Moisture Meter" was also used. A backhoe and hand tools were used to excavate the CBR and density test pits.

A5.5.2 Test Method

Field CBR and density tests were generally performed at three depths ranging from 1 to 4 feet (0.3 to 1.2 m) below ground surface at each designated location. The procedures for conducting the CBR tests were as described in the U.S. Army Corps of Engineers' TM 5-530, pp. 2-86 to 2-96. Field density tests were performed in accordance with the ASTM D 1556-64 procedure. Testing was not attempted where numerous cobbles or heavily cemented soils were encountered. Generally, three CBR tests, a field density test, and a moisture content determination were performed at each depth.

A5.5.3 Sampling

At each CBR and density test location, large bulk samples of soils at the test depths were obtained as explained in Section A5.2.3, "Sampling."

A5.5.4 Logging

Field CBR test results, field density test results, and moisture content determinations were recorded at the time of each test. All soil samples were classified and logged in accordance with the procedures outlined in Section A5.6, "Field Visual Soil Classification."

A5.6 FIELD VISUAL SOIL CLASSIFICATION

A5.6.1 General

All field classification 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 (USCS) (Table A5-1) and 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 during the investigations.

A5.6.2 Soil Description

Soil descriptions entered on the logs of borings, trenches, test pits, surficial soil samples, and ground water monitoring wells generally included the information listed below.

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

Some additional information recorded for both coarse- and fine-grained soils included: degree of cementation, secondary soil groups, esimated percentage of cobbles and boulders, and depths of changes in soil type.

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

a. USCS Symbol and Name: Based on the USCS (Table A5-1), the soils were categorized by visual and/or manual methods.

Coarse-grained soils are those in which more than 50 percent (by weight) of the individual particles are distinguishable to the unaided eye. In making this estimate, particles with an average diameter greater than 3 inches (76 mm) were excluded. In some instances coarse-grained soils were identified by sieve analysis with the No. 200 sieve size particles (1.4 mils [0.074 mm]) considered to be the smallest size distinguishable to the unaided eye. By estimating and comparing the percentage of the coarse-grained fraction larger and smaller than the No. 4 sieve size particle (about 1/4 inch or 5 mm), the coarse-grained soils were further differentiated into gravels and sands. Each coarse-grained soil symbol was then qualified as well-graded or poorly graded, or silty or clayey as discussed under gradation and plasticity. Dual USCS symbols were used to describe soils exhibiting characteristics of more than one USCS group.

Fine-grained soils are those in which more than 50 percent (by weight) of the individual particles cannot be distinguished by the unaided eye. Fine-grained soils were qualified in the field as clays or silts based on the results of dry strength, dilatancy, and plastic thread tests (as described in the ASTM D 2488-69 procedures). Dual USCS symbols were used to describe fine-grained soils exhibiting characteristics of more than one USCS group.

The USCS names with appropriate adjectives were used to describe the major soil constituent and the most prominent secondary soil group (greater than 12 percent by weight of the total sample).

b. Color: Soil color was described using the following terms.

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

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 or gravels), the size range of the particles was estimated as fine, medium, coarse, or a combined range.

d. Gradation: Based on the range of particle sizes, soils were described as well-graded or poorly graded. Well-graded indicates a coarse-grained soil which has a wide range in grain size with substantial amounts of most intermediate particles 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 Ertec drive or split-spoon sampler, the drilling rate and/or hydraulic pressure during drilling, ease (or difficulty) of trench and test pit excavation, and/or trench and test pit wall stability. For coarse-grained soils, the guidelines listed below were used to describe the consistency of the soil based on the Standard Penetration Number (N) for split-spoon penetration tests. For fine-grained soils, the field guides to shear strength presented below were used.

- Coarse-grained soils

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

Consistency	Shear Strength (ksf)	Shear Strength (kN/m^2)	Field Guide
Very Soft	<0.3	<12	Sample with height equal to twice the diameter, sags under own weight
Soft	0.3 -0.5	12 -24	Can be squeezed between thumb and forefinger
Firm	0.5 -1	25 -48	Can be molded easily with fingers
Stiff	1 -2	49 -96	Can be imprinted with slight pressure from fingers
Very Stiff	2 -4	97 -192	Can be imprinted with considerable pressure from fingers
Hard	>4	>192	Cannot be imprinted by fingers

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

Dry	:	No feel of moisture, dry like powder
Slightly Moist	:	Much less than optimum moisture
Moist	:	Near optimum moisture for soil provide apparent chesion
Very Moist	:	Much greater than optimum moisture
Wet	:	At or near saturation

g. Particle Shape: For coarse-grained soils, the particle shape was described as defined below.

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. Plasticity: For fine-grained soils the plasticity is defined from the results of manual tests for dry strength, dilatancy reaction, and the toughness of the plastic thread. The test procedures are described in Table A5-1 and the relationship of the test results to plasticity is listed below.

Plasticity Description	Dry Strength	Dilatancy Reaction	Toughness of Plastic Thread
Nonplastic	None-Very Low	Rapid	Weak
Slightly Plastic	Low-Medium	Slow	Weak-Soft
Medium Plastic	Medium-High	Slow-None	Moderately Stiff
Highly Plastic	High-Very High	None	Very Stiff

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

j. 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 (cementation) were indicated where applicable.

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

k. Secondary Soil Group: The secondary soil group was described by amount, as defined below, and by particle shape and size range for coarse-grained soils and plasticity for fine-grained soils.

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

l. Cobbles and Boulders: A cobble is a rock fragment, usually rounded or subrounded, with an average diameter of 3 to 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 larger. The presence of cobbles and/or boulders was identified by noting the sudden change in drilling difficulty 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.

m. Depths of Changes in Soil Type: During drilling of borings, the depths of changes in soil type were determined by observing samples, drilling rates, or 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.

n. Drilling and Excavating Conditions: 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.

A5.7 LABORATORY TESTS

Laboratory tests were performed on selected representative undisturbed and bulk samples. All laboratory tests (except chemical tests) were performed at Ertec Western's Long Beach laboratory. The chemical tests were conducted by Jacobs 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 below.

Type f Test	ASTM Designation
Unit Weight	D 2937-71
Moisture Content	D 2216-71
Grain-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

A5.8 DATA ANALYSIS AND INTERPRETATION

A5.8.1 Preparation of Final Logs and Field Test and Laboratory Summary Sheets

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

The Cone Penetrometer Test (CPT) results consist of continuous plots of cone resistance, friction sleeve resistance, and friction ratio versus depth from ground surface. A soil column with USCS soil types encountered in excavations at the test location is shown beside the plots. Other information presented in the figures includes surface elevation and surficial geologic unit.

Field CBR or in-situ density test summary sheets include the following information for each test site: depths of tests; USCS soil types; grain-size distributions, plasticities, and moisture content (from laboratory testing); in-situ dry unit weights; average field CBR values (for field CBR summary sheets); estimated percent of maximum dry density, and remarks concerning cementation and induration.

Laboratory test data were summarized in tables. Results of sieve analyses, hydrometer tests, liquid limit and plasticity index tests, in-situ dry unit weight, moisture content tests, and specific gravity tests and calculated degrees of saturation and void ratios were entered in the tables. Test summary sheets for triaxial compression, unconfined compression, direct shear, consolidation, chemical, laboratory CBR, and compaction tests were prepared separately.

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

Boring Logs
Trench and Test Pit Logs
Surficial Sample Logs

Cone Penetrometer Test Results
Field CBR or Density Results
Laboratory Test Results

A5.8.2 Soil Characteristics

A5.8.2.1 General

The soil characteristics are discussed in two parts, surficial soils and subsurface soils. Three tables, titled as follows, were prepared and are presented in Volume I, 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, A5.8.2.2 and A5.8.2.3, explain the data analyses and interpretation used in preparing these tables.

A5.8.2.2 Surface Soils

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

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, 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, information from published literature, and professional experience. The data was summarized in 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 to be important because roads (interconnecting and secondary) constitute a major portion of the geotechically related costs. The following paragraphs briefly discuss the development of road design data.

a. Laboratory Test Results: These results include ranges of maximum dry density (ASTM D 1557-70), optimum moisture content (ASTM D 1557-70), and California Bearing Ratio (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 (CBR) is the ratio of the resistance to penetration developed by a soil to that developed by a specimen of standard crushed-rock road-base course material and is the basis for many empirical road design methods used in this country.

b. Suitability of Soils for Road Use: The suitability of soils for use as road subgrade, subbase, or base materials was qualitatively assessed by characteristics relating 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 generally should be removed and replaced with better quality material.

[illegible] as road subbase or base.

[illegible] which exhibit negligible frost suscepti- [illegible], [illegible] drainage, and negligible volume [illegible].

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

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

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

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

i. <u>CBR Characteristics</u>: CBR, which is commonly used for road design, is dependent on soil type. During Verification studies, CBR tests were performed on several soil types which were representative of the surficial soils in the various Verification valleys. Based on these test results, a relationship between CBR and percent fines (percent passing through the No. 200 sieve) was established and is shown in Figure A5-1. Envelopes for gravelly soils, sandy soils, and fine-grained soils are shown in this figure. This plot was used to estimate the range of laboratory CBR values for the various surficial soil categories.

ii. <u>Frost Susceptibility, Drainage, and Volume Change Potential</u>: These characteristics were estimated based on the physical properties of the soils, results of consolidation tests (for volume change potential), published literature, and professional experience. The definitions of these characteristics are summarized below.

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

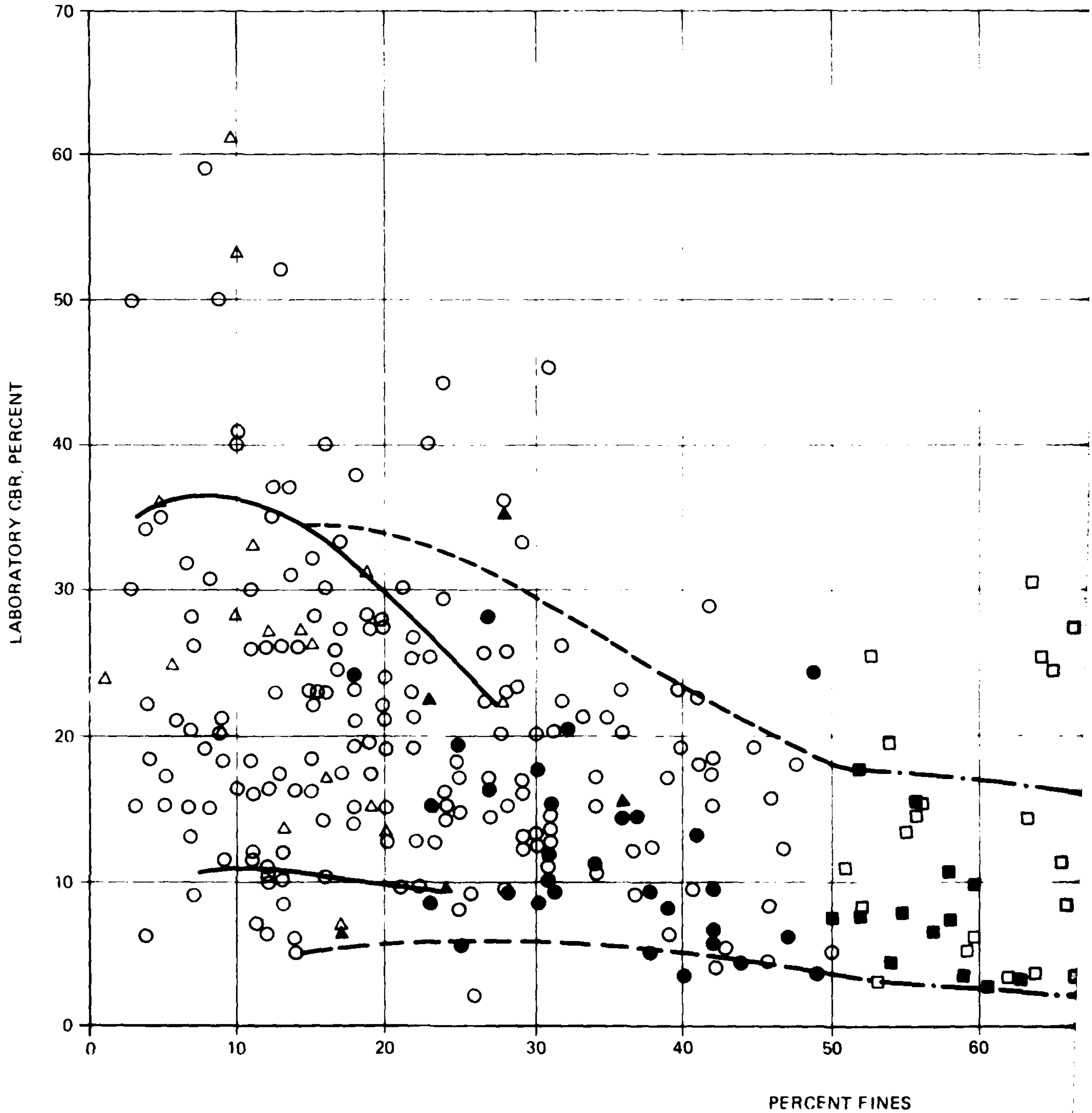
Low - negligible to little potential
Moderate - some potential
High - considerable potential

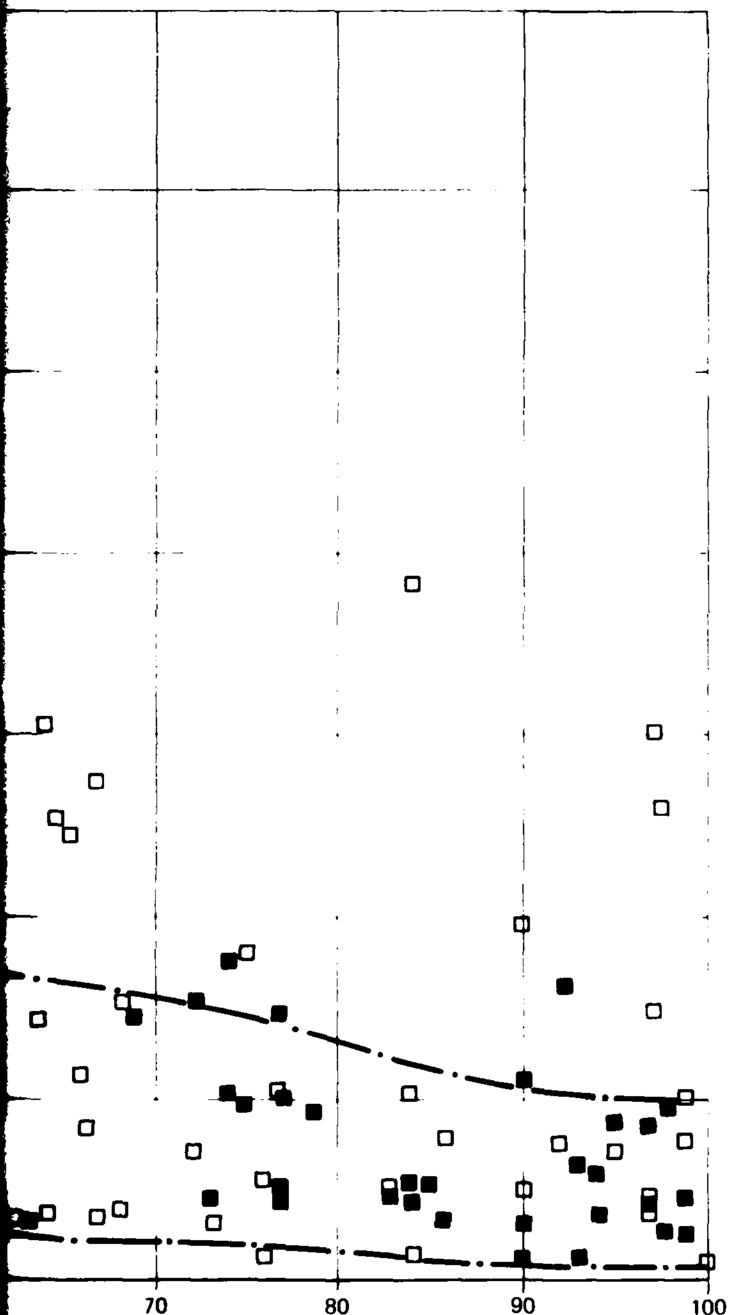
2. Drainage characteristics pertain to internal movement of water through soil.

Good - materials which drain rapidly and do not tend to become plugged with fines

Fair - natural internal drainage is fairly rapid but there is some tendency for voids to be plugged with fines

Poor - internal drainage is somewhat slow and plugging with fines can occur often


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



EXPLANATION

- △ Gravels with nonplastic fines (GM, GW, GP, GP-GM, GW-GM)
- ▲ Gravels with plastic fines (GC, GC-GM)
- ○ Sands with nonplastic fines (SP, SW, SM, SP-SM, SW-SM)
- ● Sands with plastic fines (SC, SC-SM)
- □ Silts (ML, MH)
- ■ Clays (CL, CH, CL-ML)
- ——— Envelope for gravels, gravelly sands and sands
- — — Envelope for silty sands and clayey sands
- —·— Envelope for fine grained soils

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

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

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FIGURE A5-1

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: The roads for the MX system will be built on the existing ground surface with minimum cut and fill. Therefore, the cost of roads depends 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 professional experience as well as published literature.

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

ii. Standard Penetration Test (SPT): The Standard Penetration Test (SPT) is a very widely used and accepted in geotechnical engineering practice in this country for estimating relative density and strength of soils. A literature study revealed that the ratio of cone resistance (q_c, tsf) from cone penetrometer tests to standard penetration resistance (N, blows per foot) from SPTs has a certain range for different soil types. To establish the upper limit of cone resistance for defining the "low-strength" surficial soil layer for coarse and fine-grained soils, SPTs and cone penetrometer tests were performed at the same locations in Railroad, Pine, Wah Wah, Spring, Lake, Steptoe, Fish Springs Flat, Hamlin, Sevier Desert, Snake, and White River valleys during Verification studies. The SPT (N) value and CPT (q_c) data at corresponding locations and depths were compared for coarse and fine-grained soils. The ratios of q_c/N computed for coarse and fine-grained soils were found to be comparable to those reported for similar soil types in the literature. Using these ratios for the soils prevailing in the Verification valleys, "low-strength" surficial soils were defined in terms of upper limits of cone resistances equivalent to the SPT N values. The limit was defined as medium dense for coarse-grained soils and stiff to very stiff for fine-grained soils.

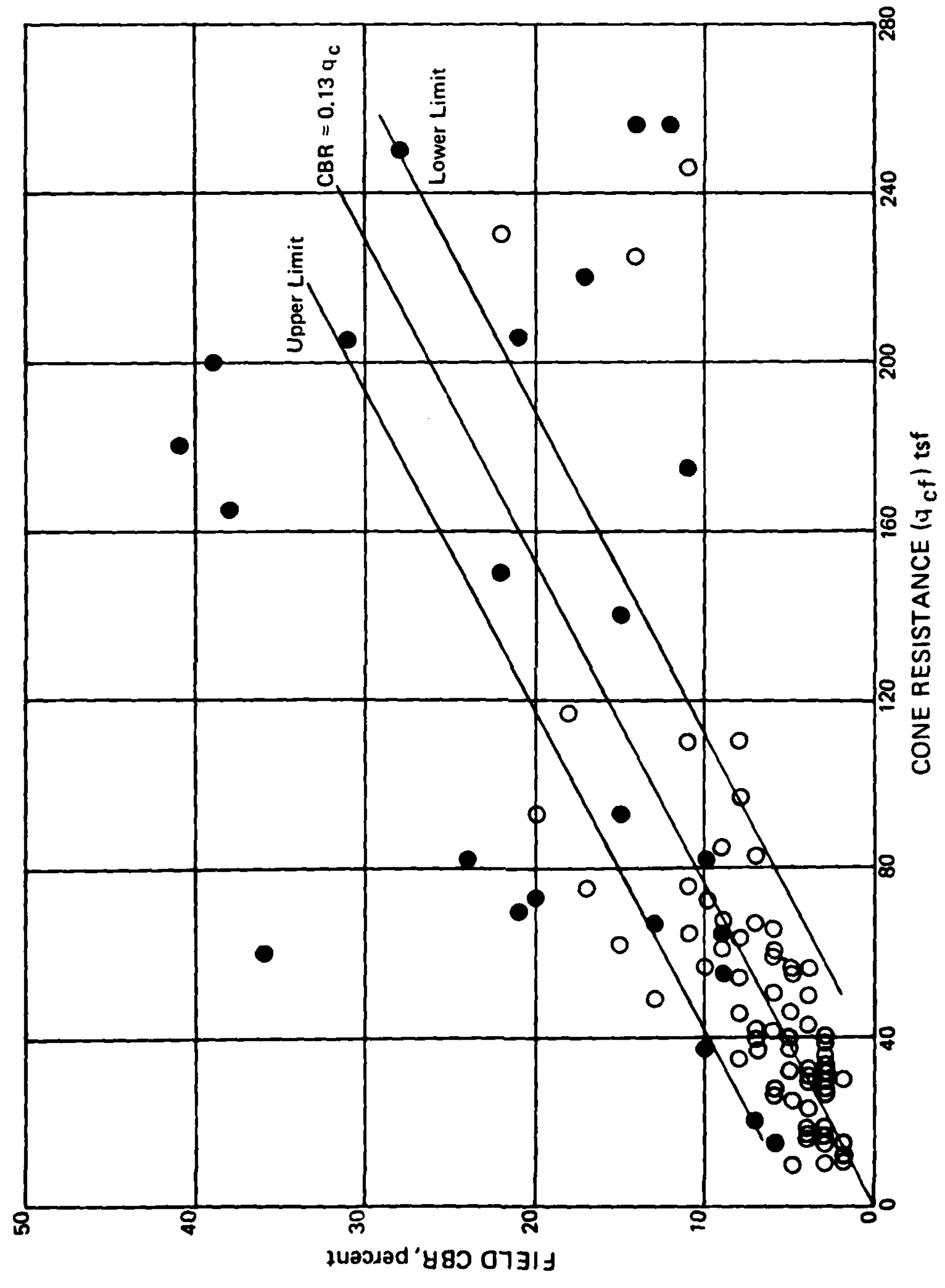
iii. <u>In-Situ Dry Density</u>: A comparison was made to identify trends existing between in-situ dry densities from 0 to 5 feet (0 to 1.5 m) and CPT results at the same locations and depths. The in-situ dry densities from field density tests (sand-cone method) and Ertec drive and pitcher samples obtained from borings were compared to the corresponding CPT cone resistance. A range of cone resistance equivalent to a relative compaction greater than 80 percent was established to define the "low-strength" surficial soils.

iv. <u>Field CBR Tests</u>: During Verification studies, CBR tests were performed in Reveille, Railroad, Pine, Wah Wah, Lake, Spring, Steptoe, Stone Cabin, Hot Creek, and Big Smoky valleys. The test results were compared to cone penetrometer tests performed at the same location. Plots of average field CBR versus average cone resistance were prepared for coarse-grained and fine-grained soils and are presented in Figures A5-2 and A5-3 respectively. Due to minimal testing in gravelly soils, Figure A5-2 shows the results of the tests in sands only. The test results show considerable scatter, but the majority of the data points fall within the bands shown in Figures A5-2 and A5-3. From these plots, 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 in terms of cone resistance (q_c) were established:

q_c <120 tsf (117 kg/cm^2) for coarse-grained soils; and
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. Using this criteria the extent of low-strength surficial soil at each CPT location was determined and the results were tabulated



NOTES:
1. Data are for coarse-grained soils tested in Reveille, Railroad, Pine, Wah Wah, Lake, Spring, Stone Cabin, Hot Creek, and Big Smoky valleys.
2. Band between the upper and lower limits includes about 75% of all the data points.
3. Depth of CBR tests is from 1 to 4 feet.

EXPLANATION
- ○ Tests in soils without cementation
- ● Tests in soils with cementation

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RELATIONSHIP BETWEEN FIELD CBR AND CPT CONE RESISTANCE FOR COARSE GRAINED SOILS VERIFICATION VALLEYS, NEVADA–UTAH

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FIGURE A5-2

in Volume I, Table 3-2, "Thickness of Low-Strength Surficial Soil."

A5.8.2.3 Subsurface Soils

Data from borings, trenches, test pits, seismic refraction surveys, and laboratory tests were summarized to present the characteristics of subsurface soils.

The soils were divided into coarse-grained and fine-grained soil categories in two ranges of depth, 2 to 20 feet and 20 to 160 feet (0.6 to 6 m and 6 to 49 m). Physical and engineering properties of the soils were then tabulated as "Characteristics of Subsurface Soils" (Volume I, Table 3-4). The table includes soil descriptions, USCS symbols, the estimated subsurface extent of each soil group, comments on the degree of cementation, estimated percent of cobbles, and ranges of values from the following laboratory test results and field tests: grain-size distribution, liquid limit, plasticity index, compressional wave velocity, dry density, moisture content, 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.

DATE

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