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Yucca Mountain Site Characterization Project

Preliminary Mapping of Surficial Geology of Midway Valley Yucca Mountain Project, NYE County, Nevada

Interim Data Report

J. R. Wesling, T. F. Bullard, F. H. Swan, R. C. Perman,
M. M. Angell, J. D. Gibson

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PRELIMINARY MAPPING OF SURFICIAL GEOLOGY OF MIDWAY VALLEY YUCCA MOUNTAIN PROJECT, NYE COUNTY, NEVADA INTERIM DATA REPORT

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ABSTRACT

The tectonics program for the proposed high-level nuclear waste repository at Yucca Mountain in southwestern Nevada must evaluate the potential for surface faulting beneath the prospective surface facilities. To help meet this goal, Quaternary surficial mapping studies and photolineament analyses were conducted to provide data for evaluating the location, recency, and style of faulting within Midway Valley at the eastern base of Yucca Mountain, the preferred location of these surface facilities. This interim report presents the preliminary results of this work.

Ten surficial map units were identified in Midway Valley, primarily on the basis of landform morphology, geomorphic position, relative preservation of the original surface morphology, desert pavement development, desert varnish cover, clast weathering, and soil development. Map units include remnants of eight separate alluvial fan and terrace surfaces, including the modern fluvial surface, an undifferentiated colluvium/debris flow terrain, and the adjacent bedrock terrain. The oldest surface (Q_0) is preserved as a single terrace remnant and may be Plio-Pleistocene. Younger surfaces, possibly ranging in age from early or middle Pleistocene (Q_1) to latest Pleistocene/early Holocene (Q_5), persist as stream terraces and alluvial fan surfaces. Holocene units occur as low terraces and vegetated bars (Q_6) along active washes (Q_7). Undifferentiated colluvial units of at least three different ages mantle the hill slopes. Preliminary descriptions of the surfaces, and the soils and underlying deposits associated with those surfaces, were made at localities representing each major map unit.

Photolineaments of possible tectonic origin were identified within undifferentiated colluvium along the Paintbrush Canyon and Bow Ridge faults. No displacement of alluvial surfaces has been recognized across lineaments in other parts of the valley.

This report was prepared under WBS 1.2.3.2.8.4.2.

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1.0 INTRODUCTION

This interim data report presents results of preliminary mapping of the surficial geology near the prospective surface facilities for the potential repository for high-level radioactive waste at Yucca Mountain, Nye County, Nevada. This ongoing work is part of Site Characterization Plan (SCP) Study 8.3.1.17.4.2, "Evaluating the Location and Recency of Faulting Near Prospective Surface Facilities" (DOE, 1988, 1989).

The primary objective of SCP Study 8.3.1.17.4.2 (DOE, 1989) is to acquire surface and near-surface geologic data to evaluate the potential for surface fault rupture within Midway Valley, the potential location of the prospective surface facilities (Figure 1-1). The SCP study consists of two activities: Activity 1, to characterize the surficial geology, including describing the lithology exposed in soil pits and exploratory trenches, and identify appropriate locations for the long (greater than 100 m) trenches; and Activity 2, to excavate and log the long and supplemental trenches (DOE, 1988). Activity 1 requires information on the distribution, age, and characteristics of Quaternary/Tertiary surficial units and Tertiary bedrock units; the structural and stratigraphic relationships of these surficial and bedrock units; and the characteristics, ages, and distribution of faults that displace these units, especially those of Quaternary age. The studies described in this interim report were conducted to provide some of the data needed to meet the objectives of Activity 1. The data obtained from SCP Study 8.3.1.17.4.2 will be used in conjunction with other site characterization activities to support (1) the siting of surface facilities, and (2) an assessment of the potential for surface faulting at the prospective site.

1.1 SCOPE OF WORK

This interim report presents the status and results to date of the following activities: (1) interpretation of surficial map units and lineaments from aerial photographs; (2) field-checking of map relations in selected areas; (3) characterization of surface morphology and surface-clast weathering of map units; and (4) descriptions of deposits and soils associated with those surfaces. Observations of deposits and of the degree of

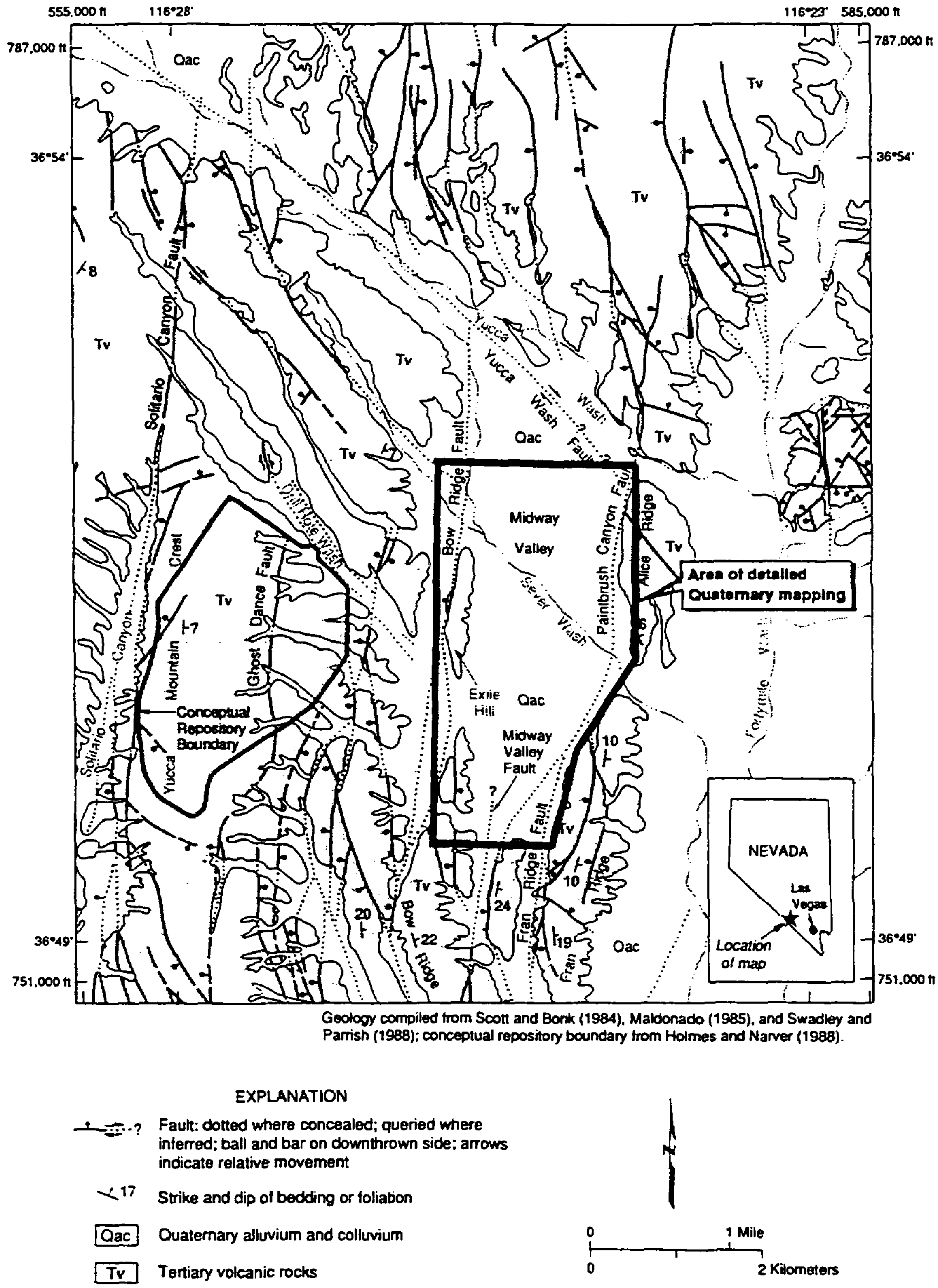

Figure 1-1. Generalized geologic map of Midway Valley showing area of detailed Quaternary mapping presented on Plates 1 and 2.

soil formation were limited to available exposures, such as channel cuts and existing soil pits and trenches.

Surficial Mapping - The surficial geology of the Midway Valley area was mapped by delineating map units on aerial photographs and examining those units in the field. Stereoscopic pairs of 1:6000-scale color and color-infrared aerial photographs were interpreted, and the geologic contacts were transferred to 1:6000-scale topographic base maps (Plates 1 and 2). Field investigations were conducted to check the geologic contacts and to collect data on the identified map units. The geomorphic surfaces and the soils and deposits associated with those surfaces were described.

Although SCP Study 8.3.1.17.4.2 (DOE, 1989) calls for soil test pits and trenches to be excavated and described as part of Activity 1, the work reported in this interim report was limited to an examination of available outcrops, most of which lie in the northern part of the valley. Excavation of soil pits and trenches has been delayed because of temporary environmental restrictions.

Photolineament Interpretation - Lineaments in the Midway Valley area were studied using aerial photographs at scales of 1:6000, 1:12,000, and 1:60,000. The purpose of this activity was to identify lineaments that cannot be attributed directly to nontectonic causes (i.e., cultural features such as roads, trails, or fences or nontectonic natural features such as depositional contacts) and that might intersect or project toward areas where the surface facilities might be located. As part of this activity, lineaments along known Quaternary active faults in the vicinity of Midway Valley (i.e., Paintbrush Canyon and Bow Ridge faults) were identified to provide calibration regarding the nature of lineaments along active faults in Midway Valley. Because the objective of the lineament analysis was to identify any feature that might be related to the potential for surface faulting in Midway Valley, and because it can be difficult to distinguish between tectonic and nontectonic lineaments, a conservative approach was taken. To avoid overlooking potentially significant features, all lineaments were mapped unless the photogeologic interpretation indicated that they could be attributed to nontectonic causes. Consequently, many of the mapped lineaments do not represent tectonic features.

Field investigations are ongoing; the results presented in this interim data report are preliminary. Additional field mapping, surface characterization, description of deposits and soils, and dating of geologic materials are needed to fulfill the study plan objectives. In particular, surface-disturbing activities, including the excavation of soil test pits and trenches, are essential to complete the required scope of work.

1.2 ACKNOWLEDGEMENTS

The investigations described in this report were conducted by the following individuals.

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Technical review of this report was provided by David Borns and Les Shephard (SNL). Editorial review was provided by Moya Melody (Geomatrix Consultants) and Catherine Hensley (SNL). This work was supported by the U.S. Department of Energy under Contract No. DE-AC04-76DP00789 to SNL.

2.0 GEOLOGIC SETTING AND PREVIOUS INVESTIGATIONS

Midway Valley is located approximately 140 km northwest of Las Vegas, Nevada, on the east side of Yucca Mountain on the Nevada Test Site (NTS) (Figure 1-1). Local elevations range from a low of about 1067 m (3500 ft[1]) in Sever Wash between Alice and Fran ridges, to 1756 m (5760 ft) on the crest of Yucca Mountain. The climate of the region is arid. Annual rainfall is less than 25 cm (DOE, 1988), and no perennial streams are located near Yucca Mountain. Two intermittent streams, Sever Wash and Yucca Wash, flow southeastward across the valley.

Midway Valley is an alluvium-filled structural and topographic valley that lies between Yucca Mountain to the west and Fran Ridge and Alice Ridge to the east (Figure 1-1). The upper Tertiary and Quaternary sediments that fill Midway Valley consist mostly of alluvial fan deposits (fluvial and debris-flow sediments), colluvial deposits, and some thin eolian deposits (described in this study; see also Hoover et al., 1981; Swadley et al., 1984; and Hoover, 1989).

The Midway Valley area lies within a system of north-trending normal faults (Scott and Bonk, 1984). This system includes the Paintbrush Canyon fault on the east side of Midway Valley and the Bow Ridge fault on the west side. Where exposed in bedrock, both faults dip steeply toward the west and have down-on-the-west displacement (Scott and Bonk, 1984). In the center of the southern part of Midway Valley, a north-trending concealed fault, which is associated with exposed bedrock faults within Bow Ridge, is mapped for approximately 2 km beneath the valley alluvium (Scott and Bonk, 1984). The bedrock faults were also mapped by Lipman and McKay (1965), who connected them to a concealed fault more than 6 km long that was mapped through the central part of Midway Valley; this central fault subsequently was named the Midway Valley fault by Neal (1986).

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[1] English units shown in parenthesis are reported in feet in the original references.

Most of the displacement along the Paintbrush Canyon and Bow Ridge faults, as well as along parallel faults elsewhere near Yucca Mountain, is interpreted by Carr (1984) to have occurred during the Miocene, more or less synchronously with a period of extensive silicic volcanism in this region. Both faults apparently have been active during the Quaternary (DOE, 1988). The apparent slip rates (vertical separation) on these two faults during the Quaternary are markedly lower than during the Tertiary (Gibson et al., 1990).

2.1 PHYSIOGRAPHY OF THE MIDWAY VALLEY/YUCCA MOUNTAIN AREA

For the purposes of this study, Midway Valley is defined as the alluvium-filled valley that is bounded on the north and south by abrupt rises in topography that are associated with Tertiary bedrock outcrops, on the west by the flank of Yucca Mountain, and on the east by Alice Ridge and Fran Ridge (Figure 1-1). Midway Valley includes parts of both Sever Wash and Yucca Wash drainage basins (Figure 2-1). Both drainage systems are tributary to Fortymile Wash (Figure 1-1).

Sever Wash Drainage Basin - Most of Midway Valley lies within the Sever Wash drainage basin. This basin, which drains the 35-km^2 area northwest of the gap between Alice and Fran ridges, includes part of the eastern flank of Yucca Mountain (Figure 2-1). Elevations in the drainage basin range from about 1058 m (3470 ft) at the mouth of Sever Wash to 1756 m (5760 ft) at the crest of Yucca Mountain, for a total basin relief of almost 700 m. Alluvium southwest of Sever Wash is derived mostly from subbasins on the eastern flank of Yucca Mountain; alluvium northeast of Sever Wash is derived from drainages in the north that are now part of the Yucca Wash drainage basin.

The Sever Wash drainage basin can be divided into two areas, based on differences in depositional and topographic characteristics: (1) Midway Valley on the east, and (2) the eastern flank of Yucca Mountain on the west (Figure 2-1). The part of Midway Valley that comprises the eastern third of the Sever Wash drainage basin is characterized by alluvial fan aggradation; only relatively minor erosion occurs within this area. Unconsolidated alluvial deposits in this area range in thickness from 0 to 150 m

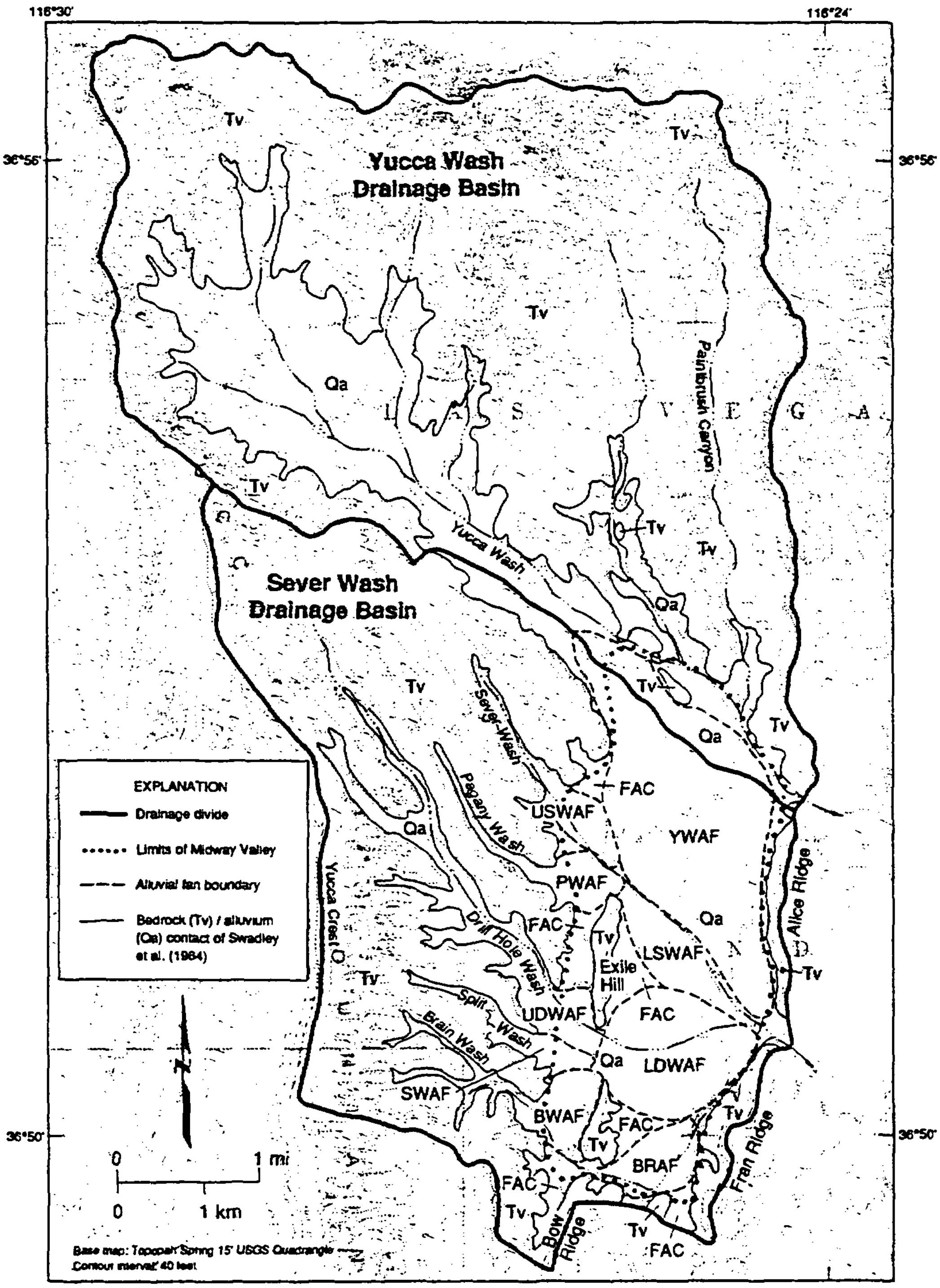

Figure 2-1. Map showing Yucca Wash and Sever Wash drainage basins west of Alice Ridge. Alluvial fans in Midway Valley include: BRAF = Bow Ridge alluvial fan; LDWAF = Lower Drill Hole Wash alluvial fan; UDWAF = Upper Drill Hole Wash alluvial fan; FAC = Area of undifferentiated small alluvial fans, alluvial and colluvium; LSWAF = Lower Sever Wash alluvial fan; USWAF = Upper Sever Wash alluvial fan; SWAF = Split Wash alluvial fan; YWAF = Yucca Wash alluvial fan

or more (Neal, 1985). Eolian and colluvial sediments comprise a minor proportion of the unconsolidated sediments in the valley.

The area west of Midway Valley generally is underlain by gently (10 to 25 degrees) east- or southeast-dipping Tertiary volcanic strata that form the dip slope of Yucca Mountain. Drainages in this part of Sever Wash drainage basin have narrow, steep-sided valleys that are inclined in the same direction but generally have steeper gradients than the dip of the underlying Tertiary strata. These drainages emerge from the mountain front west of the Bow Ridge/Exile Hill topographic trend. North of Drill Hole Wash, drainages generally flow southeast; south of Drill Hole Wash they typically flow east. These flow directions seem to reflect the direction of dip of the underlying rock units (Figure 1-1; Scott and Bonk, 1984).

Yucca Wash Drainage Basin - Yucca Wash drainage basin drains a 44-km^2 area west of the water gap where Yucca Wash exits Midway Valley at the north end of Alice Ridge (Figure 2-1). This basin includes about 1.3 km^2 of the northernmost part of Midway Valley. Elevations within the drainage basin range from about 2045 m (6708 ft) to 1110 m (3640 ft), a total basin relief of 935 m.

Like the Sever Wash drainage basin, the Yucca Wash drainage basin can be separated into two areas of differing topographic characteristics: (1) an alluviated valley along Yucca Wash, and (2) upland areas of volcanic bedrock (Figure 2-1). Yucca Wash flows southeastward, subparallel to the southern boundary of the drainage basin. A small alluvium-filled valley lies within the headwater reach; the thickness of alluvium in this reach is unknown. The valley is constricted to the southeast, where the southern drainage divide leaves the bedrock area, and widens again where it intersects Midway Valley.

North of Yucca Wash, larger tributary streams (e.g., the stream within Paintbrush Canyon) flow from north to south. Canyons are relatively steep-sided and contain narrow strips of alluvium along the valley bottoms. The tributary streams drain areas of intracaldera rhyolite flows and tuffs that form a complex stratigraphic sequence that is faulted. This geologic setting produces drainage patterns distinctly different from those in the Sever Wash drainage basin.

Evidence of Stream Capture - Several lines of evidence suggest that part or all of Yucca Wash drainage basin was captured from an ancestral Sever Wash drainage basin. First, the apex of the Yucca Wash alluvial fan coincides with the drainage divide between the two basins, suggesting that a stream once flowed near the present location of the drainage divide. The areal extent of the Sever Wash drainage basin above the Yucca Wash alluvial fan is disproportionally small relative to the size of the alluvial fan. Comparable-size drainage basins on the east flank of Yucca Mountain have much smaller fans (Figure 2-1). Second, many clasts that are found in the Yucca Wash alluvial fan, including in that part of the fan within the Sever Wash drainage basin, are similar in lithology to the rhyolite lavas of Fortymile Canyon, which crop out in the headwaters of the Yucca Wash drainage basin and not in Sever Wash. Third and finally, reconnaissance of the alluvial stratigraphy along Yucca Wash suggests that higher alluvial surfaces along the wash grade toward Sever Wash, whereas lower alluvial surfaces grade toward Yucca Wash. Additional work is needed to assess the cause and timing of stream capture. This information is important for understanding the differences in landscape evolution between the northern and southern parts of Midway Valley.

2.2 PREVIOUS STUDIES OF QUATERNARY STRATIGRAPHY NEAR THE NEVADA TEST SITE

Several researchers have investigated the stratigraphy of the Tertiary and Quaternary unconsolidated sediments in the NTS area. The major Quaternary/Tertiary stratigraphic divisions for the NTS region were defined initially by Hoover and Morrison (1980). A summary of the detailed Quaternary stratigraphy of the Yucca Mountain region was presented by Hoover et al. (1981), building on work by Hoover and Morrison (1980) as well as by Bull and Ku (1975) and Morrison (1967). Swadley and Hoover (1983) and Swadley et al. (1984) retained the stratigraphy of Hoover et al.

(1981) to describe the Quaternary stratigraphy in the NTS area and at Crater Flats to the west of Yucca Mountain, primarily for use in fault studies. Hoover (1989) elaborated on the work of Hoover et al. (1981), retaining the established stratigraphy while modifying the assigned ages of stratigraphic units proposed by Swadley et al. (1984). No detailed Quaternary geologic studies have been published on Midway Valley, although Taylor (1986) described the soils on fluvial terrace sequences along Yucca and Fortymile washes for an area that includes the northernmost part of Midway Valley.

Three major late Cenozoic stratigraphic units in the NTS region are differentiated using the concept of correlation characteristics (Hoover et al., 1981), which utilizes physical and morphologic characteristics of landscape elements, including landforms, drainage network, soils, topographic position, degree of development of desert pavement, rock varnish, depositional environment, and lithology. The oldest surficial unit, QTa, is Quaternary (early Pleistocene) and/or Tertiary (Pliocene) in age. Units Q2 and Q1 represent middle to upper Pleistocene and Holocene deposits, respectively. These major stratigraphic units in Midway Valley, as mapped by Swadley et al. (1984), are shown on Figure 2-2. Based on regional mapping within the NTS region, Q1 and Q2 are divided into several subunits by Hoover et al. (1981); however, detailed mapping of these subunits is not published for Midway Valley. A total of 10 subunits of Q1 and Q2, and possibly "three additional subunits of uncertain age that may belong in unit Q2" (Hoover et al., 1981, p. 8), are mapped in the NTS region.

Taylor (1986) mapped six Tertiary to Quaternary fluvial terraces and described 20 soil profiles on these terraces along Yucca and Fortymile washes to (1) assess the influence of time and climate on soil development, and (2) model calcic horizon development to quantify the variability in past Quaternary climates of the area. Taylor (1986) adopted with minor modification the Quaternary stratigraphic framework of Hoover et al. (1981) and Swadley (1983). Ages of map units in Taylor's study were assigned based on an inferred correlation with the stratigraphy of Hoover et al. (1981), Szabo et al. (1981), and Swadley and Hoover (1983). Taylor (1986) demonstrated that age correlates with

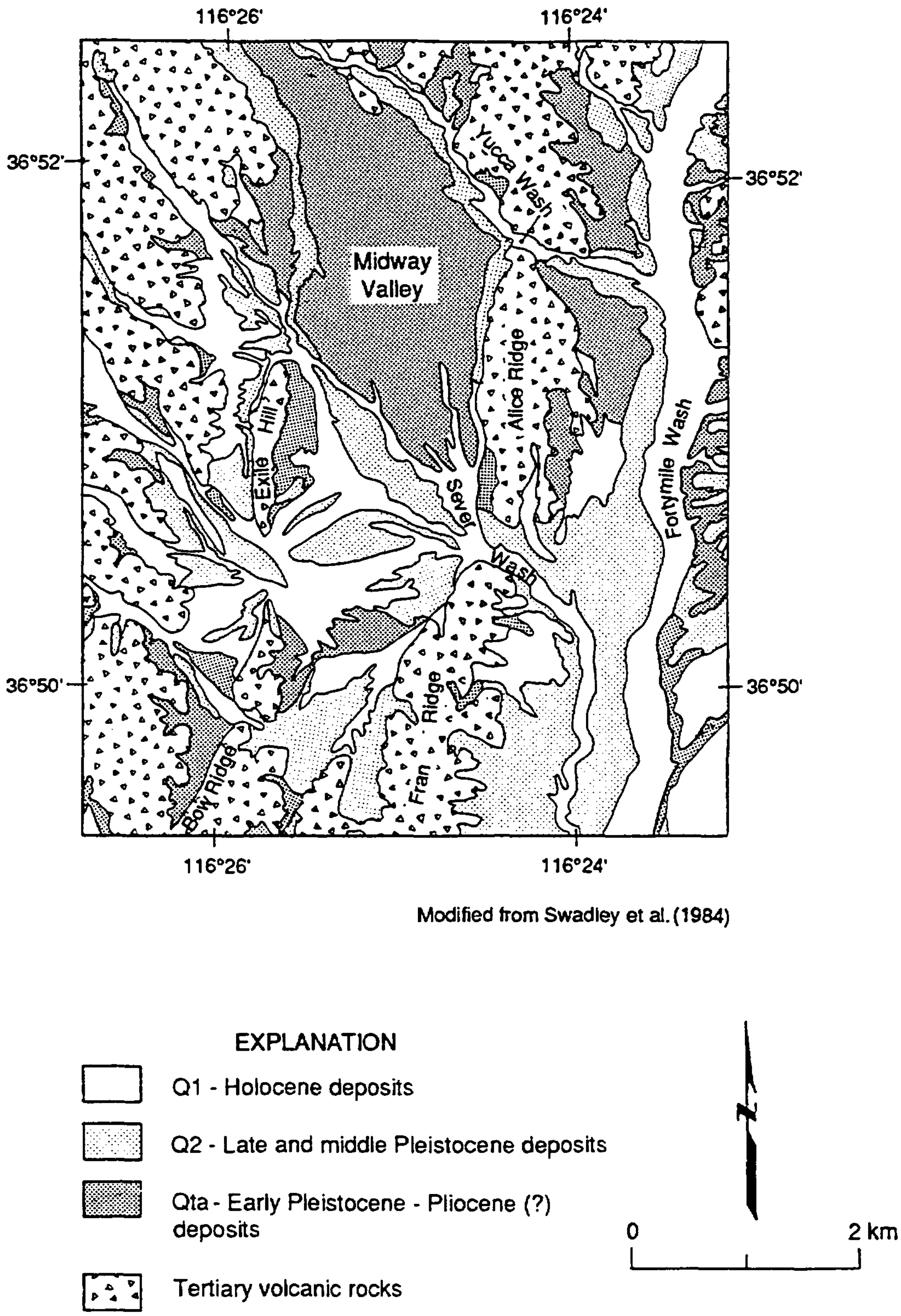

Figure 2-2. Geologic map showing Quaternary stratigraphic units of Swadley et al. (1984) in the vicinity of Midway Valley.

soil morphology and with the progressive accumulation of secondary silica, carbonate, and clay.

Peterson (1988) conducted reconnaissance soil-geomorphic studies in the Crater Flat area, less than 5 km west of Midway Valley, to evaluate previous studies. He identified five geomorphic surfaces and assigned ages to them based on radiocarbon dating of rock varnish, dating via varnish cation ratio (VCR), relative geomorphic position, and soil development. Numerical ages were assigned to the five geomorphic surfaces on the basis of VCR and radiocarbon dating of rock varnish (Dorn, 1988; Peterson, 1988). These ages may be invalid, however, because they rely on controversial approaches and methods (Harrington and Whitney, 1987; Dorn, 1988; Bierman and Gillespie, 1990, 1991; Harrington et al., 1990; Krier et al., 1990). Peterson (1988) questioned the use of the Av horizon as a major criterion for distinguishing Pleistocene from Holocene surfaces. Peterson recognized three geomorphic surfaces and their related soils within the QTa unit of Swadley and Hoover (1983) and Swadley et al. (1984) and proposed that their Q2 unit be divided into two geomorphic surfaces.

3.0 PRELIMINARY MAPPING OF SURFICIAL GEOLOGY

A primary purpose of the Quaternary geologic mapping in the Midway Valley area is to understand the nature, ages, and distribution of the near-surface deposits, soils, and geomorphic surfaces that can be used to assess the history of Quaternary faulting. To accomplish this task, the temporal relations between the deposits, and the soils and geomorphic surfaces associated with those deposits, must be established. Because of environmental restrictions, the excavation of soil pits and trenches has been delayed temporarily; thus field investigations for this study were limited to examining the few available outcrops. Consequently, the preliminary map of the surficial geology (Plates 1 and 2) is based primarily on photogeologic interpretation and on the surface expression of morphologically defined units. The characterization of the deposits and soils associated with these units is incomplete and will be a primary focus of field investigations when restrictions on surface-disturbing activities are removed.

Ten surficial geologic map units have been differentiated in the Midway Valley area. These include remnants of six separate alluvial fan and terrace surfaces (Units 0-5), which are numbered from oldest to youngest; the modern flood plain and channel (Units 6 and 7, respectively); undifferentiated colluvial deposits (Unit u), which lie along the base of and mantle the lower parts of the hillslopes bounding Midway Valley; and adjacent bedrock terrain (Unit r + u), which consists of bedrock exposures and bedrock mantled by thin talus and other colluvial deposits. The spatial and stratigraphic relations among the map units are shown on Plates 1 and 2 and on cross sections through Midway Valley (Figures 3-1 and 3-2).

Map units are defined on the basis of landform morphology, relative geomorphic position, relative degree of preservation of surface morphology, relative soil development, distinctive drainage patterns and/or density, and associated characteristics such as type and density of vegetation. "Landform morphology" refers to the shape of a particular element of the landscape, such as the distinctive semiconical shape of an alluvial fan or the characteristic topographic benches of alluvial terraces. Other criteria,

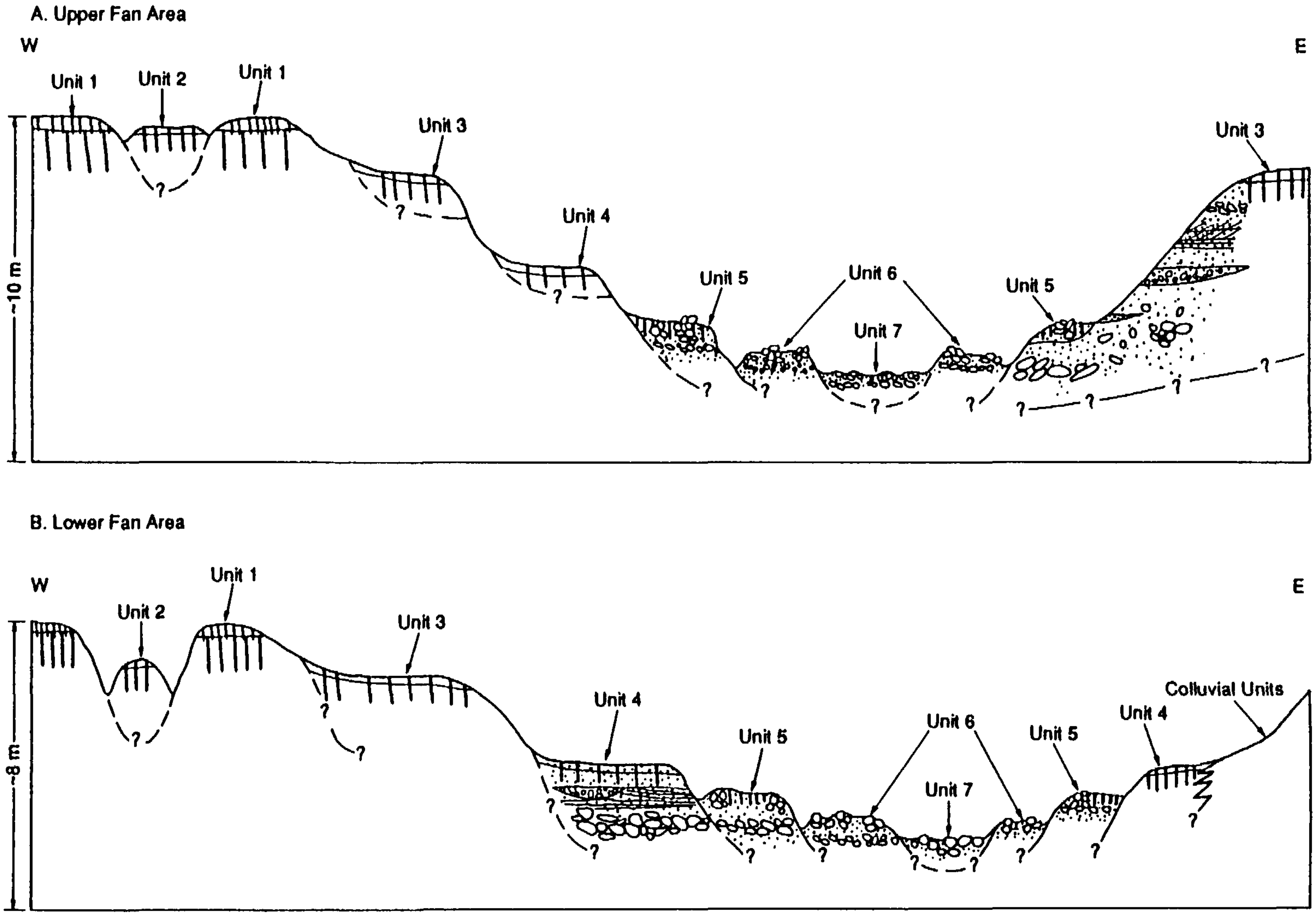

Figure 3-1. Composite cross sections showing topographic and stratigraphic relations north of Sever Wash in the (A) upper fan and (B) lower fan areas of Yucca Wash alluvial fan. Lengths and weights of vertical lines in map units represent relative degree of soil profile development; longer, thicker lines indicate stronger soil development. Not to scale.

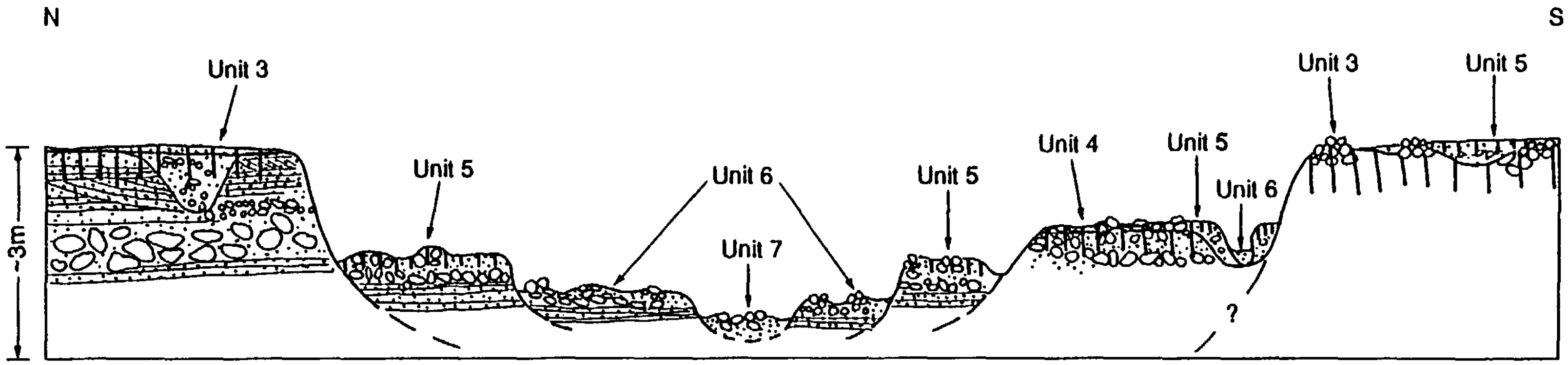

Figure 3-2. Composite cross section showing topographic and stratigraphic relations in the vicinity of the water gap between Fran and Alice ridges across the Sever Wash. Lengths and weights of vertical lines in map units represent relative degree of soil profile development; longer, thicker lines indicate stronger soil development. Not to scale.

such as relative geomorphic position and characteristic drainage pattern and density, also are useful for distinguishing among map units.

Relative age (RA) methods have been used for many years in the stratigraphic study of alpine glacial deposits (Burke and Birkeland, 1979); recently these methods were modified for the stratigraphic study of alluvial fan surfaces in desert environments (Ritter, 1987; McFadden et al., 1989). RA dating is based on the assumption that certain measurable weathering parameters are time-dependent and thus can be used to estimate the relative ages of surfaces, if parent materials of surface clasts, climatic regimes, and geomorphic/topographic settings of surfaces are similar. As part of geologic mapping for this study, RA data were collected to help characterize the surfaces associated with the various map units. Table 3-1 defines the RA parameters used in this study. Data collection transects were made using the methods of McFadden et al. (1989).

A representative surface and the deposits and soils associated with that surface were described at selected localities for each of units 1 through 7. Table 3-2 summarizes the location coordinates and the relative-age and particle-size data for the selected localities on each of the alluvial fan and terrace surfaces. Table 3-3 summarizes the soil characteristics associated with the surfaces.

TABLE 3-1

DEFINITION OF RELATIVE-AGE AND PARTICLE-SIZE PARAMETERS USED TO DESCRIBE WEATHERING CHARACTERISTICS OF ALLUVIAL FAN AND TERRACE SURFACES (SEE TABLE 3-2)

RA Parameter	Description
Varnish Cover	Rock varnish is a dark coating, composed primarily of manganese and iron oxides, clays, and organic matter, that progressively accretes on the subaerially exposed surface of clasts in all terrestrial weathering environments (Dorn, 1984). The percentage of surface area on which underlying rock fabric on the subaerially exposed part of a clast is obscured by varnish is estimated visually to the nearest 5% for each clast in a transect.
Percent Varnished Clasts	The percentage of clasts in a transect that are varnished is calculated.
Percent Having Rinds	A weathering rind is a zone of weathered (altered) rock, recognized by a discoloration, that parallels the outer surface of a clast in a manner analogous to the rind of a melon. The presence or absence of a rind is noted for each clast examined at each transect station. The percentage of clasts having rinds is calculated for each transect.
Mean Rind Thickness	The thickness of the weathering rind of each clast at each transect station is measured to the nearest 0.1 mm. Clasts that have no rinds or rinds less than 0.1 mm thick are herein defined as having a rind thickness of 0.0 mm. The hand lens used to measure this parameter has an ocular graduated at 0.1 mm. The mean rind thickness is calculated for each transect.
Percent Rubified Clasts	Rubification refers to the reddening that occurs on the bottoms of surface clasts in desert environments. For each clast along a transect, the presence or absence of rubification is noted. The data are used to calculate the percentage of clasts having rubified bottoms.
Percent Pitted Clasts	A weathering pit is a concave depression of more or less circular shape on the surface of a clast, which apparently forms from granular disintegration resulting from chemical and mechanical weathering. The presence or absence of weathering pits is noted for each clast. The percentage of clasts that have a weathering pit(s) on the subaerially exposed surface of the clast is calculated for each transect.

TABLE 3-1

DEFINITION OF RELATIVE-AGE AND PARTICLE-SIZE PARAMETERS USED TO DESCRIBE WEATHERING CHARACTERISTICS OF ALLUVIAL FAN AND TERRACE SURFACES (SEE TABLE 3-2)

RA Parameter	Description
Mean Pit Depth	The maximum depth of the deepest weathering pit on the subaerially exposed surface of the clast is measured from the bottom of the pit to the present surface of the clast by inserting into the pit a ruler or other object of a diameter less than the diameter of the pit. Weathering pit depth is measured to within +/- 10% of the total insertion measurement. Clasts having no measurable weathering pit(s) (i.e., <1.0 mm depth) are herein defined as having a pit depth of 0.0 mm. Mean pit depth is calculated for each transect.
Percent Fractured Clasts	As a clast weathers, fractures may develop that eventually split the clast. The absence or presence of these fractures is noted for each clast in a transect. The percentage of clasts having fractures is calculated for each transect.
Mean Fracture Depth	The depth of the deepest fracture is measured for each clast along a transect. The depth of a fracture is measured from the bottom of the fracture to the present surface of the clast by inserting into the fracture a ruler or other object of a diameter less than the width of the fracture. The depth of fractures are measured to within +/- 10% of the total insertion measurement. Clasts having no measurable fracture(s) (i.e., <1.0 mm depth) are herein defined as having a fracture depth of 0.0 mm. Mean fracture depth is calculated for each transect.
Hammer-Blow Percentage	Each clast under investigation is struck with a rock hammer; it is noted whether the rock gives a sharp ringing sound or a dull thud. Additionally, after being broken, a clast is examined for evidence of staining (iron oxides, manganese oxides, etc.) on the freshly broken surface. The percentage of clasts that give a ringing sound and contain staining is calculated for each transect.
Mean Maximum Surface Particle Size	The maximum intermediate diameter (b-axis) of the largest surface clast within 25 cm of the meter tick mark at each transect station is measured. Particle size is measured to within 10% of the total recorded value. The mean maximum surface particle size is calculated for each transect.

TABLE 3-1

DEFINITION OF RELATIVE-AGE AND PARTICLE-SIZE PARAMETERS USED TO DESCRIBE WEATHERING CHARACTERISTICS OF ALLUVIAL FAN AND TERRACE SURFACES (SEE TABLE 3-2)

RA Parameter	Description
Mean Surface Particle Size	The maximum intermediate diameter (b-axis) of the clast directly beneath the tick mark at each transect station is measured. Particle size is measured to within 10% of the total recorded value. The mean surface particle size is calculated for each transect.
Roundness Ratio	Surface clasts along a transect are classified as angular, subangular, rounded, or subrounded based on visual comparison with roundness charts in AGI Data Sheets (Dietrich et al., 1982) or other applicable source. The ratio of subrounded and rounded to subangular and angular clasts is calculated from these data.
Depositional Bar Relief	A depositional bar (longitudinal) is a positive-relief topographic feature that results from deposition of coarse load because of local channel conditions. Depositional bars are flanked by swales composed of relatively finer-grained sediments. Constructional relief is measured between the top of the depositional bar and the adjacent swale (Wells et al., 1987). Many researchers (cf. Wells et al., 1987; McFadden et al., 1989) have shown that depositional bar relief decreases with increasing age of alluvial surfaces. The relief of at least 10 depositional bars is measured to within 10% of the total height of the bar.

TABLE 3-2

RELATIVE-AGE AND PARTICLE-SIZE DATA FOR ALLUVIAL FAN AND TERRACE SURFACES IN NORTHERN MIDWAY VALLEY

Relative-age Parameter	Map Unit[a]						
	1	2	3	4	5	6	7
Varnish Cover (%$\pm 1\sigma$)	20 $\pm$21	--	43 $\pm$28	62 $\pm$27	1 $\pm$1	0 $\pm$0	1 $\pm$ 2
Percent Varnished Clasts	84	--	94	97	28	0	12
Percent Having Rinds	24	--	60	50	32	10	8
Mean Rind Thickness (mm$\pm 1\sigma$)	0.67 $\pm$1.42	--	1.40 $\pm$2.15	1.92 $\pm$2.55	1.57 $\pm$3.61	0.38 $\pm$1.59	0.09 $\pm$0.34
Percent Rubified Clasts	80	--	54	87	33	0	4
Percent Pitted Clasts	22	--	22	37	10	6	0
Mean Pit Depth (mm$\pm 1\sigma$)	1.2 $\pm$4.0	--	0.7 $\pm$1.8	2.4 $\pm$4.5	0.2 $\pm$0.8	0.1 $\pm$0.4	0.0 $\pm$ 0.0
Percent Fractured Clasts	14	--	36	30	2	2	6
Mean Fracture Depth (mm$\pm 1\sigma$)	0.4 $\pm$1.1	--	1.2 $\pm$2.7	3.3 $\pm$8.7	0.02 $\pm$0.1	1.3 $\pm$9.2	2.0 $\pm$ 13
Hammer-Blow Percentage	40	--	64	50	34	18	26
Mean Maximum Surface Particle Size (cm$\pm 1\sigma$)	9.0 $\pm$1.5	--	11.1 $\pm$5.7	13.6 $\pm$8.4	12.5 $\pm$11.8	10.1 $\pm$5.9	12.4 $\pm$7.5
Mean Surface Particle Size (cm$\pm 1\sigma$)	0.9 $\pm$1.5	--	2.3 $\pm$5.5	3.4 $\pm$6.5	3.2 $\pm$7.7	1.9 $\pm$3.6	3.6 $\pm$6.9
Roundness Ratio	1.4	--	0.8	2.0	1.3	4.6	2.3
Depositional Bar Relief (cm)	4.8	11.0	7.9	8.2	25.7	18.3	--

NOTE: See Table 3-1 for definition of relative-age and particle-size parameters. Data for Unit 0 were not collected for this study.

[a]Locations of sample sites: Unit 1 = MV/C-6 (234,530mN, 175,250mE); Unit 2 = JW90-24 (233,600mN, 175,530mE); Unit 3 = MV/C-2 (232,490mN, 175,530mE); Unit 4 = MV/C-5 (233,890mN, 175,430mE); Unit 5 = MV/C-1 (232,590mN, 175,430mE); Unit 6 = MV/C-4 (232,880mN, 175,110mE); Unit 7 = MV/C-3 (232,730mN, 175,290mE). Number of clasts examined (n) excluding bar relief data: n = 50 for units 1, 3, 5, 6, and 7; n = 30 for Unit 4. Number of clasts (n) examined for bar relief data: n = 30 for Unit 1; n =15 for units 2, 3, and 4; n = 11 for Unit 5; n = 10 for Unit 6.

TABLE 3-3

CHARACTERISTICS OF SOILS ON ALLUVIAL FAN AND TERRACE SURFACES IN MIDWAY VALLEY

Soil Characteristic[a]	Map Unit						
	1	2	3	4	5	6	7
Type of B or calcic horizon[b]	Kqm	Btkqm	Btkqm	Btkqm	Bwk or Btkj	Ck	N.P.[g]
Structure[c]	2c pl & m	3c pl	3m sbk	2m sbk	1vf-f sbk	sg	sg
Clay films[d]	2mk pf	4npf	3mk-kpf	3n po & co	co & v1n pf	N.P.	N.P.
Color[e]	10-7.5YR	7.5-5YR	7.5-5YR	7.5YR	10YR	10YR	10YR
Calcic horizon morphology[f]	IV	II	II?	II	I	N.P.	N.P.

[a]Terminology of Soil Survey Staff (1975) and Birkeland (1984)

[b]B horizon = a subsurface horizon that shows little or no evidence of original sedimentary or rock structure and is recognized on the basis of the kinds of material illuviated into it or residual concentrations of materials (Birkeland, 1984, p.7); K horizon = a subsurface horizon that is impregnated with carbonate to the point that the carbonate controls the morphology of the horizon (Birkeland, 1984, p.8); C horizon = a subsurface horizon that lacks properties of A and B horizons but includes material in varying stages of weathering (Birkeland, 1984, p. 8); j = juvenile or incipient formation (nonstandard terminology); k = accumulation of carbonates, m = cemented horizon, q = accumulation of silica, t = accumulation of clay, w = color or structural B

[c]Grade: sg = single grain, m = massive, 1 = weak, 2 = moderate, 3 = strong; Size: vf = very fine, f = fine, m = medium, c = coarse; Type: gr = granular, pl = plate, sbk = subangular blocky

[d]Frequency: v1 = very few, 1 = few, 2 = common, 3 = many, 4 = continuous; Thickness: n = thin, mk = moderately thick, k = thick; Location: pf = faces of peds, po = lining pores, co = colloidal stains on mineral grains

[e]Color from Munsell Soil Color Chart; Munsell Color Co., Inc. (1988).

[f]Terminology of Gile et al. (1966)

[g]N.P. = not present

3.1 DESCRIPTIONS OF MAP UNITS

A preliminary description of the surface expression of each map unit, its spatial distribution, and the characteristics of the deposits and soils associated with the unit is presented below. The deposits and soils underlying units 1 through 7 are described from existing exposures in the northeastern part of Midway Valley (Plates 1 and 2). In general, the characteristics of the deposits and soils should be representative of those associated with the same units in other parts of Midway Valley, but additional soil test pits are needed to assess the lateral variability of units.

Because of temporary environmental restrictions, the excavation of soil pits and trenches has been delayed, so that this preliminary investigation was limited to the few available exposures, which are mostly in the northern part of the valley. It is important to keep in mind that data presented in Tables 3-2 and 3-3 were obtained from a single locality on each of the units described. Although the quantitative data presented represent the characteristics of the desert pavement and soils for that locality, the individual map units cannot be characterized completely based on a single locality. During the next phase of this study, multiple soil pits will be excavated on each map unit and described to characterize the variability in the deposits, soils, and surfaces associated with each major map unit.

Localities for this preliminary study of the map units were selected based on the following criteria: (1) areas where desert pavement development is the strongest that are in close proximity to an existing outcrop that could be used for describing the deposits and soils associated with the surface; and (2) localities where the geomorphic/stratigraphic position of the surface could be established, providing information on the relative age of the unit with respect to other map units.

Unit 0

Within the mapped area, Unit 0 consists of a single terrace remnant at the north end of Alice Ridge. The surface forms a pronounced topographic bench (elevation 1168 m; 3830 ft) that is 25 m higher than Unit 1 and 46 m above the channel of Yucca Wash, which flows through the water gap immediately north of Alice Ridge. Unit 0, which is topographically and stratigraphically higher than any other alluvial fan or terrace surface, is associated with the oldest alluvial deposit identified at the surface in Midway Valley.

Deposits associated with Unit 0 consist of lag gravels on a bedrock surface eroded into the Tiva Canyon Member of the Paintbrush Tuff. Some clasts are lithologically similar to the rhyolites of Fortymile Canyon, which crop out north of Yucca Wash. Clasts derived from the rhyolites of Fortymile Canyon are sufficiently abundant and distinct to indicate that some of the gravels are exotic to Alice Ridge. The clasts were transported to their present location, probably by an ancestral drainage flowing through the water gap north of Alice Ridge. No outcrops of deposits associated with Unit 0 were observed in Midway Valley; no soils data were collected.

Unit 1

Unit 1 is the most laterally extensive alluvial fan surface in northern Midway Valley, where it is preserved at the surface only on the Yucca Wash fan north of Sever Wash. The Unit 1 fan surface has been dissected by younger drainages; it is preserved as interfluves between these younger drainages.

Locally, the desert pavement associated with the Unit 1 surface is very well developed. In most areas, however, the desert pavement has been extensively degraded. Fresh rock surfaces, fragments of carbonate and silica, and calcic soil horizons at the surface give Unit 1 a lighter tone than units 2 and 3 when viewed on aerial photographs. Surface clasts typically are not darkly varnished (Table 3-2). Angular unvarnished rock fragments are common on the surface, where larger varnished clasts have spalled, exposing fresh rock surfaces. Pedogenic calcic horizons commonly are exposed at or near the surface, and scattered platelets of $CaCO_3$ and SiO_2 are abundant on the surface, especially adjacent to drainages incised into the Unit 1 surface.

The bar-and-swale morphology of the original alluvial fan surface has not been preserved on Unit 1. The larger clasts appear to be distributed randomly on the surface rather than being concentrated in areas of well-defined bars. Depositional bar relief has been reduced to the height of the clasts above the surface. The exposed parts of some clasts are rubified, suggesting that these clasts have been rolled over (Table 3-1). Many clasts are fractured. Quantified surface characteristics for a site on Unit 1 are summarized in Table 3-2.

The deposits associated with Unit 1 are not well exposed in Midway Valley. Small, isolated outcrops indicate that the deposits consist mostly of coarse-grained, poorly sorted alluvial and debris-flow deposits. Boulders[2] that are more than 1 m in intermediate diameter are common toward the apex of the fan. The thickness of deposits associated with this surface is unknown, but could exceed tens of meters. Similarly, the areal extent of these deposits in the subsurface is unknown. They probably underlie most of the valley, but this cannot be verified from available exposures.

The deposits that underlie the Unit 1 surface may represent more than one depositional cycle. Buried carbonate horizons in stream exposures along Yucca Wash suggest that periods of alluviation may have been interrupted, allowing soils to form. However, the stratigraphic relations between these exposures and Unit 1 is not clear; the apparent soil horizons also could be the result of gully-bed cementation during the downcutting of Yucca Wash.

Unit 1 is characterized by a soil that has a thick, laminar petrocalcic horizon (Kqm) at or near the surface (Table 3-3). Because of its limited exposure in Midway Valley, the thickness of this petrocalcic horizon is unknown. In soil pits on correlative age surfaces along Yucca Wash in the northernmost part of the map area and along Fortymile Wash

[2] Unless otherwise stated, values given for clast sizes are for the largest intermediate, or b-axis, diameter; the Modified Wentworth Scale is the grain size scale used; clasts larger than sand size are defined as gravels.

to the east, pedogenic carbonate is reported to depths of more than 2.5 m and more than 1.5 m, respectively (i.e., greater than the maximum depth of the pits) (Taylor, 1986). The petrocalcic horizon typically is overlain by as much as 50 cm of eolian fine sand and silt. Soil development[3] on the eolian deposits is characterized by 10 to 7.5YR Btk and Btkq horizons that have strong, medium subangular blocky structure and continuous, moderately thick clay films. The overlying eolian silts and soil appear to be unrelated in time to the underlying petrocalcic horizon.

Unit 2

Unit 2 is recognized only in the region north of Sever Wash, where it is inset into Unit 1; here it forms a relatively large alluvial fan surface. Within that part of the Yucca Wash fan north of Sever Wash, Unit 2 also occurs along linear shallow drainages inset into Unit 1. Toward the toe of the Yucca Wash alluvial fan, some of the shallow drainages associated with Unit 2 have been truncated by younger drainages, and the soils and deposits associated with Unit 2 are exposed in the stream banks. The deposits fill relatively narrow (approximately 10-m-wide), steep-sided channels eroded into the older alluvial fan surface (Unit 1). The channels are more than 3 m deep (i.e., the limit of the available exposure).

Unit 2 has a well-developed desert pavement that contains darkly varnished clasts. The tops of some clasts are rubified, indicating that the clasts have been rolled over since stabilization of the surface. In places, varnish has formed on the upturned rubified surfaces of some clasts. Some clasts are split and fractured. Varnish also has developed on some fractured surfaces of clasts. The original bar-and-swale morphology has been reduced to the height of the larger clasts above the surface.

Unit 2 surfaces have a darker, more reddish hue than the other units. This darker color and the reddish hue are a result of several factors. The desert pavement is more compact and more continuous, and the varnish is better developed. Also, the soils and

[3] Soil terminology follows that of Soil Survey Staff (1975), Birkeland (1984), and Munsell Color Co., Inc. (1988).

deposits associated with this surface tend to be redder than those associated with the other map units.

Where exposed in a stream cut (location coordinates are given in Table 3-2), the deposits associated with Unit 2 consist of debris-flow and fluvial deposits. At this location, the surface is underlain by 2 to 2.5 m of stratified, imbricated, and cross-bedded, predominantly clast-supported sandy gravel (80 to 95 percent gravel). Average clast size is about 2 to 3 cm; the maximum size is 50 to 60 cm. Clasts are mostly rounded to subrounded; only 10 to 20 percent are subangular. This fluvial sandy gravel overlies a debris-flow deposit that consists of a poorly sorted, massive to crudely stratified, gravelly sand that contains 10 to 30 percent pebbles, cobbles, and boulders as large as 25 cm in diameter (average between 5 and 10 cm). The clasts are matrix-supported. The matrix is mostly fine to very fine sand that has a component of silt. The contact between debris-flow and fluvial subunits is sharp and is marked by a zone of laminar carbonate-silica.

A cap of eolian silt and fine sand at least 50 cm thick occurs on the upper, fluvial subunit. A strongly developed soil with Avk and 5YR Bt horizons has formed in the eolian cap. The upper part of the Bt horizon lacks $CaCO_3$ but contains a silica-cemented zone that is laminar in appearance and has 5YR 5/4-6 color. The $CaCO_3$ content increases near the base of the duripan.

Unit 3

North of Sever Wash, Unit 3 occurs as small fluvial terrace remnants along drainages eroded into units 1 and 2 on the Yucca Wash fan. It occurs south of Sever Wash as large remnant alluvial fan surfaces and as fluvial terraces. At the valley margins, Unit 3 fluvial surfaces grade laterally (upslope) into debris-flow and other colluvial deposits shed from the adjacent hillslopes, suggesting that colluvial deposits of Unit 3 age are included in the areas mapped as "undifferentiated u."

A well-developed desert pavement containing darkly varnished clasts characterizes Unit 3. This unit has a dark brown or black tone. Larger clasts, some more than 30 cm in diameter, are distributed on the surface in diffuse, poorly defined bars. The original depositional bar-and-swale morphology has been reduced to the height of individual clasts above the surface. Overturning of varnished clasts is shown by some clasts that have their rubified bottoms exposed. Subsequent varnish formation on some of the overturned clasts is indicated by varnish that partly covers the rubification. Table 3-2 describes the surface characteristics of the Unit 3 surface near the exposure described below.

Interbedded fluvial and debris-flow deposits associated with Unit 3 are exposed in a stream cut along Sever Wash (location coordinates on Table 3-2). Only the uppermost 2 m are exposed; the total thickness of Unit 3 is unknown. Field relations, however, suggest that Unit 3 probably is not more than a few meters thick in northern Midway Valley; the thickness of Unit 3 in the southern part of the valley is unknown. Two distinct depositional units are associated with the Unit 3 surface in of the stream cut: an interbedded sequence of fluvial and debris-flow deposits, and a cut-and-fill channel inset into the upper part of this sequence.

The interbedded fluvial and debris-flow deposits consist of crudely stratified gravelly sand and sandy gravel layers that range in thickness from less than 10 to about 150 cm. The layers are discontinuous, pinching out laterally over distances of only a few meters. Cobbles and boulders as large as 25 cm in diameter are common in the coarser gravel layers, particularly near the base of the exposure. Both normal and inversely graded beds were observed; some intervals contain cross-bedding. Sorting in the individual layers typically varies between poor and moderate, but some of the finer sandy layers are locally well sorted. The clasts are predominantly subangular to subrounded. Layers of massive, silty gravelly sand interpreted to be debris-flow deposits are more common in the upper part of the exposure. The gravels in these layers are matrix-supported.

The channel inset into the top of the interbedded fluvial and debris-flow deposits was once at least a meter deep. It is now backfilled with weakly stratified sandy gravel that contains cobbles and boulders as large as 40 cm in diameter and some silty sand lenses. A zone of laminar calcite silica has formed along the sharp contact between the interbedded fluvial and debris-flow deposits and the cut-and-fill channel.

A strongly developed soil has formed across both the cut-and-fill channel and the interbedded fluvial and debris-flow deposits. Soil development appears to be slightly stronger on the latter. This difference in soil development may reflect different parent materials (grain size) or differences in the age of the surface (and underlying deposits) because of channeling and backfilling after the surface was abandoned. The soil has a 7.5YR to 5YR Bt horizon that shows moderately thick to thick clay films and strong subangular blocky structure. Silica (dominant) and carbonate coatings are common on the bottoms of clasts.

Unit 4

Unit 4 consists of small fluvial terrace remnants north of Sever Wash, and of alluvial fan and fluvial terrace remnants to the south. In addition, colluvial units having surface characteristics similar to Unit 4 surfaces occur along the bases of the hillslopes. The colluvial units are not mapped separately, but are included in the undifferentiated deposits along the margin of the valley and on hillslopes (Unit u on Plates 1 and 2).

The desert pavement formed on Unit 4 is well developed but not as well packed as pavements on the older fluvial surfaces. The clast density of the pavement varies from loosely to tightly interlocking (less than 1 to 2 mm spaces between clasts); spaces between pavement clasts are filled by sand and/or silt. On surfaces that have the greatest pavement development, clasts are well varnished (Table 3-2), but clasts on most Unit 4 surfaces typically have a much lower percentage of varnish cover than those on the older fan and terrace surfaces. In accordance with the criteria listed above for selecting localities, the area having the strongest pavement development was selected for description. The pavement at this locality is especially well developed compared to most Unit 4 surfaces. The values for Unit 4 described in Table 3-2, therefore, probably represent maximum rather than typical weathering characteristics for this surface. On some clasts, varnish covers rubified areas, indicating remobilization of clasts at the surface. Fracturing or splitting of clasts is prevalent. Bar-and-swale relief on Unit 4 has been reduced to clast height above the surface.

The upper 2.5 m of the fluvial and debris-flow deposits associated with Unit 4 is exposed in a stream cut north of Yucca Wash and west of Alice Ridge (location coordinates are given in Table 3-2). The total thickness of the terrace fill associated with Unit 4 is not exposed, but probably is not more than a few meters. The deposits consist of interbedded gravelly sand and sandy gravel. The upper 1 m consists of crudely stratified fluvial gravelly sand containing discontinuous debris-flow lenses. The larger clasts, which are subangular to subrounded, range up to 15 cm in size; the mode is between 3.5 and 8 cm. The finer fraction consists of poorly sorted, subangular to subrounded, lithic-rich quartz sand. At between 1 and 2 m depth is a very coarse, sandy gravel that is well cemented by calcium carbonate and silica. The gravels are clast-supported and have an imbricate fabric. Maximum clast size is about 25 cm; mean size is about 8 cm. The cemented gravel layer overlies debris-flow and fluvial deposits similar to those in the upper 1 m of the exposure.

A strongly developed soil in the upper part of the unit has a well-developed Bt horizon characterized by silica (?) cementation (Table 3-3). An Avk horizon overlies the Bt horizon. In addition, in the intermediate cobble and boulder subunit, clast bottoms have thick coats of silica (?) and carbonate.

Unit 5

Unit 5 covers extensive areas south of Sever Wash, where it is associated with alluvial fans deposited by drainages that emanate from Yucca Mountain. North of Sever Wash, Unit 5 occurs as remnants from the flight of terraces associated with stream systems incised into the Yucca Wash alluvial fan. Colluvium having surface characteristics of

Unit 5 is a major part of the undifferentiated colluvial deposits mapped on the hillslopes along the margins of Midway Valley.

A weakly formed desert pavement is developed on Unit 5. The surface clasts have noticeably less rock varnish cover than those of the older units (Table 3-2). The surface of Unit 5 displays typical bar-and-swale morphology. The amount of bar-and-swale relief is related to landscape position and sediment sources. Coarsest-grained bars are in the proximal fan regions north, south, and west of Exile Hill. Smaller, lower, partly buried bars are in distal regions of Sever Wash, where the intervening swales are partly filled by fine-grained eolian silts and sands. Surface clasts are relatively unweathered.

Deposits associated with Unit 5 are well exposed in stream cuts along Sever Wash. Because the original bar-and-swale morphology is so well preserved, one can readily see the changes in facies between the bars and swales in the stream exposure. The deposits associated with depositional bars include non-indurated, cobble-boulder gravels and a finer-grained sand and gravel deposit. The deposits associated with swales include a finer-grained, silt-rich deposit that overlies a coarser-grained gravel and cobble deposit (probably a fossil bar), which in turn overlies a finer-grained sand and gravel deposit. The boulder gravels associated with the bars typically are about 0.5 m thick.

Weakly developed soils are formed on deposits associated with Unit 5. Soil development is stronger in the silt-rich zone in the upper 30 to 40 cm beneath the swales; soils are less developed on the bars. The soils have a Bwk or incipient Btkj horizon that has weak subangular blocky structure, colloidal stains on grains, and very few, very thin clay films. $CaCO_3$ is disseminated in the matrix. Below about 30 cm depth, the $CaCO_3$ content increases, and the bottoms of clasts have powdery coats. Hue of the soil is 10YR.

Unit 6

Unit 6 occurs along the active washes as low, less than 1-m-high floodplains and as vegetated bars along active washes. Rodent burrows are ubiquitous on this unit, most likely reflecting the ease of excavation. Deposits associated with Unit 6 are relatively loose and do not hold a well-formed free face when excavated.

Unit 6 lacks a developed desert pavement (Table 3-2). Surface clasts have little or no rock varnish cover. Relief at the surface of Unit 6 generally reflects preservation of original bar-and-swale morphology. Surface clasts are relatively unweathered.

Unit 6 contains a wide range of deposits, from fluvial to debris flow. These deposits consist of repetitive, normally and inversely graded sands, gravelly sands, and sandy gravels. The fine-grained fraction typically consists of subangular to subrounded sand. Loose sand (very coarse to very fine), pebbles, and silts are exposed at the surface. In some places bars have formed on top of bars, creating a compound bar. The unit typically has little to no eolian sediment deposited upon it. However, in some places an eolian cap that can be 5 to 10 cm thick (or more locally) may bury all but the largest surface clasts.

The soil developed on Unit 6 lacks an Av horizon. Soil development is limited to minimal oxidation of the deposit (Cox formation) and minor accumulation of $CaCO_3$. $CaCO_3$ distribution is more concentrated toward the upper 10 cm of the deposit, although $CaCO_3$ is distributed throughout the matrix. Clasts in the upper 30 cm have little visible carbonate, yet effervescence occurs when hydrochloric acid is applied. Isolated patches of powdery $CaCO_3$ on the undersides of clasts are visible under a hand lens. The amount of $CaCO_3$ on clasts increases with depth. Many clasts within the deposit also display evidence of erosion and random distribution of $CaCO_3$ coatings from remobilization and deposition.

Unit 7

Unit 7 consists of the active channels and low floodplains that are inundated during high streamflow events. No desert pavement development is observed on Unit 7. Protected areas of some surface clasts contain a minor amount of thick dark rock varnish, such as in small fractures and vesicles. This varnish is too well developed to be actively accreting on clasts in active channels, but rather is inherited from a former, stable landscape. Clasts are fresh and relatively unweathered. The original bar-and-swale relief is unaltered.

Unit 7 consists of fluvial deposits that range from fine sands and silts to coarse gravel consisting of cobbles and large boulders. Coarse bars and finer-grained swale areas characterize the active stream channels. Grain size of the bars and swales depends on position within the landscape (e.g., proximal or distal fan region) and the nature of deposits cut by active streams. In the proximal regions of alluvial fans, grain size is greater where larger material is available for transport and where streamflow is concentrated. In the distal reaches of the fans, sediment is finer grained, although coarser-grained facies exist locally. Sediment sources for Unit 7 are predominantly the older Quaternary units and sources in the headwater regions and along fluvial systems.

No *in situ* pedogenic alterations were observed for Unit 7 (location coordinates are given in Table 3-2). The overall color of the deposit is 10YR 5-6/3. The matrix of the deposit contains reworked, disseminated $CaCO_3$. Derivation of clasts from older units is indicated by the numerous clasts that have thick accumulations of $CaCO_3$. These reworked clasts are distributed randomly throughout Unit 7 deposits. The $CaCO_3$ coatings, which originally formed on the bottoms of the clasts, have no preferred orientation in the reworked deposits. Within Unit 7 deposits, $CaCO_3$ is not apparent on the undersides of clasts, but noticeable effervescence occurs when hydrochloric acid is applied.

3.2 DISTRIBUTION OF MAP UNITS

The distribution of map units within Midway Valley is shown on Plates 1 and 2. Large sediment contributions to the Yucca Wash alluvial fan from upvalley sources were cut off by stream capture of headwater source areas (Section 2.1). In contrast, alluvial fans southwest of Sever Wash continue to receive sediment contributions from their headwater areas on Yucca Mountain. The relationships between geologic units are influenced by these differences in source area contributions. The characteristics of the major alluvial fans and associated map units are listed in Table 3-4.

Area Northeast of Sever Wash - There are two major alluvial fan surfaces, map units 1 and 2, in the part of the valley northwest of Sever Wash (Plates 1 and 2). In this area, the younger map units (units 3 through 7) have limited areal extent; they occur as narrow terraces or valley fill along drainages incised into the Unit 1 and Unit 2 fan surfaces. Unit 0 is limited to a single outcrop at the north end of Alice Ridge. Colluvial units of various ages are present but undifferentiated on the west flank of Alice Ridge. Schematic cross sections that illustrate the vertical stratigraphic relationships between map units in upper and lower fan areas are shown on Figures 3-1 and 3-2.

In general, the topographic separation between fan surfaces of different ages decreases from the upper to the lower fan areas (Figures 3-1 and 3-2). Exceptions to this include the difference in height between units 1 and 2 and between units 6 and 7. The spacing between units 1 and 2 increases in a downstream direction; the spacing between units 6 and 7 is variable. The variability in spacing between surfaces 6 and 7 may reflect alternating sites of deposition and erosion along the modern channel.

Area Southwest of Sever Wash - The areal pattern of map units southwest of Sever Wash is distinctly different from that to the northeast. To the southwest, map units 3, 4, and 5 are the most areally extensive alluvial fan surfaces. Each of these units represents a major fan-building episode in the southern part of the valley. Younger map units (units 6 and 7) have a relatively small areal extent, primarily along modern

TABLE 3-4

CHARACTERISTICS OF ALLUVIAL FANS AND MAP UNITS ASSOCIATED WITH INDIVIDUAL ALLUVIAL FANS OF MIDWAY VALLEY

Characteristic	Alluvial Fan[a]			
	YWAF	LSWAF	LDWAF	BRAF
Total fan area (km^2)	5.2	1.1	2.1	0.6
Approximate maximum fan length (km)	4.88	2.59	1.84	1.28
Approximate maximum fan width (km)	2.04	0.82	1.63	0.67
Elevation of fan apex (m)	1238	1140	1143	1130
Elevation of fan toe (m)	1070	1070	1073	1093
Total fan relief (m)	168	70	70	37
Radial slope of fan (unitless)	0.034	0.027	0.038	0.029
Map unit[b]				
7	a*	a*	a*	a*
6	t*	t*	t*	t*
5	t*	f**	f***	f***
4	t*	f**	f**	f**
3	t*	f***	f***	f**
2	f**	N.O.	N.O.	N.O.
1	f****	N.O.	N.O.	N.O.

[a]YWAF = Yucca Wash alluvial fan; LSWAF = lower Sever Wash alluvial fan; LDWAF = lower Drillhole Wash alluvial fan; BRAF = Bow Ridge alluvial fan.
[b]a = active wash, t = terrace surface, f = alluvial fan surface; asterisks shows relative areal abundance of map units as follows: * = minor, ** = moderate, *** = abundant, **** = clearly abundant; N.O. = map unit not observed on alluvial fan.

drainages. Map units 1 and 2, which were not identified in this area on the basis of surficial mapping, probably are buried by the younger fan deposits. Undifferentiated colluvial and eolian deposits are present along the margins of Midway Valley south of Sever Wash.

Cross-section relationships that are both inset and overlapping are observed in the southeastern part of Midway Valley, as illustrated by Figure 3-2. Map units generally exhibit inset relationships along major drainages, such as the area adjacent to Sever Wash near the water gap between Alice and Fran ridges. Stratigraphic sequences in this area are much more compressed than those northeast of Sever Wash; the heights between successively older surfaces generally are less than a couple of meters. Unlike the Yucca Wash fan, in which all the younger units are topographically inset into older surfaces, in some places south of Sever Wash younger map units are higher than and bury the next older map unit.

Map Unit 5 is the most areally extensive unit south of Sever Wash. Deposits associated with Unit 5 bury units 3 and 4. Similarly, deposits associated with units 6 and 7 bury the older units in many places, but to a lesser extent than does Unit 5. The nature of the burial varies from an inset relationship, in which the soil developed in the older unit is completely eroded, to an overlying relationship, in which the soil and, in some instances the desert pavement, in the underlying unit may be intact at the contact with the overlying unit. Units 3 and 4 presumably overlie older deposits, but the stratigraphic relationships are not exposed.

The thickness of overlying younger deposits, as observed in natural exposures, varies from a few centimeters to at least a few meters. In several areas, such as that shown in the extreme southwest corner of Plate 2, the surfaces of depositional bars of underlying older map units are observed protruding through younger sediments. A protruding depositional bar may cover an area less than a few square meters (unmappable at 1:6000 scale) or greater than several square meters (mappable at 1:6000 scale).

4.0 LINEAMENT IDENTIFICATION AND CHARACTERIZATION

To help identify possible locations of faulting in the vicinity of Midway Valley, lineaments were identified on aerial photographs and plotted on 1:6000-scale maps. The mapping of lineaments from aerial photographs supplements field studies by revealing subtle, possibly fault-related geologic, geomorphic, and vegetative features that may be difficult to recognize through ground-based mapping. The results of this lineament study will be useful in locating sites for trench excavations across suspected fault traces and in identifying areas where active faulting is not present.

Aerial photographs used in this study were chosen from the flight lines of four photoreconnaissance surveys of the Yucca Mountain region flown between 1978 and 1989 at scales of 1:6000, 1:12,000, and 1:60,000 (Table 4-1). Figures showing the locations of the flight lines and the photographic centers of each image are provided in Appendix A. The area of the lineament study and the geographic names referenced in this section are shown on Figure 4-1.

4.1 METHODOLOGY

Lineaments were identified by visual examination of aerial photograph stereopairs using a desktop mirror stereoscope at magnifications of 1x and 3x. The lineaments then were mapped onto acetate overlays on every second image in the flight line. Each stereoscopic pair was reviewed by at least two geologists to confirm interpretations. Photolineaments are shown on Plates 3 to 6.

A reference system was established by numbering the lineaments consecutively from 1 through n on each basemap sheet, where n is the total number of lineaments on a specific sheet. The basemap sheet number (sheets 10, 11, 16, and 17, which correspond to Plates 3, 4, 5, and 6, respectively) appears as a prefix to the lineament number (e.g., "lineament 16/27" refers to lineament number 27 on sheet 16 [Plate 5]). An individual lineament that appears on two adjacent sheets is given the prefix number of the sheet on which the majority of that lineament appears. Each numbered lineament

TABLE 4-1

AERIAL PHOTOGRAPHS USED IN LINEAMENT STUDY OF MIDWAY VALLEY AREA

TYPE	APPROXIMAT E SCALE	DATE	SOURCE	I.D. NO.'S OF PHOTOGRAPHS*
Low Sun-Angle, Color	1:6000	1/12/87	Sandia National Laboratories	SNL/1-12-87/NA/031-05
Low Sun-Angle, Black and White	1:6000	12/4/85	U.S. Department of Energy	DOE/12-4-85/NA/001-033
Black and White	1:12,000	9/25/78 to 9/29/78	U.S. Geological Survey (USGS)	USGS/9-25-78/NTS/308-314 USGS/9-25-78/NTS/345-351 USGS/9-28-78/NTS/402-408 USGS/9-29-78/NTS/767-773 USGS/9-29-78/NTS/801-807 USGS/9-29-78/NTS/859-865
False-Color Infrared	1:60,000	6/25/83	USGS	USGS/6-25-83/HAP-83F/93-54 USGS/6-25-83/HAP-83F/93-55

* Each aerial photograph used in this study was assigned a unique identifier. The format of this identifier is AAAA/mm-dd-yr/BBBB/CCC, where: (1) AAAA identifies the source of the photograph (e.g., USGS = U.S. Geological Survey, SNL = Sandia National Laboratory, NBMG - Nevada Bureau of Mines and Geology; (2) mm-dd-yy gives the month (mm), day (dd), and year (yy) that the photograph was taken (3) BBBB is the flight line, if applicable (NA = no flight line designation); and (4) CCC is the frame number of the photograph.

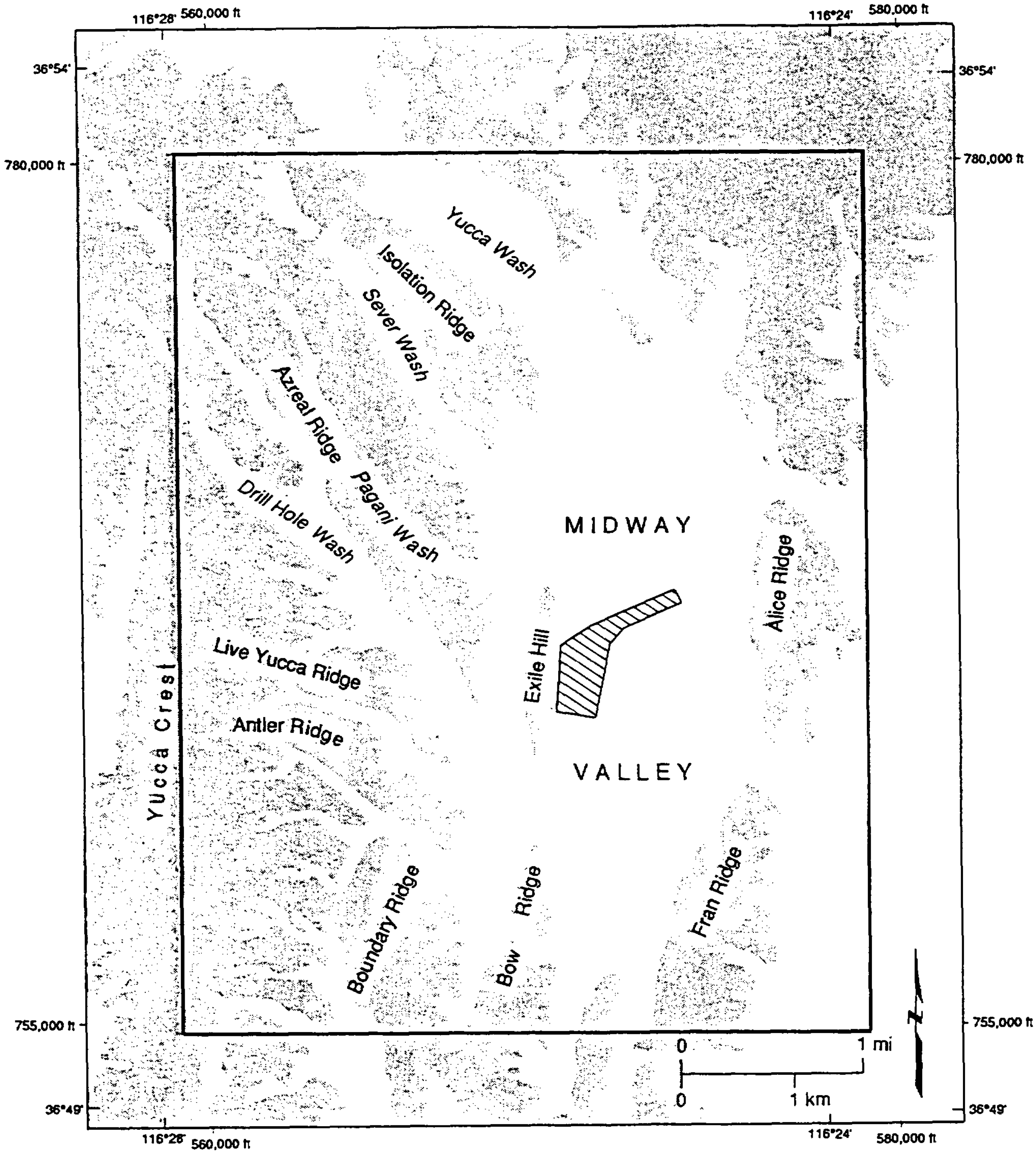

Figure 4-1. Location of the lineament study in the Midway Valley area and geographic locations referred to in text. Shaded regions represent outcrops of Tertiary bedrock; hachured area is the proposed location of the surface facilities.

on each sheet was assigned to one of three categories: lineaments in bedrock, those along bedrock/alluvial contacts, and those in alluvium. On a given sheet, the lineament numbers generally increase consecutively from west to east and north to south within each category.

Lineaments interpreted from the 1:60,000-scale photographs are plotted on a standard USGS 1:62,500 topographic basemap (Figure 4-2). These lineaments were not assigned identification numbers; nor were their attributes systematically analyzed.

The characteristic features used to define a lineament are: scarp in alluvium (AS), linear tonal contrast (T), linear break in slope (BIS), bedrock scarp (BS), topographic saddle (TS), alignment of vegetation or contrast in vegetation density or pattern (V), and linear drainage (LD). The linear elements that define each lineament are shown adjacent to the mapped lineament trace on Plates 3 to 6 and in Appendix B. In addition, displaced marker horizons (DM) and terminated marker horizons (TM) also were mapped where they can be identified on the aerial photographs. Those lineaments that have an uncertain origin but are suspected of representing cultural activity or nontectonic lithologic contacts are designated "C?" and "L?", respectively.

Only selected lineaments were checked in the field; these are concentrated in Midway Valley between Fran Ridge and Exile Hill. The investigation of identified lineaments in Midway Valley is part of the ongoing field activities for this study. The criteria for field assessment is similar to the criteria used to assess lineament expression on aerial photographs. Lineaments identified on the 1:6000-scale and 1:12,000-scale photographs are listed in tables in Appendix B. These tables give the identification number, orientation, length, and characteristic features of each lineament.

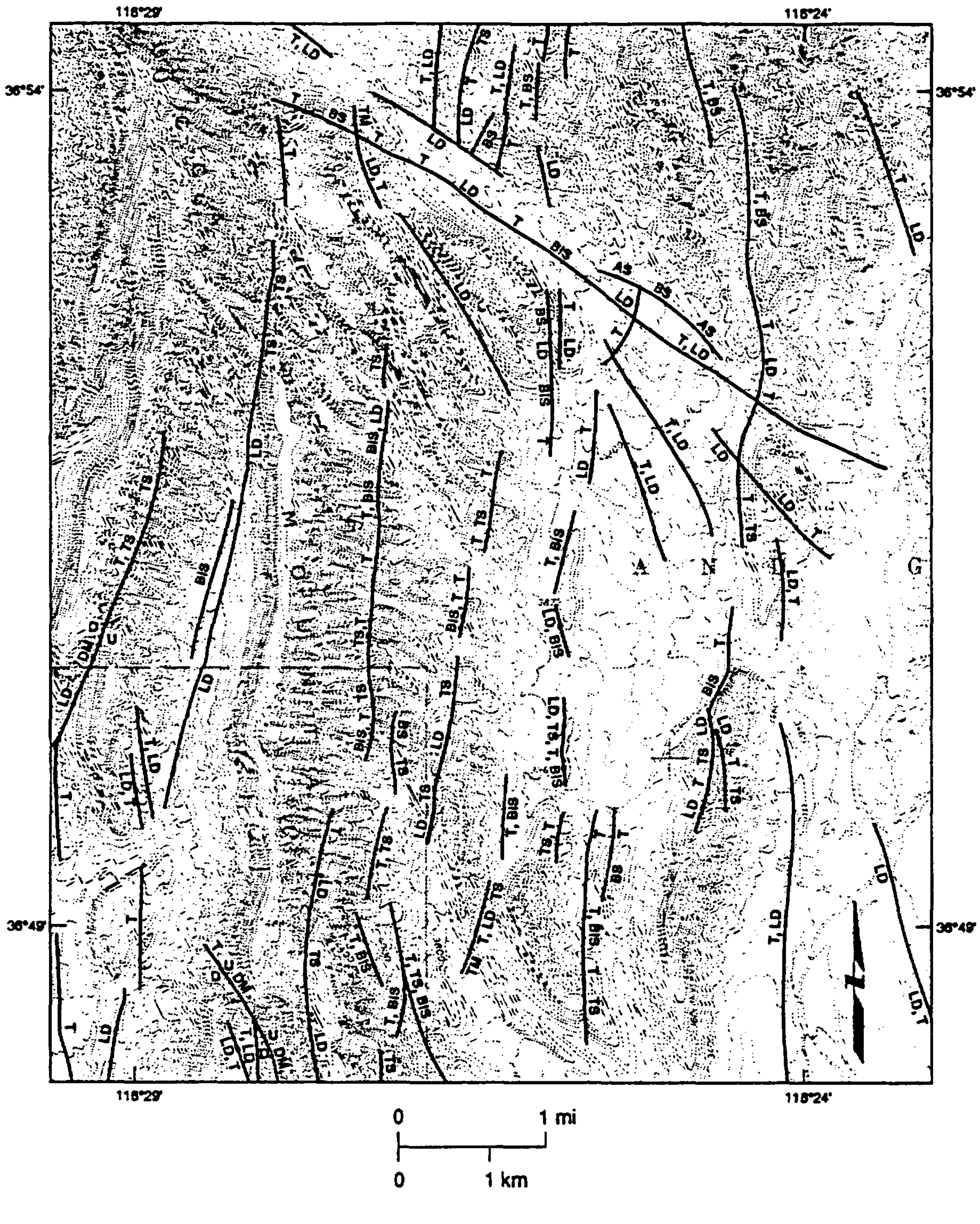

Figure 4-2. Lineaments of the Midway Valley areas compiled from 1:60,000-scale, false color infrared aerial photography (USGS/6-25-83/HAP-83F/93-54,5). AS = alluvial scarp, T = tonal contrast, BIS = break-in-slope, BS = bedrock scarp, TS = topographic saddle, LD = linear drainage, DM = displaced marker unit (U = up, D = down), TM = terminated marker horizon.

4.2 PATTERN OF MAPPED LINEAMENTS

Lineaments in the Midway Valley area are divided into three populations based on trend (Figures 4-3, 4-4, and 4-5). Eighty percent of the lineaments form two distinct populations, one trending north-south (53%), the other trending northwest-southeast (27%). The remaining 20 percent of lineaments identified are oriented east-west and northeast-southwest. The predominance of north- and northwest-trending lineaments is expected because the ridges and washes within the area also are oriented north-south and northwest-southeast. Yucca Crest and the ridges east of Yucca Mountain (i.e., Boundary Ridge, Bow Ridge, Exile Hill, Fran Ridge, and Alice Ridge) trend north-south. The ridges and washes on the northeast flank of Yucca Mountain trend almost exclusively northwest-southeast.

The distribution patterns of lineaments in the Midway Valley area are shown on Figures 4-3, 4-4, and 4-5. North-trending lineaments are concentrated in the southern part of the area (Figure 4-3). Most of these lineaments occur within or in close proximity to outcrops of Tertiary bedrock. Within the Midway Valley alluvium, most north-trending lineaments are defined by alignments of vegetation. Northwest-trending lineaments occur principally within the alluvium of Midway Valley and along northwest-tending drainages (Figure 4-4). The Yucca Wash and Sever Wash areas show concentrations of these lineaments, which typically are related to the drainage systems. East- and northeast-trending lineaments are most abundant in alluvium in the southern part of Midway Valley (Figure 4-5).

4.3 LINEAMENT EXPRESSION OF PREVIOUSLY MAPPED FAULTS

The major faults in the Midway Valley area mapped by Scott and Bonk (1984) (i.e., the Bow Ridge, Ghost Dance, Paintbrush Canyon, and Yucca Wash faults) are visible on aerial photographs. The Ghost Dance fault lies within an area where bedrock is exposed at the surface. Scott and Bonk (1984) map the other major faults as concealed in Midway Valley by unconsolidated alluvial and colluvial deposits; the locations of these faults were interpreted primarily from geophysical (aeromagnetic and electromagnetic) data or were extrapolated from bedrock outcrops. In a few places,

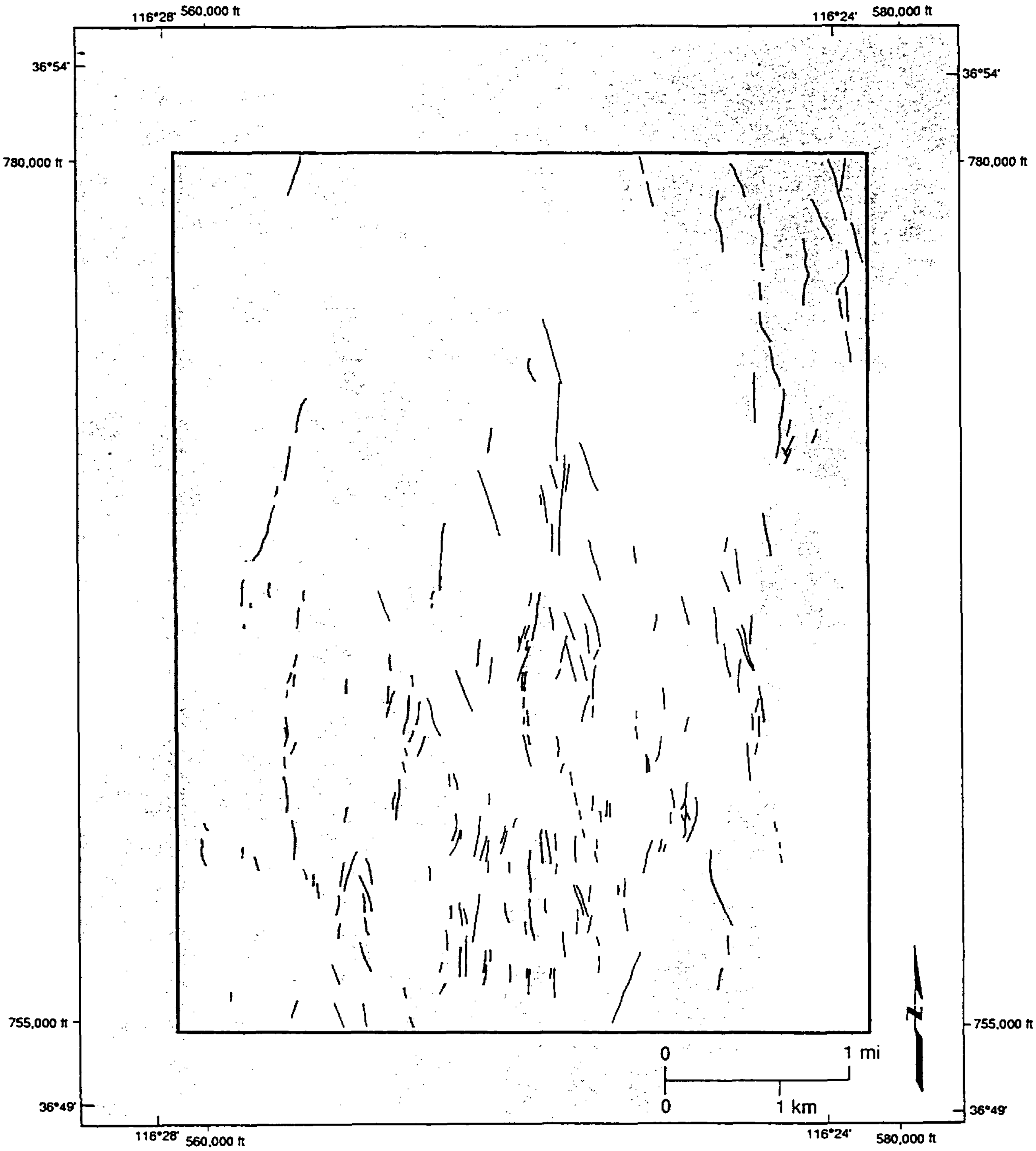

Figure 4-3. North-trending lineaments (N22.5°E to N22.5°W) in the Midway Valley area. Shaded areas represent outcrops of Tertiary bedrock.

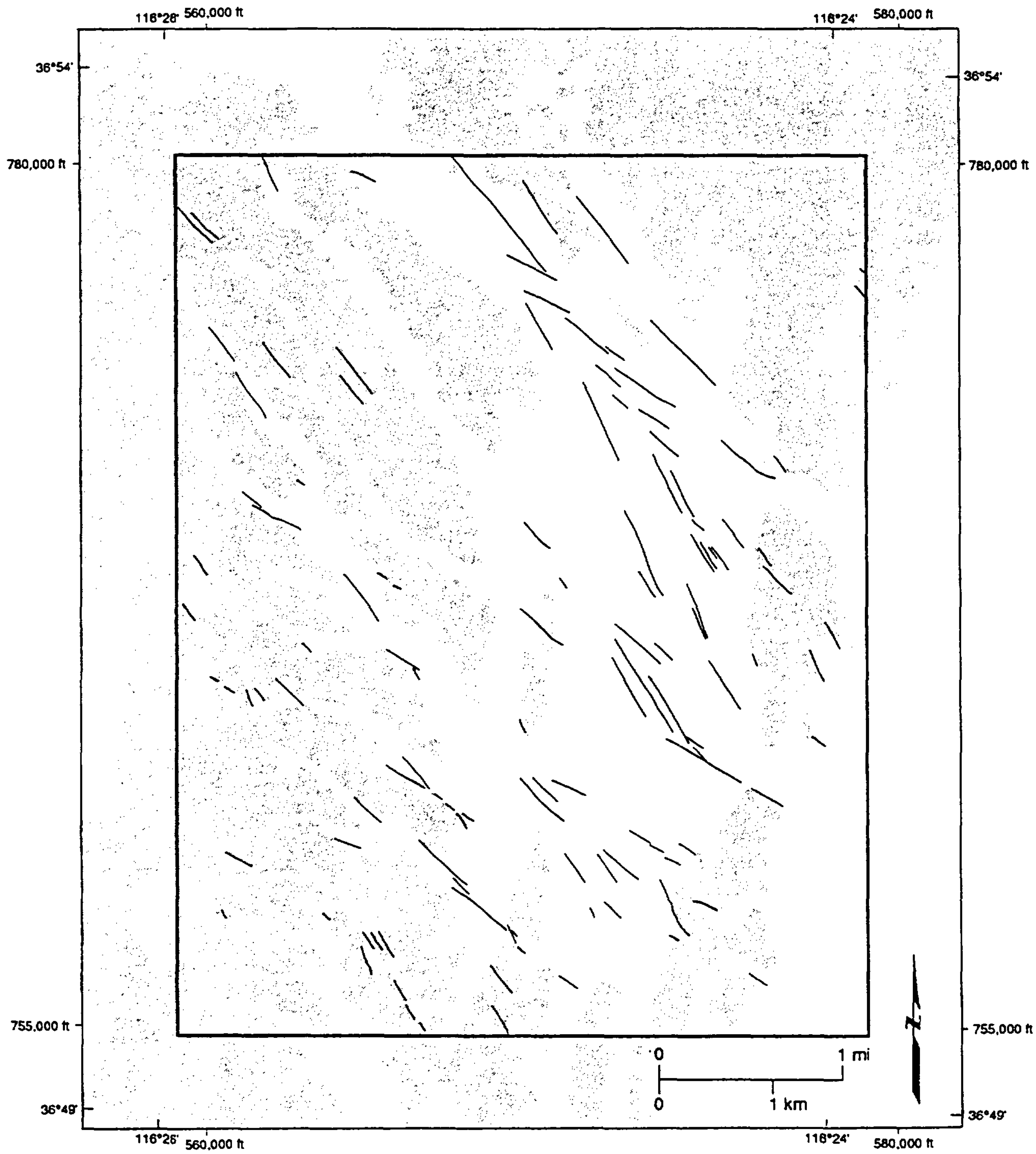

Figure 4-4. Northwest-trending lineaments (N22.5°W to N67.5°W) in the Midway Valley area. Shaded areas represent outcrops of Tertiary bedrock.

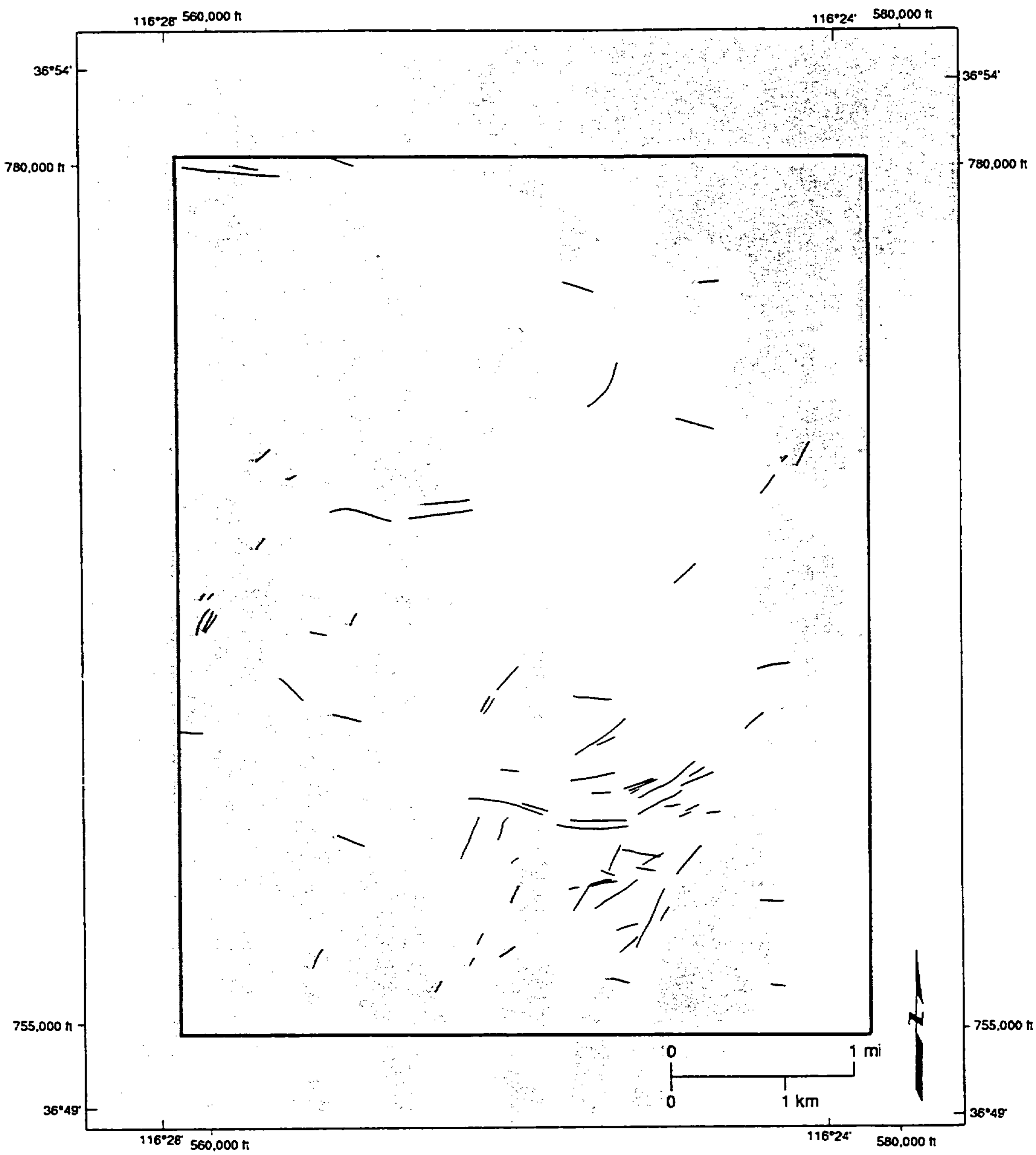

Figure 4-5. East- and northeast-trending lineaments (N90°W to N67.5°W and N90°E to N22.5°E) in the Midway Valley area. Shaded areas represent outcrops of Tertiary bedrock.

lineaments observed on the aerial photographs coincide with the mapped traces of the buried faults. The "imbricate zone" that Scott and Bonk (1984) mapped in bedrock on Yucca Mountain east of the Ghost Dance fault also is discernible on the aerial photographs. Lineaments along this trend were observed within both alluvium and bedrock. Expression of the postulated Midway Valley fault as lineaments within alluvium is equivocal on the 1:6000- and 1:12,000-scale aerial photographs; it is not apparent on the 1:60,000-scale aerial photographs.

Ghost Dance Fault - An alignment of north-trending lineaments on the east flank of Yucca Mountain extends from Azreal Ridge in the north toward Whale Back Ridge in the south. The location of these lineaments closely corresponds to the trace of the Ghost Dance fault mapped by Scott and Bonk (1984). The lineaments are characterized by tonal contrasts, linear drainages, bedrock scarps, topographic saddles, and displaced marker horizons. Comparison with the geologic map of Scott and Bonk (1984) suggests that many of the tonal contrasts may be caused by brecciation associated with faulting. Displaced marker horizons indicate down-on-the-west displacement, which is consistent with mapping by Scott and Bonk (1984). The Ghost Dance fault is well expressed as a continuous lineament on the 1:60,000-scale aerial photographs (Figure 4-2).

The Bow Ridge and Paintbrush Canyon Faults - According to the bedrock geologic map of Scott and Bonk (1984), in Midway Valley the Bow Ridge and Paintbrush Canyon faults are concealed beneath alluvium. These faults, however, are moderately well expressed as alignments of north-trending lineaments. The lineaments are associated primarily with the bedrock/alluvium contact along the margins of bedrock highs or within colluvial aprons that have local bedrock exposures (i.e., Bow Ridge/Exile Hill and Fran Ridge/Alice Ridge).

Lineaments that may be associated with the Bow Ridge fault in the Midway Valley area generally are north-trending geomorphic features. The lineaments occur along the bedrock/alluvium contact on the west side of unnamed bedrock exposures north of Bow

Ridge and on the west side of Exile Hill. North-trending lineaments within alluvium north of Exile Hill to Yucca Wash also may reflect activity on the Bow Ridge fault. No lineaments on line with this trend were observed north of Yucca Wash. The Bow Ridge fault appears as several aligned discontinuous lineaments that trend north along the west side of Midway Valley on the 1:60,000-scale photographs (Appendix A).

Lineaments suspected of being related to activity on the Paintbrush Canyon fault are similar in map pattern to those described for the Bow Ridge fault but are more numerous and more closely spaced (Plates 4 and 6; Appendix A). Most of these lineaments trend north along the bedrock/alluvium contact on the west side of Fran Ridge and Alice Ridge and also appear as bedrock lineaments within the rhyolites of Fortymile Canyon north of Yucca Wash. A lineament identified on the 1:60,000-scale aerial photographs that is approximately coincident with the mapped trace of the Paintbrush Canyon fault is nearly continuous from Fran Ridge to 7 km north of Yucca Wash. The lineament is characterized by tonal contrasts and local linear drainages, breaks in slope, and bedrock scarps (Figure 4-2).

Yucca Wash Fault - Only a small part of Yucca Wash lies within the area covered by available 1:6000-scale basemaps. Within this area, four northwest-trending lineaments are identified. The Yucca Wash alluvial fan, however, is covered entirely on the 1:6000-scale basemaps. Northwest-trending lineaments mapped over much of the fan's surface parallel the Yucca Wash drainage system. Many of these lineaments may be explained as a simple drainage pattern. However, the drainage system of Yucca Wash and the Yucca Wash fan may be fault-controlled, especially in the northern part of Midway Valley where the lineaments parallel the Yucca Wash fault. Closely spaced lineaments on trend with the southeastern projection of the Yucca Wash fault are nearly coincident with Scott and Bonk's (1984) location of the fault trace. Although this trace is not well expressed by lineaments on the fan surface, two right-lateral strike-slip faults and a colinear bedrock scarp are obvious on the west side of Alice Ridge on the 1:6000- and 1:12,000-scale aerial photographs. These fault lineaments coincide with a section of the Yucca Wash fault mapped by Frizzell and Shulters (1990). On the 1:60,000-scale aerial photographs, a continuous lineament coincides with the trace of the Yucca Wash fault as mapped by Scott and Bonk (1984) (Figure 4-2).

Other Possible Fault-Related Lineaments - Local concentrations of north-trending lineaments within alluvium west of Fran Ridge and east of Exile Hill provide equivocal support for the hypothesis of Quaternary faulting in the southern half of Midway Valley. These lineaments, however, are not tightly grouped, unlike lineaments associated with the large-displacement faults mapped in the area (e.g., Paintbrush Canyon and Bow Ridge faults). This suggests that, if present, the postulated Midway Valley fault may not extend into northern Midway Valley and is not a single strand or narrow zone that has a large displacement, but instead a zone of minor faults that have small offsets. No linear features that suggest a north-trending fault in Midway Valley were observed on the 1:60,000-scale aerial photographs.

Lineaments possibly related to the "imbricate zone" that Scott and Bonk (1984) mapped on the east flank of Yucca Mountain are apparent in both bedrock exposures and alluvial deposits. These lineaments are located on Boundary Ridge, on Live Yucca Ridge, and in alluvium east of Antler Ridge. The "imbricate zone" appears as a continuous lineament within bedrock on the 1:60,000-scale aerial photographs.

5.0 SUMMARY AND RECOMMENDATIONS

This interim data report presents results to date of an ongoing investigation to acquire surface and near-surface geologic data needed to evaluate the potential for surface fault rupture within Midway Valley (SCP Study 8.3.1.17.4.2). Activities included (1) interpreting surficial map units and lineaments from aerial photographs; (2) field-checking map relations in selected areas; (3) characterizing surface morphology and surface-clast weathering of the map units; and (4) describing deposits and soils associated with these surfaces. Because of temporary environmental restrictions, excavation of soil pits and trenches necessary to assess the variability of geologic units has been delayed. Observations of stratigraphy and soils were limited to available exposures, such as channel cuts and existing soil pits and trenches, which are located primarily in the northern part of the valley.

Ten surficial geologic map units have been differentiated in the Midway Valley area. These include remnants of eight separate alluvial fan and terrace surfaces and the modern fluvial surfaces; undifferentiated colluvium and debris-flow deposits that lie along the base, and mantle the lower parts, of the hillslopes bounding Midway Valley; and the adjacent bedrock terrain. The surfaces, and the soils and underlying deposits associated with those surfaces, were described at selected localities that are as representative as possible of each major map unit. These descriptions are preliminary; additional soil test pits are needed to assess lateral variability within the area.

The distribution of map units within Midway Valley reflects a complex pattern of sediment deposition. Large sediment contributions from upvalley sources to the Yucca Wash alluvial fan have been cut off by stream capture of headwater source areas. In contrast, alluvial fans southwest of Sever Wash continue to receive sediment from their headwater areas on Yucca Mountain. The relationships between geologic units are influenced by these differences in source area contributions.

To help identify possible locations of faulting in the vicinity of Midway Valley, lineaments were identified on aerial photographs and plotted on 1:6000-scale maps. The mapping of lineaments from aerial photographs supplements field studies by revealing subtle, possibly fault-related geologic, geomorphic, and vegetative features that may be difficult to recognize through ground-based mapping. Because the objective of the lineament analysis was to identify any feature that might be significant to the potential for surface faulting in Midway Valley, and because it can be difficult to distinguish between tectonic and nontectonic lineaments, a conservative approach was used in identifying lineaments. Unless an identified lineament could be attributed directly to nontectonic causes, it was mapped. Consequently, many of the mapped lineaments are not tectonic features.

The major faults in the Midway Valley area (the Bow Ridge, Ghost Dance, Paintbrush Canyon, and Yucca Wash faults) mapped by Scott and Bonk (1984) are visible on aerial photographs. The Ghost Dance fault, which lies within an area where bedrock is exposed at the surface, is expressed as north-trending lineaments. The other major faults are mapped as concealed by unconsolidated alluvial and colluvial deposits. The Bow Ridge and Paintbrush Canyon faults, however, are moderately well expressed as alignments of north-trending lineaments associated with the bedrock/alluvium contact along the margins of bedrock highs or within colluvial aprons that have local bedrock exposures. Expression of the postulated Midway Valley fault as lineaments within alluvium is equivocal.

Recommendations

The following observations and recommendations, which are based on the work completed to date, are intended to provide focus and further guidance for the remainder of this and related SCP activities.

- Additional stratigraphic control is required to distinguish and characterize map units. This control requires excavating test pits in six principal areas of Midway Valley: the three major alluvial fans (Yucca Wash fan, Drillhole Wash fan, and Bow Ridge fan), along Yucca Wash and Fortymile Wash, and in the area of the prospective surface facilities. Not all of the surficial map units are present at each of the six areas. For each map unit to be characterized on each fan, a minimum of two test pits should be excavated: one on the proximal part of the fan, and one on the distal part. Stratigraphic information from these test pits would be used to assess variations in soil development and thicknesses of the deposits that underlie each surficial unit. Additionally, soil test pits are needed to characterize the surface and near-surface deposits and soils near prospective exploratory trenches.

- Information on the ages of Quaternary units is required to reconstruct the history of Quaternary tectonic activity in the Midway Valley area. Available numerical dating methods (including cation ratio, radiocarbon, and thermoluminescence dating) should be reviewed to select the most appropriate methods. To the extent possible, multiple methods should be used to obtain corroborating evidence for numerical ages.

- The geologic mapping performed for this interim report should be extended along Yucca and Fortymile washes to facilitate regional correlations and to provide greater opportunity for obtaining geologic materials suitable for numerical age dating.

- Field observations indicate that multiple colluvial units can be differentiated that correlate to the alluvial fan and terrace surfaces mapped in Midway Valley. The projected surface traces of the basin-bounding faults typically lie near the bases of hillslopes that are underlain by these colluvial deposits. Detailed maps (e.g., 1:3000 scale) should be prepared for key localities such as the east flank of Exile Hill near the prospective portal for the exploratory shaft and related surface facilities; the west flank of Exile Hill along the Bow Ridge fault near Trench 14; the area around trenches A-1 and A-2 along the Paintbrush Canyon fault on Alice Ridge; and selected localities where multiple colluvial surfaces are particularly well expressed at the surface. Because the colluvial deposits occur in stacked surfaces and exposures are limited, soil test pits would greatly facilitate preparation of these detailed maps. The mapping also would enable assessment of the potential that debris flows on the east side of Exile Hill could be reactivated and could present a hazard to the prospective surface facilities.

- The total amount of Quaternary displacement should be assessed across Midway Valley, and across individual faults where possible. Detailed bedrock mapping should be conducted in the Exile Hill area and along the west sides of Fran and Alice ridges to provide control on the amount of displacement across the valley. The cumulative Quaternary displacement across the Paintbrush Canyon fault in Midway Valley could be constrained by advancing borings into bedrock in the Sever Wash area between Alice and Fran ridges. The difference in elevation of the bedrock across the fault then could be measured and used to assess the long-term Quaternary slip rate.

- Selected lineaments in the Midway Valley area that were recognized on aerial photographs should be examined in the field and assessed for their potential as tectonic features.

Studies to analyze the paleoenvironmental history of the Yucca Mountain region will provide important opportunities to date surficial deposits in the region. The more detailed studies proposed to reconstruct the Quaternary history of the Midway Valley area should be coordinated with other studies proposed in the SCP.

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APPENDIX A

LOCATIONS OF AERIAL PHOTOGRAPHS USED IN THE LINEAMENT STUDY

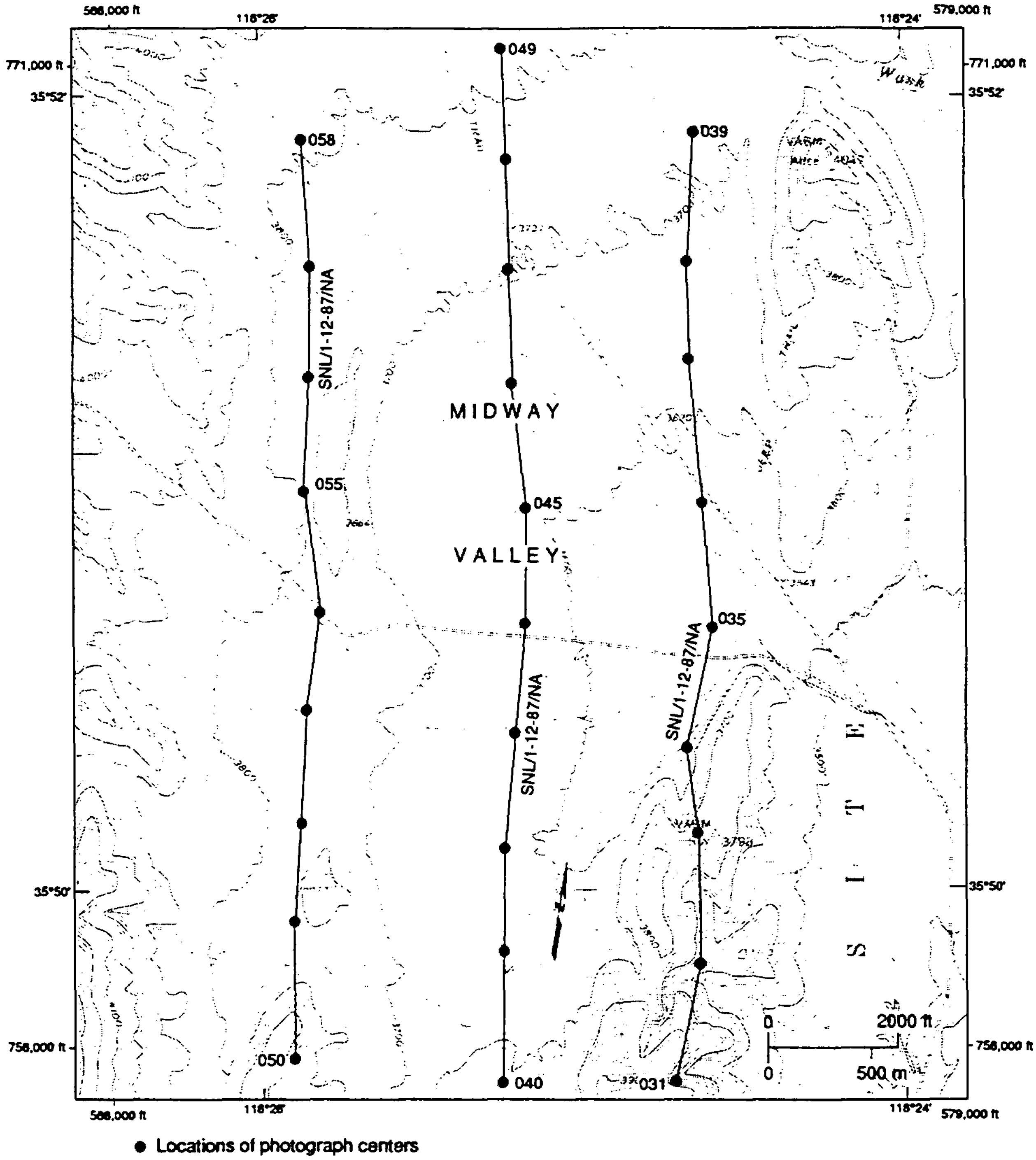


Figure A-1. 1:6,000-scale, color, afternoon low sun angle aerial photographs of the Midway Valley area used in the lineament study. Photographs taken by Sandia National Laboratories.

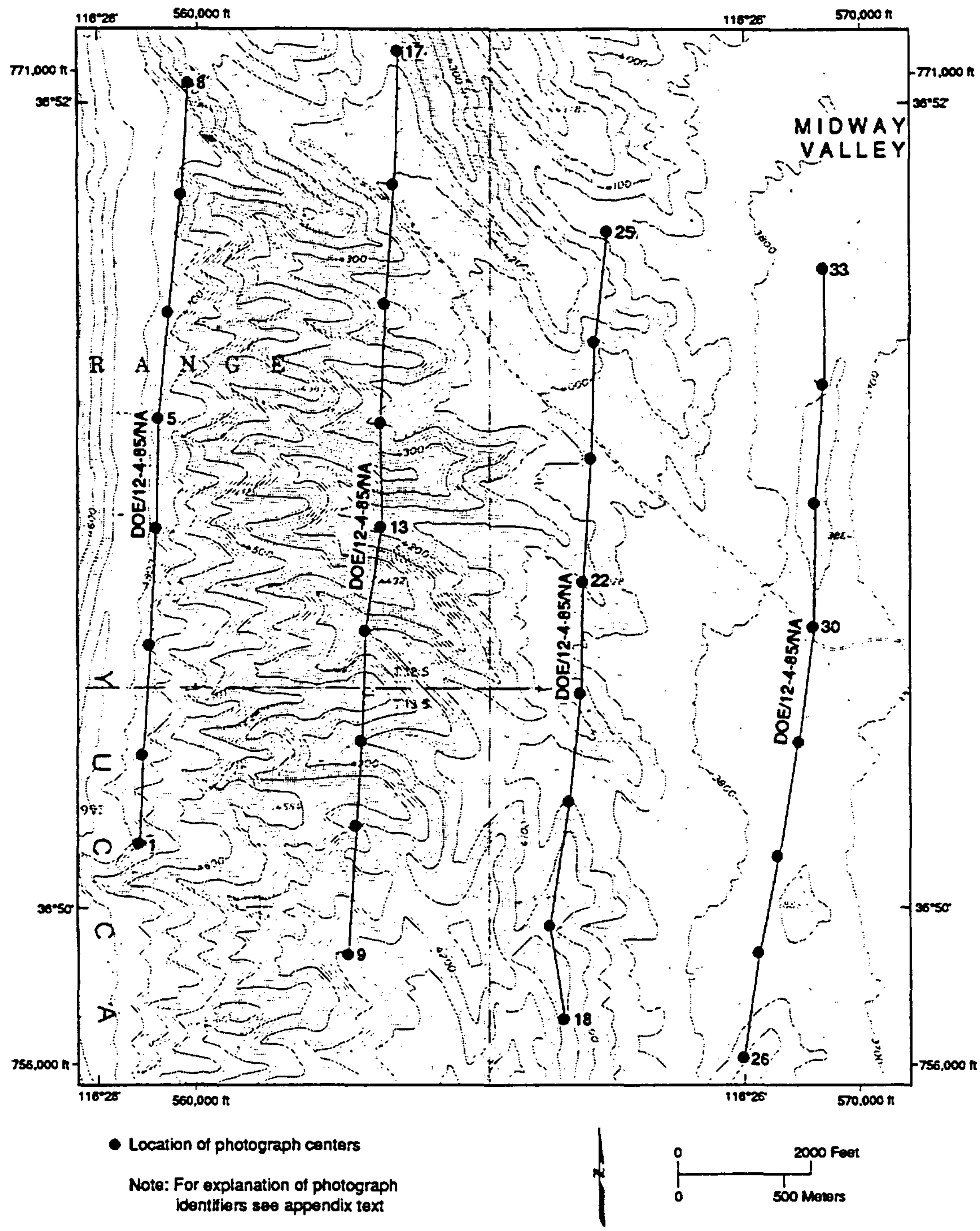


Figure A-2. 1:6,000-scale black and white aerial photographs of the Midway Valley area used in the lineament study. Photographs taken by the U.S. Department of Energy.

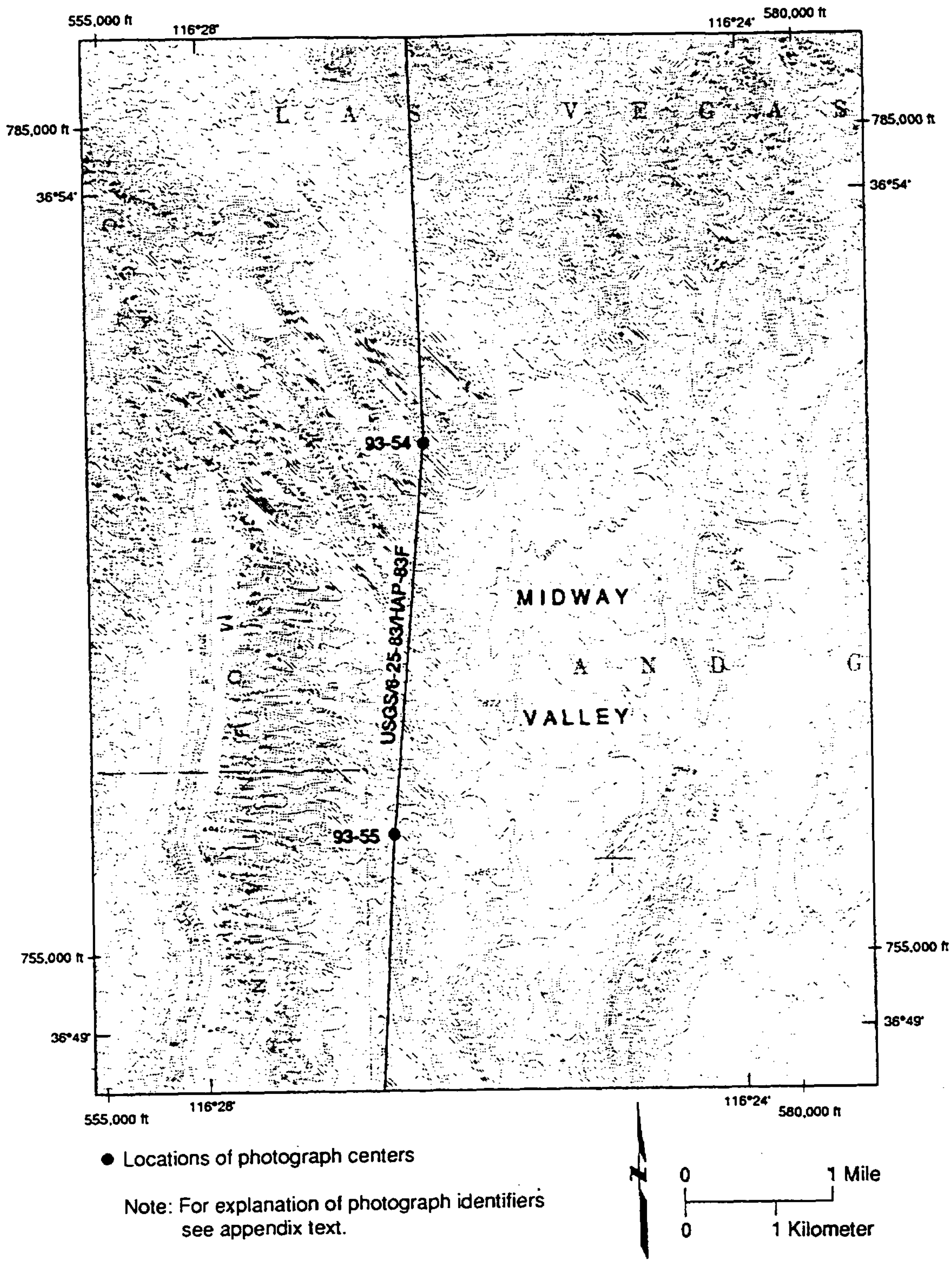
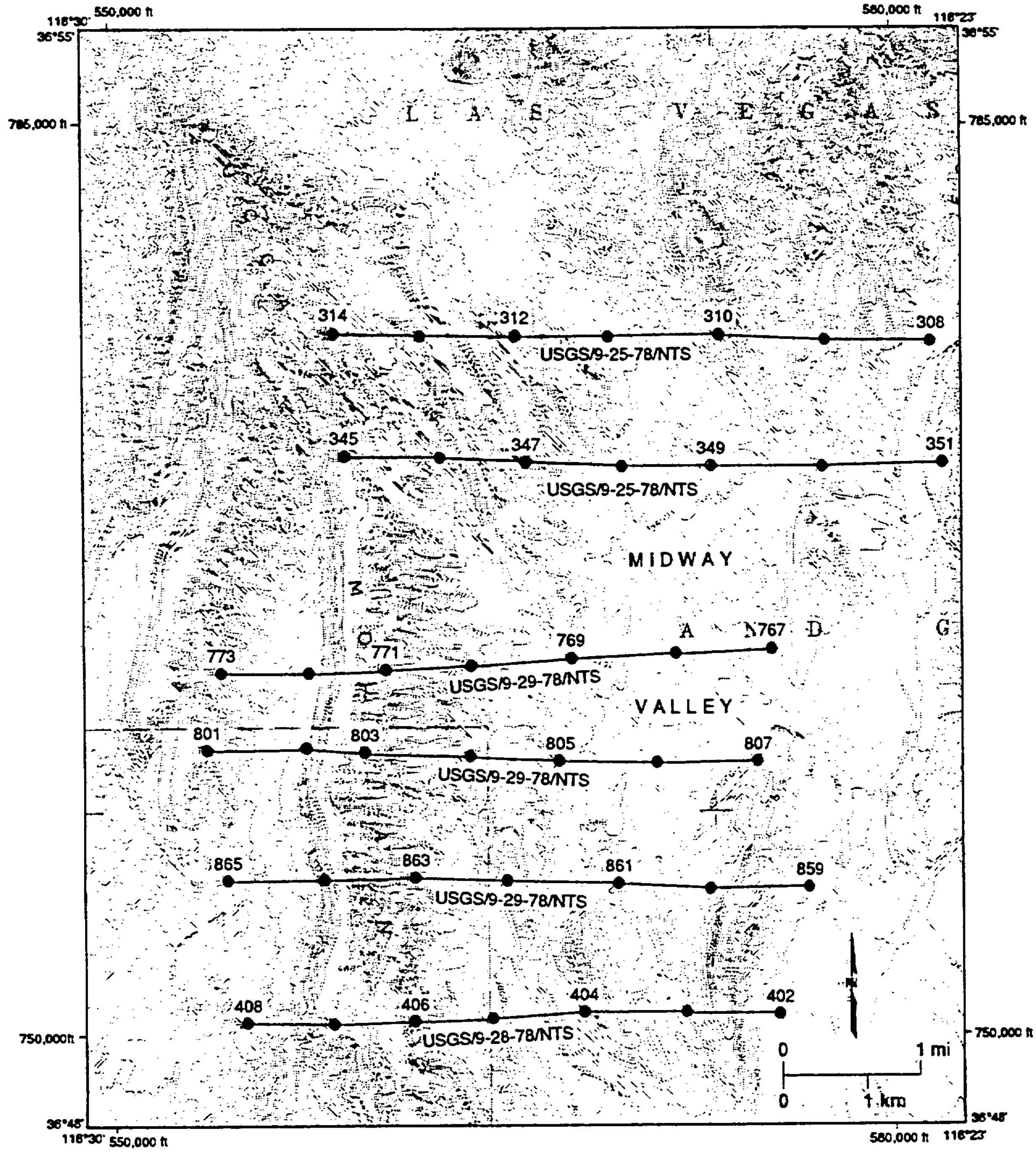


Figure A-3. 1:60,000-scale, false-color infrared aerial photographs of the Midway Valley area used in the lineament study. Photographs acquired from the U.S. Geological Survey.



● Locations of photograph centers

Note: For explanation of photograph identifiers see appendix text.

Figure A-4. 1:12,000-scale, black and white, aerial photographs of the Midway Valley area used in the lineament study. Photographs taken by U.S. Geological Survey.

APPENDIX B

CHARACTERISTICS OF LINEAMENTS ON PLATES 3, 4, 5 AND 6

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 3 (SHEET #10)
Page 1 of 3

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
10/1	N85W	880	X				X		X							
10/2	N80W	220	X							X				X		
10/3	N25W	360+	X				X			X						
10/4	N17E	390+	X				X			X						
10/5	N70W	240			X			X		X						
10/6	N66W	230			X					X						
10/7	N40W	1260		X					X	X		X				
10/8	N46W	425	X						X	X						
10/9	N48W	335	X						X	X						
10/10	N38W	365		X					X							
10/11	N38W	380		X					X					X		
10/12	N39W	545	X						X	X						
10/13	N36W	510		X					X							

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 3 (SHEET #10)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
10/14	N41W	320	X						X	X						
10/15	N19E	335	X				X			X	X					
10/16	N67E	245	X				X			X						
10/17	N47E	180	X							X						
10/18	N09E	175	X							X	X					
10/19	N21E	200	X				X		X	X	X					
10/20	N57E	80	X				X			X						
10/21	N56W	80	X						X	X						
10/22	N20W	340			X				X	X						
10/23	N52W	205		X					X			X				
10/24	N15E	105	X						X	X						
10/25	N81W	570	X				X			X			X			
10/26	N83E	370	X						X	X						

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 3 (SHEET #10)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
10/27	N81E	530	X					X	X	X						
10/28	N03E	600	X		X		X	X	X	X		X				
10/29	N61W	465		X				X	X							
10/30	N20E	540	X		X		X		X	X		X	X			
10/31	N36W	190	X					X		X						
10/32	N38E	145	X						X							
10/33	N60W	110	X							X						
10/34	N64W	90	X							X						

L(m) = Length in meters (rounded to nearest 5 meters)

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Q_a = Alluvium

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BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 4 (SHEET #11)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
11/1	N30W	490		X						X		X				
11/2	N18W	720		X					X							
11/3	N10W	200	X							X	X					
11/4	N04W	725			X				X	X						
11/5	N03W	1020			X	X			X	X		X				
11/6	N03W	215			X	X			X			X				
11/7	N08E	250			X				X	X						
11/8	N10W	340			X				X	X						
11/9	N05W	110			X				X							
11/10	N45W	330			X				X			X				
11/11	N03W	265			X	X			X			X				
11/12	N34W	115			X	X										
11/13	N34W	520	X					X		X		X				

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 4 (SHEET #11)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
11/14	N38W	750		X					X							
11/15	N65W	350			X	X			X							
11/16	N75W	280			X	X				X						
11/17	N64W	440			X					X						
11/18	N50W	480			X				X	X						
11/19	N55W	205			X					X						
11/20	N46W	805			X	X			X	X						
11/21	N50W	290			X				X							
11/22	N57W	680			X			X		X						
11/23	N25W	770			X				X							
11/24	N50W	180			X				X	X						
11/25	N58W	320			X				X							
11/26	N75W	330			X					X						

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
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Q_a = Alluvium

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BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 4 (SHEET #11)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
11/27	N34E	505			X					X						
11/28	N47W	340			X				X	X						
11/29	N50W	590			X					X						
11/30	N19W	450			X				X							
11/31	N27W	575			X				X							
11/32	N26W	440			X				X	X						
11/33	N24W	845			X				X							
11/34	N51W	125			X				X							
11/35	N37W	320			X				X							
11/36	N32W	385			X				X	X						
11/37	N30W	290			X				X	X						
11/38	N36W	150			X				X	X						
11/39	N38W	260			X				X	X						

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
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L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 4 (SHEET #11)
Page 4 of 7

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
11/40	N10E	145			X				X							
11/41	N15W	385			X				X							
11/42	N09W	180			X							X				
11/43	N32W	260			X				X			X				
11/44	N47E	270			X				X	X		X				
11/45	N19W	205			X				X							
11/46	N06W	320			X	X				X						
11/47	N16W	185+	X						X						X	
11/48	N17W	245	X				X								X	
11/49	N05W	510	X				X		X	X	X				X	
11/50	N22W	325	X				X			X						
11/51	N02W	580	X							X	X					
11/52	N25W	400	X				X		X	X						

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
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T = Tonal Contrast
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APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 4 (SHEET #11)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
11/53	N16W	565	X													
11/54	N08W	320	X				X			X						
11/55	N17W	415	X				X					X			X	
11/56	N84E	155	X				X			X						
11/57	N05W	170	X				X	X		X						
11/58	N01W	515	X						X	X	X				X	
11/59	N05W	215	X							X					X	
11/60	N50W	90+		X			X			X						
11/61	N10W	180+	X						X	X						
11/62	N05W	310		X				X		X		X				
11/63	N39W	160+	X				X			X						
11/64	N20W	315	X				X			X						
11/65	N10W	280		X				X	X			X				

L(m) = Length in meters (rounded to nearest 5 meters)

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Q_a = Alluvium

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BS = Bedrock Scarp
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C? = Possible Cultural Feature

CHARACTERISTICS OF LINEAMENTS ON PLATE 4 (SHEET #11)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
11/66	N15W	400	X				X		X	X						
11/67	N02W	430	X						X							
11/68	N05E	600	X				X			X						
11/69	N12E	155	X				X									
11/70	N22E	125	X							X						
11/71	N36W	160		X				X	X	X						
11/72	N38E	70	X						X	X						
11/73	N18W	110	X							X		X				
11/74	N21E	155	X						X	X						
11/75	N21E	170	X						X	X						
11/76	N28E	230	X						X	X						
11/77	N38E	235		X				X		X						
11/78	N13W	380	X				X			X		X	X			

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
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T = Tonal Contrast
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C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 4 (SHEET #11)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
11/79	N30W	180	X				X						X			
11/80	N45W	355	X				X		X							
11/81	N29E	150			X							X				
11/82	N09E	120			X							X				
11/83	N14E	155			X							X				
11/84	N09E	80			X							X				
11/85	N28W	75		X				X				X				

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
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BS = Bedrock Scarp
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T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

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TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES											
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/1	N34E	85	X							X		X				
16/2	N31E	80	X							X						
16/3	N03E	250	X							X						
16/4	N04W	145	X													
16/5	N03W	115	X					X		X						
16/6	N40W	175	X							X						
16/7	N27E	305	X							X		X				
16/8	N24E	245	X							X						
16/9	N31E	210	X							X		X				
16/10	N	40	X											X		
16/11	N03W	40	X											X		
16/12	N10E	210	X													
16/13	N76W	150	X				X			X						

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/14	N18E	155	X				X		X	X						
16/15	N45W	110	X						X	X						
16/16	N12E	125	X						X	X						
16/17	N59E	190	X			X				X						
16/18	N59W	95	X			X				X						
16/19	N58W	100	X							X						
16/20	N25W	125	X							X						
16/21	N40W	120	X	X		X				X						
16/22	N47W	305					X	X						X		
16/23	N08E	115	X							X						
16/24	N05E	100	X							X			X			
16/25	N05W	65	X							X						
16/26	N90W	190	X						X							

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)
Page 3 of 12

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/27	N	100	X				X									
16/28	N01E	270	X				X			X			X			
16/29	N19E	90	X							X						
16/30	N02W	115	X							X						
16/31	N07W	330	X				X		X	X	X		X			
16/32	N18W	85	X							X						
16/33	N03W	355	X						X	X		X	X			
16/34	N09W	265	X							X						
16/35	N60W	245	X					X	X	X					X	
16/36	N04E	100	X							X						
16/37	N17W	125	X							X						
16/38	N13W	90	X							X						
16/39	N03E	105	X							X				X		

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/40	N08W	145	X				X			X						
16/41	N23W	95	X							X				X		
16/42	N49W	80	X											X		
16/43	N26E	150	X							X						
16/44	N04E	65	X												X	
16/45	N16E	170	X						X	X						
16/46	N27E	110		X						X						
16/47	N35W	480			X				X	X		X				
16/48	N22W	300		X				X	X	X						
16/49	N12E	90	X						X	X						
16/50	N04E	40	X											X		
16/51	N60W	325		X			X		X							
16/52	N53W	630			X				X	X		X				

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/53	N05E	235	X							X		X				
16/54	N15E	240		X				X		X		X				
16/55	N40E	290			X				X	X						
16/56	N02W	170	X							X						
16/57	N26W	110		X				X				X				
16/58	N19W	390		X			X		X						X	X
16/59	N01E	150								X				X		
16/60	N06W	120		X						x		x				
16/61	N54W	200			X				X	X						
16/62	N04E	150	X				X			X						
16/63	N15W	250	X						X		X			X		
16/64	N10E	350	X				X		X	X						
16/65	N12E	190	X							X						

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/66	N20W	350		X				X		X		X				
16/67	N27E	170		X				X		X						
16/68	N34E	175			X					X		X				
16/69	N75W	240		X				X	X							
16/70	N20E	180	X							X	X					
16/71	N59W	420		X			X		X							
16/72	N14W	125			X					X						
16/73	N39W	360			X				X			X				
16/74	N20W	85			X					X						
16/75	N06W	120			X					X		X				
16/76	N17W	170			X			X		X						
16/77	N87W	180			X			X		X						
16/78	N46W	320		X			X		X							

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
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DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
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APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/79	N06E	170	X							X	X					
16/80	N06E	360	X							X	X					
16/81	N51W	105		X					X			X				
16/82	N54W	90		X												
16/83	N82W	445			X											
16/84	N02E	105			X							X				
16/85	N12E	145	X							X						
16/86	N05E	245	X							X						
16/87	N30W	130	X					X								
16/88	N56W	120		X					X	X						
16/89	N24E	130		X				X	X							
16/90	N09E	120			X							X				X
16/91	N25E	220			X			X				X				

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/92	N50W	155		X			X		X							
16/93	N69W	240		X			X		X							
16/94	N46W	565		X			X		X	X						
16/95	N21E	270	X				X			X						
16/96	N01E	100	X				X									
16/97	N14E	230			X							X				
16/98	N07E	210			X							X				
16/99	N07E	85			X							X				
16/100	N17E	150			X							X				
16/101	N15E	215			X							X				
16/102	N14E	95			X					X		X				
16/103	N08E	220		X			X		X			X				
16/104	N17E	350		X					X							

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/105	N22W	335	X			X				X		X			X	
16/106	N15W	220	X				X					X		X		
16/107	N02W	125		X								X				
16/108	N46W	210			X				X	X						
16/109	N03W	120			X							X				
16/110	N47E	90			X				X			X				
16/111	N01W	90			X							X				
16/112	N09E	185	X				X			X				X		
16/113	N05W	155	X				X			X						
16/114	N53W	635			X				X	X						
16/115	N26E	170		X								X				
16/116	N06E	120	X				X			X		X		X		
16/117	N15W	190	X													

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES											
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/118	N34W	185	X							X		X				
16/119	N36W	190	X						X	X	X					
16/120	N30W	280	X				X			X					X	
16/121	N04E	95	X							X						
16/122	N10E	210		X						X		X				
16/123	N15E	150		X				X		X		X				
16/124	N12E	440		X								X				X
16/125	N13W	200		X				X				X				
16/126	N25W	260	X						X							
16/127	N01W	150		X				X				X				
16/128	N03E	355		X								X				X
16/129	N23E	130			X				X			X				
16/130	N30W	160		X				X	X							

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/131	N57W	60		X								X				
16/132	N22W	180			X				X							
16/133	N30W	215	X							X		X				
16/134	N13E	80	X							X						
16/135	N	240		X				X		X		X				
16/136	N29E	90		X								X				
16/137	N10E	175		X		X						X				
16/138	N11E	210		X			X	X	X							
16/139	N39W	330	X						X		X		X			
16/140	N	90		X								X				
16/141	N54E	170		X			X		X	X						
16/142	N03W	155	X				X									
16/143	N20W	235+		X					X							

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 5 (SHEET #16)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
16/144	N08W	210					X									
16/145	N16W	85	X									X				
16/146	N30W	160	X							X		X				
16/147	N28E	95	X							X						
16/148	N22E	85	X							X						
16/149	N22W	100	X							X						
16/150	N32W	115	X							X						
16/151	N31W	240+	X						X							

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 6 (SHEET #17)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/1	N07E	125			X							X				
17/2	N09E	445		X				X	X			X				
17/3	N52W	505	X		X					X						
17/4	N13W	205	X				X									
17/5	N17E	245		X												
17/6	N22E	145		X								X				
17/7	N13E	260		X				X		X		X				X
17/8	N04E	115		X					X	X						
17/9	N09E	100	X					X		X						
17/10	N19E	340	X					X		X						
17/11	N22E	120		X				X		X		X				X
17/12	N04E	200	X							X						
17/13	N04E	200	X					X		X						

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 6 (SHEET #17)
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LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/14	N02W	110	X									X				
17/15	N08W	150	X							X		X				
17/16	N25W	130		X				X	X							
17/17	N04E	85		X						X		X				
17/18	N17W	280						X	X			X				
17/19	N11W	100	X							X		X				
17/20	N45W	540			X				X	X						
17/21	N48W	305							X							
17/22	N75W	240			X	X										
17/23	N19E	335		X					X			X				
17/24	N03W	300	X				X			X					X	
17/25	N09W	295	X				X			X					X	
17/26	N01W	175		X						X		X				

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 6 (SHEET #17)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/27	N02W	360	X						X	X	X	X				
17/28	N02E	100		X				X				X				
17/29	N08W	355	X						X	X	X					
17/30	N01E	140	X					X		X						
17/31	N09W	100	X						X	X						
17/32	N54W	95			X				X							
17/33	N01E	100	X									X				
17/34	N	215	X							X	X	X				
17/35	N01E	110	X									X				
17/36	N03W	240	X				X			X						
17/37	N33W	220		X				X		X		X				
17/38	N20W	505			X				X	X		X				
17/39	N16W	270			X				X			X				

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/40	N25W	295			X											
17/41	N23W	515			X				X			X				
17/42	N06W	325			X	X			X							
17/43	N22W	240		X					X	X						
17/44	N09W	250			X				X	X		X				
17/45	N49W	540			X	X			X	X						
17/46	N06W	160			X				X							
17/47	N11W	325			X	X			X	X						
17/48	N14W	340		X					X	X						
17/49	N17W	230			X				X	X						
17/50	N19W	100			X							X				
17/51	N29W	590			X				X	X						
17/52	N33W	970			X				X	X						

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BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

CHARACTERISTICS OF LINEAMENTS ON PLATE 6 (SHEET #17)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/53	N46W	220			X	X				X		X				
17/54	N34W	520			X				X							
17/55	N04E	295			X	X						X				
17/56	N31W	710			X											
17/57	N08W	180			X				X	X						
17/58	N85W	335			X							X				X
17/59	N12E	215			X			X	X	X		X				
17/60	N03E	105			X							X				
17/61	N01E	75			X							X				
17/62	N16E	150			X					X		X				
17/63	N08W	180			X							X				
17/64	N54E	550			X	X				X		X				
17/65	N63E	170			X				X			X				

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
V = Vegetative Alignment/Contact

DM = Displaced Marker Horizon
TM = Terminated Marker Horizon
L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 6 (SHEET #17)
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LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/66	N05W	130			X							X				
17/67	N09E	240			X							X				
17/68	N60W	780			X				X							
17/69	N57W	180			X				X							
17/70	N47W	230			X				X							
17/71	N12W	80			X							X				
17/72	N09W	120			X							X				
17/73	N80E	370			X				X							
17/74	N06W	155			X							X				X
17/75	N10W	140			X							X				X
17/76	N57E	720			X				X	X		X				
17/77	N61E	170			X				X	X						
17/78	N68E	330			X				X	X						

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
BS = Bedrock Scarp
BIS = Break-in-Slope
LD = Linear Drainage
T = Tonal Contrast
TS = Topographic Saddle
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DM = Displaced Marker Horizon
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L? = Possible Non-Tectonic Lithologic Contact
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APPENDIX B

CHARACTERISTICS OF LINEAMENTS ON PLATE 6 (SHEET #17)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/79	N67W	35			X					X						
17/80	N86E	160			X				X	X					X	
17/81	N72E	290			X				X	X					X	
17/82	N69E	280			X				X			X				
17/83	N64E	110			X				X			X				
17/84	N06W	175			X							X				
17/85	N62E	450			X				X	X						
17/86	N01E	510			X			X		X		X				
17/87	N14W	130			X							X				
17/88	N	155			X							X				
17/89	N13W	90			X							X				
17/90	N03E	150			X							X				
17/91	N07W	140			X							X				

L(m) = Length in meters (rounded to nearest 5 meters)

BRX = Bedrock
BRX/Q_a = Bedrock/Alluvium Contact
Q_a = Alluvium

AS = Alluvial Scarp
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DM = Displaced Marker Horizon
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L? = Possible Non-Tectonic Lithologic Contact
C? = Possible Cultural Feature

APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 6 (SHEET #17)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/92	N79W	170			X				X							
17/93	N19E	100			X							X				
17/94	N10E	260			X			X		X						
17/95	N60E	145			X				X							
17/96	N80E	115			X				X							
17/97	N90E	490			X				X	X					X	
17/98	N90E	620			X	X				X					X	
17/99	N60W	230			X					X					X	
17/100	N05E	85			X					X		X				
17/101	N21W	120			X							X				
17/102	N21W	90			X							X				
17/103	N64E	120			X				X							
17/104	N02W	240			X							X				

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	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/105	N15W	90			X							X				
17/106	N03W	105			X							X				
17/107	N25E	240			X							X				
17/108	N66W	145			X					X						
17/109	N15E	320			X							X				
17/110	N15E	120			X							X				
17/111	N13E	70			X							X				
17/112	N56W	170			X				X							
17/113	N25W	325			X					X						
17/114	N20W	85			X							X				
17/115	N46W	305			X					X						
17/116	N50W	420			X					X						
17/117	N80W	350			X				X	X						

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LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES											
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/118	N60E	210			X			X		X						
17/119	N65W	140			X					X						
17/120	N75W	140			X				X							
17/121	N80W	160			X				X	X						
17/122	N76E	95			X							X				
17/123	N19W	280			X							X				
17/124	N22W	280			X					X		X				
17/125	N33E	270			X					X						
17/126	N78E	205			X				X							
17/127	N	145			X				X	X						
17/128	N80E	240			X	X			X							
17/129	N02W	80			X							X				
17/130	N02W	180			X							X				

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APPENDIX B
CHARACTERISTICS OF LINEAMENTS ON PLATE 6 (SHEET #17)

LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/131	N56E	450			X				X	X		X				
17/132	N04W	215			X			X		X		X				
17/133	N04W	90			X				X			X				
17/134	N04W	110			X							X				
17/135	N28W	100			X			X		X		X				
17/136	N12E	175			X							X				
17/137	N45W	190			X					X						
17/138	N12W	175			X					X		X				
17/139	N72E	200			X				X							
17/140	N12W	90			X			X				X				
17/141	N48E	210			X				X							
17/142	N02E	145			X					X		X				
17/143	N20W	405		X					X							

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LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/144	N19W	415		X				X	X	X						
17/145	N03E	265	X				X			X						
17/146	N30W	270		X					X	X						
17/147	N03E	305			X					X						
17/148	N24W	130	X					X		X						
17/149	N78E	300	X				X		X							
17/150	N25W	295	X					X		X						
17/151	N09W	325		X				X		X		X				
17/152	N12E	120		X						X		X				
17/153	N04W	160		X						X		X				
17/154	N49E	220		X				X	X	X						
17/155	N02E	205		X				X		X						
17/156	N04W	335		X					X							

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LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/157	N10E	140		X								X				
17/158	N55W	130	X							X						
17/159	N30E	510		X				X	X							
17/160	N60W	320		X				X	X							
17/161	N31E	325		X			X	X	X							
17/162	N82W	100	X						X							
17/163	N11W	85										X				
17/164	N08W	65										X				
17/165	N12W	80		X								X				
17/166	N17W	720	X						X		X		X			
17/167	N70W	80	X										X			
17/168	N27W	590	X				X		X	X		X				
17/169	N66W	200	X						X					X		

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LINEAMENT #	DIMENSIONS		LITHOLOGIC GROUP			CHARACTERISTIC FEATURES										
	TREND	L(m)	BRX	BRX/Q_a	Q_a	AS	BS	BIS	LD	T	TS	V	DM	TM	L?	C?
17/170	N89W	190	X						X							
17/171	N26E	575		X		X						X				
17/172	N35E	140		X				X		X						
17/173	N64W	100		X					X							
17/174	N02W	150		X			X				X		X			
17/175	N72W	155		X					X	X						
17/176	N20E	720		X					X			X				
17/177	N11E	210	X				X		X		X			X		
17/178	N55W	200		X					X							
17/179	N87W	110		X					X							

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APPENDIX C

RELEVANT YUCCA MOUNTAIN PROJECT DATA AND INFORMATION BASES

Information from the Reference Information Base Used in this Report

This report contains no information from the Reference Information Base.

Candidate Information for the Reference Information Base

This report contains no candidate information for the Reference Information Base.

Candidate Information for the Site & Engineering Properties Data Base

This report contains no candidate information for the Site and Engineering Properties Data Base.

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