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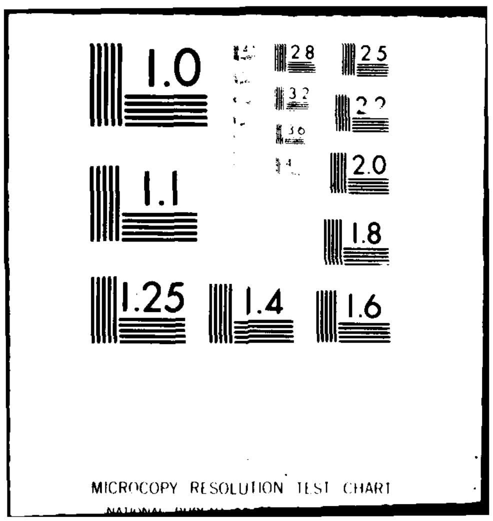
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MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

AGGREGATE RESOURCES STUDY
WHIRLWIND VALLEY
UTAH

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

FUGRO NATIONAL, INC.
Consulting Engineers and Geologists

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This report contains the Valley-Specific Aggregate Resources Study evaluation for Whirlwind Valley and surrounding areas in Utah. It is the fifth in a series of reports that contains valley-specific aggregate information on the location and suitability of basin-fill and rock sources for concrete and road-base construction materials. The findings presented are based on field reconnaissance and limited laboratory testing, existing data from the Utah State Department of Highways, a previous regional aggregate investigation, and Verification Studies.

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AGGREGATE RESOURCES STUDY

WHIRLWIND VALLEY

UTAH

Prepared for:

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

Prepared by:

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3777 Long Beach Boulevard
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6 June 1980

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FOREWORD

This report was prepared for the Department of the Air Force Ballistic Missile Office (BMO) in compliance with Contract No. F04704-80-C-0006, CDRL Item No. 004A2. It presents the results of Valley-Specific Aggregate Resources studies within and adjacent to selected areas in Utah that are under consideration for siting the MX system.

This volume contains the results of the aggregate resources study in Whirlwind Valley. It is the fifth of several Valley-Specific Aggregate Resources investigations which will be prepared as separate volumes. Results of this report are presented as text, appendices, and two drawings.

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EXECUTIVE SUMMARY

This report contains the Valley-Specific Aggregate Resources Study (VSARS) evaluation for Whirlwind Valley and surrounding areas in Utah. It is the fifth in a series of reports that contains valley-specific aggregate information on the location and suitability of basin-fill and rock sources for concrete and road-base construction materials. The findings presented are based on field reconnaissance and limited laboratory testing, existing data from the Utah State Department of Highways, a previous regional aggregate investigation, and Verification studies.

A classification system based on aggregate type and potential use was developed to rank the suitability of all basin-fill and rock aggregate sources. Four aggregate types have been designated; coarse, fine, and coarse and fine (multiple) aggregates derived from basin-fill sources and crushed rock aggregates derived from rock sources. Each aggregate type was then classified using the following definitions:

- Class I — Potentially suitable concrete aggregate and road-base material source.
- Class II — Possibly unsuitable concrete aggregate/potentially suitable road-base material source.
- Class III — Unsuitable concrete aggregate or road-base material source.

Decisions on assigning a particular aggregate source to one of the three classes were determined from existing and Fugro National laboratory aggregate tests performed as part of this

study (abrasion resistance, soundness, and alkali reactivity), and to a lesser degree from field visual observations.

Emphasis in this study was placed on the identification and delineation of Class I basin-fill, coarse aggregate. These deposits are considered to be the primary sources of concrete and road-base construction materials. Results of the study are presented on a 1:125,000 scale aggregate resources map (Drawing 2) and are summarized as follows:

1. Coarse Aggregate - Major Class I coarse aggregate basin-fill sources are located in older lacustrine deposits (Aolg), east of the Swasey Mountains and the House Range. Additional Class I coarse aggregate sources whose boundaries could not be delineated are also located in alluvial fan (Aafs) and stream channel (Aals) deposits in the northwestern part of the study area.

   Potentially suitable Class II coarse aggregate sources are widespread and extensive in the study area. Although boundaries of specific deposits could not be delineated, they are typically located within alluvial fans flanking Class I and/or Class II rock sources and older lacustrine deposits.

2. Fine Aggregate - Most coarse aggregate basin-fill sources are also potential multiple sources (coarse and fine) that will supply varying quantities of fine aggregate either from the natural deposit or during processing. Specific Class I

fine aggregate sources were identified and delimited in older lacustrine deposits (Aols) located east of the Swasey Mountains.

3. Crushed Rock - Prominant Class I crushed rock aggregate sources and their locations within the study area are:

   a. Marjum Limestone (Ls) primarily exposed in the northern House Range and southern Swasey Mountains.

   b. Dome Limestone (Ls) exposed principally within the Crickett Mountains.

   c. Basalt and andesitic flows (Vb) within and east of the Little Drum Mountains in the north and south of Delta along the eastern boundary.

The useability of any of these rock units as crushed rock aggregate sources will depend on their location and accessibility within the study area and their minability.

Additional aggregate testing and field investigations will be required to further refine the lateral and vertical extents of classification boundaries and to define exact physical and chemical characteristics of a particular basin-fill or rock source within the valley area.

1.0 INTRODUCTION

1.1 STUDY AREA

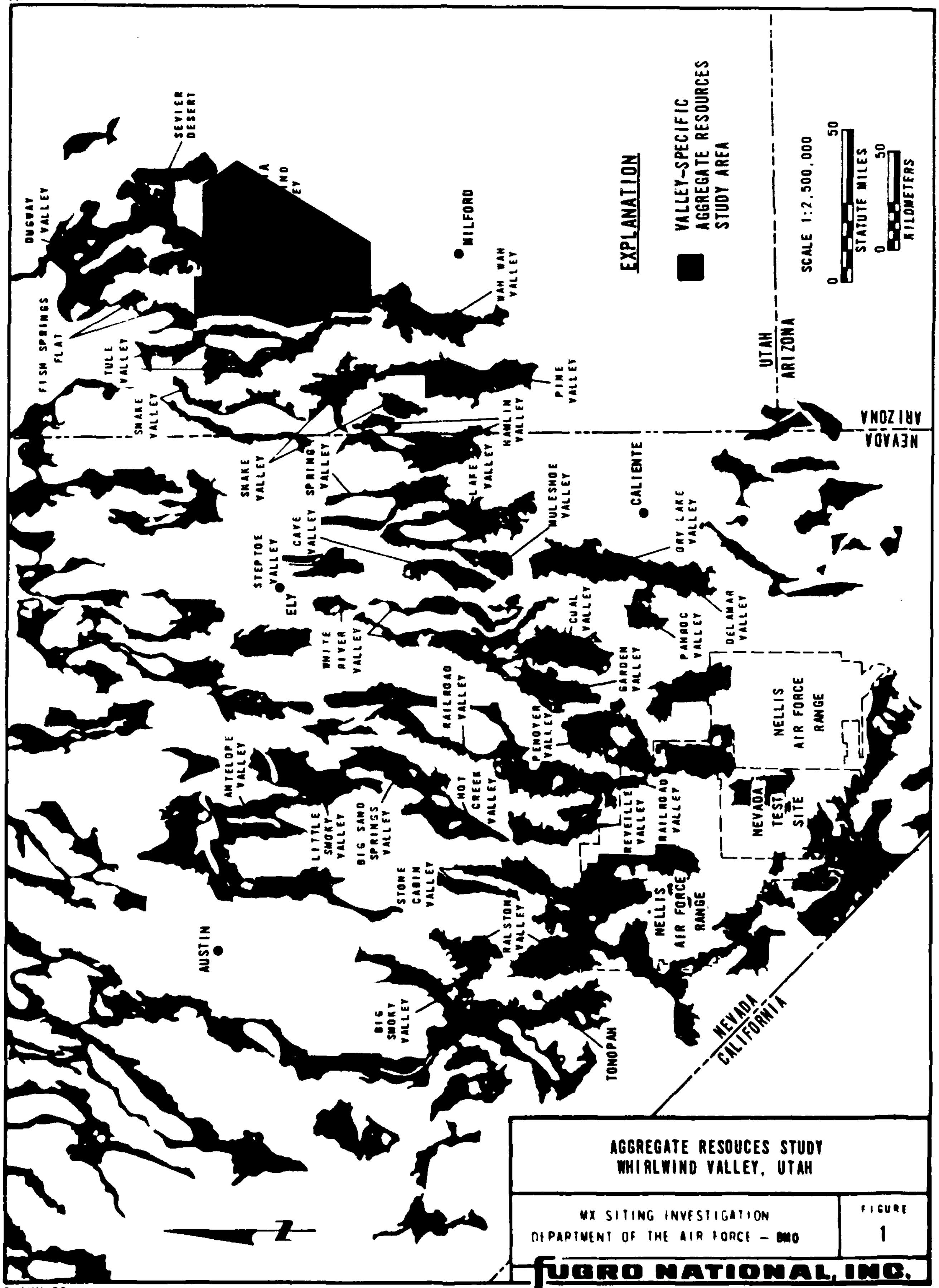
This report presents the results of the Valley-Specific Aggregate Resources Study completed for Whirlwind Valley (Figure 1). Located in western Millard and Juab counties, Utah, the area contains north-south trending alluvial basins separated by carbonate and volcanic rock mountain ranges. The House Range and the Swasey Mountains border the site on the west and Sevier Desert marks the eastern boundary.

U.S. Highway 5 and 60 provides access to the central study region and State Highway 257, provides access to areas along the eastern border. A network of unpaved roads and 4-wheel-drive trails crisscross the study area (Drawing 1).

The valley area is mainly comprised of undeveloped desert rangeland administered by the Bureau of Land Management (BLM). The town of Delta, Utah, lies just within the northeastern border of the Valley-Specific study area and is serviced by the mainline of the Union Pacific Railroad from Salt Lake City, Utah, to Las Vegas, Nevada.

1.2 BACKGROUND

The MX aggregate program began in 1977 with the investigation of Department of Defense (DOD) and Bureau of Land Management (BLM) lands in California, Nevada, Arizona, New Mexico, and Texas (FN-TR-20D). Refinement of the MX siting area added portions of Utah and Nevada that were not studied in the initial Aggregate



AGGREGATE RESOUCES STUDY
WHIRLWIND VALLEY, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	FIGURE 1

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Resources Evaluation Investigation (AREI). This additional area (Figure 2), defined as the Utah Aggregate Resources Study area (UARSA), was evaluated in the Fall of 1979 and a second general aggregate resources report (FN-TR-34) was submitted on 3 March 1980. Both general aggregate investigations were designed to provide regional information of the general location, quality, and quantity of aggregates that could be used in the construction of the MX system.

Subsequent to the general studies, Valley-Specific Aggregate Resources Studies (VSARS) were developed in FY 79 to provide more detailed information on potential aggregate sources in specified valley areas.

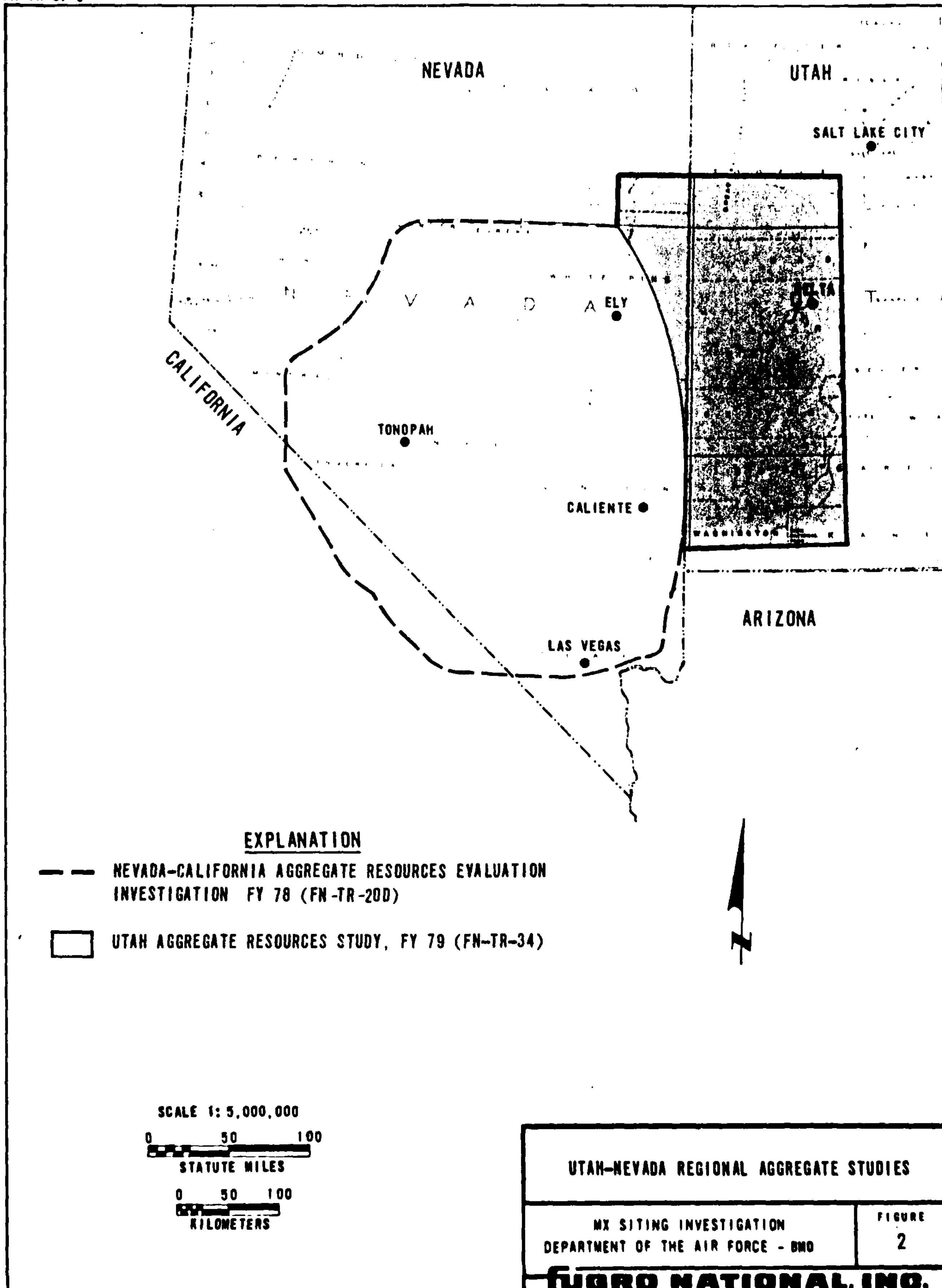
1.3 OBJECTIVES

The primary objective of the VSARS program is to classify on a valley basis, basin-fill and rock deposits for suitability as concrete and road base construction materials. The VSARS format is designed to select and present the locations of the most acceptable aggregate sources for preliminary construction planning and follow-on, detailed aggregate investigations.

1.4 SCOPE

The scope of this investigation required office and field investigations and included the following:

(1) Collection and analysis of available existing data on the quality and quantity of potential concrete aggregate and road base material sources. American Society of Testing and Materials (ASTM) standards and Standard Specifications for Public Works Construction (SSPWC) were used to evaluate quality.



UTAH-NEVADA REGIONAL AGGREGATE STUDIES

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FIGURE 2

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(2) Aerial and ground reconnaissance of all identified potential aggregate sources in the valley area, with more detailed investigation and sample collection of likely basin-fill (coarse and fine aggregates) and rock (crushed rock aggregates) construction material sources.

(3) Laboratory testing to supplement available existing data and to provide detailed information to assist in determining the suitability of specific basin-fill or rock deposits as construction material sources within the valley area.

(4) Development and application of an aggregate classification system (Section 2.5) that emphasizes aggregate type (coarse, fine, or crushed rock) and potential construction use (concrete and/or road base).

2.0 STUDY APPROACH

2.1 EXISTING DATA

Collection of existing test data from available sources was an important factor in the VSARS program. The principal source of existing data directly pertaining to aggregate construction materials was the Utah State Department of Highways (Appendix A). The majority of this information is related to the use of aggregate material for asphaltic concrete, base course in road construction, or ballast material. However, many of the suitability tests for these types of construction materials are similar to those for concrete and were applicable to this investigation (Appendix A).

2.2 SUPPLEMENTAL FUGRO NATIONAL DATA

Supplemental Fugro National data were obtained from: (1) field data and supplementary test data compiled during the general aggregate resources study (FN-TR-34), (2) Whirlwind Valley Verification study (FN-TR-27-IA), and (3) the current Valley-Specific Aggregate Resources Study (Appendix A).

The primary objective of the initial, general aggregate study was a regional evaluation and ranking of all potential aggregate sources. One data point from the general aggregate study was located within the VSARS study area (Drawing 1) and consequently supplied specific aggregate information. This stop included a 150-pound rock sample collected for limited laboratory testing (Appendix A).

Verification geologic maps were an initial source of information on the type and extent of basin-fill units within specific valley areas. In addition, Verification study data included information from two trench locations of at least 5 feet depth (Drawing 1). While the Verification studies are not specifically designed to generate aggregate data, the sampling techniques and testing procedures (Appendix A) are applicable to the aggregate evaluation.

The VSARS program required aerial and ground reconnaissance of the study area to collect additional information to verify conditions determined during the data review. Included in the 27 field station data stops was the collection of 20 samples for laboratory testing. Potential coarse and fine aggregate basin-fill samples were collected by channel sampling stream cuts or man-made exposures. Potential crushed rock aggregate samples were obtained from exposures of fresh or slightly weathered material whenever possible. The weight of the samples collected ranged between 100 and 150 pounds. Hand samples, which generally did not exceed 5 pounds in weight, were collected for office analyses.

Identification of basin-fill materials in all field studies followed ASTM D2488-69 Description of Soils (Visual-Manual Procedure), and the Unified Soil Classification System (Appendix C). Rock identifications followed procedures described in the

Quarterly of the Colorado School of Mines (1955) and Standard Investigative Nomenclature of Constituents of Natural Mineral Aggregates (ASTM C294-69).

2.3 DATA ANALYSIS

Geologic and engineering criteria were used in the evaluation of potential aggregate sources within the study area. This was supplemented by laboratory analysis of selected samples during the Valley-Specific aggregate testing program (Table 1). Coarse aggregate is defined as plus 0.185 inch (4.699 mm) fine gravel to boulders basin-fill material. Fine aggregate is defined as minus 0.375 inch (9.52 mm) coarse to fine sand basin-fill material. While all laboratory tests supplied definitive information, the soundness, abrasion, and alkali reactivity results were considered the most critical in determining the use and acceptability of a potential aggregate source.

2.4 PRESENTATION OF RESULTS

Results of the study are presented in text, tables, two 1:125,000 scale maps, and appendices. Drawing 1 presents the location of the 56 existing test data and supplemental Fugro data sites within the study area. Drawing 2 presents the location of all Fugro National laboratory sample sites and all potential basin-fill and rock aggregate sources within the valley area. In addition, these potential aggregate sources are classified according to proposed aggregate use and type (Section 2.5).

ASTM TEST	SAMPLE TYPE AND NUMBER OF TESTS		
	COARSE	FINE	ROCK
ASTM C-88; SOUNDNESS BY USE OF MAGNESIUM SULFATE	11	9	4
ASTM C-131; RESISTANCE TO ABRASION BY USE OF THE LOS ANGELES MACHINE	11		4
ASTM C-136; SIEVE ANALYSIS	15	15	
ASTM C-289; POTENTIAL REACTIVITY OF AGGREGATES (CHEMICAL METHOD)	0	3	0
ASTM C-127 AND C-128; SPECIFIC GRAVITY AND ABSORPTION	7	5	2

AGGREGATE TESTS
WHIRLWIND VALLEY
AGGREGATE RESOURCES STUDY, NEVADA

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TABLE 1

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Geologic unit symbols utilized in Drawing 2 relate to standard geological nomenclature whenever possible. Undifferentiated basin-fill and rock units were established primarily to accomodate accuracy of data and map scale and may contain deposits which could supply significant quantities of high quality materials. A conversion table to relate these geologic symbols to the geologic unit nomenclature used in the Fugro National Verification studies is contained in Appendix E.

All contacts which represent distinct boundaries between geologic units are shown as solid lines in Drawing 2. The contacts are dashed where the depicted data were extrapolated beyond the limits of the source data or where accuracy of the data may be questionable. Local small deposits of one geologic unit may be found in close association with a larger deposit of a different geologic unit. Due to the reconnaissance level of the field investigation or scale limitations, these smaller deposits could not be depicted on the aggregate resources map and have been combined with the more prevalent material. Similarly, potential aggregate source classifications are preliminary and may contain lesser amounts of material of another use or type. Therefore, all classification lines delimit the best aggregate evaluations possible at this level of investigation. In cases of highly variable rock or basin-fill units and limited aggregate tests, boundaries could not be drawn and information is presented as point data on Drawing 2.

Appendices contain tables summarizing the basic data collected during Fugro National's supplemental field investigations, the results of Fugro National's supplemental testing programs, and existing test data gathered from various outside sources (Appendix A), an explanation of caliche development (Appendix B), the Unified Soil Classification System (Appendix C), photographs of typical aggregate sources within the study area (Appendix D), and a geologic unit cross reference table (Appendix E).

2.5 PRELIMINARY CLASSIFICATION OF POTENTIAL AGGREGATE SOURCES

A system was developed to preliminarily classify all potential aggregate sources in the study area. This classification is designed to present the best potential sources of coarse, fine, coarse and fine (multiple source), and crushed rock aggregate types within a Valley-Specific area (Drawing 2) based on potential aggregate use (Table 2). Concrete aggregate parameters are the principal consideration in this report as materials suitable for use as concrete aggregate are generally acceptable for use as road-base material. Therefore, the three classifications described below were based primarily on results of the abrasion, soundness, and alkali reactivity tests.

Class I — Potentially suitable concrete aggregate and road base material source. Coarse and crushed rock aggregates which either passed abrasion, soundness, and alkali reactivity tests or passed abrasion and soundness tests and were not tested for alkali reactivity; fine aggregates which either passed soundness and alkali reactivity tests or passed soundness tests and were not tested for alkali reactivity.

Class II — Possibly unsuitable concrete aggregate/potentially suitable road-base material source. Coarse, fine,

AGGREGATE CHARACTERISTIC[1]			AGGREGATE USE CLASSIFICATION: CLASS I	CLASS II	CLASS III
ABRASION RESISTANCE, PERCENT WEAR[2]			< 50	< 50	> 50
SOUNDNESS, PERCENT LOSS[3]	COARSE AGGREGATE	Na SO_4	< 12	> 12	> 12
		Mg SO_4	< 18	> 18	> 18
	FINE AGGREGATE	Na SO_4	< 10	> 10	> 10
		Mg SO_4	< 15	> 15	> 15
POTENTIAL ALKALI REACTIVITY[4]			INNOCUOUS TO POTENTIALLY DELETERIOUS	DELETERIOUS	DELETERIOUS

1. AGGREGATE CHARACTERISTIC BASED ON STANDARD TEST RESULTS
2. ASTM C131 (500 REVOLUTIONS)
3. ASTM C88 (5 CYCLES)
4. ASTM C289

PRELIMINARY AGGREGATE CLASSIFICATION SYSTEM
VALLEY-SPECIFIC AGGREGATE RESOURCES STUDY

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DEPARTMENT OF THE AIR FORCE - BMO

TABLE 2

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and crushed rock aggregates which either failed the soundness and/or alkali reactivity tests or were classified only by field visual observations or other test data.

Class III <u>Unsuitable concrete aggregate or road base material source</u>. Coarse and crushed rock aggregates which failed abrasion test and were excluded from further testing. Fine, and rarely, coarse aggregates composed of significant amounts of clay- and silt-sized particles.

Sources not specifically identified as Class I, II, or III from the three critical test results or clay- and silt-sized particle content, are designated as Class II sources. All classifications are preliminary with additional field reconnaissance, testing, and case history studies needed to confirm adequacy, delimit areal boundaries, and define exact physical and chemical characteristics.

The following publications/sources were used in defining the three use classifications:

(1) ASTM C33-74A Standard Specifications for Concrete Aggregate,

(2) SSPWC Part II Construction Sections 200-1.1, 1.4, 1.5, and 1.7,

(3) Literature applicable to concrete aggregates,

(4) Industrial producers of concrete aggregates, and

(5) Consultants in the field of concrete aggregates.

3.0 GEOLOGIC SETTING

3.1 PHYSIOGRAPHY

The study area lies entirely within the Basin and Range physiographic province and is divisible into two distinct sections. Primary physiographic features of the western section are controlled by block faulting which has produced the uplifted north-south trending mountains and intervening down-dropped alluvial filled basins. The eastern section of the study area is dominated by the broad, low-lying Sevier Desert and its associated deposits of Pleistocene Lake Bonneville.

Elevations within the valley range from about 5600 feet (1707 m) near the northern end of Whirlwind Valley to approximately 4520 feet (1378 m) on the floor of Sevier Lake in the extreme southern section of the study area.

The Swasey Mountains and the House Range form the western border of the study area and the Cricket Mountains form the southeastern border. The eastern and northeastern portion of the area is dominated by the Sevier Desert while the north cental section is bounded by the Little Drum Mountains (Drawing 2). Topographic relief between mountain ridges and basins is generally greatest along the west-central valley margin where it averages approximately 2000 feet (610 m). The study area is characterized by closed drainage with Sevier Lake dominating the southern terminus of the system.

3.2 LOCATION AND DESCRIPTION OF GEOLOGIC UNITS

Rocks representing the Paleozoic and Cenozoic eras occur within and adjacent to the Valley-Specific area (Drawing 2). These rocks are of various igneous (intrusive and extrusive) metamorphic and sedimentary lithologies.

Paleozoic sedimentary rocks consist predominantly of thin to very thick bedded quartzites, limestones, and dolomites with interbedded sandstone, shale, and siltstone. They occur extensively in the western half of the study area within the Swasey, Little Drum, and Crickett mountains and the House Range.

Cenozoic rocks unconformably overlie Paleozoic units. These rocks consist of Tertiary and Quaternary volcanic rocks comprising welded and nonwelded tuffs and lava flows of basaltic to rhyolitic composition. Extrusion of these rocks is speculated to have occurred during Oligocene to Pleistocene time.

Unconformably overlying the Tertiary rocks are Quaternary volcanic rocks and unconsolidated basin-fill deposits consisting of alluvial fan, older lacustrine, and stream channel and terrace material. These deposits reach a combined thickness of many hundreds to thousands of feet in the valley axis.

Geologic deposits have been grouped into seven rock and four basin-fill geologic units for use in discussing potential aggregate sources. The grouping of these units was based on similarities in physical and chemical characteristics and map scale limitations. The resulting units simplify discussion and presentation without altering the conclusions of the study.

3.2.1 Rock Units

Geologic rock units were grouped into seven categories (Drawing 2): quartzite (Qtz), limestone (Ls), carbonate rocks undifferentiated (Cau), sedimentary rocks undifferentiated (Su), granite (Gr), basalt (Vb), and volcanic rocks undifferentiated (Vu). Class II granitic rocks are of limited areal extent exposed only in the interior portion of the central House Range and because of poor access are considered an unlikely source and will not be discussed.

3.2.1.1 Quartzite - Qtz

The Prospect Mountain Quartzite, of Cambrian age, crops out extensively in the Cricket Mountains (Drawing 2). This formation consists of reddish brown to white, thin to thick bedded, well indurated, fine-grained quartzite containing up to 10 percent feldspar grains. It contains interbeds of less resistant quartzite, micaceous shale, pebble conglomerate, and arkosic sandstone layers. Diabase dikes and sills of basaltic appearance locally intrude this formation.

3.2.1.2 Limestone - Ls

Limestone is a carbonate rock which is hard, durable, thin to thick bedded and a major cliff former within the study area. Principal limestone formations include the Cambrian Marjum, Dome, Notch Peak, and Weeks limestones, and the Ordovician lower Pogonip Group. These limestones are typically medium to dark gray, fine to medium grained, fossiliferous, and sparsely cherty with well developed bedding and jointing. Limestones are most extensive within the Swasey Mountains and House Range in the western section of the study area (Drawing 2).

3.2.1.3 Carbonate Rocks Undifferentiated - Cau

Materials classifed as undifferentiated carbonate rocks include thick, complex sequences of limestone and dolomite with thin interbeds of sandstone, siltstone, and shale. Principal formations in this unit include unnamed Upper Cambrian limestone, and the Upper Cambrian Orr Formation. These cliff forming rocks are chiefly limestone and typically light to dark gray in appearance, thin to thick bedded, dense, cherty, fossiliferous, and durable. This unit crops out in the extreme southern House Range and in the northern Little Drum Mountains (Drawing 2).

3.2.1.4 Sedimentary Rocks Undifferentiated - Su

Geologic formations mapped as undifferentiated sedimentary rocks include interbedded sandstone, shale, dolomite, limestone, and quartzite. These deposits are characterized by poorly indurated material with complex, thin to thick bedding. The highly interbedded nature of these units prevents separation into individual rock types. Principal geologic formations included within this unit are the Pioche Shale and Swasey and Whirlwind formations which principally crop out in the northern House Range, southern Swasey Mountains, and Cricket Mountains (Drawing 2). These formation are also present as numerous small units throughout the study area.

3.2.1.5 Basalt - Vb

Tertiary and Quaternary basalt was identified during the field investigation south of Delta within the Sevier Desert and within and east of the Little Drum Mountains at the northern end of the study area (Drawing 2). Where observed, it is characteristically dense, dark gray to black, thick bedded to massive, locally vesicular, and poorly jointed with scattered interbeds of volcanic agglomerates and pumice tuffs. In the Little Drum Mountains it overlies early Tertiary lava flows of intermediate to silicic composition.

3.2.1.6 Volcanic Rocks Undifferentiated - Vu

Undifferentiated volcanic rocks form extensive rock units in the northern part of Whirlwind Valley within the Little Drum Mountains and within the House Range at the southern end of the study area (Drawing 2). These rocks are early Tertiary in age and consist predominantly of welded and nonwelded pyroclastics (air falls, ash flows, ignimbrites) of silicic composition and scattered lava flows of andesitic to rhyolitic composition. Individual rock units have not been delineated separately because of map scale limitations and complex but similar composition.

3.2.2 Basin-Fill Units

Four basin-fill units are mapped and labelled within the study area (Drawing 2). These consist of older lacustrine (Aol), alluvial fan (Aaf), stream channel and terrace (Aal), and undifferentiated alluvial deposits (Au). Gravel (g) and sand (s) grain size designations (e.g. Aafg) have been assigned to basin-fill units in the Verification mapped areas. The most extensive basin-fill units in the Whirlwind Valley study area are the fine grained deposits (silts and clays) of Sevier Lake (modern playa) and ajoining clayey lacustrine and stream channel deposits. These have been mapped and labelled as unsuitable aggregate sources and will not be discussed.

3.2.2.1 Older Lacustrine Deposits - Aol

Older lacustrine deposits were formed during late Pliocene/early Pleistocene time in response to a much wetter climate. These deposits are widely distributed throughout the study area and are usually interbedded with or overlain by alluvial fan deposits (Drawing 2). Observed size gradations range from coarse gravel to sand, silt, and clay. Older lacustrine shoreline deposits (sandbars, sand spits, deltas) of Pleistocene Lake Bonneville typically consist of sand and gravel and are particularly well developed at elevations of approximately 5150 to 5200 feet (1570 to 1585 m) and 4800 feet (1463 m) above mean sea level, but generally occur at all elevations below 5200 feet.

3.2.2.2 Alluvial Fan Deposits - Aaf

Alluvial fans bordering the mountain fronts and extending out into the valley basins are the most extensive potential basin-fill aggregate deposits mapped and labelled within the study area (Drawing 2). They are typically homogeneous to poorly stratified mixtures of boulders, cobbles, gravel, sand, silt, and clay that grade from very coarse grained near the rock/alluvium contact to fine grained near the valley centers.

Individual fan units contain poorly to well graded, angular to subangular particles that exhibit considerable lateral and vertical textural variation. Composition of the surrounding source rock strongly controls the textural properties of material formed in alluvial fan deposits. Fan units formed at the base of carbonate or quartzitic rocks are characteristically coarse grained, whereas fans developed from volcanic sources tend to be fine grained. Caliche development in soils (Appendix B), a natural process of soil development in arid climates, ranges from none in younger fans to stage III in older units.

3.2.2.3 Stream Channel and Terrace Deposits - Aal

Stream channel and terrace deposits within the study area are associated with primary and secondary ephemeral streams (Drawing 2). Secondary ephemeral streams commonly transect alluvial fan deposits and trend normal to the ranges toward the valley axis. Most are too small or indistinct to be depicted on Drawing 2 and have been grouped with adjacent, more prominent units (i.e., alluvial fan, undifferentiated alluvium). These deposits vary from homogeneous to poorly stratified mixtures of sand, gravel, cobbles, and boulders near mountain fronts to sand, silt, and clay near valley centers.

3.2.2.4 Alluvial Deposits Undifferentiated - Au

Undifferentiated alluvial deposits consist of combinations of basin-fill units in areas that were not examined and mapped during the Verification program. Located predominantly in the eastern half of the study area, this group includes alluvial fan, older lacustrine, stream channel and terrace (including deposits associated with the Sevier River), and pediment deposits. These alluvial deposits are homogeneous to stratified mixtures of boulders, cobbles, gravel, sand, silt, and clay derived from a wide range of rock types. Composition varies according to the characteristics of the individual units and the lithology of the source rock. Undifferentiated alluvial deposits are generally located along the inside margins of the Valley-Specific boundaries in the northeastern and in the central part of the study region south of the Little Drum Mountains (Drawing 2).

4.0 POTENTIAL AGGREGATE SOURCES

Based on the results of field visual observations and aggregate testing, potential basin-fill and rock sources were divided into three basic material types (i.e., coarse, fine, and crushed rock) and classified into one of three use categories (Section 2.5). Basin-fill deposits tested in the study area may be placed within a multiple type category, (coarse and fine aggregate source). Coarse aggregate (gravel to boulders) includes material predominantly retained on the No. 4 sieve (greater than 0.185 in.; 4.75 mm). Fine aggregate (predominantly sand) includes material entirely passing the 3/8 inch sieve (less than 0.375 in.; 9.5 mm) and almost entirely passing the No. 4 sieve.

Classification boundaries (Drawing 2) of basin-fill aggregate sources were generalized and will require additional studies to accurately define their location. Boundaries of identified crushed rock sources are based on the areal map extent of the geologic formations tested (i.e., Prospect Mountain Quartzite, Marjum Limestone, Pogonip Group) and not on the aggregate geologic units (i.e., Qtz, Ls, Do) described in Section 3.2.1.

In the following discussion, the best potential coarse, fine, or crushed rock source within each Class I and Class II category is presented first followed by sources with successively lower potential. This ranking of deposits is preliminary and is based upon an analysis of all Fugro National and available existing data.

4.1 BASIN-FILL SOURCES

4.1.1 Coarse Aggregate

4.1.1.1 Potentially Suitable Concrete and Road Base Material Sources - Class I

Class I coarse aggregate sources are located in Whirlwind Valley in older lacustrine deposits (Aolg) between the Little Drum and the Swasey mountains, and east of the House Range in the northwestern section of the study area. They consist predominantly of moderately well-graded, medium dense, stratified, sandy gravel composed primarily of carbonate clasts. Coarse fragments are subrounded and sufficient material exists for crushing. Four samples were tested from widely separated locations with acceptable losses in the abrasion resistance and soundness tests. Alkali reactivity tests were not done on these samples. Overburden consists of 3 to 10 feet (1 to 3 meters) of discontinuous caliche horizons and alluvial fan material.

Access to these deposits is provided by several unpaved roads that crisscross the area and minability is considered good to excellent. Although general boundaries have been drawn around these deposits, additional field reconnaissance and testing will be necessary to accurately define the limits of this source.

A Class I coarse aggregate source was also identified in an alluvial fan deposit (Aafs) east of the central House Range. Field observations indicate that the deposit is a poorly graded medium dense, homogeneous, sandy gravel composed predominantly of carbonate clasts. The material passed the abrasion and soundness requirements for Class I coarse aggregate, but was not tested for alkali reactivity. Sand comprises approximately 25 percent of this source. Good access is provided by numerous unpaved roads and minability is considered to be very good.

A stream channel and terrace deposit (Aals) also located east of the central House Range was identified as a Class I coarse aggregate source from laboratory testing. Field observations indicate the deposit is poorly graded, loose, gravelly sand which contains approximately 40 percent gravel. The coarse fraction passed Class I requirements for abrasion and soundness tests, although soundness losses were high. Alkali reactivity tests were not made on the coarse fraction. Boundaries of this and the preceding allvial fan deposit could not be defined at this level of investigation.

Based of field observations and laboratory tests, Class I coarse aggregate material may be available from alluvial fans bordering Class I and/or II rock sources or within unmapped older lacustrine deposits throughout the study area.

4.1.1.2 Possibily Unsuitable Concrete Aggregate/ Potentially Suitable Road-Base Material Sources - Class II

A specific Class II coarse aggregate source was identified in an older lacustrine unit within an alluvial fan deposit (Aafs) at the southern end of the Little Drum Mountains. The deposit consists of well graded, medium dense, homogeneous, gravelly sand, with gravels comprising approximately 38 percent of the unit.

Soundness losses for the coarse fraction exceeded Class I specifications, resulting in a class II ranking. Boundaries could not be delineated at this level of investigation and the access and minability of this source are considered good to excellent.

Based on field observations additional Class II coarse aggregate sources are available in alluvial fan material (Aafg) located near the rock/alluvium contact of most Class I or Class II rock sources and in unmapped older lacustrine deposits, (Drawing 2).

4.1.1.3 Unsuitable Concrete Aggregate or Road-Base Material Sources - Class III

No unsuitable coarse aggregate sources were identified in the Whirlwind Valley region during Valley Specific studies.

4.1.2 Fine Aggregate Sources

4.1.2.1 Potentially Suitable Concrete Aggregate and Road-Base Material Sources - Class I

Class I fine aggregate sources were identified in two locations in northern Whirlwind Valley between the Little Drum and the Swasey mountains (Drawing 2). These older lacustrine deposits (Aols) consist of moderately well to poorly graded, medium dense, crudely stratified, gravelly sands. Soundness losses were high but within Class I fine aggregate requirements, and where tested, alkali reactivity results were within Class I standards. Carbonate gravel clasts comprise between 17 and 41 percent of these deposits and tests yield acceptable Class I coarse aggregate values for abrasion resistance and soundness losses, but were untested for alkali reactivity. Where sufficient quantities of gravel exist these deposits would be good multiple type sources. Boundaries of these sources are preliminarily depicted at one location and could not be drawn at the other. Both will require further field investigations for accurate definition. These deposits are easily accessible by existing unpaved roads and the minability is considered excellent.

Class I fine aggregate is available from coarse older lacustrine deposits (Aolg) in central Whirlwind Valley east of the House Range (Drawing 2). These Class I coarse deposits (Section 4.1.1.1) contain as much as 47 percent fine aggregate material (multiple type source) which passed soundness test requirements for a Class I fine aggregate source. However, alkali reactivity tests were not performed. Boundaries of the deposit have been tentatively depicted, but will require additonal field studies to accurately locate final limits. The access and minability are considered to be very good.

A Class I fine aggregate source was also identified in an older lacustrine deposit north of the Cricket Mountains. Field observations of this localized unit, located within the generalized unsuitable aggregate area, indicate that the deposit is poorly graded, loose, crudely stratified, gravelly sand. Carbonate gravel clasts comprise about 17 percent of this deposit and test results were well within Class I standards for both the fine and coarse fractions. Alkali reactivity tests were not performed on either fraction. Overburden thickness is less than 1 meter and caliche is poorly developed (Stage I). The deposit boundaries could not be delineated at this level of investigation. Access and minability of this source is considered excellent.

Based on field observations, additional Class I fine aggregate sources may exist in alluvial fan deposits located adjacent to most Class I and/or Class II crushed rock sources and in older lacustrine deposits located throughout the study area (Drawing 2).

4.1.2.2 Possibly Unsuitable Concrete Aggregate Potentially Suitable Road-Base Materials Sources - Class II

Class II fine aggregate was identified in older lacustrine deposits at the extreme southern end of the Little Drum Mountains and north of Long Ridge in the central portion of the valley (Drawing 2). Field observations indicate these samples are poorly to moderately well graded, medium dense, gravelly sand containing up to 40 percent gravel. Excessive soundness losses occurred during testing of these two separate sources resulting in a Class II ranking. Alkali reactivity tests were not made on either of these sources. Overburden averages less than 1 meter in thickness. Specific boundaries of these deposits could not be defined at this level of investigation and will require further field studies to accurately delimit. The source at the southern end of the Little Drum Mountains is intermixed with a larger alluvial fan unit (Aafg) while the source north of Long Ridge is located within a much larger, generally defined lacustrine unit (Aols). Good access is provided by numerous dirt roads and the minability is considered good to excellent for both sources.

Another Class II fine aggregate deposit was identified in alluvial fan material (Aafg) at the southern end of the Little Drum Mountains. The deposit consists of poorly graded, medium dense to loose, gravelly sand with gravel comprising about 38 percent of the unit (multiple type source). Abrasion and soundness losses were within Class I standards for the coarse fraction, whereas, soundness losses were excessively high for the fine fraction, resulting in a Class II ranking. An alkali reactivity test was completed on the fine fraction, which proved innocuous. Accurate boundaries of this very heterogeneous deposit could not be drawn on the basis of test results from only one location.

In the extreme northeastern portion of the study area, east of Delta, a stream channel and terrace deposit of the Sevier River within undifferentiated alluvium (Au) was identified as a Class II fine aggregate source. This deposit consists of moderately to well graded, loose, gravelly sand. Soundness losses were excessively high resulting in a Class II ranking. The boundaries of this deposit could not be delineated at this level of investigation, but based on field observations will generally parallel the course of the Sevier River. Access and minability are considered good to excellent.

4.1.2.3 Unsuitable Concrete Aggregate or Road-Base Material Sources - Class III

Class III fine aggregate sources are generally located in low-lying areas and are composed predominantly of older lacustrine and recent playa deposits (Drawing 2). These sediments are typically interbedded and stratified, moderately dense, fine sand, silt, and clay.

4.2 CRUSHED ROCK SOURCES

4.2.1 Potentially Suitable Concrete Aggregate and Road-Base Material Sources - Class I

Class I crushed rock sources are common in the northwestern and western portions of the study area within the House Range and the Swasey and Little Drum mountains. Less extensive deposits are located in the Cricket Mountains in the southern portion of the region. These deposits primarily consist of the Cambrian Marjum and Dome limestones (Ls) and Tertiary and Quaternary basalt flows (Vb).

The Marjum Limestone forms the most extensive Class I carbonate rock in the study area, cropping out primarily within the House Range and Swasey Mountains. Field observations indicate that this formation is typically very hard, fine to medium grained, thick-bedded dolomitic limestone with minor deleterious materials and good splitting characteristics. Laboratory test data indicate these rocks meet Class I specificiations with acceptable abrasion and soundness losses, although alkali reactivity tests were not performed. The access and minability of these rocks is generally considered good.

The Dome Limestone crops out in the Cricket Mountains and in scattered localities throughout the House Range on the western side of the study area (Drawing 2). It has been previously quarried from a locality in the eastern Cricket Mountains where field observations indicate the rock unit is characteristically very hard, fine grained and has favorable splitting characteristics. The limestone passed abrasion and soundness requirements for a Class I crushed rock aggregate. Alkali reactivity tests were not made on this source. Deleterious material included chert and scattered veins of calcite. The access and minability are generally good to very good.

Basalt and andesite flows (Vb) within and east of the Little Drum Mountains at the northern end of the study area and south of Delta (Drawing 2) represent potential Class I crushed rock aggregate sources. Laboratory test results obtained during the VSARS program and the Utah Aggregate Resources Study indicate these potential sources meet Class I specifications for abrasion and soundness losses. Alkali reactivity tests were not performed during either study. However, due to the presence of volcanic glass particles observed during field reconnaissance, tests should be made to evaluate the alkali reactivity potential. Field observations indicate the rocks are hard and have favorable splitting characteristics. Access to these sources is especially good because of their central location in the Sevier Desert. Minability is considered generally good to very good.

4.2.2 Possibly Unsuitable Concrete Aggregate/Potentially Suitable Road-Base Material Class II

No Class II crushed rock aggregate sources were specifically identified from the laboratory testing program.

Extensive sedimentary and volcanic rock units indicated on Drawing 2 as Class II crushed rock sources were classified only by field visual observations. Characterized by highly variable lithologic compositions, these potential sources will require further field observation and laboratory testing to determine their acceptability.

4.2.3 Unsuitable Concrete Aggregate or Road-Base Material Sources Class III

One small Class III crushed rock aggregate source was specifically identified from the laboratory testing program. This source was in relatively soft member of the Orr Formation (Cau), located in the extreme southeastern portion of the House Range.

5.0 CONCLUSIONS

Results of the Valley-Specific aggregate investigation indicate that sufficient supplies of potentially good to high quality (Class I and II) basin-fill and crushed rock aggregate material are available within the Whirlwind Valley study area to meet construction requirements of the MX system (Drawing 2).

5.1 *POTENTIAL BASIN-FILL AGGREGATE SOURCES*

5.1.1 Coarse Aggregate

Major Class I basin-fill coarse aggregate deposits have been identified within older lacustrine deposits (Aolg) located east of the Swasey Mountains and the House Range in the northwestern section of the study area.

Additional Class I coarse aggregate sources whose boundaries could not be delineated are also located in alluvial fan (Aafs) and stream channel (Aals) deposits in the northwestern section of the study area east of the central House Range.

Field observations indicate additional sources of Class I coarse aggregate may be available in alluvial fan deposits adjacent to the rock/alluvium contact of Class I and/or Class II crushed rock sources or unmapped older lacustrine deposits.

Potentially suitable Class II coarse aggregate sources are widespread and extensive in the study area. Although boundaries of specific deposits could not be delineated, they are typically located within alluvial fans flanking Class I and/or Class II rock sources and older lacustrine deposits.

5.1.2 Fine Aggregate

While most coarse aggregate sources will supply quantities of fine aggregate either from the natural deposits or during processing, several fine aggregate sources were sampled and tested. A major potential fine aggregate source was located in older lacustrine deposits (Aols) east of the Swasey Mountains in the northwestern part of the study area.

Further field reconnaissance will be required to accurately delineate Class I fine aggregate sources identified in older lacustrine and alluvial fan deposits in the study area. Based on field observations, additional potential sources may exist in other alluvial fan units derived from Class I and/or Class II rock sources and older lacustrine deposits.

Specific Class II fine aggregate sources were located in alluvial fan and older lacustrine deposits south of the Little Drum Mountains in the central section of the study area and within undifferentiated alluvial material (Au) northeast of Delta, Utah in the northeastern portion of the study area. Specific deposit boundaries could not be delineated at this level of investigation and will require additional field studies to accurately define.

5.2 POTENTIAL CRUSHED ROCK AGGREGATE SOURCES

Class I crushed rock sources exist in most sections of the study area. The most suitable deposits and their corresponding locations are listed as follows.

a. Marjum Limestone (Ls) - Northwestern portion of the study area (northern House Range and southern Swasey Mountains).

b. Dome Limestone (Ls) - South-central portion of the area of investigation (Crickett Mountains).

c. Basalt and Andesitic Flows (Vb) - Northern and eastern sections of the Valley-Specific study area (Little Drum Mountains and vicinity and south of Delta).

Class I crushed rock sources (Marjum Limestone - Ls) exposed within the southern Swasey and northern House Range could provide crushed rock material for much of the study area because of their good accessibility and minability.

Extensive, undifferentiated volcanics and sedimentary units and limestone which are widely distributed throughout the study area comprise most of the Class II crushed rock sources delineated on Drawing 2. Classification was based primarily on field visual observations.

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APPENDIX A

Fugro National Field Station and Supplementary
Test Data and Existing Test Data Summary Tables -
Whirlwind Valley

EXPLANATION OF FUGRO NATIONAL FIELD STATION AND SUPPLEMENTARY TEST DATA

Fugro National field stations were established at locations throughout the Valley-Specific study area where detailed descriptions of potential basin-fill or rock aggregate sources were recorded (Drawing 1). All field observations and laboratory test data on samples collected at selected stations are presented in Table A-1. Data entries record conditions at specific field station locations that have been generalized in the text and Drawing 2. Detailed explanations for the column headings in Table A-1 are as follows:

Column Heading	Explanation
Map Number	This sequentially arranged numbering system was established to facilitate the labelling of Fugro National field station locations and existing data sites on Drawing 1 and to list the correlating information on Tables A-1 and A-2 in an orderly arrangement.
Field Station	Fugro National field station data are comprised of information collected during: o The Valley-Specific Aggregate Resources Study; sequentially numbered field stations were completed by two investigative teams (A and B). The Whirlwind Valley Candidate Deployment Area (WWCDP) designation is obsolete. o The general aggregate investigation in Utah (UGS). o The Verification study in Whirlwind Valley; trench data (WW-T) were restricted to information below the soil horizon (1 to 2 meters).
Location	Lists major physiographic or cultural features in/or near which field stations or existing data sites are situated.

Column Heading	Explanation
Geologic Unit	Generalized basin-fill or rock geologic units at field station or existing data locations. Thirteen classifications, emphasizing age and lithologic distinctions were developed from existing geologic maps to accomodate map scale of Drawing 2.
Material Description	Except in cases where soil or rock samples were classified on laboratory results, the descriptions are based on field visual observations utilizing the Unified Soil Classification System (See Appendix C for detailed USCS information).
Field Observations	
Boulders and/or Cobbles, Percent	The estimated percentage of boulders and cobbles is based on an appraisal of the entire deposit. Cobbles have an average diameter between 3 and 12 inches (8 and 30 cm); boulders have an average diameter of 12 inches (30 cm) or more.
Gravel	Particles that will pass a 3-inch (76 mm) and are retained on No. 4 (4.75 mm) sieve.
Sand	Particles passing No. 4 sieve and retained on No. 200 (0.075 mm) sieve.
Fines	Silt or clay, soil particles passing No. 200.
Plasticity (Index)	Plasticity index is the range of water content, expressed as percentage of the weight of the oven-dried soil, through which the soil is plastic. It is defined as the liquid limit minus the plastic limit. Field classification followed standard descriptions and their ranges are as follows: None - Nonplastic (NP) (PI, 0 - 4) Low - Slightly plastic (PI, 4 - 15) Medium - Medium plastic (PI, 15 - 30) High - Highly plastic (PI, > 31)
Hardness	A field test to identify materials that are soft or poorly bonded by estimating their resistance to impact with a rock hammer; classified as either soft, moderately hard, hard, or very hard.

Column Heading	Explanation
Weathering	Changes in color, texture, strength, chemical composition or other properties of rock outcrops or rock particles due to the action of weather; field classified as either fresh or slight(ly), moderate(ly) or very weathered.
Deleterious Materials	Substances potentially detrimental to concrete performance that may be present in aggregate; includes organic impurities, low density material, (ash, vesicules, pumice, cinders), amorphous silica (opal, chert, chalcedony), volcanic glass, caliche coatings, clay coatings, mica, gypsum, pyrite, chlorite, and friable materials, also, aggregate that may react chemically or be affected chemically by other external influences.
Laboratory Test Data	
Sieve Analysis (ASTM C 136)	The determination of the proportions of particles lying within certain size ranges in granular material by separation on sieves of different size openings; 3-inch, 1 1/2-inch, 3/4-inch, 3/8-inch, No. 4, No. 8, No. 16, No. 30, No. 50, No. 100 and No. 200.
No. 8, No. 50	Asterisked entries used No. 10 and No. 40 sieves, respectively.
Abrasion Test (ASTM C 131)	A method for testing abrasion resistance of an aggregate by placing a specified amount in a steel drum (the Los Angeles testing machine), rotating it 500 times, and determing the material worn away.
Soundness Test (ASTM C 88) CA, FA	CA = Coarse Aggregate FA = Fine Agregate The testing of aggregates to determine their resistance to disintegration by saturated solutions of magnesium sulfate. It furnishes information helpful in judging the soundness of aggregates subject to weathering action, particularly when adequate information is not available from service records of the material exposed to actual weathering conditions.

Column Heading	Explanation
Specific Gravity and Absorption (ASTM C 127 and 128)	Methods to determine the Bulk Specific Gravity, Bulk SSD Specific Gravity (Saturated - Surface Dry Basis), and Apparent Specific Gravity and Absorption as defined in ASTM E12-70 and ASTM C 125, respectively.
Alkali Reactivity (ASTM C 289)	This method covers chemical determination of the potential reactivity of an aggregate with alkalies in portland cement concrete as indicated by the amount of reaction during 24 hours at 80°C between 1 N sodium hydroxide solution and aggregate that has been crushed and sieved to pass a No. 50 (300- m) sieve and be retained on a No. 100 (150- m) sieve.
Aggregate Use	I = Class I; potentially suitable concrete aggregate and road-base material source. II = Class II; possibly unsuitable concrete aggregate/potentially suitable road-base material source. III = Class III; unsuitable concrete aggregate or road base material source. c = coarse aggregate f = fine aggregate f/c = fine and coarse aggregate cr = crushed rock All sources not specifically identified as Class I, II, or III from the abrasion, soundness, or alkali reactivity tests or the content of clay- and silt-sized particles, are designated as Class II sources.

MAP NUMBER	FIELD STATION	LOCATION	GEOLOGIC UNIT	MATERIAL DESCRIPTION	USCS SYMBOL	BOULDERS AND/OR COBBLES, PERCENT	DISTRIBUTION OF MATERIAL FINER THAN COBBLES, PERCENT		
							GRAVEL	SAND	FINES
1	WWCDP-A1	Whirlwind Valley	Aols	Gravelly Sand	SW				
2	WWCDP-A2	Whirlwind Valley	Aolg	Sandy Gravel	GP				
3	WWCDP-A3	Whirlwind Valley	Ls	Limestone					
4	WWCDP-A4	Whirlwind Valley	Aolg	Sandy Gravel	GP				
5	WWCDP-A5	Whirlwind Valley	Aolg	Sandy Gravel	GW				
6	WWCDP-A6	Whirlwind Valley	Aolg	Gravelly Sand	SW				
7	WWCDP-A7	Whirlwind Valley	Aafg	Gravelly Sand	SW				
8	WWCDP-A8	Whirlwind Valley	Ls	Limestone					
9	WWCDP-A9	Whirlwind Valley	Aolg	Gravelly Sand	SW				
10	WWCDP-A10	Whirlwind Valley	Aolg	Gravelly Sand	SW				
11	WWCDP-A11	Whirlwind Valley	Aolg	Gravelly Sand	SW				
12	WWCDP-A12	Sevier Desert	Aolg	Gravelly Sand	SP				
13	WWCDP-A13	Whirlwind Valley	Aals	Gravelly Sand	SP				

FIELD OBSERVATIONS							SIEVE ANALYSIS, PERCENT PASSING (ASTM C 136)								
DISTRIBUTION OF MATERIAL FINER THAN COBBLES, PERCENT			PLASTICITY	HARDNESS	WEATHERING	DELETERIOUS MATERIALS									
GRAVEL	SAND	FINES					3"	1½"	¾"	⅜"	NO. 4	NO. 8	NO. 16	NO. 30	NO. 50
			None			Caliche Coatings	100	100	93.9	83.5	75.8	70.4	64.8	56.0	46.9
			None			2% Chert, Caliche Coatings	100	98.8	86.2	26.3	9.6	6.7	5.8	4.0	2.5
				Very Hard	Slight	None									
			None			Caliche Coatings	100	100	99.0	85.8	40.1	14.8	12.8	11.7	8.8
			None			Caliche Coatings	100	98.2	93.1	76.0	50.3	28.1	19.7	17.9	15.5
			Low			<5% Volcanic Glass, Caliche, <5% Low Density Materials	100	87.7	82.8	69.5	62.2	51.4	39.4	27.4	14.8
			Low			Caliche Coatings	98.6	90.5	80.0	70.5	61.9	53.1	39.6	22.3	9.6
				Very Hard	Slight	None									
			None			None	100	100	98.1	93.2	83.2	64.4	35.3	16.1	7.9
			None			<5% Volcanic Glass, Caliche Coatings	100	97.5	86.9	70.8	59.0	38.4	29.8	21.8	7.9
			Low			Caliche and Clay Coatings	100	100	97.0	87.7	69.9	56.0	43.0	30.8	17.5
			Low			2% Chert	100	100	99.4	94.6	82.9	71.5	62.7	55.3	44.3
			None			4% Chert	100	99.5	98.5	91.2	60.8	37.2	23.7	12.9	5.5

LABORATORY TEST DATA

...STM C 136)				ABRASION TEST (ASTM C 131)	SOUNDNESS TEST (ASTM C 88)		SPECIFIC GRAVITY AND ABSORPTION (ASTM C 127 AND C 128)								ALKALI REACTIVITY (ASTM C 289)	
							COARSE AGGREGATE				FINE AGGREGATE					
							SPECIFIC GRAVITY			PERCENT ABSORPTION	SPECIFIC GRAVITY			PERCENT ABSORPTION		
...O. ...0	NO. 50	NO. 100	NO. 200	PERCENT WEAR	PERCENT LOSS CA	PERCENT LOSS FA	BULK	BULK SSD	APPAR-ENT		BULK	BULK SSD	APPAR-ENT		CA	F...
.0	46.9	15.6	4.8			7.94					2.64	2.75	2.96	4.06		
.0	2.5	1.8	1.0	28.9	3.56		2.83	2.87	2.94	1.35						
				24.6	1.18		3.04	3.05	3.07	0.24						
.7	8.8	4.3	2.5	24.9	2.14											
.9	15.5	7.0	3.3	31.2	5.95	4.58	2.68	2.69	2.72	0.55	2.61	2.63	2.66	0.83		
.4	14.8	6.8	2.3		38.16											Innoc...
.3	9.6	4.5	2.1	25.4	6.17	15.71	2.61	2.63	2.66	0.69	2.58	2.60	2.64	0.95		Innoc...
.1	7.9	3.8	1.8	27.8	10.68	14.54	2.54	2.59	2.68	1.97	2.64	2.77	3.03	4.89		Potent... Deletr...
.8	7.9	1.8	0.8	25.4	6.28		2.61	2.65	2.72	1.47						
.8	17.5	6.7	1.2	23.6	8.13	14.35										
.3	44.3	5.0	0.6	20.2	2.20	5.94	2.75	2.77	2.81	0.84						
.9	5.5	1.8	0.9	19.4	17.06		2.66	2.70	2.77	1.46						

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ST SS	SPECIFIC GRAVITY AND ABSORPTION (ASTM C 127 AND C 128) — COARSE AGGREGATE — SPECIFIC GRAVITY — BULK	BULK SSD	APPARENT	PERCENT ABSORPTION	FINE AGGREGATE — SPECIFIC GRAVITY — BULK	BULK SSD	APPARENT	PERCENT ABSORPTION	ALKALI REACTIVITY (ASTM C 289) — CA	FA	AGGREGATE USE
94					2.64	2.75	2.96	4.06			If IIc
	2.83	2.87	2.94	1.35							Ic
	3.04	3.05	3.07	0.24							Icr
											Ic IIf
58	2.68	2.69	2.72	0.55	2.61	2.63	2.66	0.83			Ic/f
										Innocuous	IIf/c
71	2.61	2.63	2.66	0.69	2.58	2.60	2.64	0.95		Innocuous	IIf Ic
											IIcr
54	2.54	2.59	2.68	1.97	2.64	2.77	3.03	4.89		Potentially Deletrious	If/c
	2.61	2.65	2.72	1.47							IIf Ic
35											If/c
94	2.75	2.77	2.81	0.84							If/c
	2.66	2.70	2.77	1.46							IIf Ic

FUGRO NATIONAL FIELD STATION AND SUPPLEMENTARY TEST DATA WHIRLWIND VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE A-1
PAGE 1 OF 3

FUGRO NATIONAL, INC.

MAP NUMBER	FIELD STATION	LOCATION	GEOLOGIC UNIT	MATERIAL DESCRIPTION	USCS SYMBOL	BOULDERS AND/OR COBBLES, PERCENT	DISTRIBUTION OF MATERIAL FINER THAN COBBLES, PERCENT		
							GRAVEL	SAND	FINES
14	WWCDP-A14	Whirlwind Valley	Aafs	Sandy Gravel	GP				
15	WWCDP-A15	Whirlwind Valley	Ls	Limestone					
16	WWCDP-A19	Whirlwind Valley	Aol	Silty Clay	CL	0	0	5	95
17	WWCDP-A21	House Range	Ls	Limestone					
18	WWCDP-A25	Swasey Mountains	Do	Dolomite					
19	WWCDP-A26	Little Drum Range	Vu	Latite					
20	WWCDP-A27	Sevier Desert	Aal	Gravelly Sand	SW				
21	WWCDP-B1	Whirlwind Valley	Aolg	Sandy Gravel	GP				
22	WWCDP-B2	Whirlwind Valley	Vu	Rhyodacite					
23	WWCDP-B3	Whirlwind Valley	Aolg	Sandy Gravel	GP				
24	WWCDP-B4	Whirlwind Valley	Aafs	Sandy Gravel	GP	5	60	40	0
25	WWCDP-B5	Whirlwind Valley	Aafs	Gravelly Sand	SP	10	35	65	0
26	WWCDP-B6	Sevier Lake	Ls	Limestone					

FIELD OBSERVATIONS						SIEVE ANALYSIS, PERCENT PASSING (ASTM C 136								
RIBUTION OF ERIAL FINER AN COBBLES, PERCENT		PLASTICITY	HARDNESS	WEATHERING	DELETERIOUS MATERIALS									
SAND	FINES					3"	1½"	¾"	3/8"	NO. 4	NO. 8	NO. 16	NO. 30	NO. 50
		None			10% Chert, Caliche Coatings	53.2	48.1	39.8	31.8	25.6	21.4	16.8	13.1	10.8
			Very Hard	Slight	5% Chert									
5	95	Med.			Clay									
			Hard	Moderate	5% Chert									
			Hard	Fresh	None									
			Hard	Slight	5% to 10% Volcanic Glass									
		None				100	100	99.3	92.9	83.9	76.2	68.6	57.7	32.5
		None			0% Chert	100	78.3	55.5	44.8	40.0	35.6	27.2	16.2	10.2
			Hard	Slight	5 to 10% Volcanic Glass									
		None			None	98.6	96.0	88.4	75.4	47.8	17.0	8.0	6.5	4.6
40	0	None			Caliche Coatings									
65	0	None			Caliche Coatings									
			Very Hard	Slight	None									

LABORATORY TEST DATA

...M C 136)				ABRASION TEST (ASTM C 131)	SOUNDNESS TEST (ASTM C 88)		SPECIFIC GRAVITY AND ABSORPTION (ASTM C 127 AND C 128)								ALKALI REACTIVITY (ASTM C 289)	
							COARSE AGGREGATE				FINE AGGREGATE					
							SPECIFIC GRAVITY			PERCENT ABSORPTION	SPECIFIC GRAVITY			PERCENT ABSORPTION		
	NO. 50	NO. 100	NO. 200	PERCENT WEAR	PERCENT LOSS CA	PERCENT LOSS FA	BULK	BULK SSD	APPARENT		BULK	BULK SSD	APPARENT		CA	FA
	10.8	8.0	2.3	21.4	4.13	9.77										
				37.3	21.13											
				51.9												
7	32.5	5.9	0.9			7.26					2.53	2.61	2.04	2.48		
2	10.2	3.2	0.9			19.14										
				17.8	8.53		2.63	2.66	2.72	1.28						
5	4.6	2.8	1.2	29.9	6.34											

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…TEST …8) LOSS FA	SPECIFIC GRAVITY AND ABSORPTION (ASTM C 127 AND C 128) COARSE AGGREGATE SPECIFIC GRAVITY BULK	BULK SSD	APPARENT	PERCENT ABSORPTION	FINE AGGREGATE SPECIFIC GRAVITY BULK	BULK SSD	APPARENT	PERCENT ABSORPTION	ALKALI REACTIVITY (ASTM C 289) CA	FA	AGGREGATE USE
[illegible].77											Ic/f
											IIcr
											IIIf
											IIIcr
											IIcr
											IIcr
[illegible].26					2.53	2.61	2.04	2.48			If
[illegible].14											IIc/f
	2.63	2.66	2.72	1.28							Icr
											Ic IIf
											IIc/f
											IIf/c
											IIcr

FUGRO NATIONAL FIELD STATION
AND SUPPLEMENTARY TEST DATA
WHIRLWIND VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE A-1

FUGRO NATIONAL, INC.

MAP NUMBER	FIELD STATION	LOCATION	GEOLOGIC UNIT	MATERIAL DESCRIPTION	USCS SYMBOL	BOULDERS AND/OR COBBLES, PERCENT	DISTRIBUTION OF MATERIAL FINER THAN COBBLES, PERCENT		
							GRAVEL	SAND	FINES
27	WWCDP-B10	Sevier Desert	Aol	Sandy Gravel	GP	0	60	40	0
28	UGS-A11	Sevier River	Aal	Silty Clay	CL	0	0	5	95
29	UGS-A15	Black Rock	Vb	Basalt					
30	UGS-A16	Sevier Desert	Aol	Sandy Gravel	GP	T	65	30	5
31	UGS-A17	Cricket Mountains	Su	Limestone					
32	UGS-A39	Sevier Desert	Aal	Gravelly Sand	SP	0	20	80	T
33	UGS-B38	Cricket Mountains	Ls	Limestone					
34	UGS-B40	Cricket Mountains	Aaf	Sandy Gravel	GP	20	60	40	T
35	WW-T1	Whirlwind Valley	Aols	Silty Gravel	GM				
36	WW-T3	Whirlwind Valley	Aafs	Silty Clay	CL				

FIELD OBSERVATIONS														
...ION OF ...FINER ...LES. ...T					SIEVE ANALYSIS, PERCENT PASSING (ASTM C 136)									
FINES	PLASTICITY	HARDNESS	WEATHERING	DELETERIOUS MATERIALS	3"	1½"	¾"	⅜"	NO. 4	NO. 8	NO. 16	NO. 30	NO. 50	N... 1...
0	None			10 to 20% Volcanics and Low Density Materials										
95	High			Clay										
		Very Hard	Moderate	None										
5	None			Caliche Coatings										
		Very Hard	Fresh	5% Chert, Calcite Veins										
T	None			10% Volcanic Particles										
		Hard	Slight	None										
T	None			<5% Volcanic Glass										
	None					100	93	80	65	53*		43*		37
	High							100	99	95*		88*		82

LABORATORY TEST DATA

)		Abrasion Test (ASTM C 131)	Soundness Test (ASTM C 88)		Specific Gravity and Absorption (ASTM C 127 and C 128)								Alkali Reactivity (ASTM C 289)		Aggregate
					Coarse Aggregate				Fine Aggregate						
					Specific Gravity			Percent Absorption	Specific Gravity			Percent Absorption			
No. 100	No. 200	Percent Wear	Percent Loss CA	Percent Loss FA	Bulk	Bulk SSD	Apparent		Bulk	Bulk SSD	Apparent		CA	FA	
															II
															III
															II
															II
		32.3	0.77												I
															II
															II
															II
37	33														II
82	74														III

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SS TEST (C 88)	SPECIFIC GRAVITY AND ABSORPTION (ASTM C 127 AND C 128)								ALKALI REACTIVITY (ASTM C 289)		AGGREGATE USE
T LOSS	COARSE AGGREGATE				FINE AGGREGATE						
	SPECIFIC GRAVITY			PERCENT ABSORPTION	SPECIFIC GRAVITY			PERCENT ABSORPTION			
FA	BULK	BULK SSD	APPAR-ENT		BULK	BULK SSD	APPAR-ENT		CA	FA	
											IIc/f
											IIIf
											IIcr
											IIc/f
											Icr
											IIf
											IIcr
											IIc/f
											IIc/f
											IIIf

FUGRO NATIONAL FIELD STATION
AND SUPPLEMENTARY TEST DATA
WHIRLWIND VALLEY, UTAH

MX SITING INVESTIGATION
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TABLE A-1
PAGE 3 OF 3

FUGRO NATIONAL, INC.

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EXPLANATION OF EXISTING DATA

Existing data pertaining to aggregates were extracted from the Utah State Department of Highways' Materials Inventory county reports. These reports are compilations of avaiable site data from existing files and records and are intended to accurately locate, investigate, and catalog materials needed for highway construction. Explanations for column headings which appear in Table A-2, that have not been previously discussed in Table A-1, are given below:

Column Heading	Explanation
Site Number	Utah State Department of Highways pit or site number. Locations correspond to map numbers listed on this table and placed on Drawing 2.
Material Description USCS Symbol	To maintain conformity within the study, the Utah State Department of Highways classification system (A.A.S.H.O.) was converted to the Unified Soil Classification System (USCS) utilizing the sieve analyses' size distribution and the plasticity indices.
Sieve Analysis	The size distribution of fine and coarse aggregate samples was determined by sieving. In some samples, particles greater than 1 inch in size (>1 inch) were crushed to 1 inch maximum size and remixed with the remaining sample before sieving. In these cases, data entries under 1 inch are 100 percent, preceeded by before crushing percentages.
No. 10, No. 40	Samples tested after mid-1963 used No. 8 and No. 50 sieves, respectively. These entries are marked with asterisks.
Soundness Test	The testing of aggregates to determine their resistance to disintegration by saturated solutions of sodium sulfate. It furnishes information helpful in judging the soundness of aggregates subject to weathering action,

Column Heading	Explanation
Soundness Test (cont.)	particularly when adequate information is not available from service records of the material exposed to actual weathering conditions.

MAP NUMBER	SITE NUMBER	DATA SOURCE	LOCATION	GEOLOGIC UNIT	MATERIAL DESCRIPTION	USCS SYMBOL
49	14090	USDH Millard County	Long Ridge	Au	Sandy Gravel	GP-GM
50	14091	USDH Millard County	Long Ridge	Aols	Sandy Gravel	GP-GM
51	14092	USDH Millard County	Long Ridge	Aols	Gravelly Sand	SP-SM
52	14093	USDH Millard County	Whirlwind Valley	Aols	Clayey Gravel	GC-GM
53	14094	USDH Millard County	Whirlwind Valley	Aols	Clayey Gravel	GM-GC
54	14095	USDH Millard County	Whirlwind Valley	Aols	Clayey Gravelly Sand	GM-SM
55	14096	USDH Millard County	Sawtooth Cove	Aafs	Sandy Gravel	GM-GC
56	14097	USDH Millard County	Sawtooth Cove	Aafs	Sandy Gravel	GP

USCS SYMBOL	SIEVE ANALYSIS: BEFORE CRUSHING, PERCENT		SIEVE ANALYSIS: PERCENT PASSING AFTER CRUSHING TO 1" MAXIMUM SIZE						ABRASION TEST (ASTM C 131)	SOUNDNESS TEST (ASTM C 88) PERCENT LOSS		PLASTICITY INDEX (ASTM D 423 and D 424)
	>3"	>1"	1"	½"	NO. 4	NO. 10	NO. 40	NO. 200	PERCENT WEAR	CA	FA	
GP-GM	1.1	15.4	100	72.8	48.6	38*.0	23*.2	11.8	22.6	1.87	5.39	NP
GP-GM	2.8	22.7	100		50.7	41.1	24.1	5.3				4
SP-SM			100		54.5	41.9	18.6	7.3	19.1			NP
GC-GM	3.9	15.0	100		49.4	27.4	15.8	8.0	23.9			7
GM-GC	2.9	12.4	100		50.2	34.7	21.1	10.4	30.1			6
GM-SM	0	10.6	100		57.8	44.7	30.9	12.1	26.0			5
GM-GC	3.0	19.1	100		39.1	25.6	12.4	5.4	26.1			4
GP	2.9	24.3	100		38.5	21.4	11.5	5.0	24.7			NP

EXISTING TEST DATA
WHIRLWIND VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE A-2
PAGE 1 OF 2

FUGRO NATIONAL, INC.

MAP NUMBER	SITE NUMBER	DATA SOURCE	LOCATION	GEOLOGIC UNIT	MATERIAL DESCRIPTION	US SYM
37	14069	USDH Millard County	E. Sevier Desert	Au	Poorly Graded Sand	SP-
38	14072	USDH Millard County	Central Sevier Desert	Au	Gravelly Sand	SP-
39	14073	USDH Millard County	Central Sevier Desert	Au	Gravelly Sand	SP-
40	14074	USDH Millard County	Central Sevier Desert	Au	Sand with some Silt	SP
41	14075	USDH Millard County	Central Sevier Desert	Au	Silty Gravelly Sand	SP-
42	14076	USDH Millard County	S. Sevier Desert	Aaf	Sandy Gravel	GP-
43	14077	USDH Millard County	S. Sevier Desert	Au	Sandy Gravel	GP-
44	14085	USDH Millard County	W. Sevier Desert	Au	Sandy Gravel	GP
45	14086	USDH Millard County	W. Sevier Desert	Au	Silty Sand	SP-
46	14087	USDH Millard County	W. Sevier Desert	Au	Sandy Gravel	GP
47	14088	USDH Millard County	W. Sevier Desert	Au	Gravelly Sand	SP-
48	14089	USDH Millard County	Long Ridge	Aols	Sandy Gravel	GP

USCS SYMBOL	SIEVE ANALYSIS: BEFORE CRUSHING, PERCENT		SIEVE ANALYSIS: PERCENT PASSING AFTER CRUSHING TO 1" MAXIMUM SIZE						ABRASION TEST (ASTM C 131)	SOUNDNESS TEST (ASTM C 88) PERCENT LOSS		PLASTICITY INDEX (ASTM D 423 and D 424)
	>3"	>1"	1"	½"	NO. 4	NO. 10	NO. 40	NO. 200	PERCENT WEAR	CA	FA	
SP-SM						100	99.8	6.7				NP
SP-SM		0.6	100		77.5	67.2	54.2	9.6	17.5			
SP-SM			100		76.3	62.2	39.3	5.8	17.4			NP
SP						100	84.3	4.7				NP
SP-SM			100		85.5	66.3	26.0	5.3				NP
GP-GM	1.6	21.4	100		47.0	39.3	21.1	5.1	33.8			NP
GP-GM	0	6.8	100		48.3	31.3	20.6	11.1	26.1			NP
GP			100		33.4	26.2	17.3	2.1	23.8			NP
SP-SM		0	100	98.6	96.1	78.7	62.9	10.0				NP
GP	0	2.9	100		35.0	16.3	7.3	1.8	19.6			NP
SP-SM		1.0	100		78.6	63.6	37.1	7.3				NP
GP		7.6	100		13.9	5.8	4.8	0.8				NP

EXISTING TEST DATA
WHIRLWIND VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE A-2

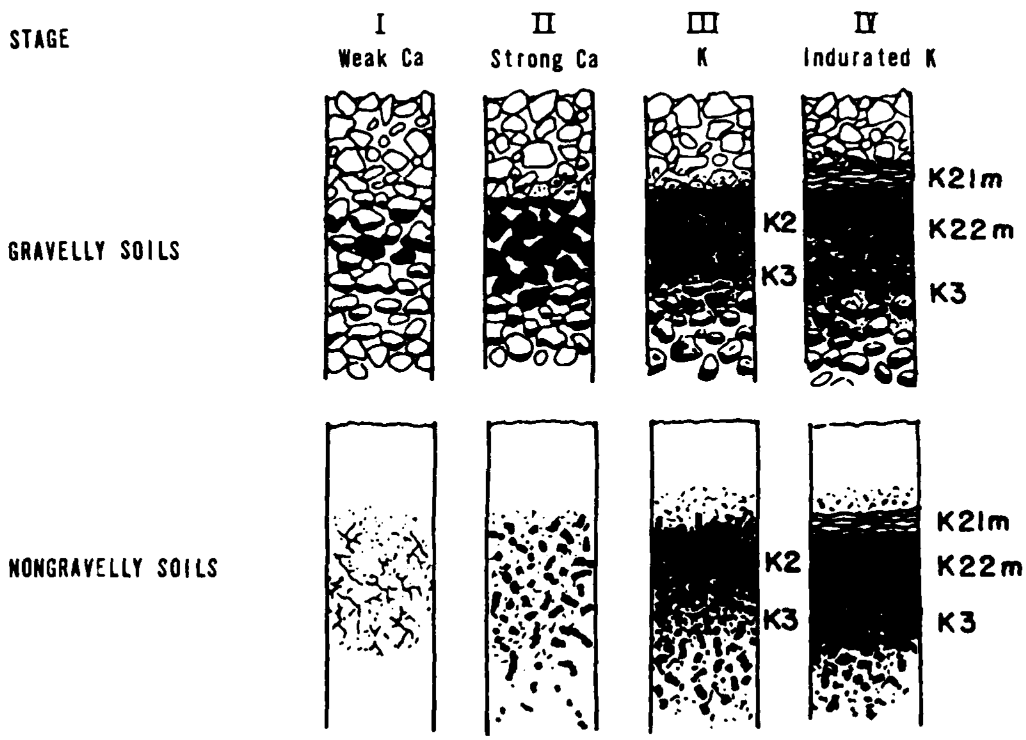
FUGRO NATIONAL, INC.

APPENDIX B

Summary of Caliche Development

DIAGNOSTIC CARBONATE MORPHOLOGY

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	Laminar horizon overlying plugged horizon



Stages of development of a caliche profile with time. Stage I represents incipient carbonate accumulation, followed by continuous build-up of carbonate until, in Stage IV, the soil is completely plugged.

SUMMARY OF CALICHE DEVELOPMENT

MX SITING INVESTIGATION
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FIGURE B-1

FUGRO NATIONAL, INC.

Reference: Gile, L.H. Peterson, F.F., and Grossman, R.B., 1965, The K horizon: A master horizon of carbonate accumulation: Soil Science, v. 99, p. 74-82.

APPENDIX C

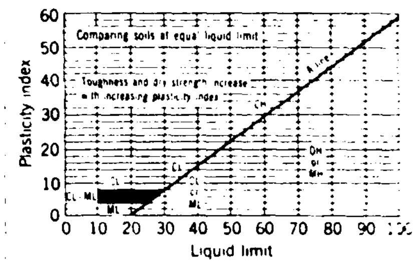
Unified Soil Classification System

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

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

Identification Procedures on Fraction Smaller than No. 40 Sieve Size

Major Divisions		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols [a]	Typical Names	Information Required for Describing Soils
Fine-grained soils. More than half of material is *smaller* than No. 200 sieve size (The No. 200 sieve size is about the smallest particle visible to naked eye)	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	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions
		Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	Example: *Clayey silt*, brown; slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (*ML*)
	Silts and clays liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	
		Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils		Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity chart for laboratory classification of fine grained soils

From Wagner, 1957.
[a] *Boundary classifications*. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW-GC*, well graded gravel-sand mixture with clay binder.
[b] All sieve sizes on this chart are U.S. standard.

Field Identification Procedure for Fine Grained Soils or Fractions

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

Dilatancy (Reaction to shaking):
After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.
Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.
Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):
After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.
High dry strength is characteristic for clays of the *CH* group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):
After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.
After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.
The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.
Highly organic clays have a very weak and spongy feel at the plastic limit.

UNIFIED SOIL CLASSIFICATION SYSTEM

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE C-1

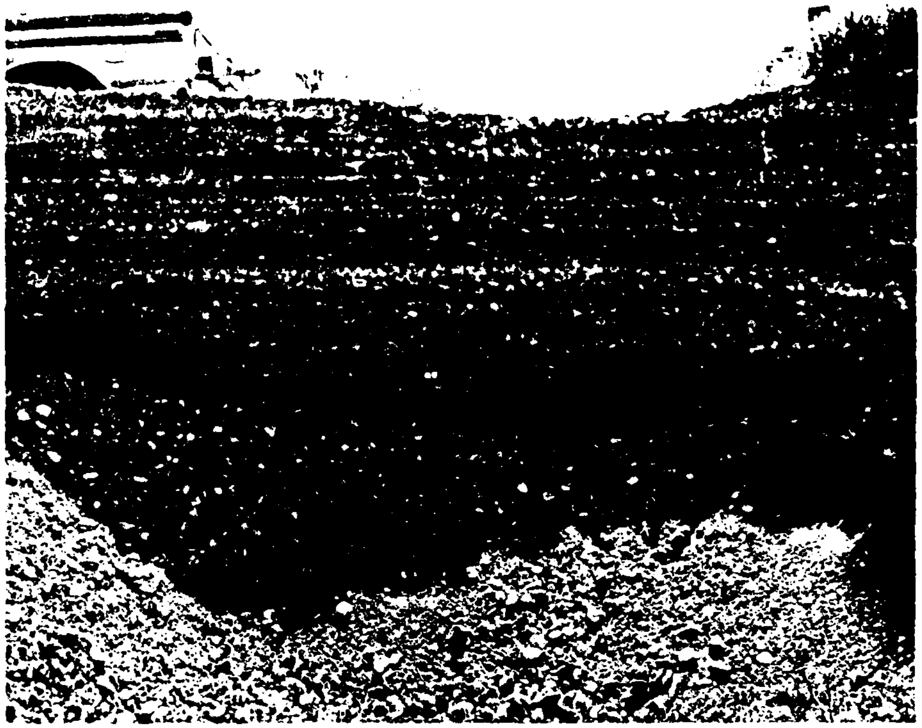
FUGRO NATIONAL, INC.

APPENDIX D

Whirlwind Valley
Study Area Photographs

Gravel pit located in Older Lacustrine Deposit (Aolg) in northern Whirlwind Valley; Class I coarse aggregate source (Station 23). See Figure D-2 for detail.

WHIRLWIND VALLEY STUDY AREA PHOTOGRAPH	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	FIGURE D-1
FUGRO NATIONAL, INC.	



Detail of stratified Older Lacustrine Deposit (Aolg) shown in Figure D-1 within northern Whirlwind Valley; Class I coarse aggregate source (Station 23).

WHIRLWIND VALLEY
STUDY AREA PHOTOGRAPH

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DEPARTMENT OF THE AIR FORCE - BMO

FIGURE
D-2

FUGRO NATIONAL, INC.

Cliff forming cherty limestone of the Notch Peak Formation (Ls), exposed in the House Range; Class I crushed rock aggregate source (Station 15).

WHIRLWIND VALLEY
STUDY AREA PHOTOGRAPH

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FIGURE D-3

FUGRO NATIONAL, INC.

APPENDIX E

Fugro National Geologic Unit Cross Reference

UARSA POTENTIAL AGGREGATE SOURCE SYMBOLS	FUGRO NATIONAL GENERAL GEOLOGIC UNIT EXPLANATION
	ROCK
	Shown in regions where rock is exposed, the areally predominant (greater than 70 percent) rock type is indicated. In those areas where two rock types occur the predominant rock type is shown followed by the subordinate rock type (e.g., $S_{2_{gp}}$/I_{4_r}). Rock may be subdivided into bedrock (B).
	I — IGNEOUS (UNDIFFERENTIATED): Rocks formed by solidification of a molten or partially molten mass.
Gr	I_1 — Intrusive: Plutonic rocks formed by solidification of molten material beneath the surface (e.g., granite, granodiorite, diorite, gabbro).
Vu	I_2 — Extrusive (intermediate and acidic): Volcanic rocks of intermediate and acidic composition formed by solidification of molten material at or near the surface (e.g., rhyolite, latite, dacite, andesite).
Vb	I_3 — Extrusive (basic): Volcanic rocks of basic composition generally formed by solidification of molten materials at or near the surface (e.g., basalt).
Vu	I_4 — Extrusive (pyroclastic): Rocks formed by accumulation of volcanic ejecta (e.g., ash, tuff, welded tuff, agglomerate).
Su	S — SEDIMENTARY (UNDIFFERENTIATED): Rocks formed by accumulation of clastic solids, organic solids and/or chemically precipitated minerals.
Su, QTz	S_1 — Arenaceous and/or Siliceous Rocks: Composed of sand size particles (e.g., sandstone, orthoquartzite) or of cryptocrystalline silica (e.g., opal, chert).
Ls, Do, Cau	S_2 — Carbonate Rocks: Composed predominantly of calcium carbonate detritus or chemical precipitates (e.g., limestone, dolomite, chalk).
	S_3 — Argillaceous Rocks: Composed of clay and silt-sized particles (e.g., siltstone, shale, claystone).
	S_4 — Evaporite Rocks: Precipitated from solution as a result of evaporation (e.g., halite, gypsum, anhydrite, sylvite).
Su	S_5 — Coarse Clastic Rocks: Composed of gravel-sized or larger clasts (e.g., conglomerate, breccia).
Mu	M — METAMORPHIC (UNDIFFERENTIATED): Rocks formed through recrystallization in the solid state of preexisting rocks by heat and pressure.
Mu	M_1 — Coarse grained: rocks formed by higher-grade regional metamorphism, either banded or granular (e.g., gneiss, granulite, amphibolite).
Mu	M_2 — Fine grained: schistose rocks formed by lower grade regional metamorphism (e.g., schist, slate, phyllite).
Mu	M_3 — Nonfoliated: rocks formed chiefly by contact metamorphism (e.g., hornfels, marble).
QTz	M_4 — Metaquartzite: rocks formed by metamorphism of highly siliceous rocks.
	BASIN-FILL
	A — BASIN-FILL DEPOSITS: Fine- to coarse-grained materials deposited principally by wind, water or gravity.
Aal	A_1 — Younger Fluvial Deposits: Major modern stream channel and flood-plain deposits.
Au, Aal	A_2 — Older Fluvial Deposits: Older incised stream channel and flood-plain deposits in elevated terraces bordering major modern drainages.
Au	A_3 — Eolian Deposits: Wind-blown deposits of sand occurring as either thin sheets (A_{3s}) or dunes (A_{3d}).
Aol	A_4 — Playa and Lacustrine Deposits: Deposits occurring in modern, active playas (A_{4a}) or in either inactive playas or older lake beds and abandoned shorelines associated with extinct lakes (A_{4i}).
Aaf	A_5 — Alluvial Fan Deposits: Alluvial deposits consisting of debris flow and water laid alluvium near mountain fronts, grading into predominantly water laid alluvium deposited in shifting distributary channels near the basin center. Younger (A_{5y}), intermediate (A_{5i}) and older (A_{5o}) alluvial fans are differentiated by surface soil development, terrain conditions and present depositional/erosional environment.
Au	A_1/A_5 — Mixed non-rock units: Most areally extensive unit is listed first.
Aaf	A_{3s} (A_5) — Parenthetic unit underlies thin veneer of overlying mapped unit.

FUGRO NATIONAL GEOLOGIC UNIT CROSS REFERENCE

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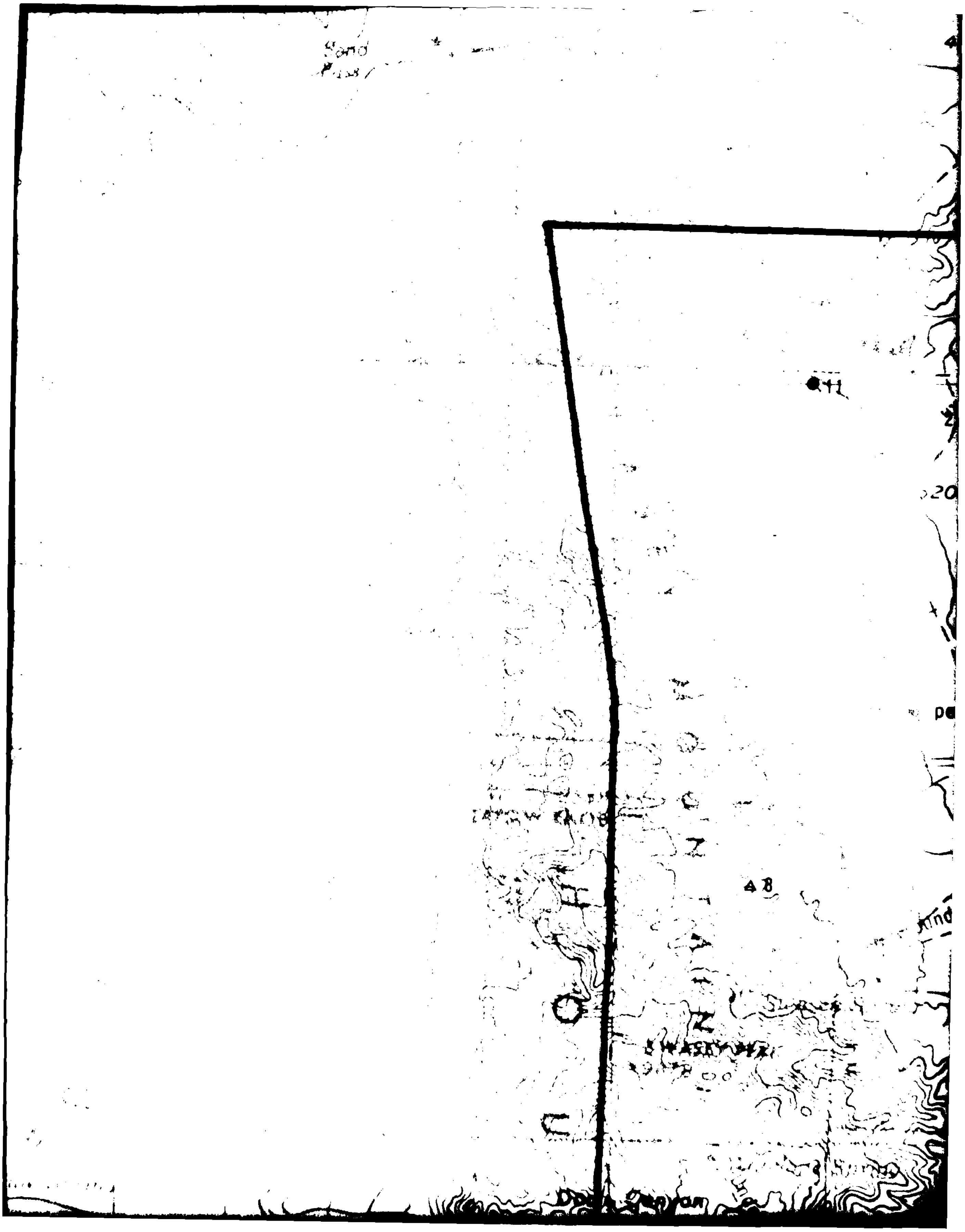
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE E-1

FUGRO NATIONAL, INC.



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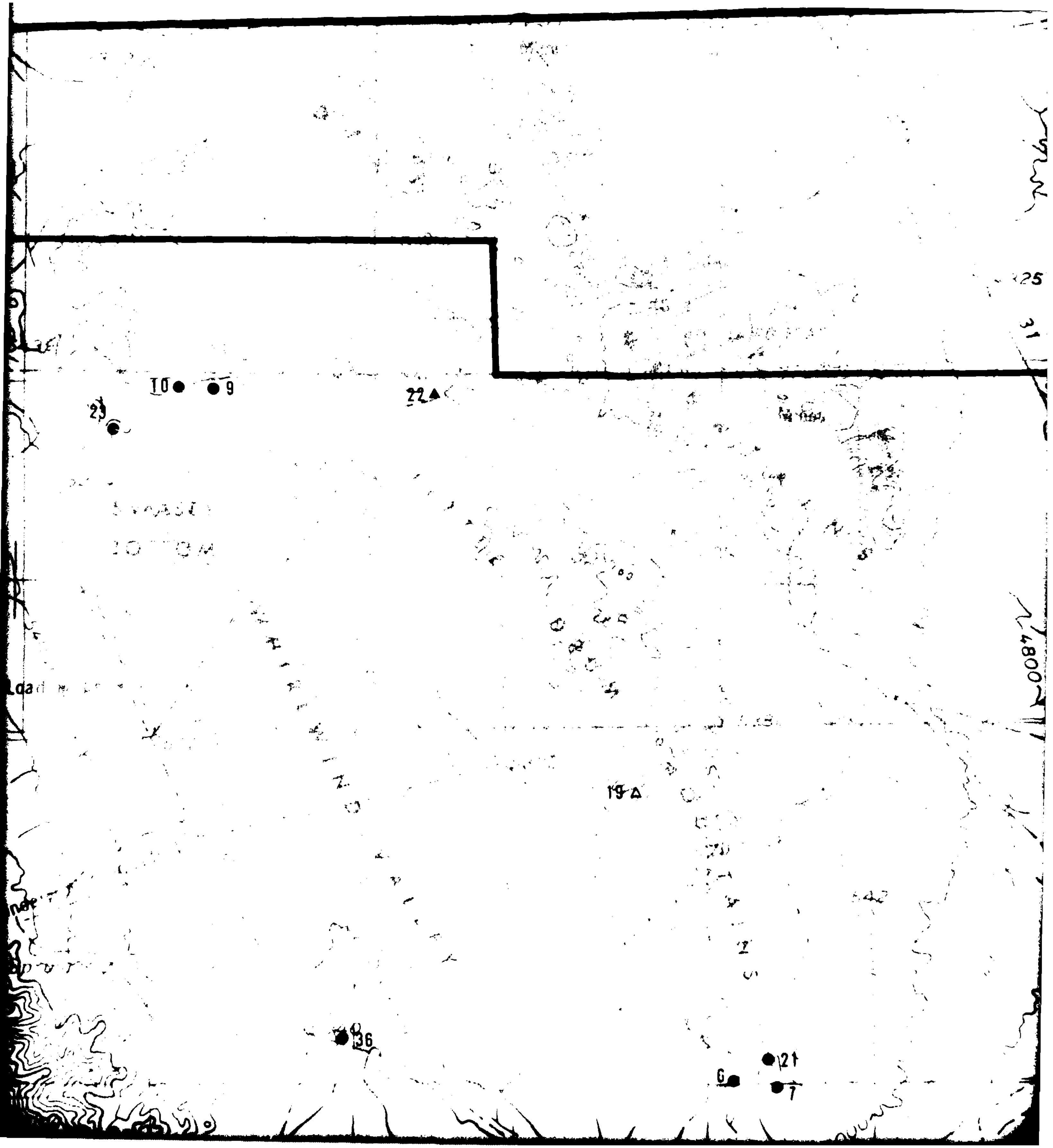
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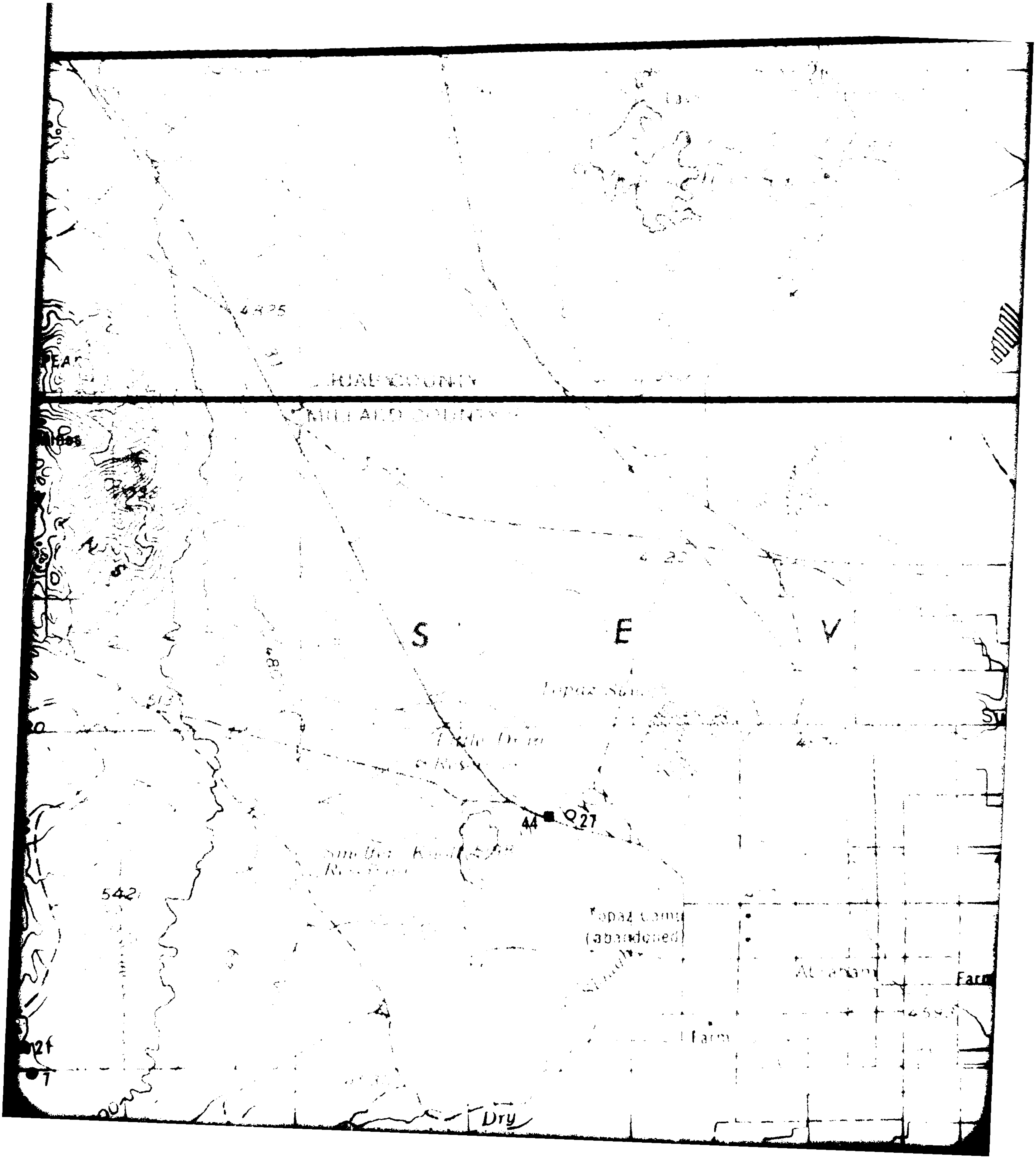

JUAB COUNTY
MILLARD COUNTY
4825
S
E
V
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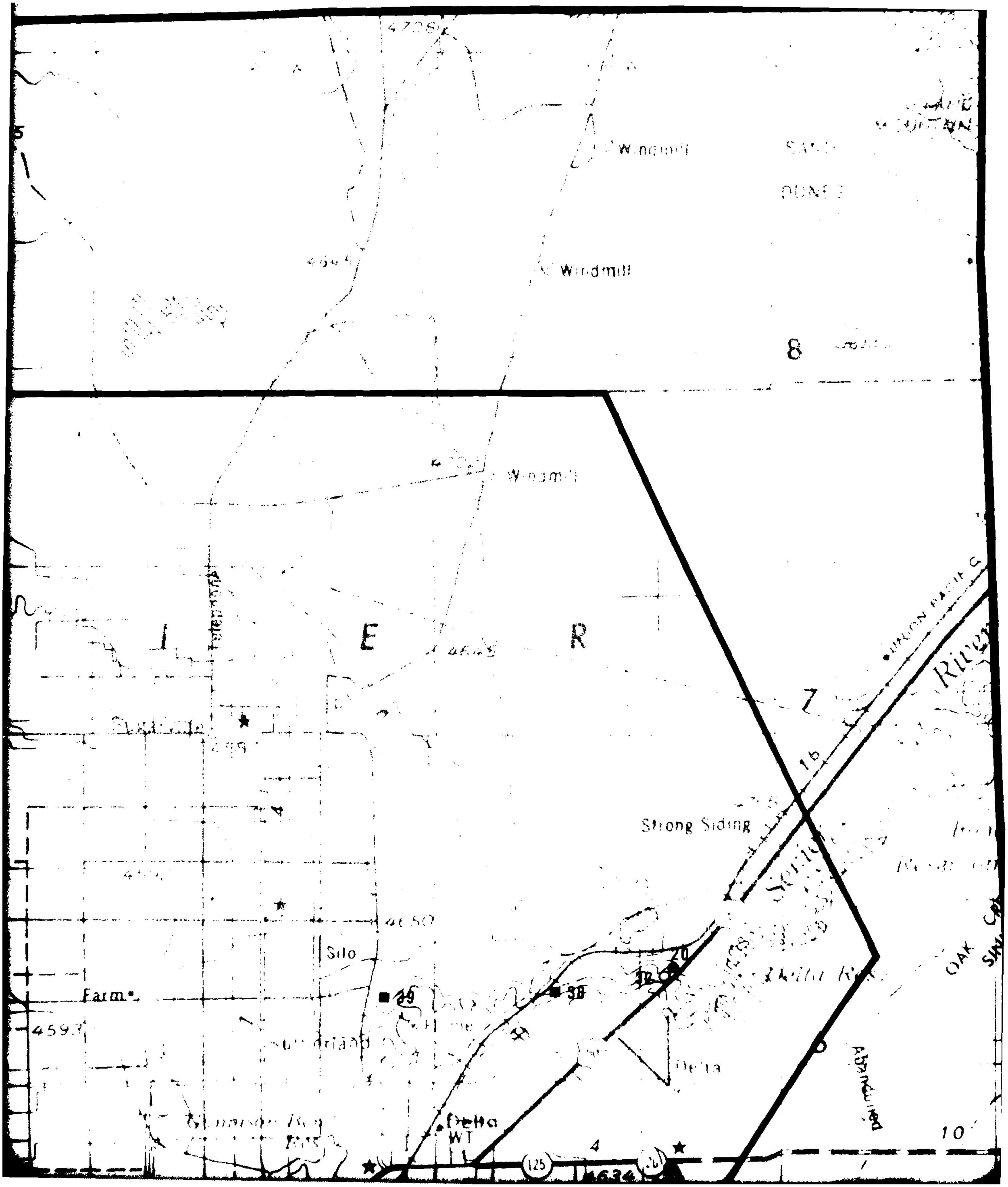
27
542
Topaz Camp
(abandoned)
Farm
Dry



Windmill
8
E
R
7
River
Strong Siding
Silo
Farm
Delta
WT
Delta
Abandoned
OAK
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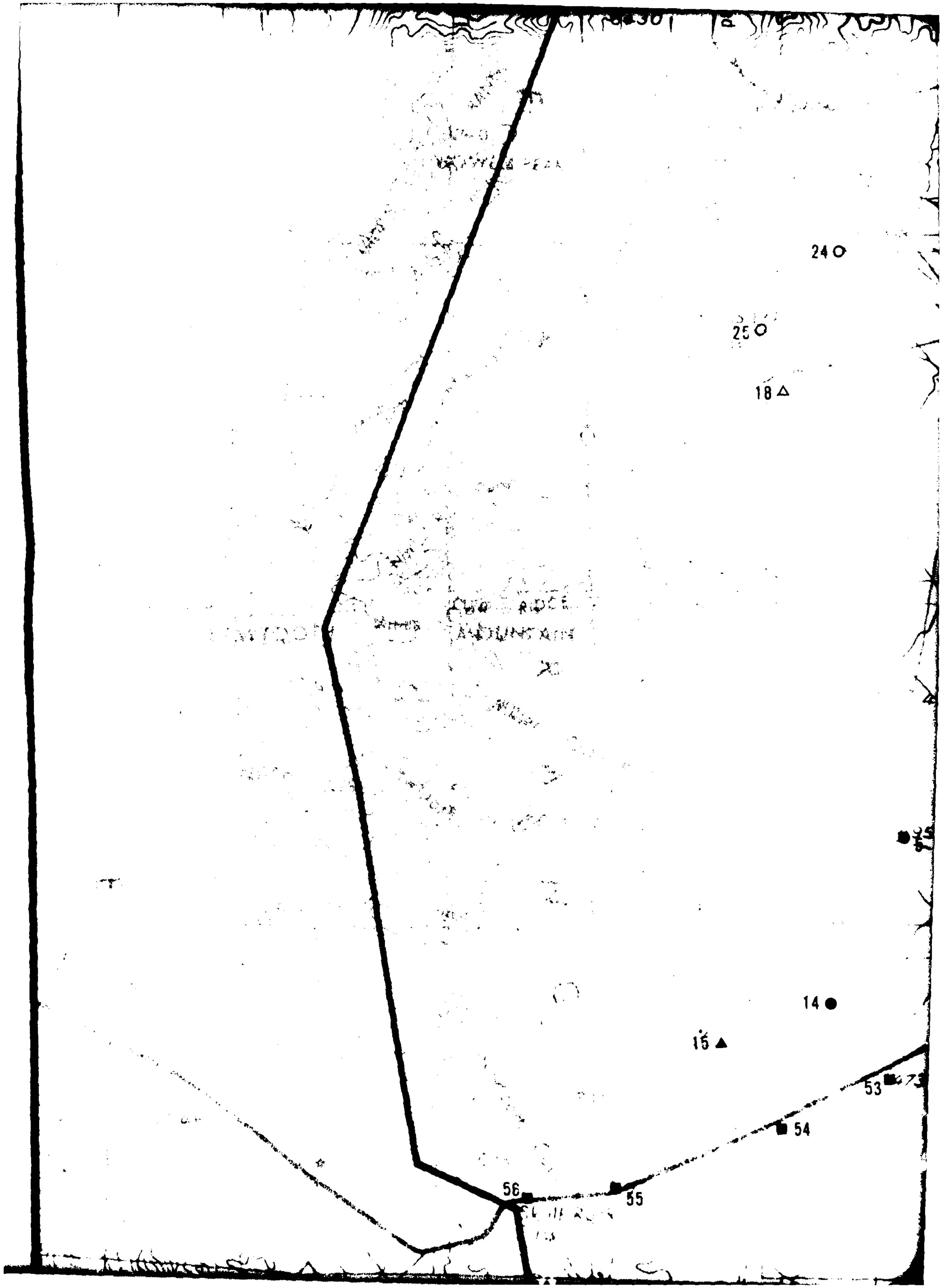
4593
4634
125
10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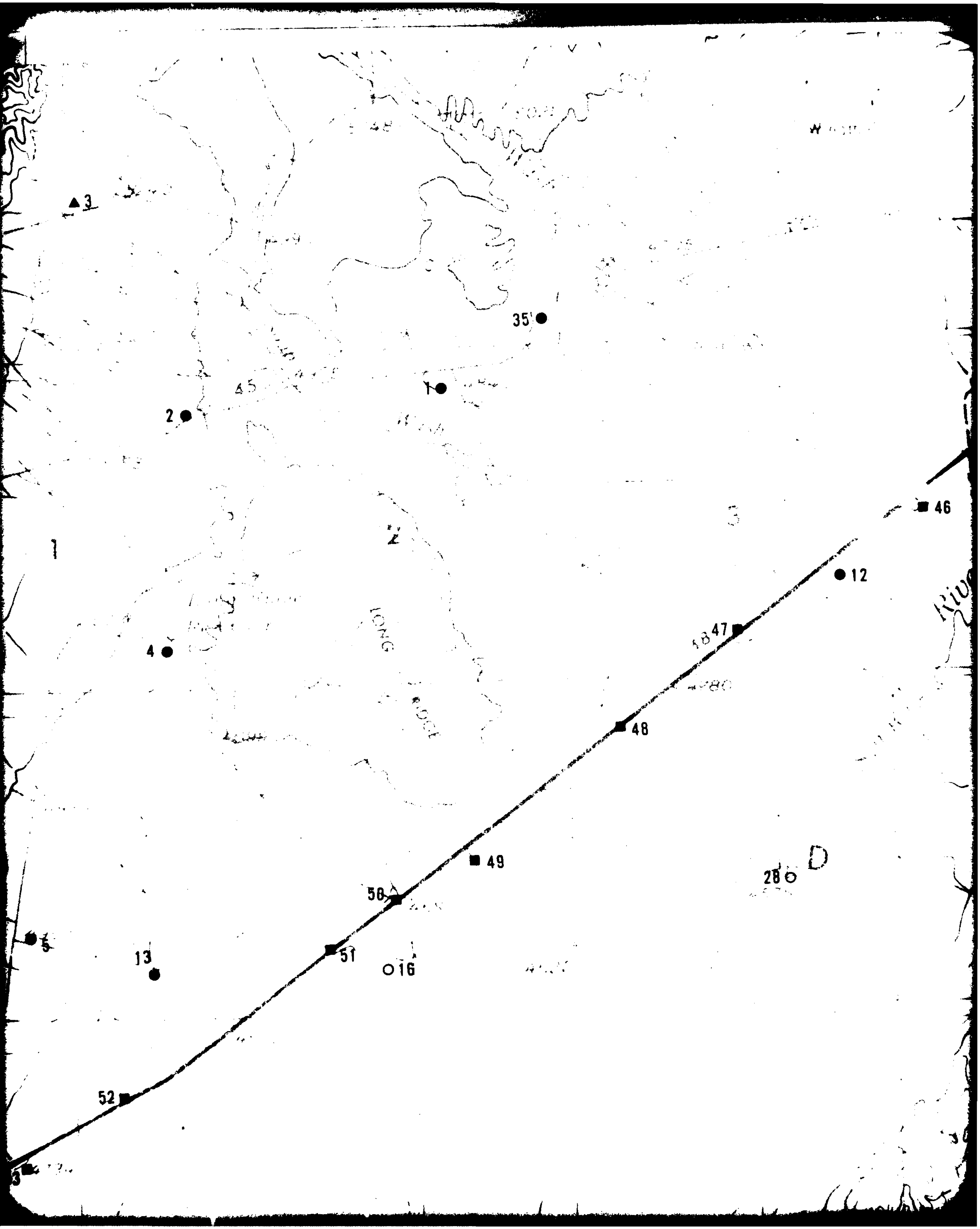

3
35
1
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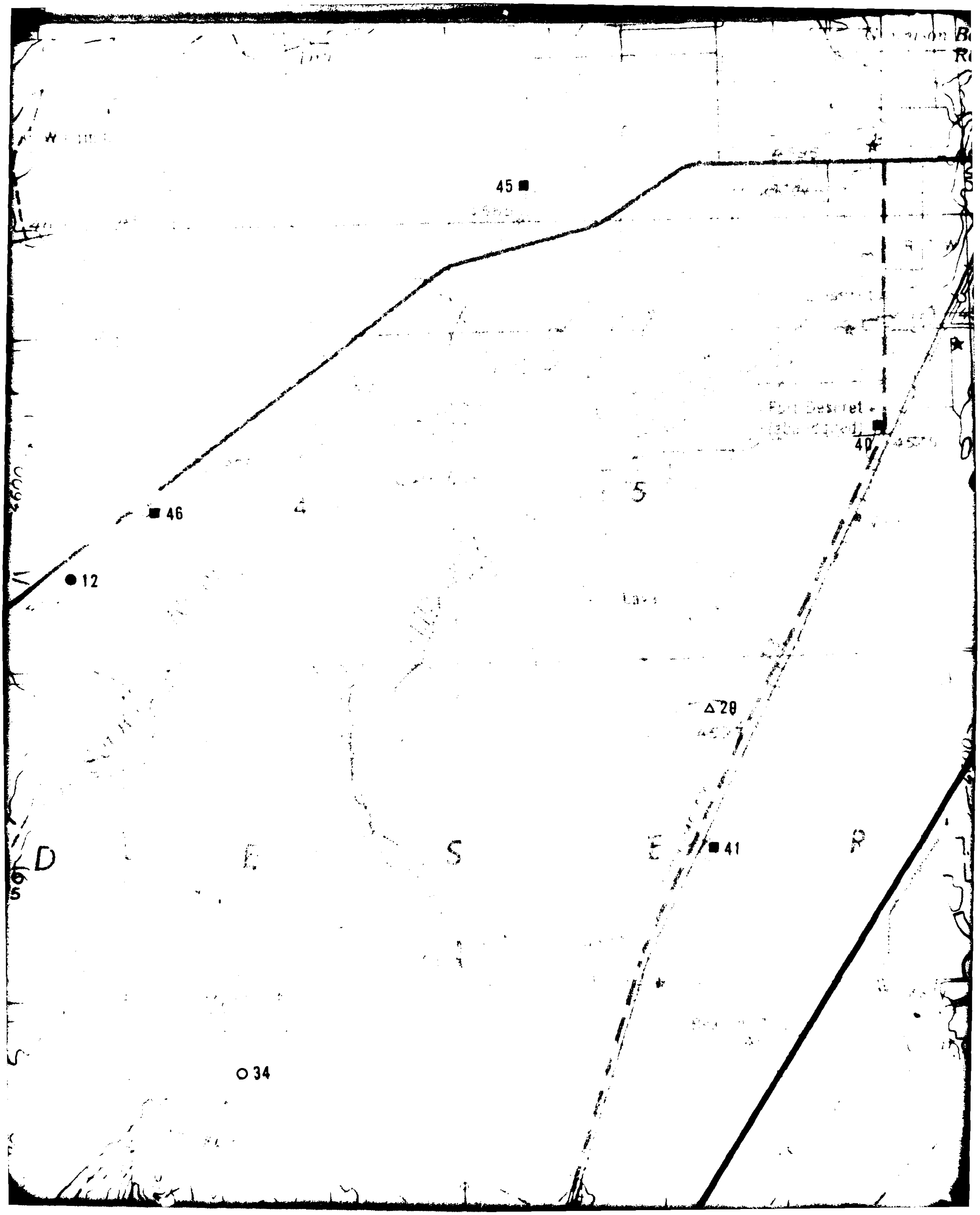
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4
5
Fort Deseret
40
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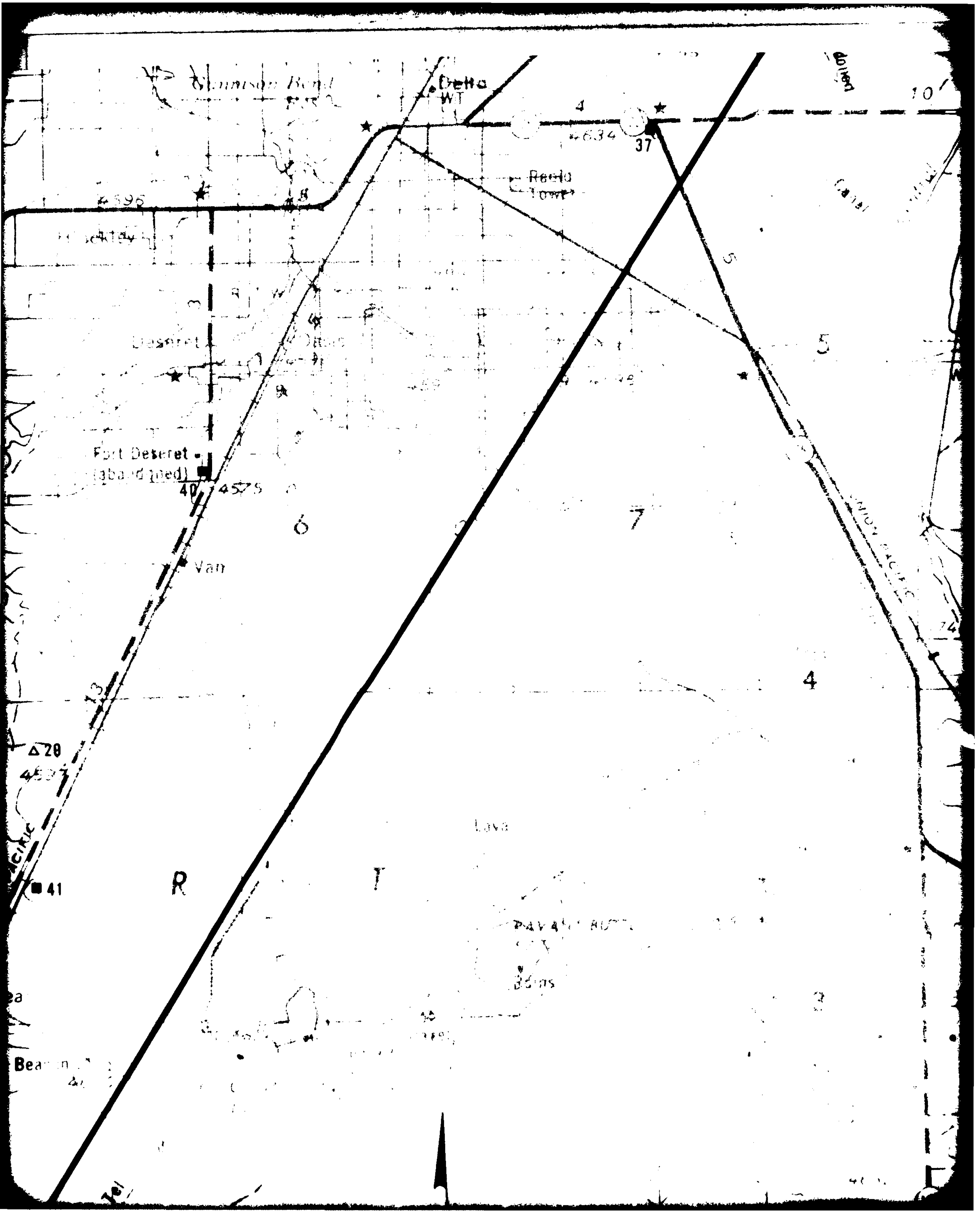

Delta
WT
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37
5
Fort Deseret
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7
5
Van
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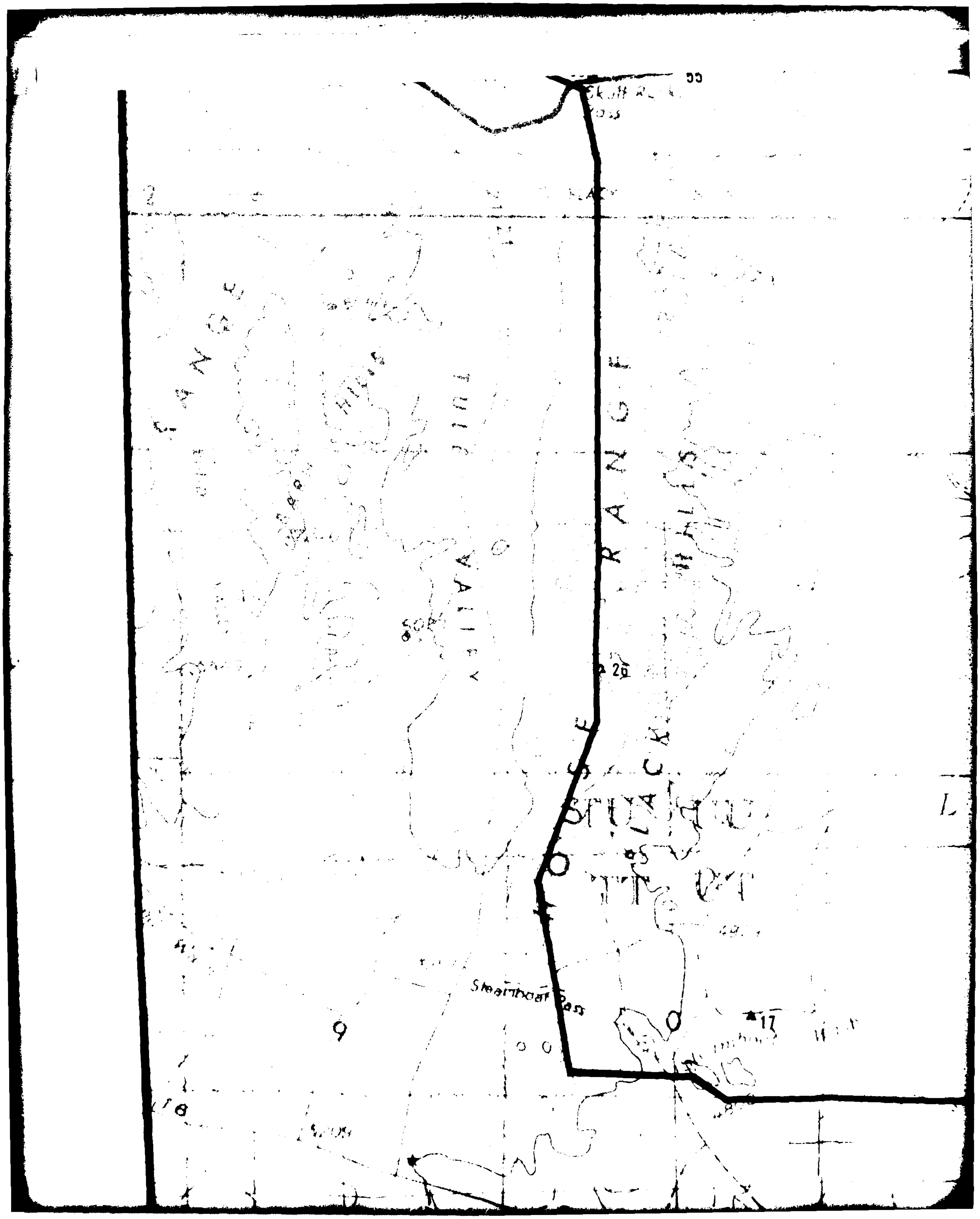
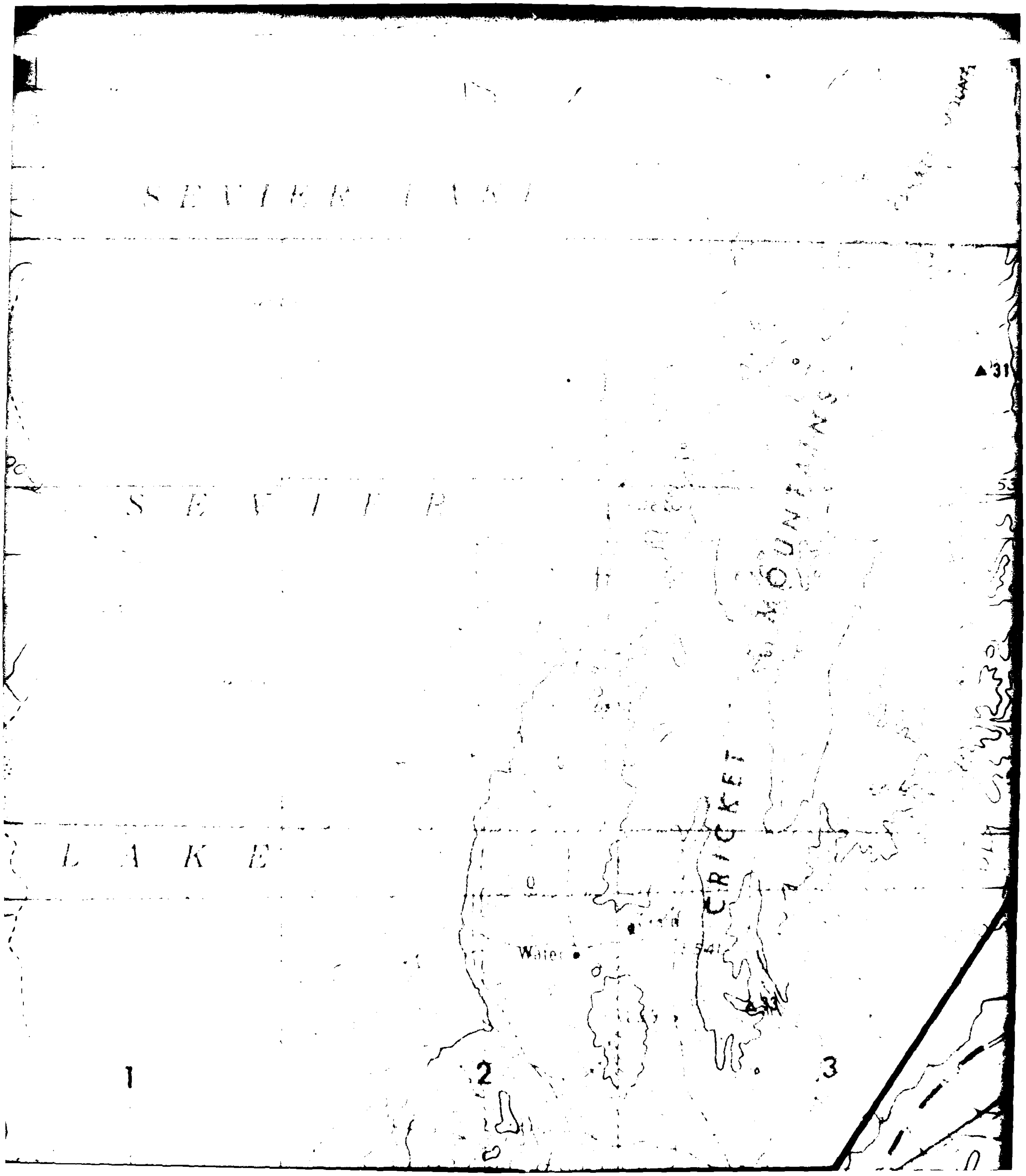
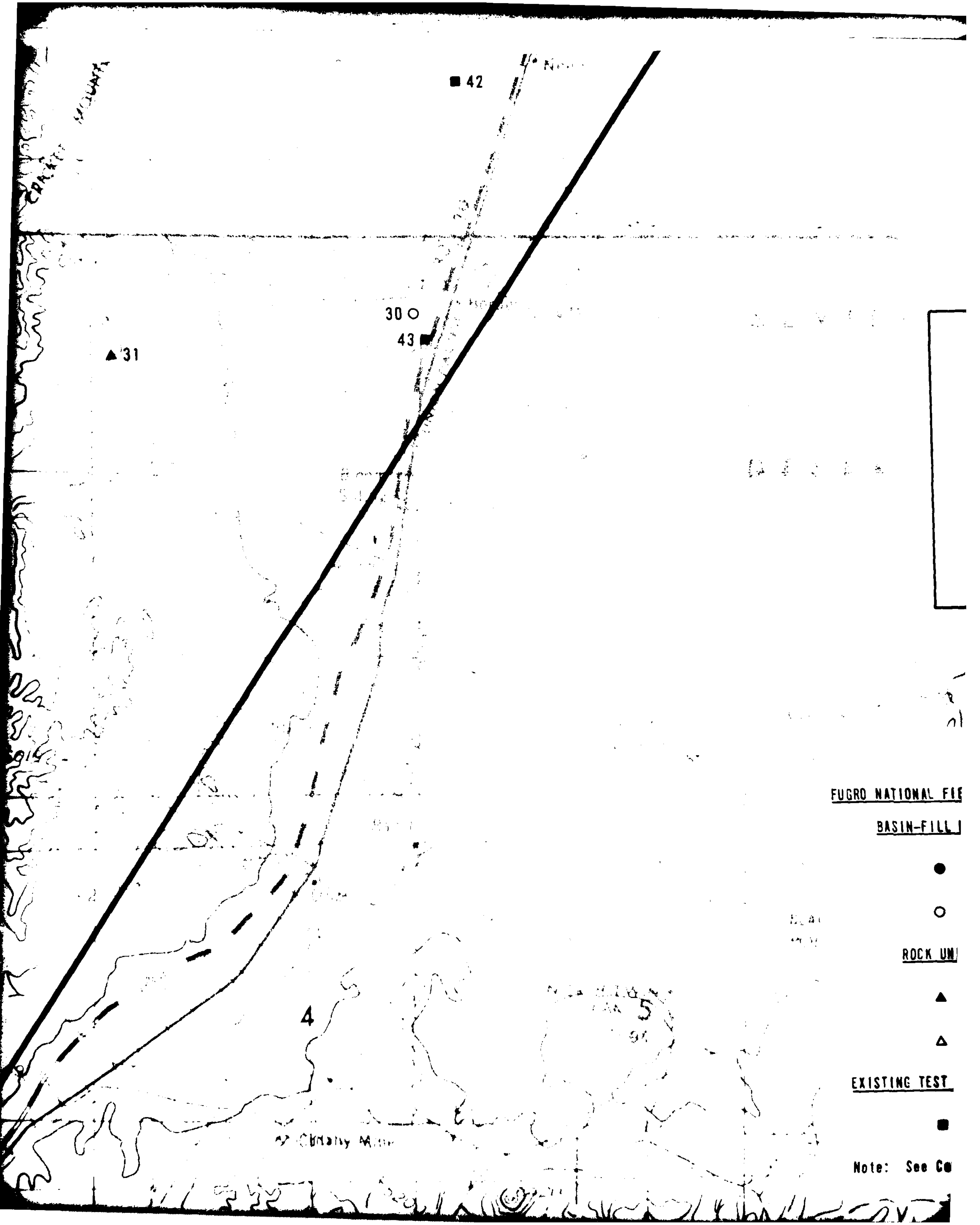
R
T
4
Lava
3
UNION PACIFIC
10


Steamboat Pass


SEVIER LAKE
SEVIER
LAKE
CRICKET MOUNTAINS
Water
1
2
3


42
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43
31
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5
FUGRO NATIONAL FIE
BASIN-FILL
ROCK UN
EXISTING TEST
Note: See Co

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STATUTE MILES

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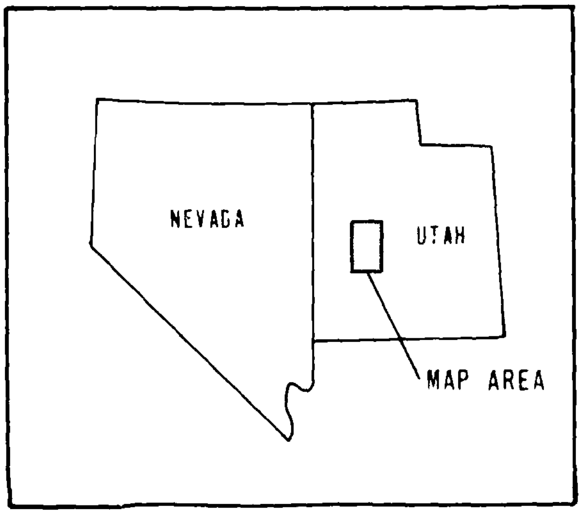
LOCATION MAP



EXPLANATION

FUGRO NATIONAL FIELD STATIONS

BASIN-FILL UNITS (Potential Coarse and or Fine Aggregates)

● Data Stop, Sampled and Tested

○ Data Stop

ROCK UNITS (Potential Crushed Rock Aggregates)

▲ Data Stop Sampled and Tested

△ Data Stop

EXISTING TEST DATA SITES

■ Test Data Available

Note: See Corresponding Map Number in Appendix A for Detailed Information

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UNCLASSIFIED FN-TR-37-E NL

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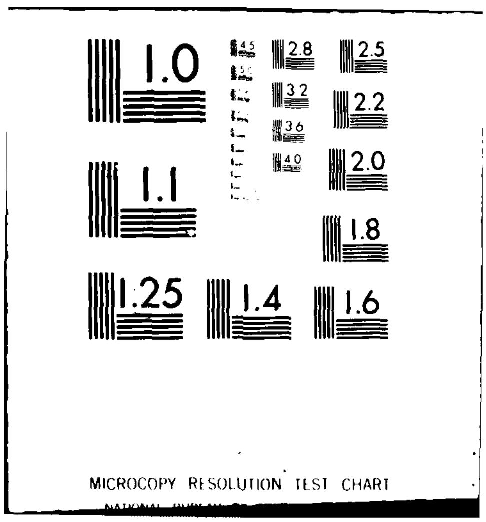
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2.2
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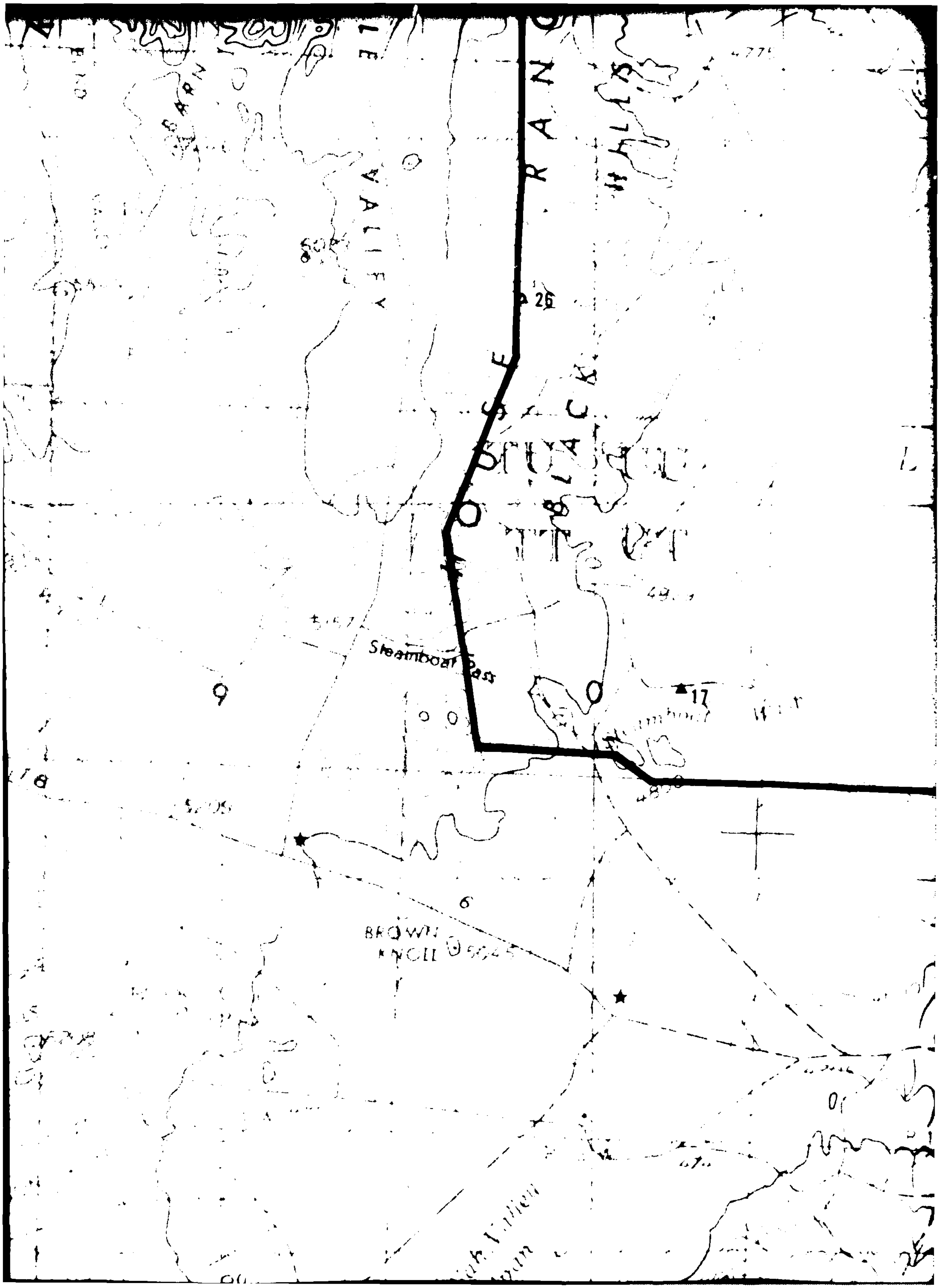
4.0
4.5
MICROCOPY RESOLUTION TEST CHART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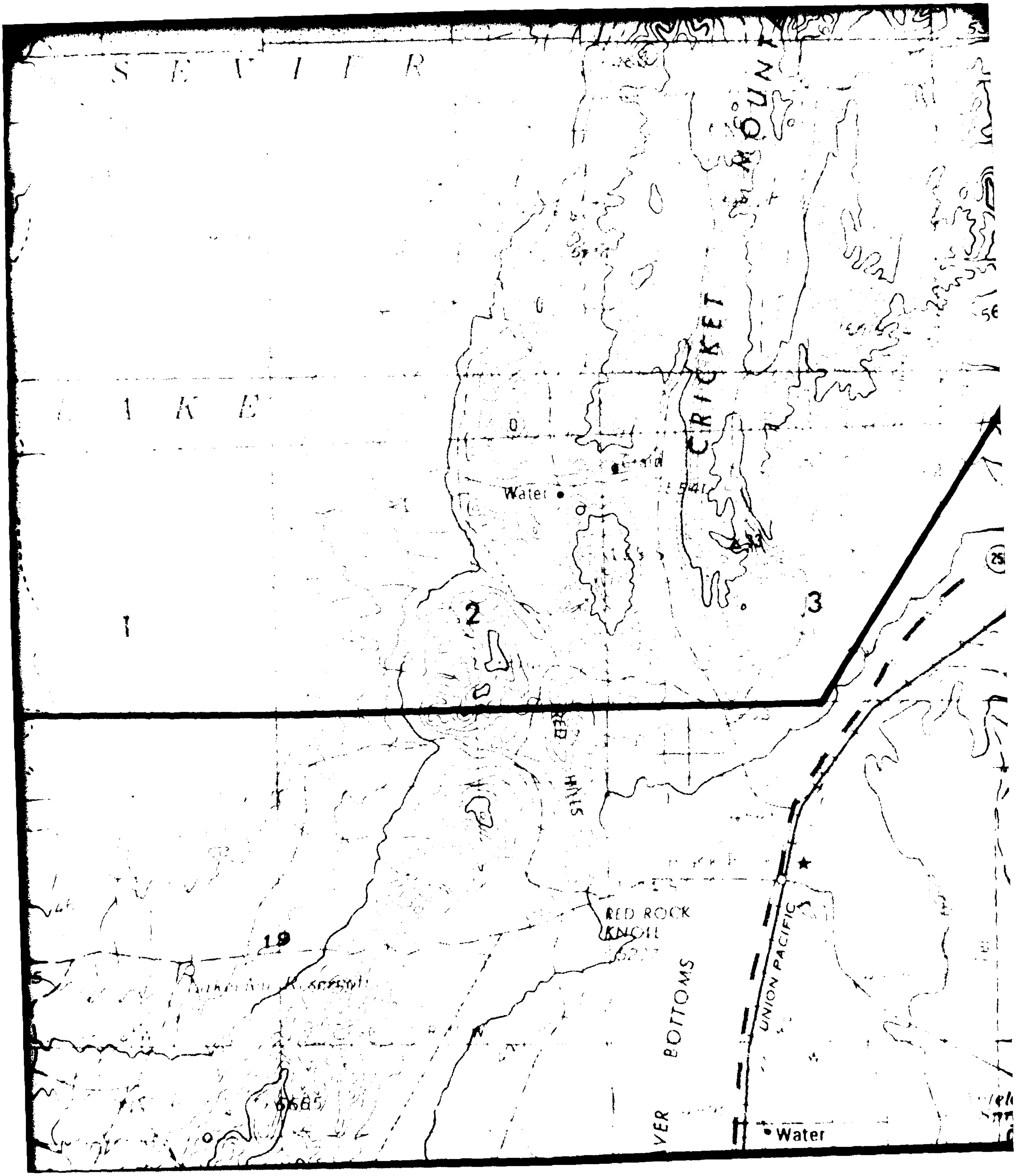
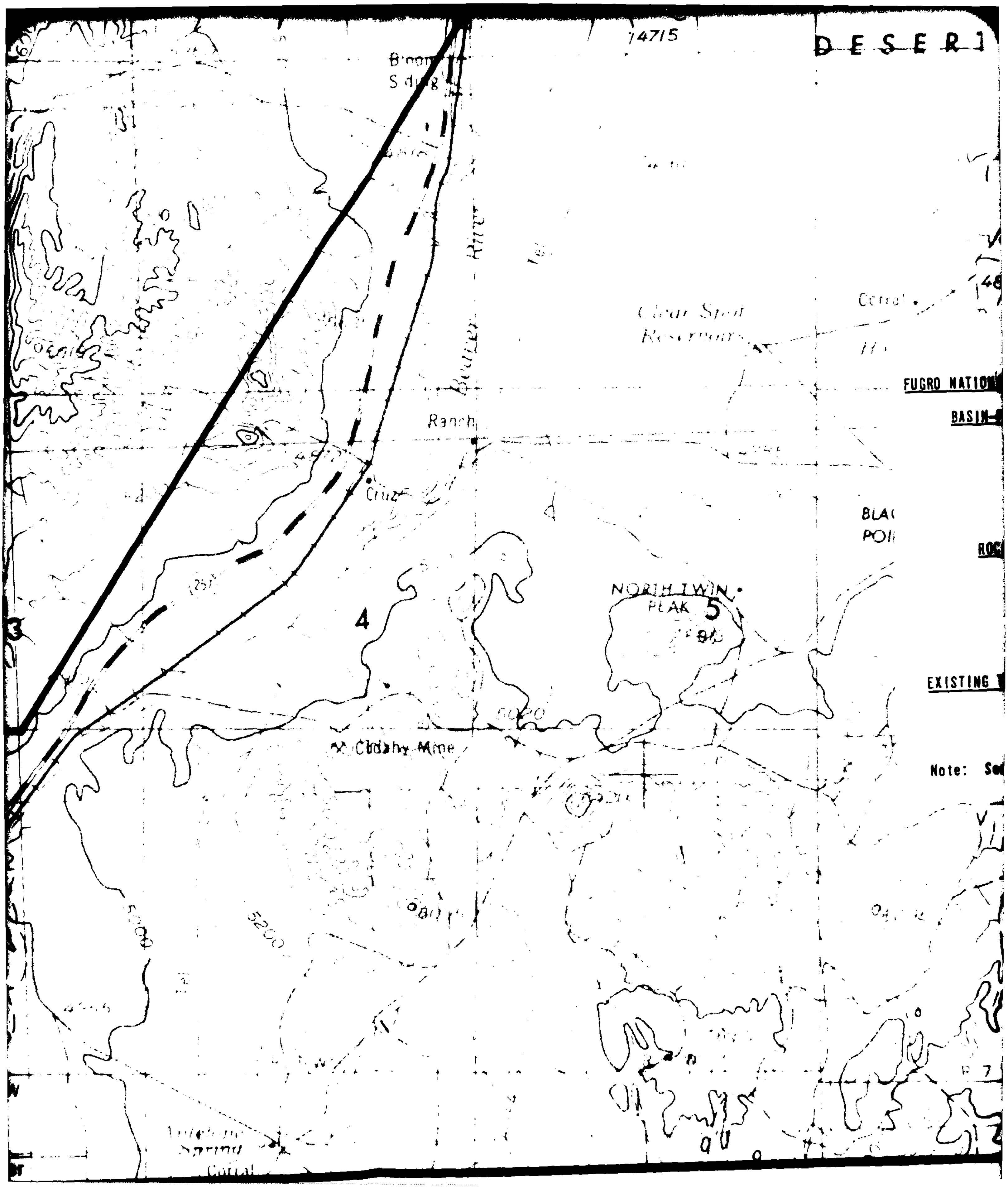
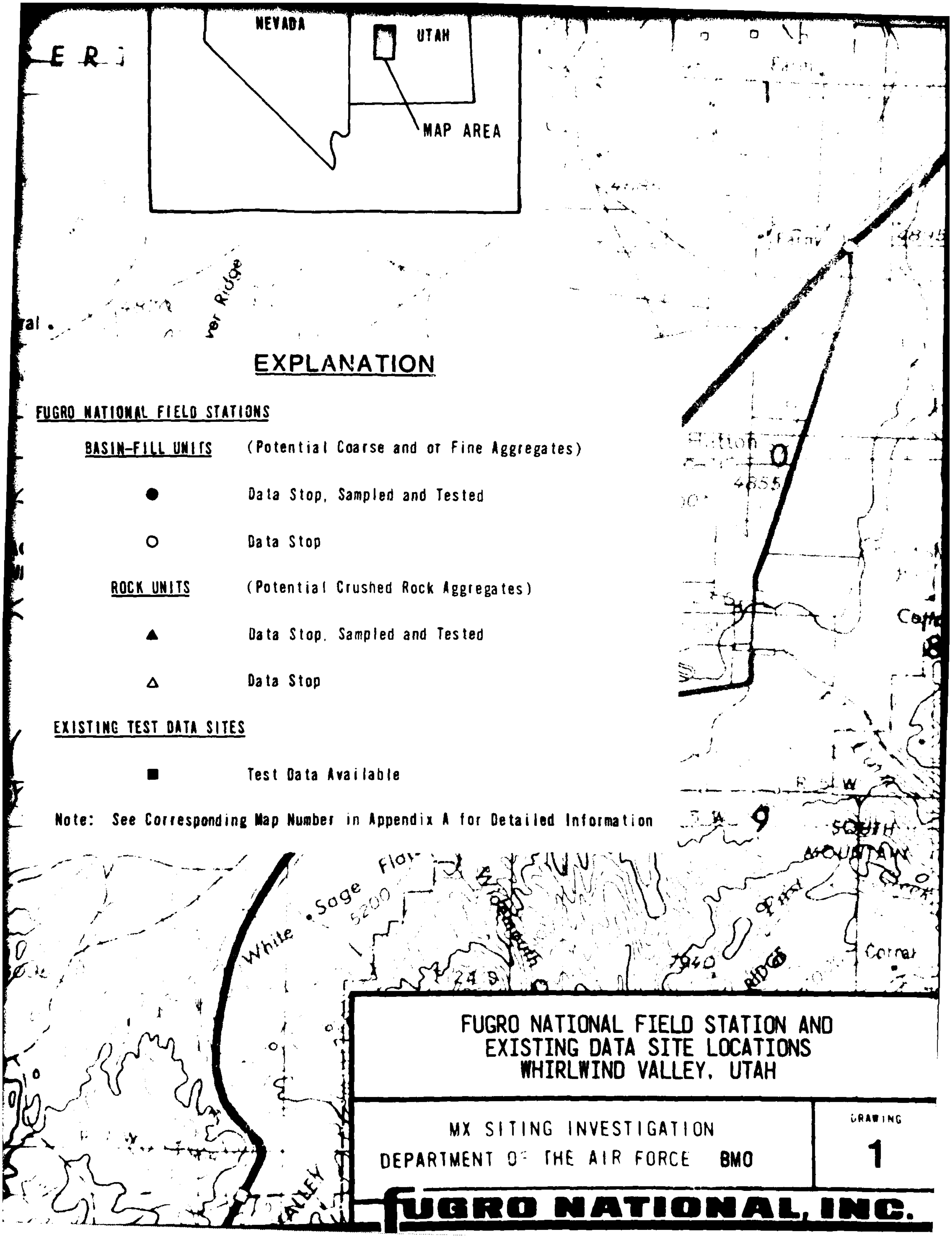
BROWN KNOLL
VALLEY
HOUSE
RANGE
BLACK
HILLS


S E V I E R
L A K E
CRICKET
MOUNT
Water
RED
HILLS
RED ROCK
KNOLL
BOTTOMS
UNION PACIFIC
Water
1
2
3
19
6685


14715
DESER
Broom Siding
Clear Spot Reservoir
Corral
FUGRO NATIO
BASIN
Ranch
Cruz
BLA
POI
ROC
NORTH TWIN PEAK
5
4
Cudahy Mine
EXISTING
Note: Se
5200
Spring
Corral



EXPLANATION

FUGRO NATIONAL FIELD STATIONS

BASIN-FILL UNITS (Potential Coarse and or Fine Aggregates)

- ● Data Stop, Sampled and Tested
- ○ Data Stop

ROCK UNITS (Potential Crushed Rock Aggregates)

- ▲ Data Stop, Sampled and Tested
- △ Data Stop

EXISTING TEST DATA SITES

- ■ Test Data Available

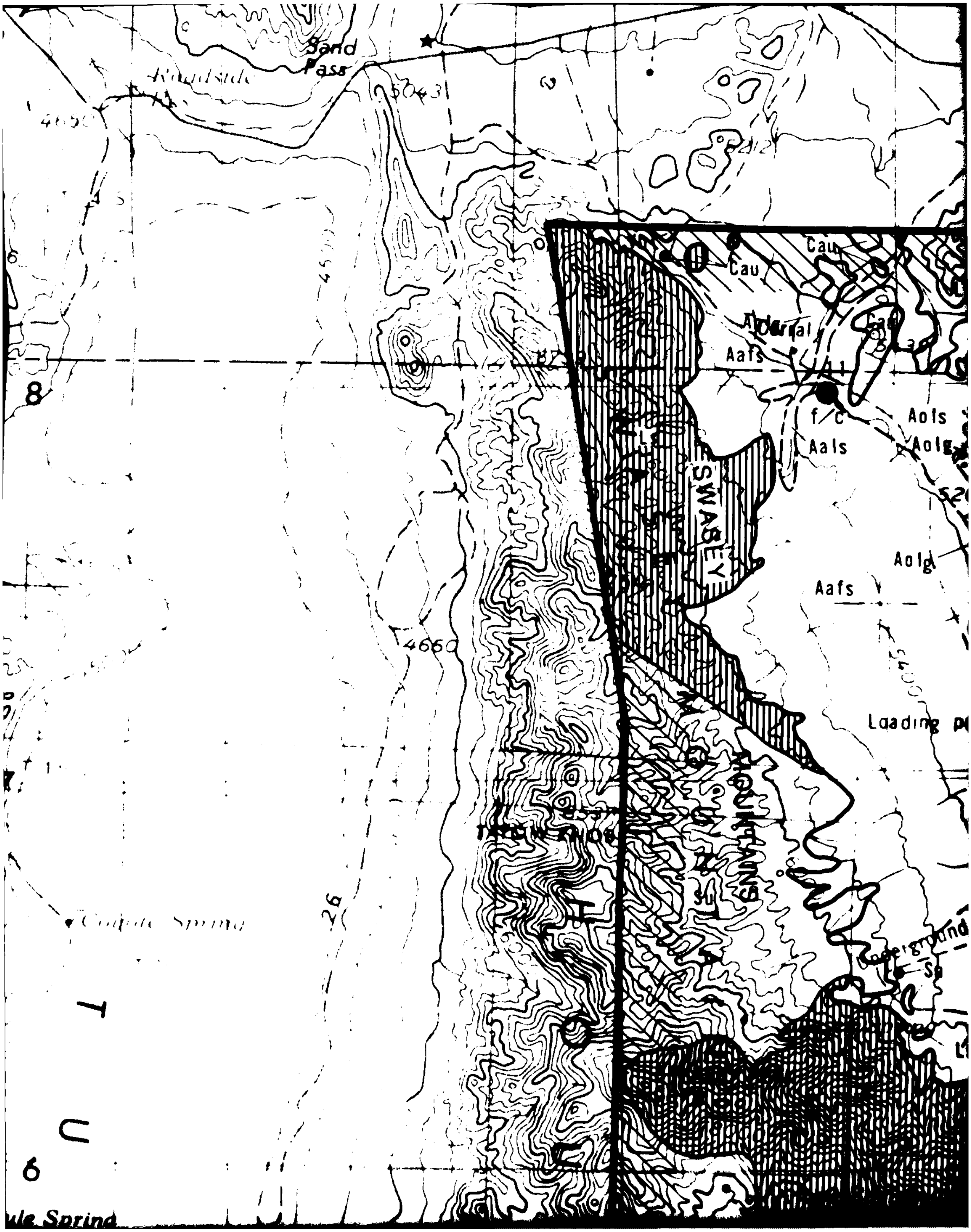
Note: See Corresponding Map Number in Appendix A for Detailed Information

FUGRO NATIONAL FIELD STATION AND EXISTING DATA SITE LOCATIONS WHIRLWIND VALLEY, UTAH

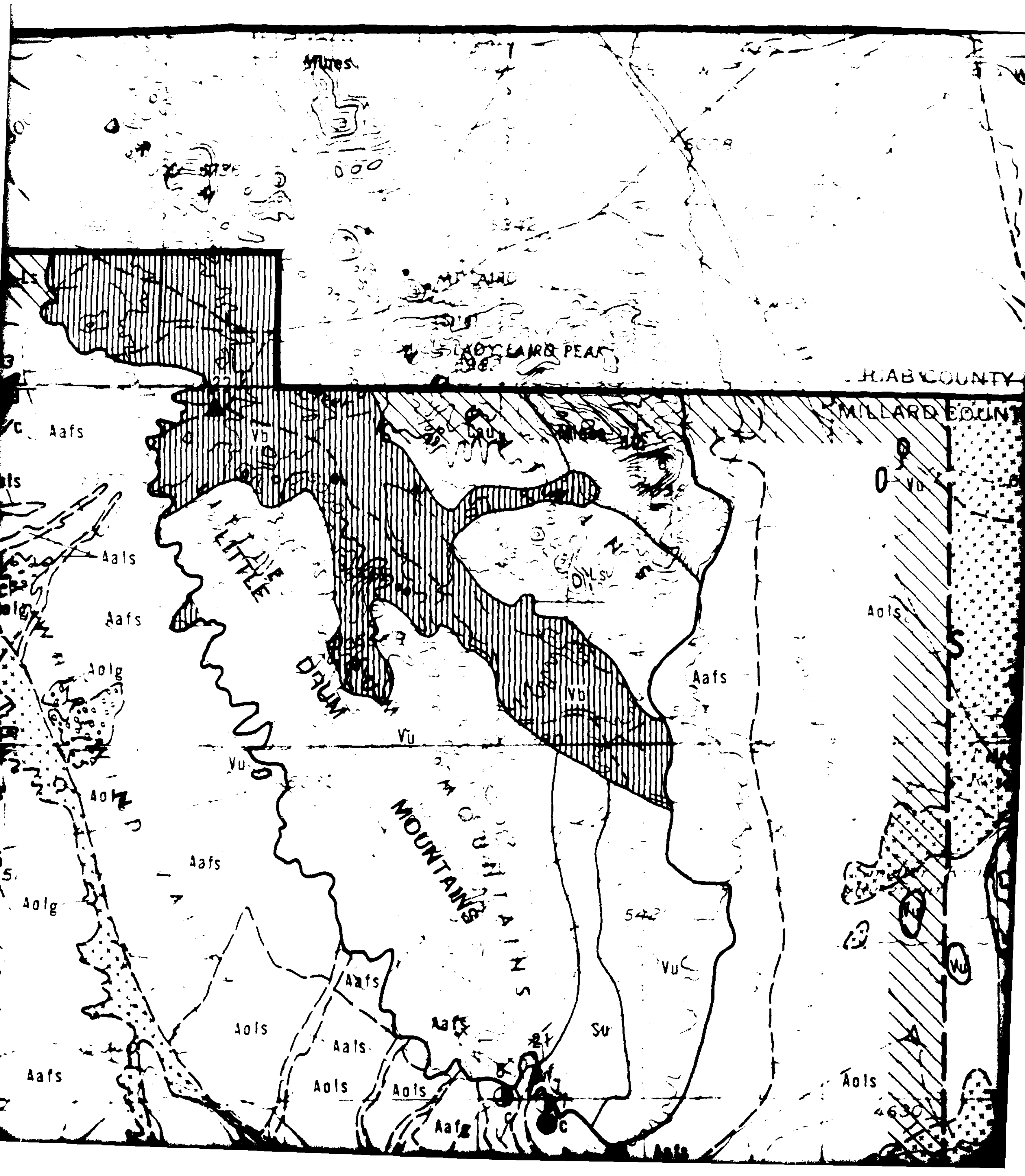
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

DRAWING 1

FUGRO NATIONAL, INC.



Sand Pass
Roadside
5043
4650
8
SWASEY
MOUNTAINS
Cau
Aafs
Aals
Aols
Aolg
f/c
Loading
4660
26
6
T
U
Coyote Spring
Underground
ule Spring


Mines
LADY LAIRD PEAK
JUAB COUNTY
MILLARD COUNTY
LITTLE DRUM MOUNTAINS
MOUNTAINS
Aafs
Aals
Aolg
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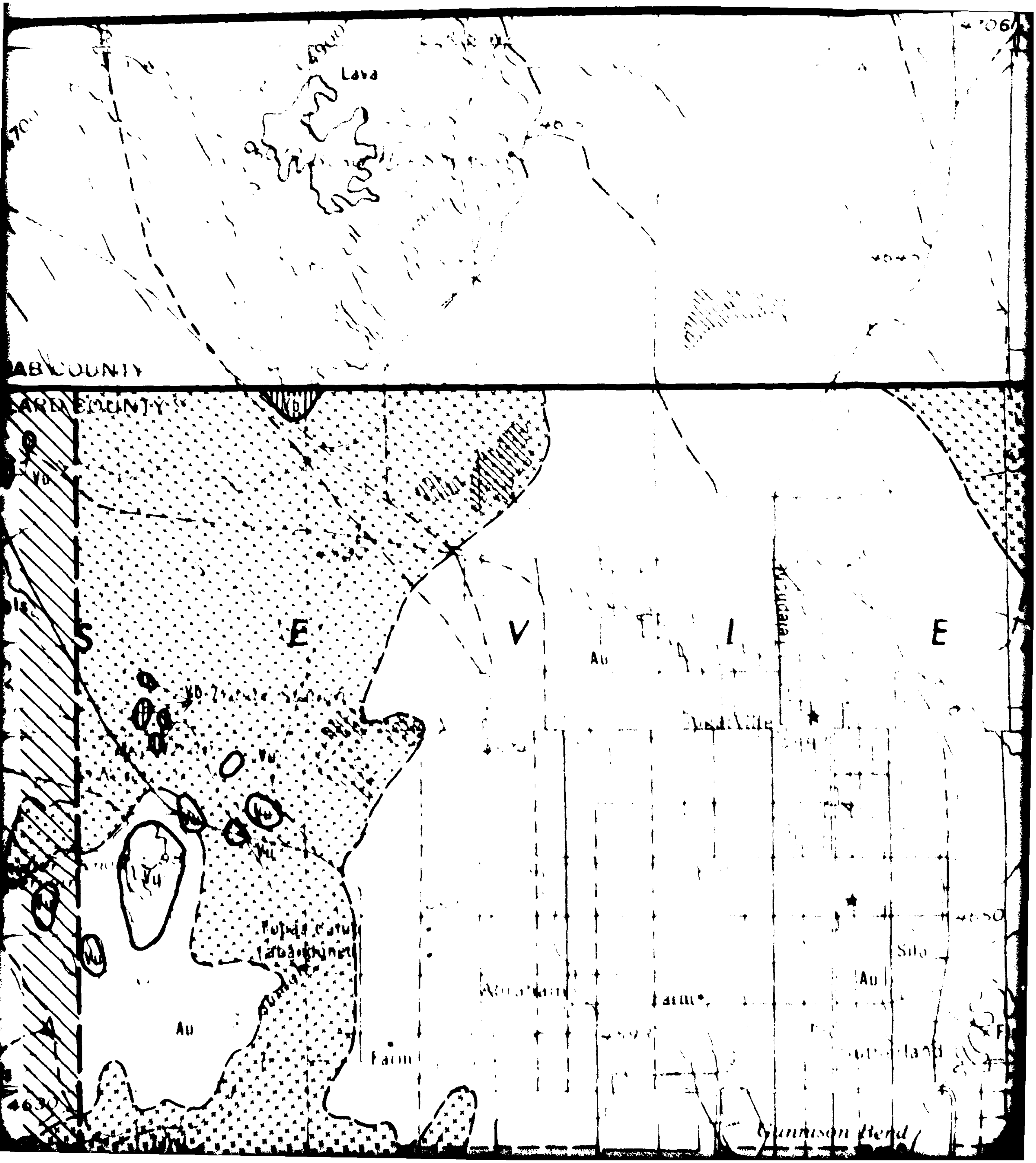
Vb
Vu
Su
542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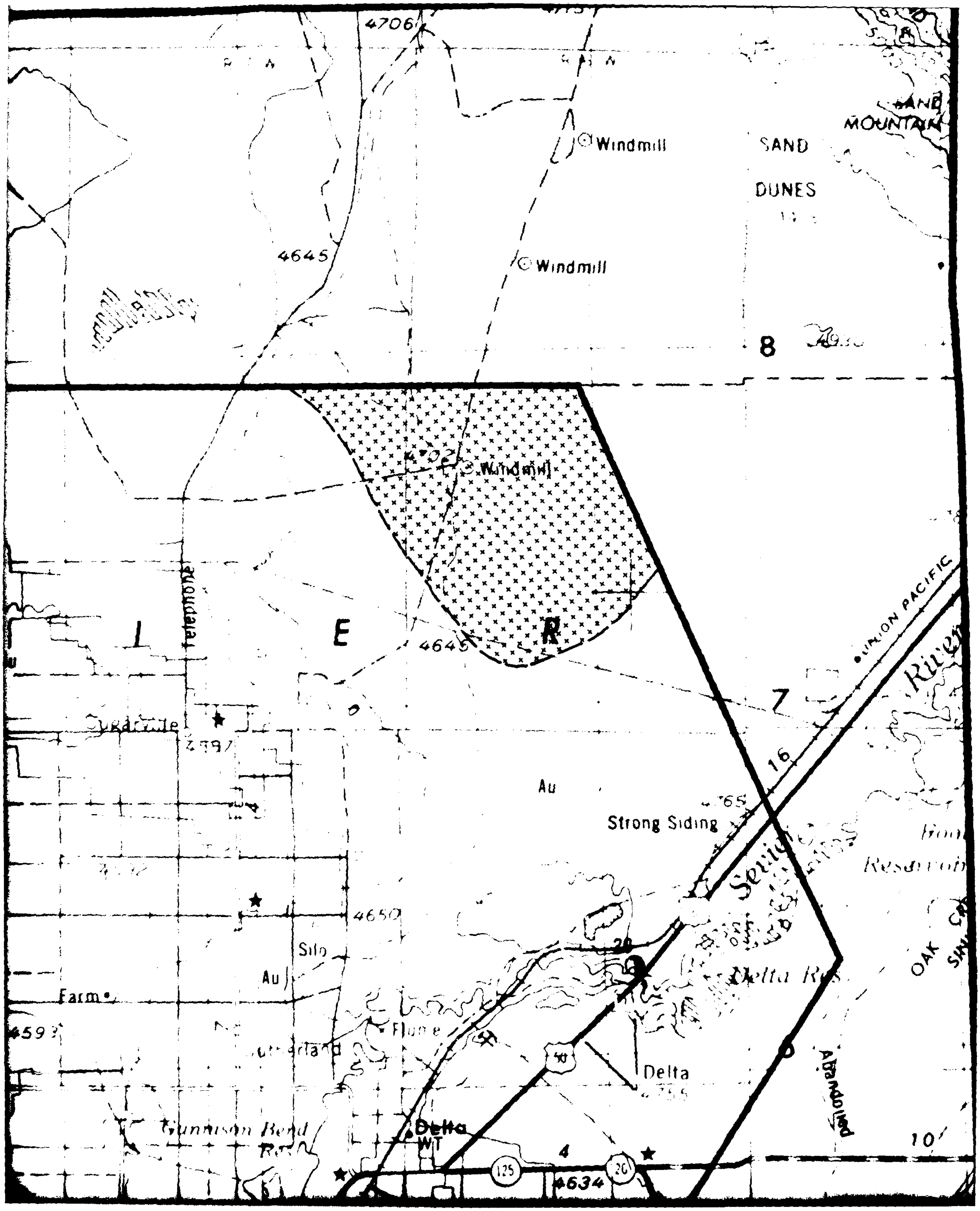
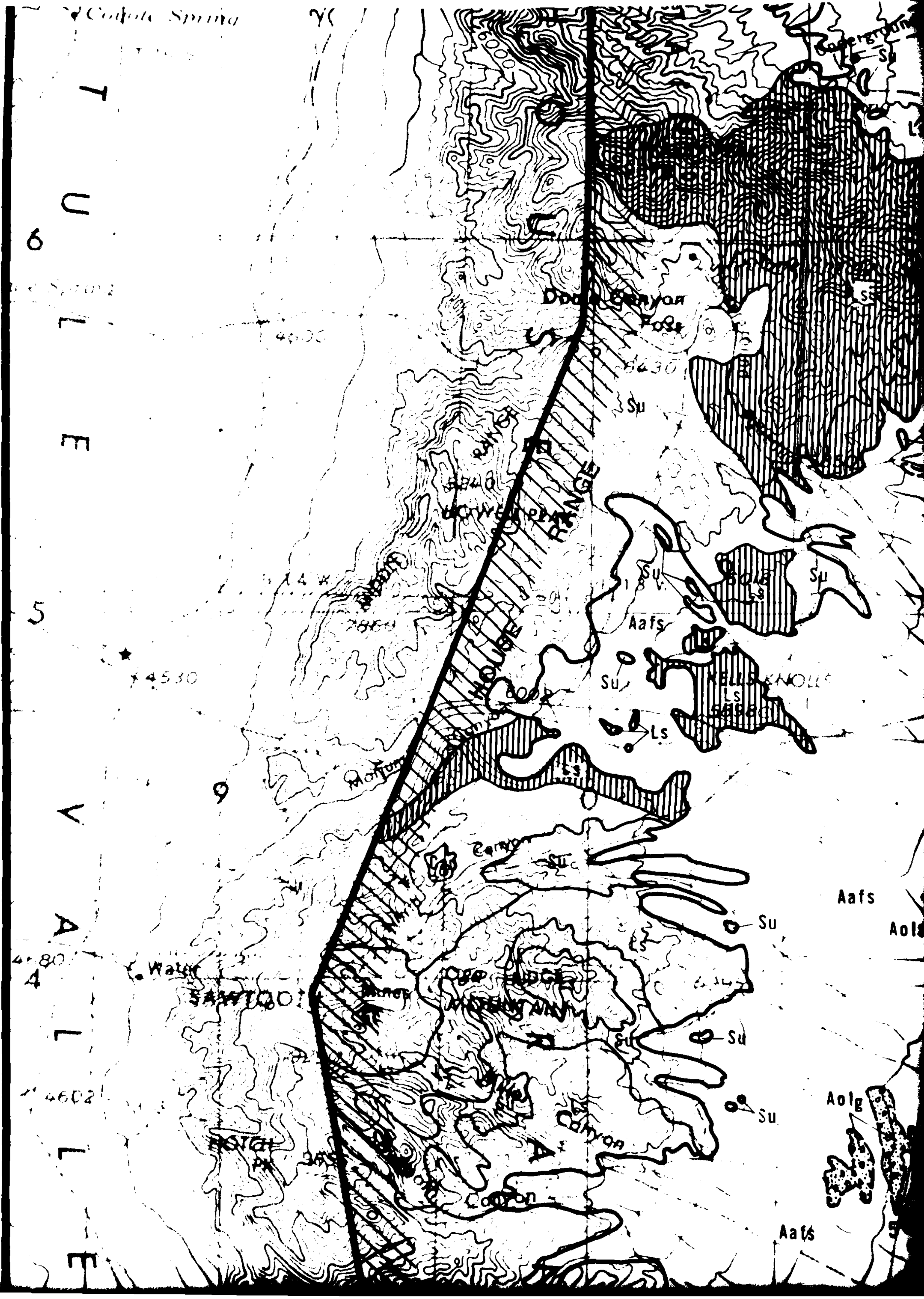
Au
Vu
Vb
S E V I E
Silo
Farm
Gunnison Bend



4706
Windmill
SAND
DUNES
SAND
MOUNTAIN
4645
Windmill
8
Windmill
I
E
R
4645
7
UNION PACIFIC
River
16
Au
Strong Siding
Sevier
Reservoir
Delta Res
OAK
Silo
Au
Farm
Flume
Delta
Gunnison Bend
Delta
WT
4
4634
125
50
10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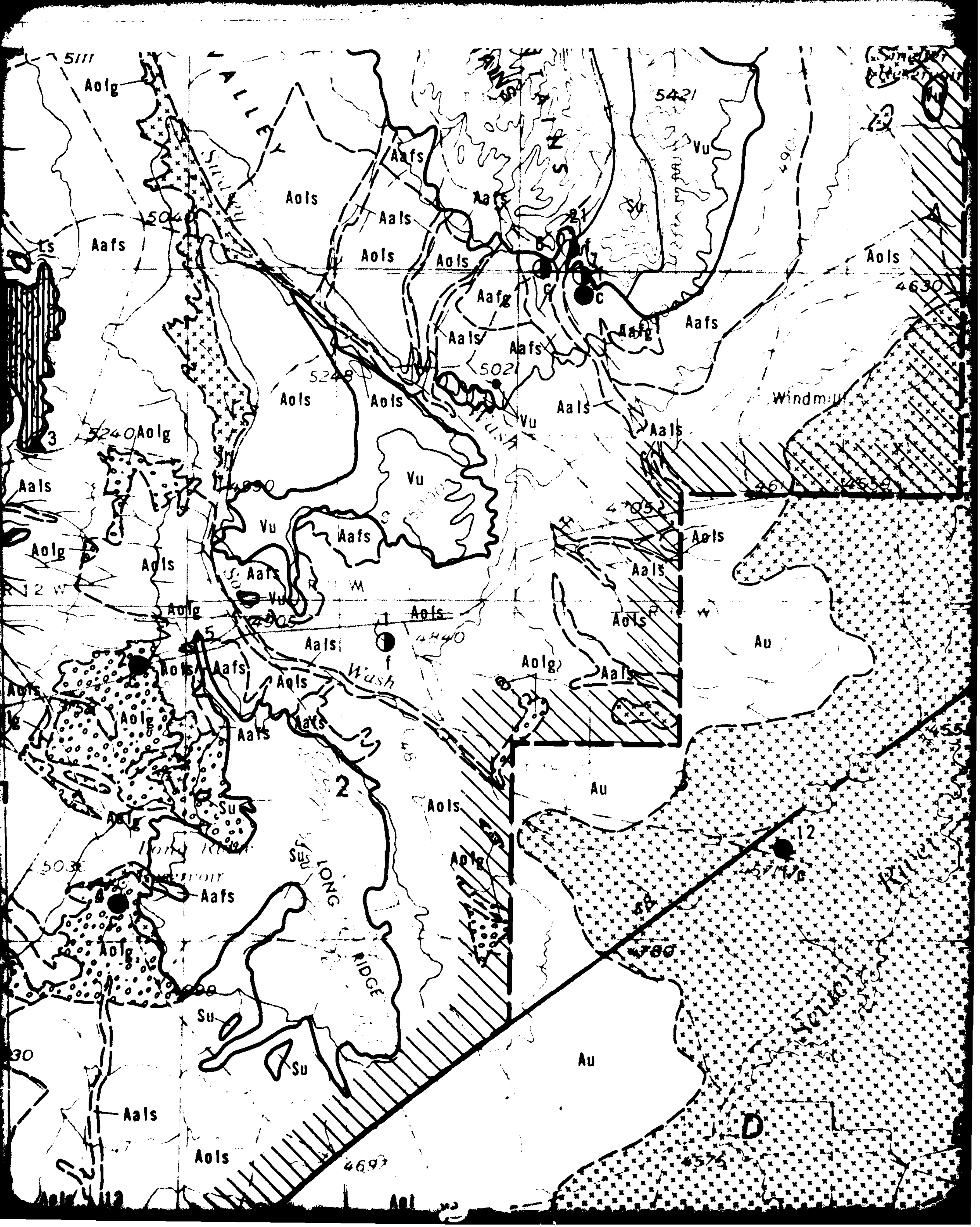
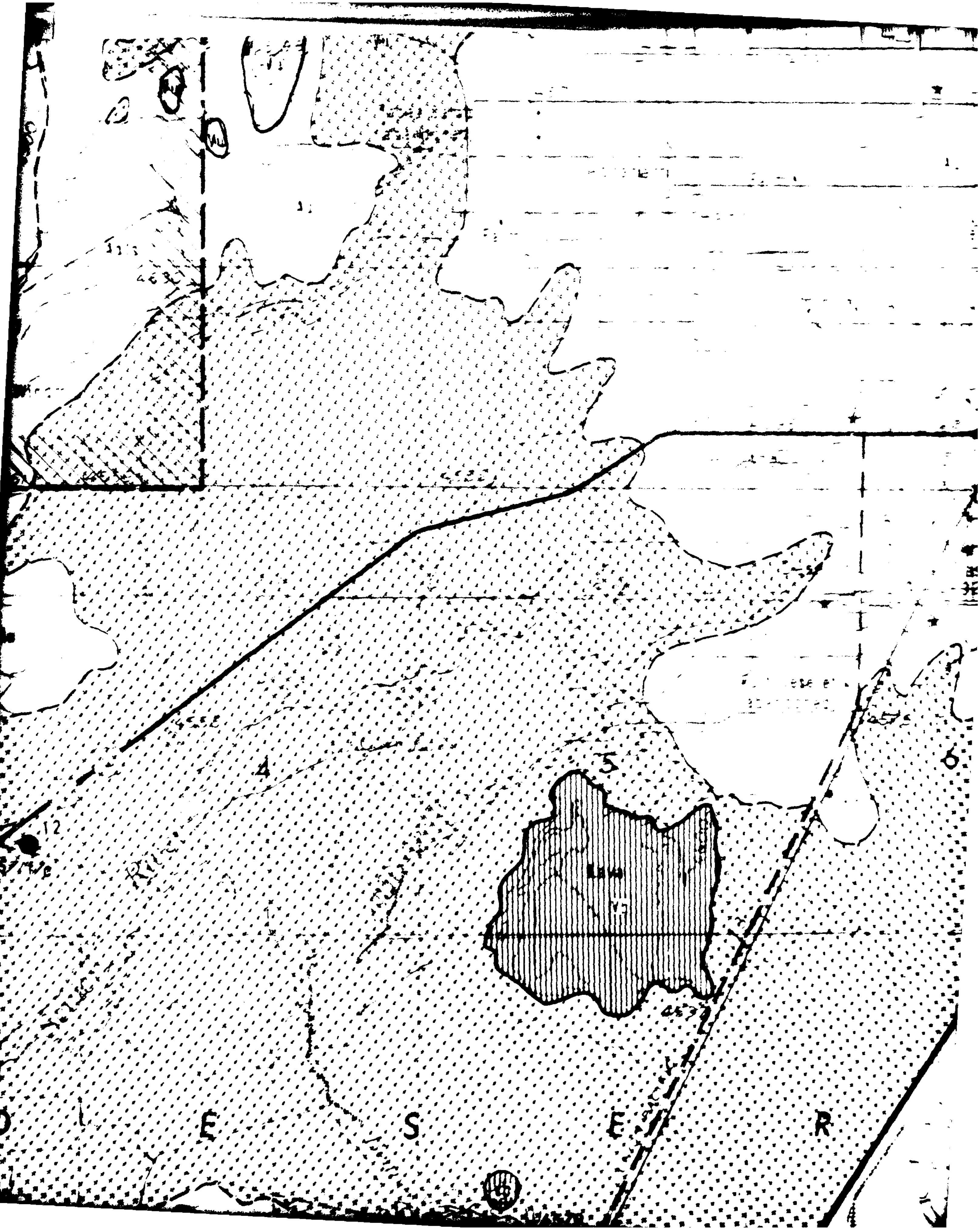
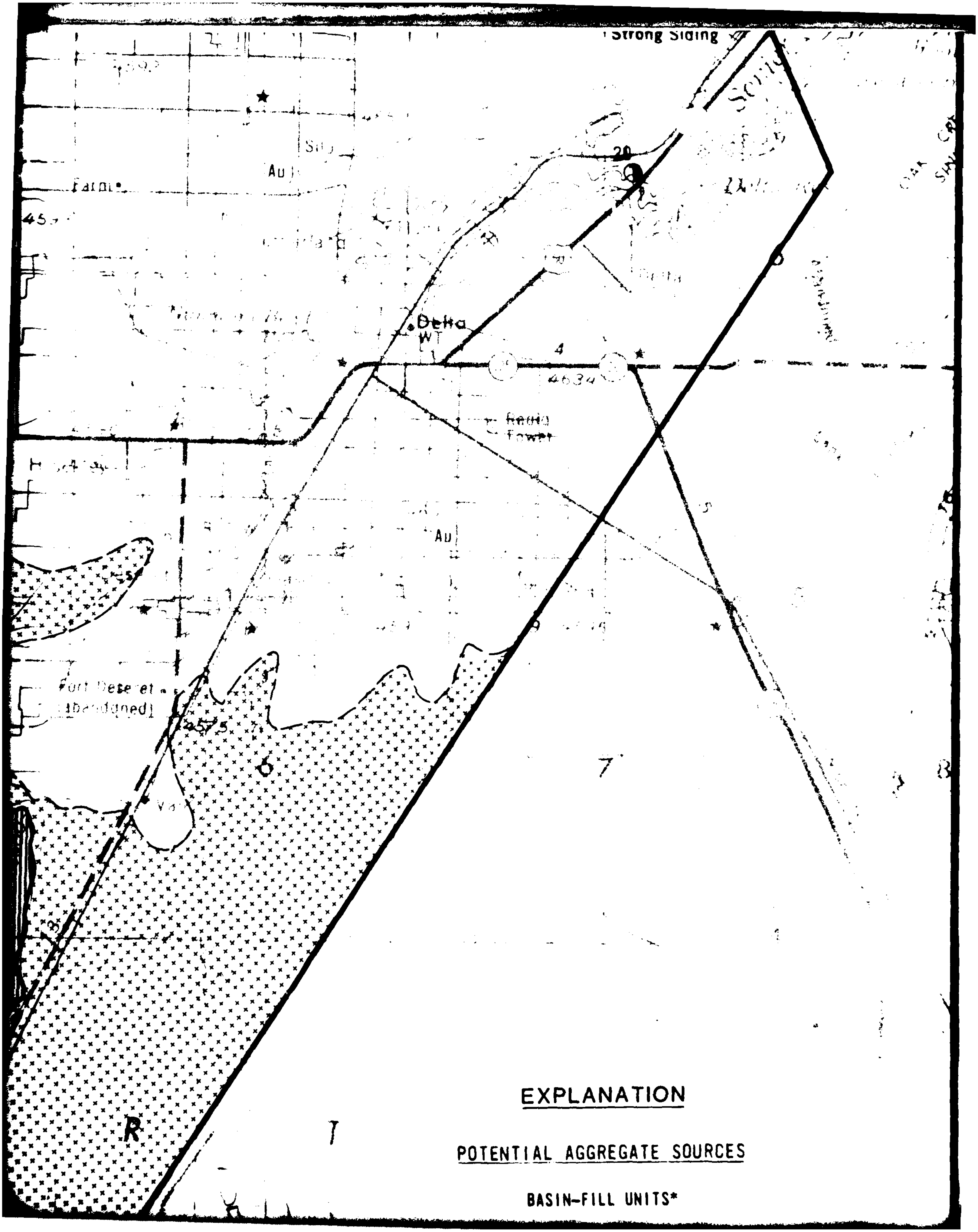
HOUSE RANGE
Dome Canyon
Su
Ls
Aafs
Aolg
KELLS KNOLLS
Canyon
Water
Mines


VALLEY
5421
Aolg
Aafs
Aols
Aals
Aafg
Vu
Au
Su
Ls
Wash
Windmill
LONG
RIDGE
R 12 W
5240
5248
4890
4905
4840
4705
4630
4575
12
D

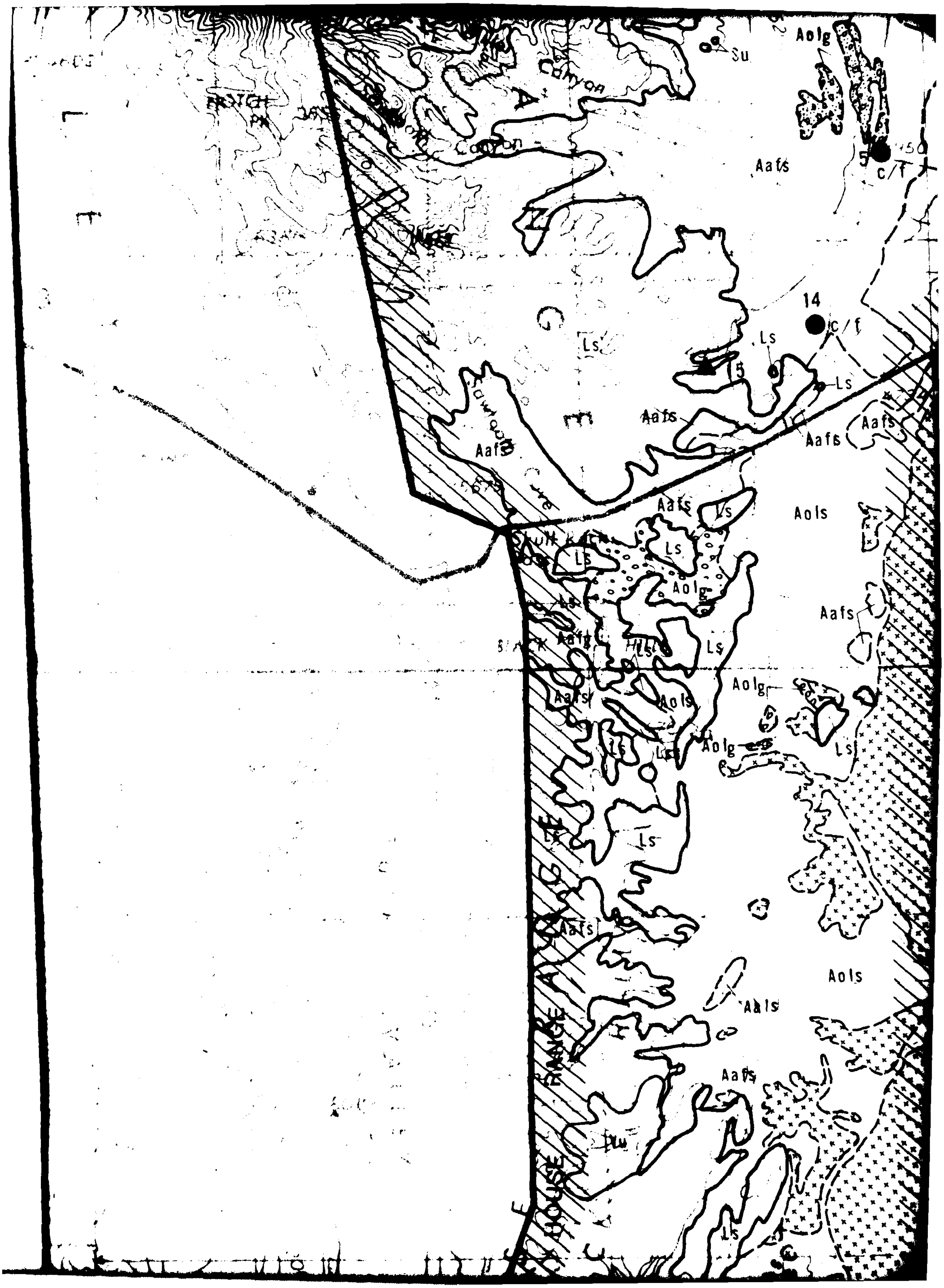

4
5
6
12
D E S E R

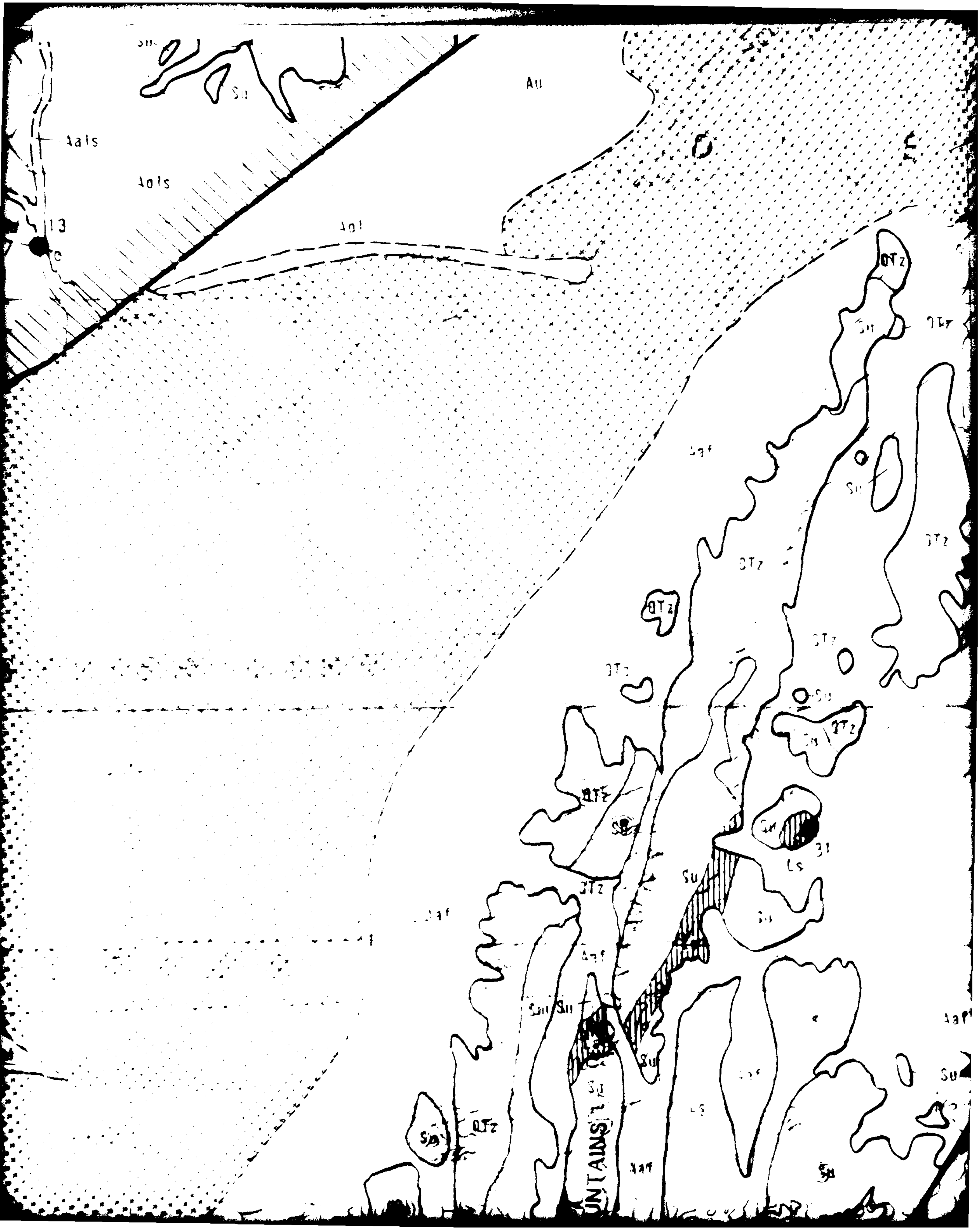


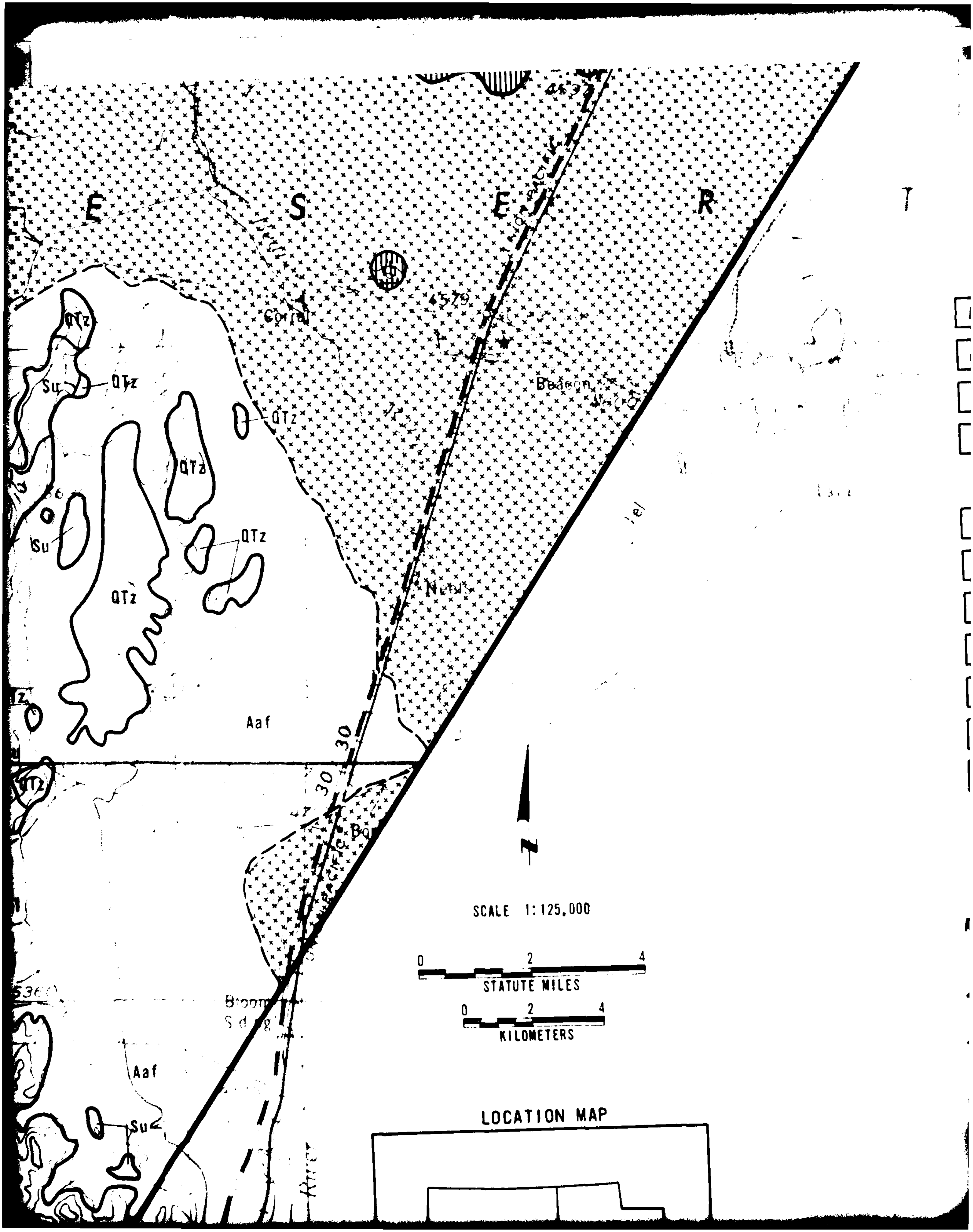
EXPLANATION

POTENTIAL AGGREGATE SOURCES

BASIN-FILL UNITS*


Aolg
Su
Canyon
Aafs
5
c/f
14
c/f
Ls
Ls
Ls
Aafs
Aafs
Aafs
Aafs
Aafs
Aols
Ls
Ls
Aolg
Aafs
Ls
Aafs
Aolg
Aafs
Aols
Ls
Ls
Aolg
Ls
Ls
Aafs
Aols
Aals
Aafs
Ls


Au
Su
Aals
Aols
13
Aol
QTz
Aaf
Cs
31
UNTAINS


E S E R
T
Corral
4579
Beacon
QTz
Su
QTz
QTz
QTz
Su
QTz
QTz
Aaf
30
30
Aaf
Su
SCALE 1:125,000
0 2 4
STATUTE MILES
0 2 4
KILOMETERS
LOCATION MAP

EXPLANATION

POTENTIAL AGGREGATE SOURCES

BASIN-FILL UNITS

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

ROCK UNITS

[illegible]	[illegible]
[illegible]	[illegible] rocks [illegible]
[illegible]	[illegible] rocks
[illegible]	[illegible]
[illegible]	Limestone
[illegible]	[illegible] rocks [illegible]
[illegible]	Sedimentary rocks [illegible]

[illegible]

SYMBOLS

Qaf [illegible]

[illegible]

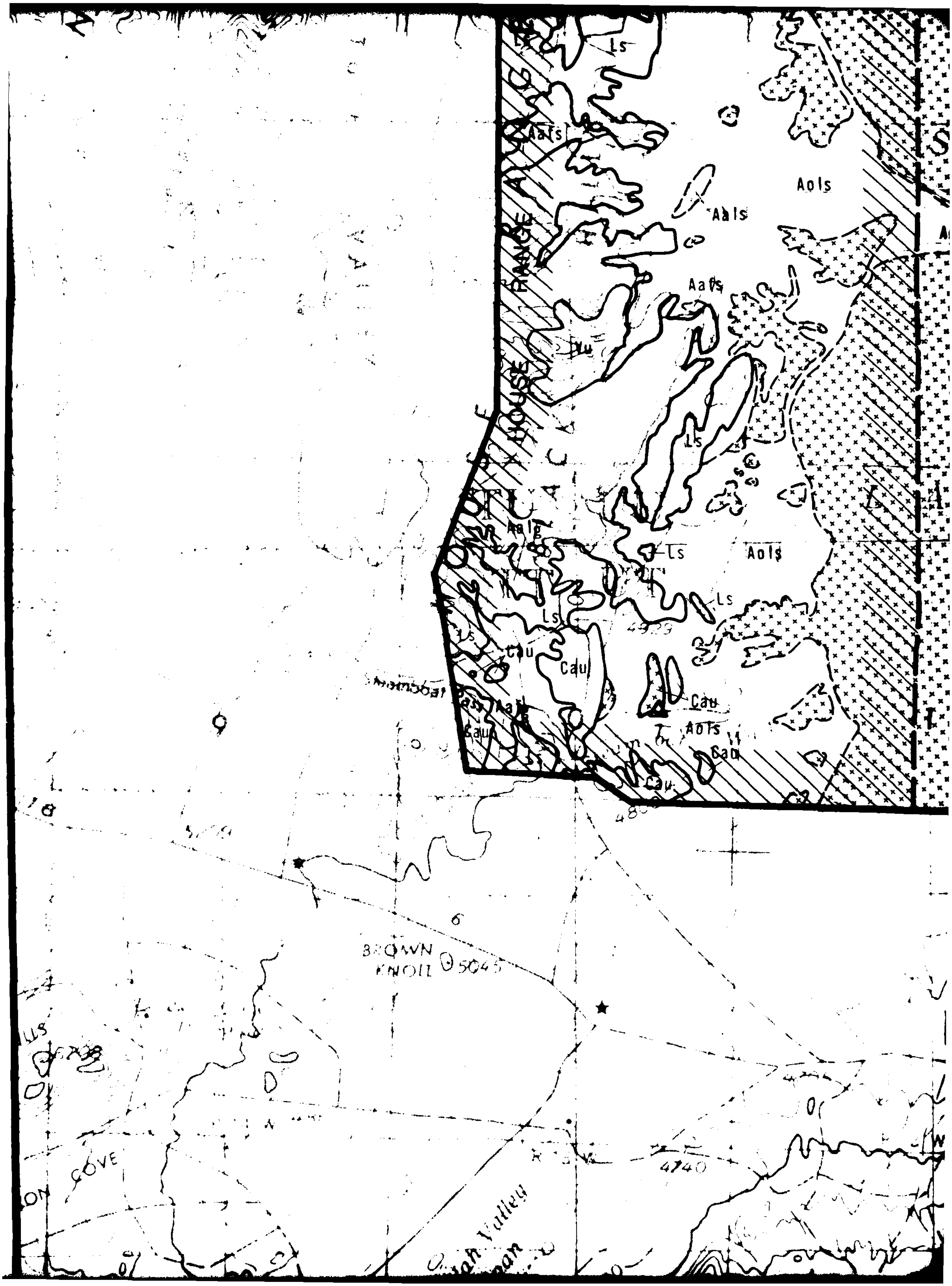
[illegible]

[illegible]

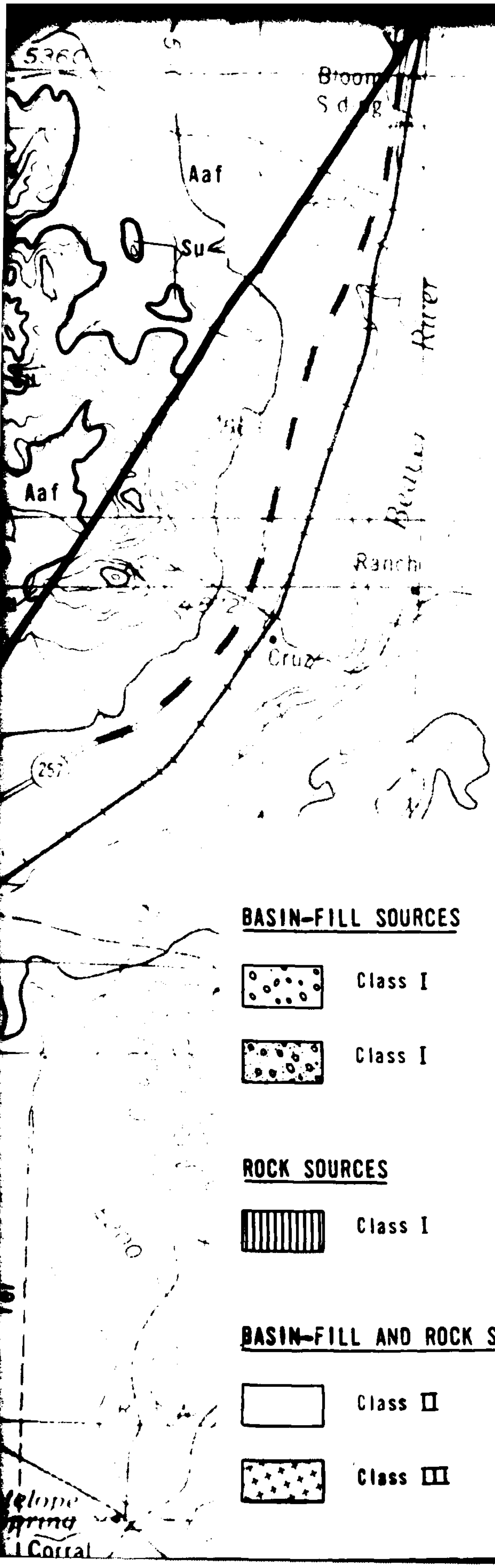
[illegible]

ROAD NATIONAL AGGREGATE RESOURCES SAMPLED AND TESTED FIELD STATIONS

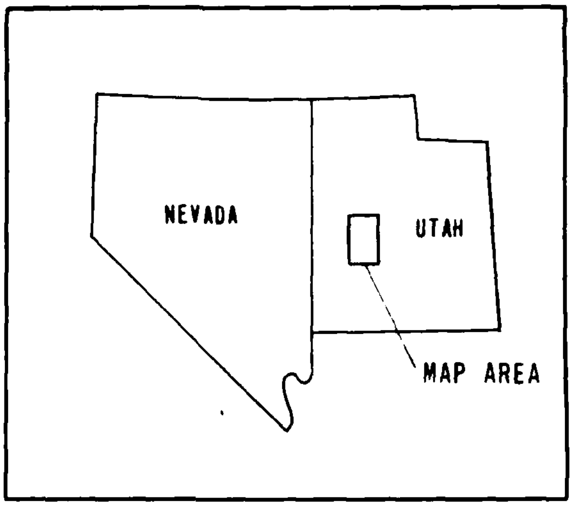
BASIN-FILL AGGREGATE SAMPLE COARSE (c) AND FINE (f)	CRUSHED ROCK SAMPLE	CLASSIFICATION


Ls
Aals
Aols
HOUSE RANGE
Aalg
Cau
BROWN
KNOLL 5045
4740
COVE
Valley

S E V I E R
L A K E
Aols
Aol
Aaf
Su
Ls
Qtz
Water
CRICKET MOUNTAINS
2
3
Au
Wu
RED HILLS
19
RED ROCK KNOLL
5237
BOTTOMS
UNION PACIFIC
VER
4890
Water



LOCATION MAP



CLASSIFICATION SYSTEM

BASIN-FILL SOURCES

[pattern]	Class I	- Potentially Suitable Coarse,
[pattern]	Class I	- Potentially Suitable Coarse and Fine (Multiple Source) Concrete Aggregate and Road-Base Material Source

ROCK SOURCES

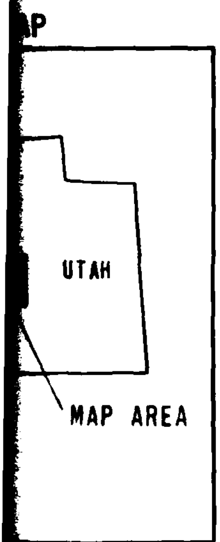
[pattern]	Class I	- Potentially Suitable Crushed Rock, Concrete Aggregate and Road-Base Materials Source

BASIN-FILL AND ROCK SOURCES

[blank]	Class II	- Possibly Unsuitable Coarse, Fine and or Crushed Rock Concrete Aggregate Potentially Suitable Road-Base Material Source
[pattern]	Class III	- Unsuitable Coarse, Fine and or Crushed Rock Concrete Aggregate or Road-Base Material Source

4

4



SYSTEM

e,

e and Fine (Multiple Source)
d-Base Material Source

ed Rock,
d-Base Materials Source

, Fine and or Crushed Rock Concrete Aggregate
Base Material Source

d/or Crushed Rock
-Base Material Source

Aafg Material type (Aaf) and Grain Size Designation (g)
Grain size designations are gravel (g) and sand (s)
Material type (Aaf) and Grain Size designation (g)

Geologic Contact, Dashed Where Approximate

Approximate Concrete Aggregate and or
Road-Base Materials Source Boundary

Verification Study Area

FUGRO NATIONAL AGGREGATE RESOURCES SAMPLED
AND TESTED FIELD STATIONS

BASIN-FILL AGGREGATE SAMPLE COARSE (c) AND FINE (f)	CRUSHED ROCK SAMPLE	CLASSIFICATION
●	▲	CLASS I
◑	◭	CLASS II
○	△	CLASS III

Note: See Corresponding Map Number in Appendix A for Detailed Information

AGGREGATE RESOURCES MAP
WHIRLWIND VALLEY, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

DRAWING
2

FUGRO NATIONAL, INC.

DATE

ILME