UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PRELIMINARY INTERPRETATIONS OF GEOLOGIC RESULTS OBTAINED FROM BOREHOLES UE25a-4, -5, -6, AND -7, YUCCA MOUNTAIN, NEVADA TEST SITE

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By

Richard W. Spengler and J. G. Rosenbaum

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PRELIMINARY INTERPRETATIONS OF GEOLOGIC RESULTS OBTAINED
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ABSTRACT

A study of the subsurface geology was undertaken in association with the Nevada Nuclear Waste Storage Investigations to identify any near-surface structural features that may be present beneath one of four linear northwest-trending washes that transect the northeastern part of Yucca Mountain at the Nevada Test Site. Four drill holes were continuously cored to depths of about 500 feet. In descending order, the drill holes penetrated the Tiva Canyon, Yucca Mountain, Pah Canyon, and Topopah Spring Members of the Paintbrush Tuff of Tertiary age. These units consist almost entirely of nonwelded to densely welded rhyolitic ash-flow tuffs, separated by thin beds of air-fall and reworked tuff.

The Yucca Mountain and Pah Canyon Members are of particular interest because their total thicknesses were penetrated in each of the four holes. A comparison of thickness variations of both units indicate progressive thinning from northwest to southeast, which appears consistent with that of typical thinning away from source areas located to the northwest.

An analysis of oriented core samples taken within the densely welded Topopah Spring Member in each drill hole indicates two complementary sets of high-angle fractures striking N. 12° W. and N. 37° E. Compilations of fracture frequencies show that core from drill holes located close to the wash margins is more fractured than core from drill holes near the center of the wash. The northeasterly margin of the wash shows evidence of minor faulting inferred from the presence of a zone of en echelon shear fractures found in core from hole UE25a-4. These shear fractures are high angle, show evidence of brecciation, and most strike parallel to the wash lineation. Identification of structure along the southwest edge of the wash was independently obtained through the analysis of eutaxitic structure within core of the Topopah Spring Member, and confirmed by paleomagnetic studies within the same member. Measurements of foliation attitudes in drill holes UE25a-4, -5, and -7 indicate a mean strike direction of about N. 10° W. within the wash. In marked contrast, the mean foliation attitude in UE25a-6, located outside the wash trend, strikes N. 23° E. This 33° change in strike occurs abruptly over a distance of about 1,000 feet. The difference between these orientations, as well as the absence of vertical offset along shear fractures in UE25a-4 and between drill holes seem best explained by tectonic rotation that occurred about a near-vertical axis as a result of minor strike-slip or oblique-slip movement within the wash. As no abrupt changes in thickness were apparent in the Yucca Mountain and Pah Canyon Members, the magnitude of displacement along the structure is considered to be of small scale. Additional subsurface information, particularly in the area underlying ridges northeast of the wash, is needed not only to confirm the existence of the structure but also to aid in determining the amount of lateral movement.

INTRODUCTION

Since 1978, the USGS (U.S. Geological Survey) has been providing technical assistance in characterizing suitable rock masses at or contiguous to the NTS (Nevada Test Site) for long-term storage of high-level nuclear waste. Current efforts have been focused on investigating Yucca Mountain, a volcanic highland situated along the western boundary of NTS in southern Nevada (fig. 1). Detailed stratigraphic and structural studies have been in progress along a northeastern segment of the highland in a wedge-shaped area bounded by Basin and Range faults, most of which trend north-northeast. A series of four locally steep-walled, nearly parallel, linear washes transect the northeastern half of the area of interest and display trends similar to major faults to the northeast (fig. 2). Prior to the present study, drill hole UE25a-1, located about 1,600 feet southeast of the edge of the area of interest, was cored to a depth of 2,500 feet (Spengler and others, 1979). Subsurface information derived from the upper 500 feet of this drill hole is included in this report to compare with recently acquired data.

Recent (1979) surface electrical surveys have been conducted by both the University of Utah and the USGS perpendicular to the trend of the washes in an attempt to better understand factors that have influenced the present drainage pattern. Preliminary data of both pole-dipole and dipole-dipole resistivity/IP electrical methods indicate numerous vertical and horizontal discontinuities between adjacent resistive bodies that strongly suggest a broad zone of faulting, fracturing, and (or) brecciation (D. B. Hoover, written commun., 1979). Within the major wash, resistivity contrasts have been inferred by Smith and Ross (1979 to indicate faulting that may have dropped the area of the wash with respect to ridges on either side, and may extend to depths greater than 1,500 feet.

To verify the existence of structural discontinuities suggested by the linear washes and electrical anomalies, a drilling program was initiated in June 1979, to obtain geologic information within the southernmost of four northwest-trending washes. The intention of the present account is to provide detailed stratigraphic and structural data obtained from the drilling program. Final interpretations of geophysical surveys are not discussed in detail here. However, relevant surface data concerning the geologic setting will be given to support preliminary interpretations.

All measurements related to borehole locations and depths are given in this report in English units. If metric units are desired, refer to the following conversion factors.

Multiply English units	By	To obtain metric units
foot (ft)	0.3048	meters (m)
inch (in.)	2.54	centimeters (cm)
mile	1.6	kilometers (km)

ACKNOWLEDGMENTS

Valuable assistance in compiling fracture frequency data was contributed by R. B. Livermore of Fenix & Scisson, Inc., and by J. E. Turney of Colorado Geological Survey (formerly USGS). M. P. Chornack and R. B. Livermore provided surveying assistance. Acknowledgment is also given to geologists M. J. Baldwin, M. P. Chornack, A. C. Gordon, R. B. Livermore, and L. D. Parrish of Fenix & Scisson, Inc., for their assistance in monitoring sampling operations.

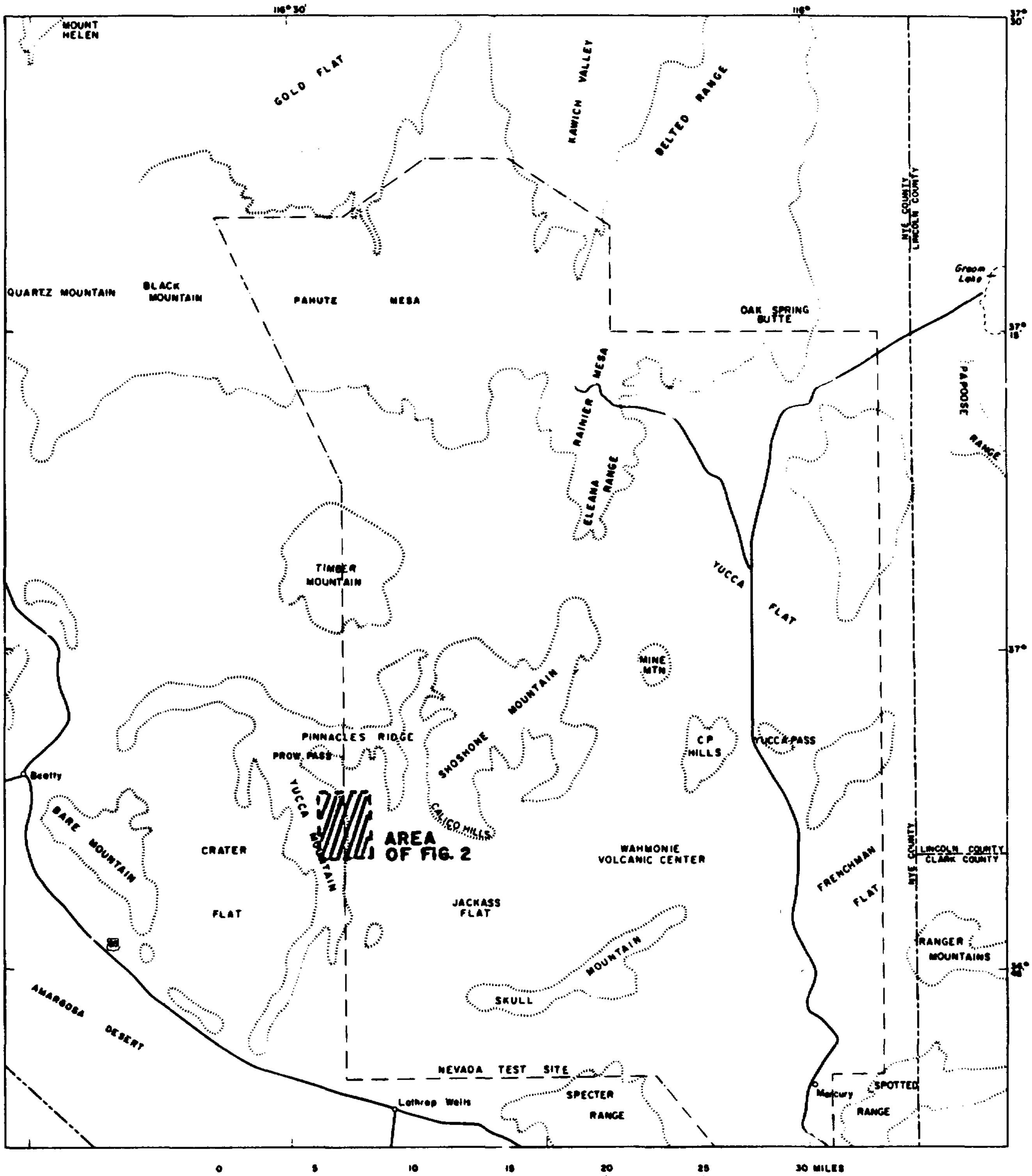

Figure 1.--Index map of the Nevada Test Site and vicinity showing location of study area.

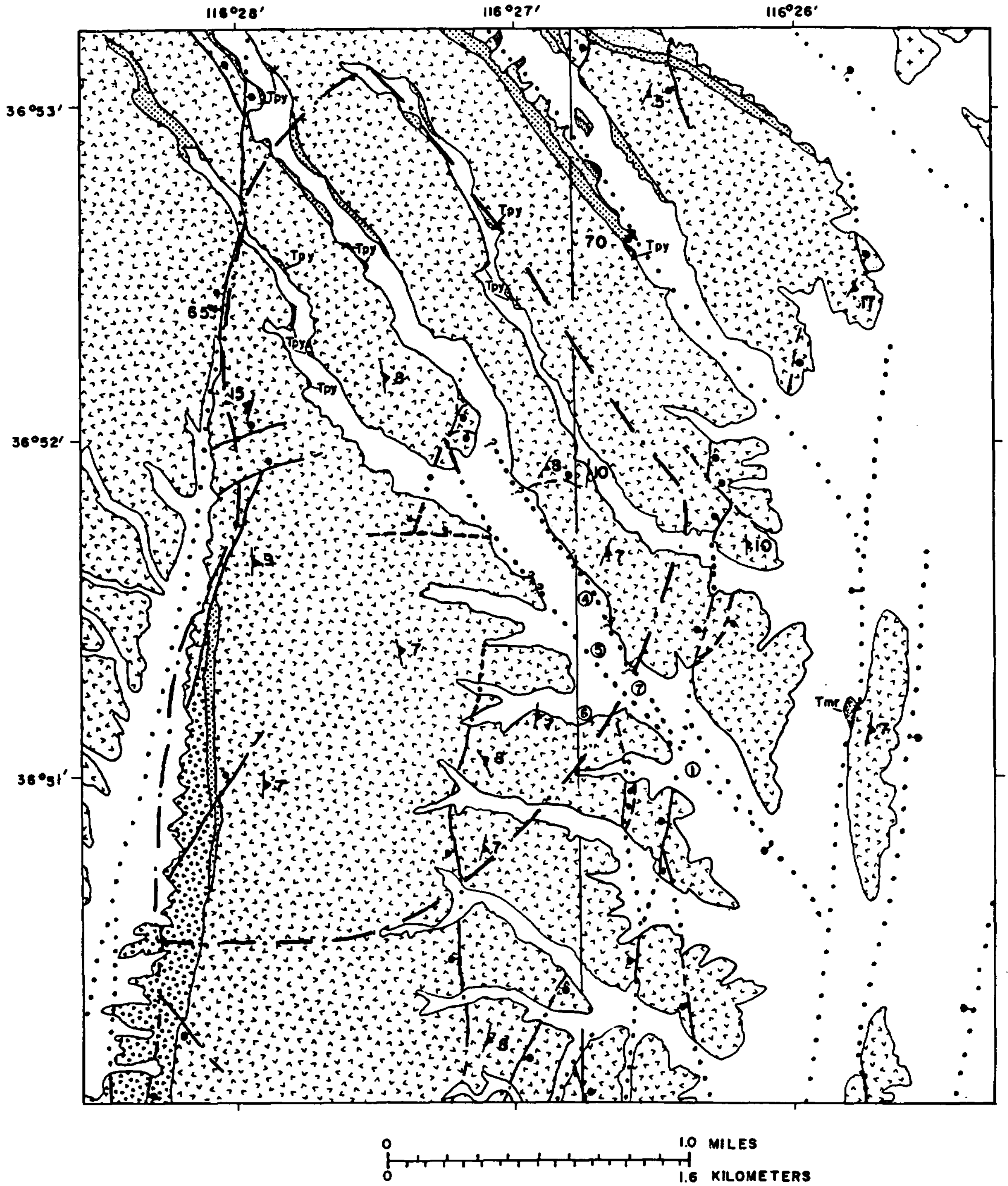

FIGURE 2- GENERALIZED GEOLOGIC MAP OF THE AREA OF INTEREST

EXPLANATION

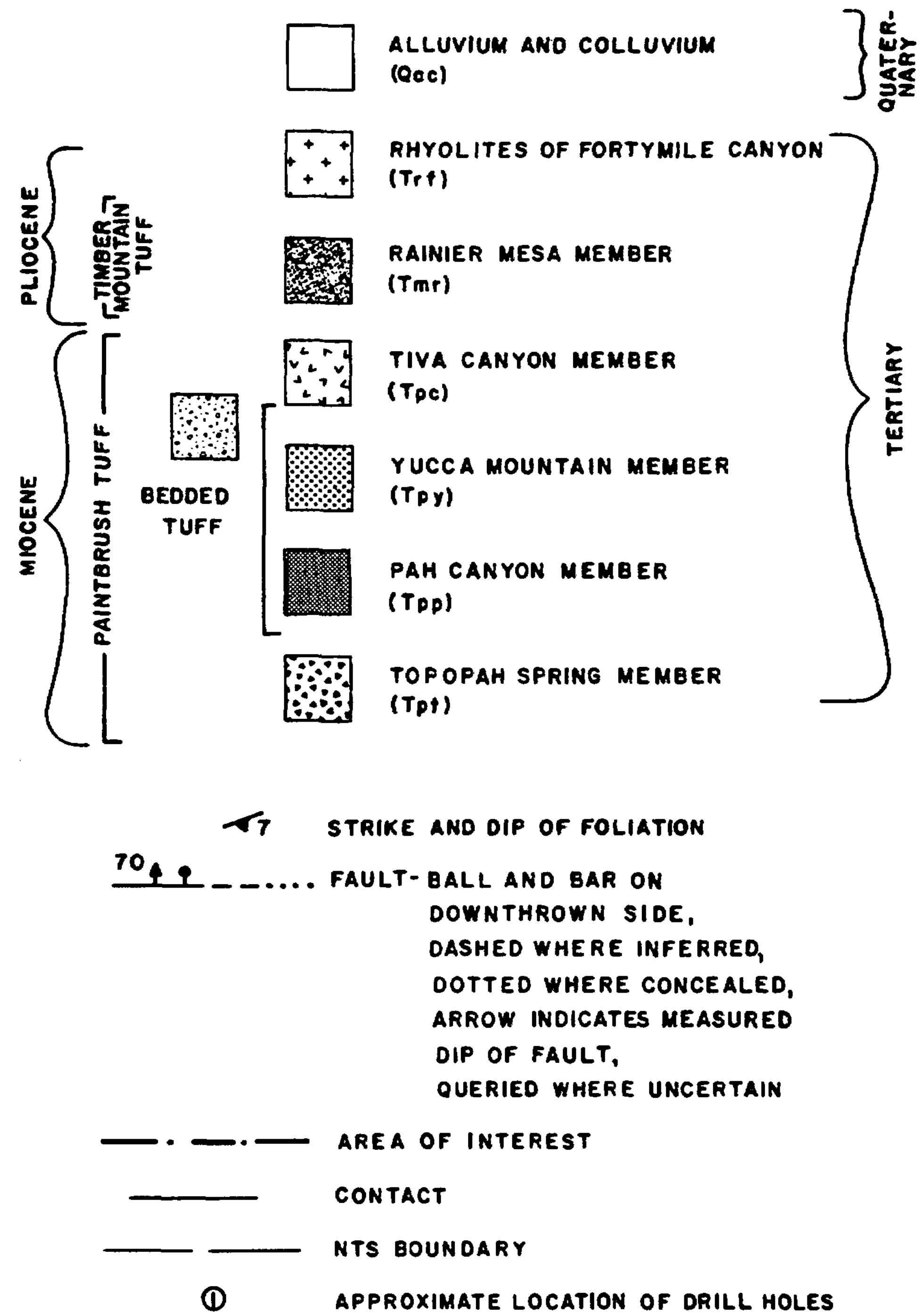

FIGURE 2.--
CONTINUED

METHOD OF STUDY

In order to acquire subsurface structural information about the origin of the major northwest-trending wash in the center of the area of interest at Yucca Mountain (fig. 2), a total of four drill holes, designated as UE25a-4, -5, -6, and -7, were continuously cored from the bottom of surface casing (70 to ±120 ft) to depths of about 500 feet. Core sizes were 3.5 and 2.5 inches. All holes were drilled as close as possible to vertical, except UE25a-7, which was intentionally inclined 26° toward a direction of S. 51° W.

Geographic constraints limited investigations to that part of the major wash situated within the NTS boundaries, thus, UE25a-4 was positioned near the northeast side of the wash in an attempt to sample a conductive zone where particularly abrupt resistivity contrasts were noted from surface electrical surveys (Smith and Ross, 1979; D. B. Hoover, written commun., 1979). Similarly, the intent of UE25a-7 was to intersect a resistive discontinuity along the southwestern edge of the wash. UE25a-5 was drilled near the middle of the wash, and UE25a-6 was sited at the mouth of a small tributary outside the wash trend to act as a control drill hole and to complete a triangular array between UE25a-5 and -7 for future hole-to-hole electrical surveys.

Of the 1,580 feet cored in all four drill holes, nearly 43 percent was taken using oriented core techniques to provide data on the spatial relationships of any faults and (or) fracture zones present in bedrock underlying the wash. The method employs the use of an orienting core barrel, similar to conventional core barrels, except that three triangular scribes are mounted in the shoe at the base of the inner barrel. Asymmetric arrangement of the three scribes allows the reference scribe mark to be easily identified. A survey instrument, which includes a compass and multishot camera is enclosed within a nonmagnetic drill collar and mounted on top of the inner core barrel, alined with the orienting scribe. During coring operations, drilling is suspended at 2- to 3-foot intervals to allow the camera to take an orientation photograph unaffected by vibration. This process is continued until a full core run is completed. With the drift direction of the hole and reference groove orientations recorded, plunge directions of structural features in the core can then be determined.

Preliminary examination of welded tuff foliation planes in core indicated that, whereas there was an obvious preferred orientation in each of the holes, several individual directions deviated significantly from the dominant cluster, which prompted concern that some of this scatter might be the result of misorientation of some of the core segments. Conceivably, misorientation could occur for the following reasons: (1) in the absence of geologic evidence, it is often necessary to assume that core loss occurs at the bottom of a given run. If this assumption is in error, then the depth assigned to a particular segment of core, and therefore its orientation, may also be in error (Rowley and others, 1971); (2) inaccuracy in orientation can potentially occur if fractured segments of core rotate within the throat of the core bit prior to entry into the inner barrel where the core is scribed; and (3) excessive torque during coring in fractured rock can cause twisting of the core barrel and result in misalinement of the survey instrument and reference scribe. If this misalinement is not accounted for after each core run, an error in the direction of the reference groove can occur.

Measurements of the paleomagnetic directions of samples taken from various core segments provided a means of checking orientations. Welded tuffs possess a thermoremanent magnetization which parallels the geomagnetic field at the time of cooling. Therefore, measurement of the remanent magnetizations of a group of well-oriented core samples from the same flow unit should produce a well-grouped set of paleomagnetic directions.

A set of paleomagnetic samples, 1 inch in diameter, was collected from each of the drill holes such that their orientation with respect to the reference groove was maintained. These samples were taken from core segments where measurements of fracture and (or) foliation orientations had been obtained. The natural remanent magnetization and remanence after alternating field demagnetization at a peak field of 200 oersteds for each sample was obtained with spinner magnetometer. The paleomagnetic directions obtained from the Topopah Spring Member after alternating field demagnetization are presented on figure 3. Inspection of this data reveals two important features. First, for each drill hole the majority of points form a fairly tight cluster. Second, in each drill hole there are a number of samples with remanent directions that vary significantly from the mean direction of the "well grouped" samples.

In essentially all cases, the scattered directions are close to directions that can be obtained by rotation of the mean direction of the clustered samples about the axis of the core. Therefore, it is very likely that the core segments from which these anomalous samples were obtained were misoriented as a result of one or more of the factors previously discussed. For this reason, each core segment that was apparently misalined was reoriented by rotation about the core axis by the angle that minimized the difference between its remanent directions and the mean direction of the "well grouped" samples.

STRATIGRAPHY

Almost all of the exposed ash-flow tuffs in the northern part of Yucca Mountain are Miocene in age. This volcanic section, designated Paintbrush Tuff, totals more than 1,000 feet in thickness and forms a group of tuffs closely related genetically, chemically, and petrographically (Orkild, 1965).

All four core holes penetrated the four members constituting the Paintbrush Tuff which include, in descending order: (1) the lower portion of the Tiva Canyon, (2) Yucca Mountain, (3) Pah Canyon, and (4) the upper part of the Topopah Spring. Lithologically, the upper and lowermost members consist predominantly of densely welded devitrified ash-flow tuff and enclose a sequence of nonwelded ash-flow tuff and tuffaceous beds that include the Yucca Mountain and Pah Canyon Members. Together these members account for about one-third of the cored interval and often appear extremely friable, vitric, and, in some instances, slightly argillic. Tables 1-4 provide a detailed description of the various subunits making up each of the four members. A graphic representation of stratigraphic and structural characteristics is provided on figure 4.

Nearly all of the area of interest is covered by more than 200 feet of the Tiva Canyon Member (fig. 2), the youngest of the four members. The unit forms steep slopes covered with talus. Relief between ridge tops and wash bottoms commonly varies between 200 and 300 feet. The Tiva Canyon consists of massive, densely welded rhyolitic tuff containing variable amounts of lithophysal cavities. About a mile north of the drill-hole sites the underlying Yucca Mountain Member crops out along wash margins.

Alluvium

Surficial deposits filling the wash are predominantly made up of ash-flow and bedded tuff debris ranging in size from silt to boulder-size fragments. Along the margins of the wash, these deposits extend to a depth of 30 feet as indicated by drill holes UE25a-4 and -6. Thickness of the alluvium increases substantially toward the middle of the wash where it was determined to be 90 and 137 feet thick in drill holes UE25a-5 and -7, respectively. Most contacts between alluvium and bedrock were determined by examination of bit cuttings prior to coring, and, in at least one case (UE25a-5), sample contamination precluded the recognition of a discrete tuff/alluvium boundary. No attempt was made to distinguish between colluvium and alluvium, except in UE25a-7 where the lowermost part of material filling the wash was cored.

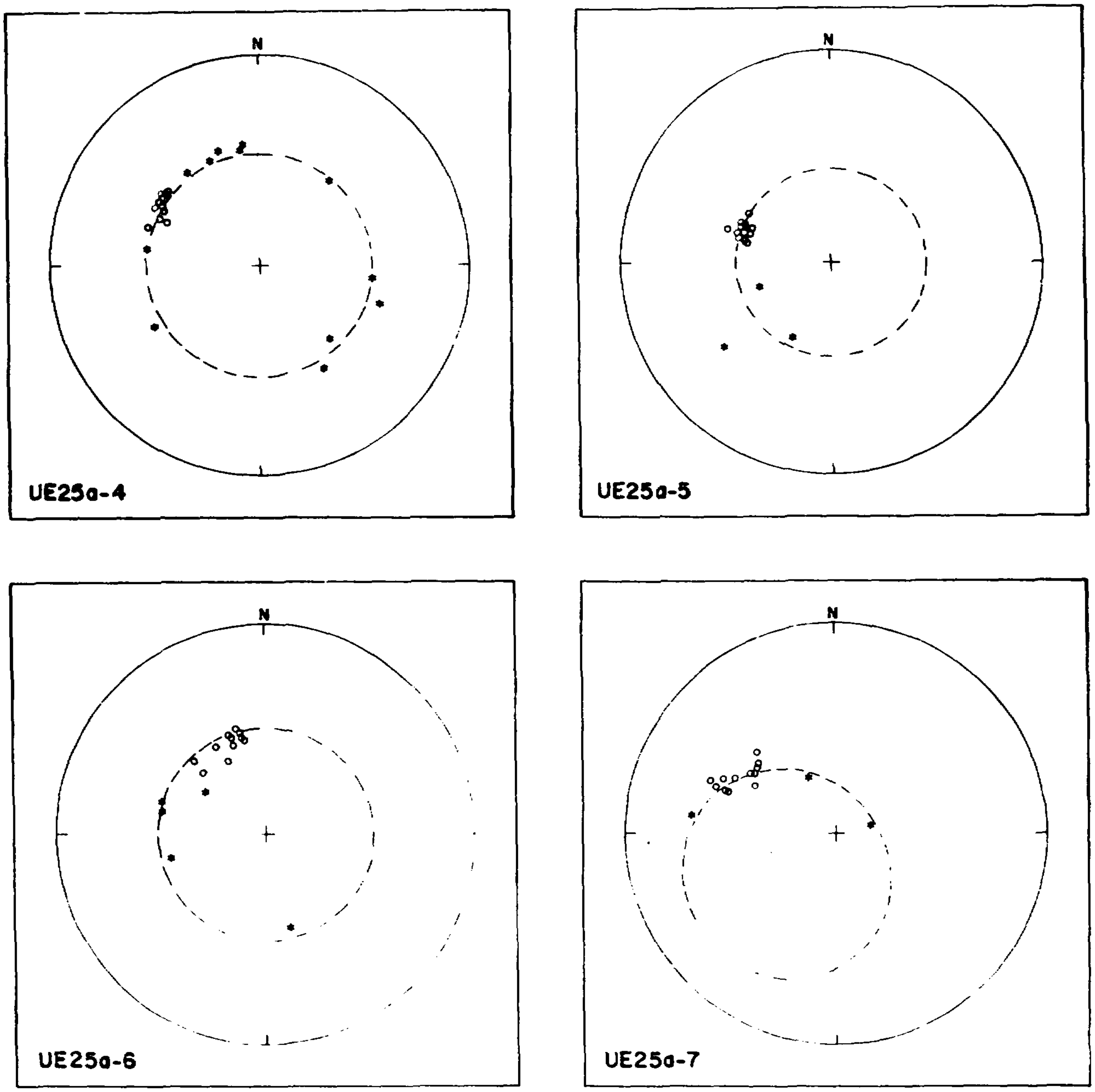

Figure 3.--Equal-area projection of paleomagnetic directions on Topopah Spring Member after alternating field demagnetization at 200 oersteds for samples from drill holes UE25a-4, -5, -6, and -7. (The selection of "well-grouped" points (+) and scattered points (*) is arbitrary. The dashed curves are produced by rotation of the mean direction of the "well-grouped" samples about the core axis.)

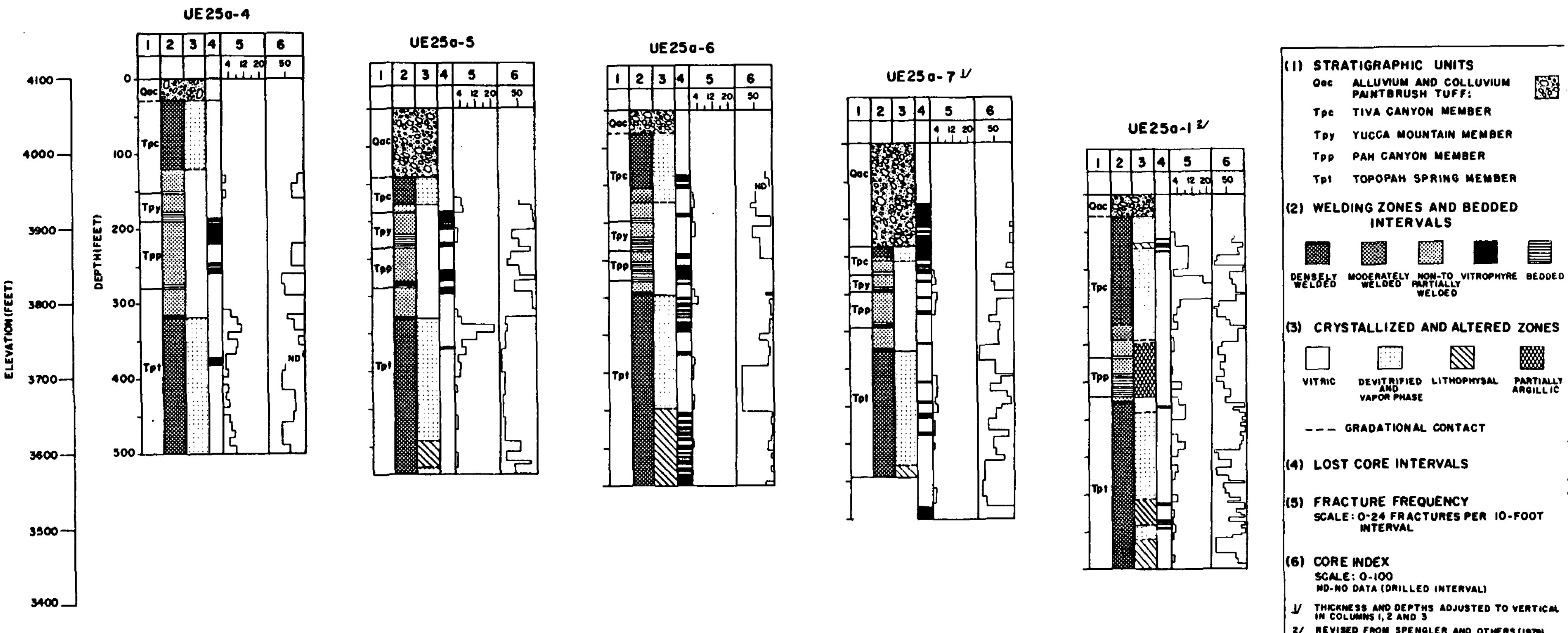

FIGURE 4-- STRATIGRAPHIC AND STRUCTURAL FEATURES IN DRILL HOLES UE25a-4,-5,-6,-7, AND -1

Table 1.--Lithologic log of drill hole UE25a-4

Stratigraphic and lithologic description	Thickness of interval (feet)	Depth to bottom of interval (feet)
Alluvium, gravel, sand, and silt consisting of ash-flow and ash-fall tuff debris	30.0	30.0
Paintbrush Tuff		
Tiva Canyon Member		
Tuff, ash-flow, pale-red, moderately to densely welded; pumice, light-gray and pale red, devitrified, 1 percent sanidine phenocysts	91.0	121.0
Tuff, ash-flow, grayish-orange to moderate-yellow-brown and pale-yellowish-brown, partially welded to nonwelded, vitric; pumice, pale-red and grayish-orange-pink, 1 mm-3 cm, vitric, increase in size and abundance downward, some altered to clay; abundant black and moderate-brown glass shards, increase in abundance downward, less than 1 percent phenocrysts (lower 5 ft friable)	29.7	150.7
Bedded tuff		
Tuff, bedded/reworked, moderate-reddish-orange, friable; pumice, grayish-orange-pink, 1-2 mm, altered to clay; 1 percent phenocrysts, subrounded; sparse red-brown volcanic lithic fragments, well rounded	1.0	151.7
Tuff, bedded/reworked, pale-red, friable; pumice, grayish-orange-pink to moderate orange pink, 1-5 mm, altered to clay, some vitric; less than 1 percent phenocrysts; sparse black volcanic glass shards, rare pale-red volcanic lithic fragments	1.0	152.7
Yucca Mountain Member		
Tuff, ash-flow, yellowish-gray, nonwelded, vitric; pumice, grayish-orange-pink, 1-3 mm, vitric; abundant yellowish-gray glass shards, sparse pale-red volcanic lithic fragments; core slightly altered and friable from 170 to 173.0 feet, clay (plastic) from 173.0 to 177.2 feet	26.5	179.2
Bedded tuff		
Tuff, air-fall/reworked, light-olive-gray, friable (unconsolidated), vitric; abundant colorless glass shards, rare pale-red volcanic lithic fragments	11.8	191.0
Pah Canyon Member		
Tuff, ash-flow, moderate-brown to red-brown, nonwelded, vitric, friable to unconsolidated (slightly altered to clay); pumice, very pale orange and light gray, less than 2 mm, vitric (some clay); sparse red-brown volcanic lithic fragments; unit grades into underlying unit	30.5	221.5
Tuff, ash-flow, moderate- to dark-yellowish-brown, nonwelded (friable), slightly argillic; pumice, light-olive-brown, vitric (slightly argillic), 1 mm-5 cm, less than 1 percent phenocrysts, rare biotite, sparse pale-red volcanic lithic fragments, sparse black glass shards	46.7	268.2

Table 1.--Lithologic log of drill hole UE25a-4--Continued

Stratigraphic and lithologic description	Thickness of interval (feet)	Depth to bottom of interval (feet)
Pah Canyon Member--Continued		
Tuff, ash-flow, grayish-orange, nonwelded, friable, argillic; pumice, white, vitric (slightly argillic), 1-5 mm; less than 1 percent phenocrysts, sparse pale-red volcanic lithic fragments, sparse black glass shards	6.5	274.7
Bedded tuff		
Tuff, reworked, grayish-orange to dark-yellowish-brown, friable; pumice, white vitric (slightly altered to clay), conspicuous black glass shards; 1-2 percent phenocrysts, sparse pale-red volcanic lithic fragments (altered to clay from 275 to 280.0 ft) (moderate red from 279.0 to 280.0 ft)	5.3	280.0
Topopah Spring Member		
Tuff, ash-flow, moderate-reddish-brown to moderate-brown and grayish-orange, nonwelded, vitric, friable to poorly indurated, slightly argillic; pumice, grayish orange pink and white, vitric (some altered to clays), conspicuous black glass fragments, less than 1 percent phenocrysts	30.0	310.0
Tuff, ash-flow, light-gray, nonwelded to partially welded, vitric, greater than 90 percent pumice, light-gray, less than 1 percent phenocrysts	6.8	316.8
Tuff, ash-flow, vitrophyre, black and grayish-red, perlitic, densely welded, contains abundant calcite veinlets (randomly oriented), 5-7 percent phenocrysts (quartz, feldspar)	3.2	320.0
Tuff, ash-flow, grayish-brown to moderate-red, densely welded, devitrified; pumice, grayish-red, devitrified, 2-5 mm; 7-10 percent phenocrysts (rare biotite, pyroxene, hornblende); abundant, thin (1 mm) calcite veinlets, randomly oriented (quartz latitic caprock), highly crushed interval from 332.1 to 346.9 feet	26.9	346.9
Tuff, ash-flow, pale-red to grayish-red, moderately to densely welded, devitrified (some vapor phase); pumice, pale-red to grayish-red and light-gray, devitrified (some vapor phase), 2 mm-2 cm, 3-7 percent phenocrysts; crushed intervals 346.9-365.5, 369.5-372.0, and 414-416 feet; predominantly vapor phase from 363.1 to 367.5 feet and 431.9 to 433.7 feet	153.1	500.0
TD		500.0

Table 2.--Lithologic log of drill hole UE25a-5

Stratigraphic and lithologic description	Thickness of interval (feet)	Depth to bottom of interval (feet)
Alluvium/colluvium, gravel, sand, silt consisting of ash-flow and air-fall tuff debris	90.0	90.0
Paintbrush Tuff		
Tiva Canyon Member		
Tuff, ash-flow, pale-red to grayish-red, densely welded, devitrified, 2-3 cm; 1-2 percent phenocrysts (quartz, sanidine); less than 1 percent pale-red volcanic lithic fragments	38.0	128.0
Tuff, ash-flow, moderate-yellow-brown, nonwelded to partially welded, vitric; grayish-orange and pale-red pumice, 2-10 mm, altred to clay, less than 1 percent phenocrysts, abundant glass shards (core from 138.6 to 153 ft lost)	10.6	138.6
Yucca Mountain Member		
Tuff, ash-flow, very pale orange to pale-yellowish-brown, vitric; pumice, white to grayish-pink, less than 1 mm, slightly argillic, less than 1 percent phenocrysts; contains colorless to light-gray glass shards	14.0	167.0
Bedded tuff		
Tuff, bedded/reworked, pale-reddish-brown and very light gray, moderately indurated, vitric; pumice, grayish-orange-pink, vitric, less than 5 mm; less than 1 percent phenocrysts, less than 1 percent pale-red volcanic lithic fragments	18.3	185.3
Pah Canyon Member		
Tuff, ash-flow, pale-red to pale-reddish-brown, nonwelded, vitric; pumice, light-olive-gray, pale-olive, and pale-red, vitric (slightly argillic), as large as 5 cm; less than 1 percent phenocrysts, rare bronze biotite; unit becomes progressively more argillic downhole, intensely argillic and friable from 210 to 228.0 feet	44.3	229.6
Bedded tuff		
Tuff, ash-fall and reworked, light-olive-gray to greenish-gray and pale-yellowish-brown (mottled), friable, thick-bedded; pumice, white to greenish-gray, vitric (some argillic, less than 1 percent phenocrysts; conspicuous bronze biotite, less than 1 percent pale-red volcanic lithic fragments, altered to moderate-red clay (plastic) from 234.7 to 236.0 feet	7.5	237.1
Topopah Spring Member		
Tuff, ash-flow, grayish-orange, nonwelded, vitric; pumice, very light gray, vitric, 1-2 percent phenocrysts, abundant black and moderate-reddish-brown glass fragments; 1 percent pale-red volcanic lithic fragments	30.9	268.0
Tuff, ash-flow, light-bluish-gray and greenish-gray, nonwelded (extremely friable and poorly consolidated) to moderately welded, vitric, consists almost entirely of light-bluish-gray pumice fragments, vitric, 1 mm-1.5 cm	9.0	277.0

Table 2.--Lithologic log of drill hole UE25a-5--Continued

Stratigraphic and lithologic description	Thickness of interval (feet)	Depth to bottom of interval (feet)
Topopah Spring Member--Continued		
Tuff, ash-flow, grayish-red and black (mottled), densely welded, vitrophyre; pumice, moderate-reddish-brown, vitric, 10-15 percent phenocrysts (feldspar, quartz), perlitic	2.0	279.0
Tuff, ash-flow, grayish-brown, densely welded, devitrified, contains 15-20 percent phenocrysts of sanidine, plagioclase, hornblende, biotite, pyroxene; pumice, grayish-red, devitrified and vapor phase (quartz latitic caprock)	30.6	309.6
Tuff, ash-flow, grayish-red, moderately to densely welded, devitrified; pumice, white to pale-red and light-gray, 2 mm-1 cm, as large a 7 cm, vapor phase and devitrified; 5-7 percent phenocrysts; sparse, light-gray volcanic lithic fragments, as large as 3 cm, predominantly vapor phase from 328 to 329.8 feet	132.8	442.4
Tuff, ash-flow, light-gray to moderate-light-gray and grayish-red (mottled), densely welded, devitrified; pumice, light-gray to white and pale-red, devitrified (some vapor phase), 2 mm-5 cm contains lithophysae, generally 2-4 cm in diameter, as large as 6 cm in diameter, lines with quartz, feldspar; groundmass contains 1-2 percent phenocrysts (predominantly sanidine)	36.3	478.7
Tuff, ash-flow, grayish-red-purple, densely welded, devitrified; pumice, white to light-gray, devitrified, 1 mm-1 cm; less than 1 percent phenocrysts, sparse, pale-red and light-gray volcanic lithic fragments, 1-3 cm	8.3	487.0
TD		487.0

Table 3.--Lithologic log of drill hole UE25a-6

Stratigraphic and lithologic description	Thickness of interval (feet)	Depth to bottom of interval (feet)
Alluvium (no samples recovered)	20.0	20.0
Paintbrush Tuff		
Tiva Canyon Member		
Tuff, ash-flow, light-gray to pale-red, devitrified, densely welded; pumice, light-gray and pale-red,devitrified, less than 1 percent phenocrysts	60.0	80.0
Tuff, ash-flow, pale-red, moderately welded, devitrified; pumice, light-gray and pale-red vapor phase, as large as 8 cm, 1-3 percent phenocrysts	3.5	83.5
Tuff, ash-flow, pale-red, densely welded, devitrified; pumice, pale-red and light-gray, devitrified, 2 mm-2 cm, 1-2 percent phenocrysts (predominantly sanidine)	19.5	103.0
Tuff, ash-flow, pale-red to grayish-red, partially to moderately welded, devitrified; pumice, grayish-red and moderate-reddish-orange, 5 mm-3 cm, 1-2 percent altered to moderate-reddish-orange clay; less than 1 percent phenocrysts, sparse, pale-red volcanic lithic fragments	20.1	123.1
Tuff, ash-flow, pale-red to moderate-brown and moderate-yellowish-brown, nonwelded to partially welded, vitric; pumice, grayish-red, argillite 2-10 mm; 1-2 percent phenocrysts, abundant glass shards	21.1	144.2
Bedded tuff		
Tuff, bedded/reworked, pale-yellowish-brown, poorly consolidated (friable), moderately argillic, poorly bedded, sparse, pale-red volcanic lithic fragments	5.1	149.3
Yucca Mountain Member		
Tuff, ash-flow, grayish-orange-pink to grayish-orange, and yellowish-gray, nonwelded, vitric; pumice, grayish-orange-pink to white, vitric, 1-4 mm, less than 1 percent phenocrysts, sparse, pale-red volcanic lithic fragments, abundant glass shards	20.0	169.3
Bedded tuff		
Tuff, bedded/reworked, very light gray to light-gray, unconsolidated, poorly bedded, vitric; mixture of pale-red volcanic fragments and white to light-gray vitric pumice	2.7	172.0
Tuff, bedded/reworked, moderate-yellowish-brown; poorly consolidated to unconsolidated, predominantly sand-size granules and volcanic lithic fragments, subrounded to well rounded, very little pumice	2.4	174.4
Tuff, bedded/reworked, grayish-orange-pink, poorly consolidated, predominantly grayish-orange-pink and white vitric pumice, subrounded to well rounded; abundant black and pale-red volcanic lithic fragments	10.0	184.4

Table 3.--Lithologic log of drill hole UE25a-6--Continued

Stratigraphic and lithologic description	Thickness of interval (feet)	Depth to bottom of interval (feet)
Bedded tuff—Continued		
Tuff, ash-fall, very light gray, vitric; pumice, predominantly very light gray, vitric; sparse red-brown volcanic lithic fragments, conspicuous bronze biotite	3.8	188.2
Pah Canyon Member		
Tuff, ash-flow, grayish-orange-pink, nonwelded; pumice, white and yellowish-gray, vitric, 2-8 mm; 2-4 percent phenocrysts, some glass shards, sparse, pale-red volcanic lithic fragments	13.6	201.8
Bedded tuff		
Tuff, bedded/reworked, grayish-orange-pink, unconsolidated, abundant subrounded volcanic lithic fragments; some white to light-gray and moderate-orange-pink, vitric pumice (core from 208.1 to 227.0 ft lost)	25.2	227.0
Topopah Spring Member		
Tuff, ash-flow, grayish-orange-pink to moderate-brown, nonwelded, vitric; pumice, very light gray, vitric (some argillic), 5 mm-2 cm; 2-3 percent phenocrysts (conspicuous pale-bronze biotite), abundant glass shards; abundant pale-red volcanic lithic fragments, 2 mm-1.5 cm	10.6	237.6
Tuff, ash-flow, pale-red and medium-light-gray, nonwelded to partially welded, vitric, consists of 90 percent pale-red and medium-light-gray vitric pumice, 1 mm-2 cm; sparse pale-red volcanic lithic fragments	4.1	241.7
Tuff, ash-flow, vitrophyre, moderate-reddish-brown and black, vitric, densely welded, 20-30 percent phenocrysts (quartz, feldspar)	4.3	246.0
Tuff, ash-flow, grayish-red, densely welded, devitrified; pumice, moderate-orange-pink and grayish-red, devitrified, 1 mm-1 cm, 15-20 percent phenocrysts (conspicuous biotite) (quartz latitic caprock)	17.5	263.5
Tuff, ash-flow, pale-red, densely welded, devitrified; pumice, pale-red and very light gray, devitrified (some vapor phase), 2 mm-9 cm; 5-7 percent phenocrysts	136.1	399.6
Tuff, ash-flow, light-brownish-gray to very light gray, densely welded, devitrified; pumice, very light gray and grayish-red, devitrified, 2 mm-7 cm, contains abundant lithophysae, very light gray, 1-6 cm in diameter, lines with quartz and feldspar	100.4	500.0
TD		500.0

Table 4.--Lithologic log of drill hole UE25a-7
[Numbers in parenthesis are thickeness and depth adjusted for inclination of drill hole]

Stratigraphic and lithologic description	Thickness of interval (feet)	Depth to bottom of interval (feet)
Alluvium/colluvium, boulders, gravel, and sand consisting of ash-flow and bedded tuff, nonwelded to densely welded, vitric to devitrified. Cored interval from 80 to 153 feet consists of colluvium of cobble- to boulder-size tuff fragments of variable lithology and orientation. Caliche coatings are common	153.0 (137.5)	153.0 (137.5)
Paintbrush Tuff		
Tiva Canyon Member		
Tuff, ash-flow, grayish-red and medium-gray, densely welded, devitrified; pumice, light-gray and light-brownish-gray, devitrified, 1 mm-1 cm; 1 percent phenocrysts (sanidine), upper 2.6 feet contains sparse (less than 1 percent) lithophysae as large as 3 cm in diameter; interval from 158.7 to 169.1 feet contains abundant spherulites commonly 5 mm in diameter, some as large as 2 cm	16.1 (14.5)	169.1 (152.0)
Tuff, ash-flow, pale-yellowish-brown, moderately welded, devitrified; pumice, light-brown and grayish-red, 1 mm-1 cm, dominantly vapor phase, slightly argillic; less than 1 percent phenocrysts; less than 1 percent pale-reddish-brown and light-gray volcanic lithic fragments	4.4 (3.9)	173.5 155.9)
Tuff, ash-flow, pale-brown to grayish-orange, partially welded to nonwelded, vitric; pumice, pale-red and grayish-orange, commonly 2.6 mm, as large as 1 cm, argillic; less than 1 percent phenocrysts, mainly sanidine; size and abundance of pumice increases downward; abundance of black glass shards increases toward base of unit	16.5 (14.9)	190.0 (170.8)
Bedded tuff		
Tuff, bedded/reworked, pale-yellowish-brown (upper 0.5 ft), pale-reddish-brown, slightly indurated, argillic; over 80 percent pumice, white to pale-yellowish-orange, argillic; 3-5 percent pale-reddish-brown and black volcanic lithic fragments	4.2 (3.7)	194.2 (174.5)
Yucca Mountain Member		
Tuff, ash-flow, grayish-orange, and yellowish-gray, nonwelded, vitric; pumice, grayish-orange-pink, vitric (some argillic), 1-2 percent, 1-3 mm, as large as 1 cm, abundant colorless and black glass shards, rare phenocrysts	18.7 (16.9)	212.9 (194.4)

Table 4.--Lithologic log of drill hole UE25a-7--Continued

Stratigraphic and lithologic description	Thickness of interval (feet)	Depth to bottom of interval (feet)
Bedded tuff		
Tuff, reworked/bedded, pale-yellowish-brown and light-olive-gray, moderately indurated, thick-bedded; over 50 percent pumice, white to light-gray and light-olive-gray, vitric, slightly argillic abundant well-rounded phenocrysts of quartz and feldspar, abundant grayish-red and black volcanic lithic fragments, as large as 1 cm	7.3 (5.5)	220.2 (197.9)
Pah Canyon Member		
Tuff, ash-flow, moderate-orange-pink to grayish-orange-pink, nonwelded, vitric; pumice, yellowish-gray and pinkish-gray, greater than 30 percent, 5 mm-5 cm, vitric, slightly argillic, less than 1 percent phenocrysts, conspicuous black biotite, sparse pale-red volcanic lithic fragments; unit grades downward into underlying unit	32.1 (28.9)	252.3 (226.8)
Tuff, ash-flow, grayish-orange-pink to light-brown, nonwelded, vitric; pumice, grayish-orange, 5 mm, as large as 5 cm, vitric, less than 1 percent phenocrysts, sparse, pale-red volcanic lithic fragments, grades into underlying unit	11.7 (10.5)	264.0 (237.3)
Tuff, ash-flow, grayish-pink, nonwelded, vitric; pumice, grayish-pink, as large as 5 cm, vitric; less than 1 percent phenocrysts (rare biotite), sparse, pale-red volcanic lithic fragments	1.8 (1.6)	265.8 (238.9)
Bedded tuff		
Tuff, bedded/reworked, grayish-orange-pink, slightly indurated, poorly sorted; 50 percent pumice, grayish-orange-pink, subrounded to subangular, slightly argillic, 2-5 mm, conspicuous amount of black glass fragments and pale-red volcanic lithic fragments, interval from 271.0 to 272.5 feet is stained light red, argillic	6.9 (6.2)	272.7 (245.1)
Topopah Spring Member		
Tuff, ash-flow, grayish-orange-pink to very pale orange, nonwelded, vitric; pumice, white to grayish-orange-pink; pumice, white to grayish-orange-pink, vitric and argillic, 5-30 mm; 2-3 percent phenocrysts (quartz, sanidine); conspicuous hornblende and bronze biotite; conspicuous pale-red and moderate-red volcanic lithic fragments	24.9 (22.4)	297.6 (267.5)
Tuff, ash-flow, light-gray and pale-yellowish-brown, nonwelded to partially welded, vitric; pumice, greater than 60 percent, light-gray and pale-yellowish-brown and moderate-reddish-orange, vitric, 2-20 mm, concpicuous black and moderate-reddish-brown glass fragments, minor pale-red volcanic lithic fragments, sparse biotite	6.9 (6.2)	304.5 (273.7)
Tuff, ash-flow, dark-reddish-brown to black, vitrophyre, densely welded, 15-20 percent phenocrysts, predominantly sanidine, sparse biotite	3.5 (3.1)	308.0 (276.8)

Table 4.--Lithologic log of drill hole UE25a-7--Continued

Stratigraphic and lithologic description	Thickness of interval (feet)	Depth to bottom of interval (feet)
Topopah Spring Member--Continued		
Tuff, ash-flow, pale-red to grayish-brown, densely welded, devitrified, 10 percent phenocrysts (sanidine, biotite, pyroxene); sparse moderate-reddish-brown pumice (quartz latitic caprock)	15.0 (13.5)	323.0 (290.3)
Tuff, ash-flow, pale-red to grayish-red and light-gray, moderately to densely welded, devitrified; pumice, white to medium-gray and blackish-red, 1 mm-4 cm, as large as 7 cm, vapor phase and devitrified; 3-5 percent phenocrysts (feldspar, hornblende, quartz, biotite, magnetite) light-gray volcanic lithic fragments, rhyolitic, 1-2 cm (conspicuous vapor phase from 338.0 to 354.5 ft)	155.8 (140.0)	478.8 (430.3)
Tuff, ash-flow, pale-red, densely welded, devitrified; pumice, white to medium-gray and pale red, 2 mm-7 cm, vapor phase and devitrified, contains as much as 30 percent lithophysae, 2-5 cm in diameter, lined with quartz and feldspar; 2-3 percent sanidine	21.2 (19.1)	500.0 (499.4)
TD		500.0 (449.4)

In UE25a-7, colluvium was cored from 80 to 153 feet, most of which consisted of core segments ranging in length from 0.3 to 0.6 foot. These core segments show abrupt changes in lithologic characteristics and fragments are commonly coated with caliche. On the basis of the four shallow drill holes, as well as UE25a-1 (Spengler and others, 1979), the bedrock surface appears deeply eroded forming a V-shaped configuration whose lowest point lies close to the middle of the wash.

Paintbrush Tuff

Tiva Canyon Member

Only the lowermost part of the Tiva Canyon Member, which consists mainly of densely welded ash-flow tuff, was found in any of the four shallow drill holes. This unit progressively grades downward to a nonwelded basal unit averaging about 18 feet thick. The base of the ash-flow tuff rests on 2-5 feet of bedded tuff.

Yucca Mountain Member

The Yucca Mountain Member, recognized in UE25a-4, -5, -6, and -7, represents the distal edge of an ash-flow tuff that thickens toward the northwest. Within the study area, the unit is nonwelded, vitric, and contains an abundance of colorless and black unaltered glass shards. The Yucca Mountain is quite uniform in lithologic characteristics and varies in thickness from 16.9 to 28.4 feet in the drill holes. The member was not found in UE25a-1, indicating that it wedges out between drill holes UE25a-7 and -1 (Spengler and others, 1979). Five, to as much as 19 feet of bedded tuff separate the Yucca Mountain from the underlying Pah Canyon Member. The bedded interval includes air-fall, reworked tuff, and tuffaceous sand, most of which is thick bedded and vitric.

Pah Canyon Member

As much as 83 feet of the Pah Canyon was cored within the area of interest. Similar to the Yucca Mountain Member, the Pah Canyon consists of vitric, nonwelded ash-flow tuff most of which is extremely friable. Despite their similar physical characteristics, the Pah Canyon is easily distinguishable by the presence of large (5 mm) light-olive-gray and pale-red pumice fragments. Although not previously recognized in UE25a-1, reexamination of the upper 500 feet of core indicated the presence of 22 feet of the unit within the bedded interval between the Tiva Canyon and Topopah Spring Members (Spengler and others, 1979).

A significant change in thickness of the Pah Canyon ash-flow tuff sheet was noted in UE25a-6 where it decreases to 14 feet. The ash-flow tuff rests on an interval of thick-bedded, reworked and air-fall tuff that varies in thickness from 5 to as much as 25(?) feet. The base of the interval is conspicuously marked by about a foot of light- to moderate-red clay that exhibits a high degree of plasticity in drill holes UE25a-4 and -5. X-ray analysis of a sample taken from UE25a-5 indicates that montmorillonite (and layers of illite) constitute about 50 percent of this 1-foot interval (P. D. Blackmon, written commun., 1979). In UE25a-7 only iron-staining was apparent within this particular basal subunit.

Topopah Spring Member

Over 50 percent of the cored interval in each drill hole consisted of the Topopah Spring Member, most of which is densely welded, rhyolitic, devitrified ash-flow tuff. All drill holes except UE25a-4 extend downward into an inner zone of the welded tuff where lithophysal cavities are well developed. The rhyolitic portion of the tuff grades upward into a quartz latitic caprock ranging in thickness from 10 to 30 feet and characterized by a relative abundance of phenocrysts (10-15 percent), including quartz, feldspar, plagioclase, biotite, pyroxene, and hornblende. In turn, the caprock is overlain by a thin, black to reddish-brown vitrophyre generally less than 5 feet thick. The uppermost part of the ash-flow sheet is nonwelded and mostly vitric.

Variations in Thickness

The observed thicknesses of ash-flow tuff sheets within the area of interest show only slight variations, which appear consistent with that of progressive thinning of units in a south to southeasterly direction, away from source areas. As shown in table 5 and on figure 5, the Yucca Mountain and Pah Canyon Members are thickest in the drill holes located to the northwest and progressively thin toward the southeast. A possible exception occurs at UE25a-6 where the Pah Canyon shows an abrupt thinning towards the southwest. One possible explanation for this discrepancy may be the assignment of lost core intervals. In the absence of geologic evidence, lost core is commonly recorded at the bottom of a particular core run, where it is assumed that core drops out of the core barrel prior to recovery. It had been reported by coring specialists that core loss may have occurred near the upper part of some core runs, particularly in the nonwelded zones where unconsolidated material was "blown away" prior to entering the core barrel. If this situation had occurred in the ash-flow tuff of the Pah Canyon and underlying bedded sequence, then these rocks would be under- and overrepresented, respectively. This explanation appears reasonable for the anomalous thickness in UE25a-6, although too little information is available for verification.

A review of regional isopach maps of the Yucca Mountain and Pah Canyon Members within the area outlined on figure 2 shows the two units thinning in a south to southeasterly direction at a rate of about 16 feet per 1,000 feet and 18 feet per 1,000 feet, respectively (Byers and others, 1976; P. P. Orkild, written commun., 1979). Borehole data indicates an average thinning of the Yucca Mountain and Pah Canyon to be about 5 feet per 1,000 feet and 17 feet per 1,000 feet, respectively. This comparison clearly illustrates the lack of any recognizable changes in thickness within the wash other than that of normal thinning and suggests the absence of any major structure.

STRUCTURE

Foliation attitudes, measured on outcrops in the immediate vicinity of the drill holes, indicate that the Tiva Canyon Member strikes in a north to northeasterly direction and gently dips to the east and southeast (Lipman and McKay, 1965) (fig. 2). In the northern part of the area of interest, where the base of the Tiva Canyon is exposed along wash margins, recent surveying has shown that the base of the member commonly strikes from N. 41° to 55° E. but ranges from N. 41° E. to N. 77° E. A least-squares fit of a plane to the elevations of the base of the member in the four shallow core holes and UE25a-1 indicates a strike of

Table 5.--Summary of thickness (in feet) variations found in drill holes UE25a-4, -5, -6, -7, and -1

Stratigraphic interval	UE25a-4	UE25a-5	UE25a-6	UE25a-7	UE25a-1[1]
Alluvium	30	90	20	137.5	30
Tiva Canyon[2]	120.7	48.6	124.2	33.3	187.0
Bedded tuff	2.0	[3]0	5.1	3.7	1.2
Yucca Mountain	26.5	28.4	20.0	16.9	0
Bedded tuff	11.8	18.3	18.9	5.5	0
Pah Canyon	83.7	44.3	[3]13.6	42.4	22.5
Bedded tuff	5.3	7.5	[3]25.2	6.2	30.5
Topopah Spring	220.0	249.9	287.0	204.3	[4]----

[1]Revised from Spengler and others, 1979.

[2]Not full thickness of the member.

[3]Thicknesses uncertain due to excessive amounts of core loss within these intervals.

[4]Total thickness of ash-flow sheet of Topopah Spring Member in UE25a-1 is approximately 1,090 feet.

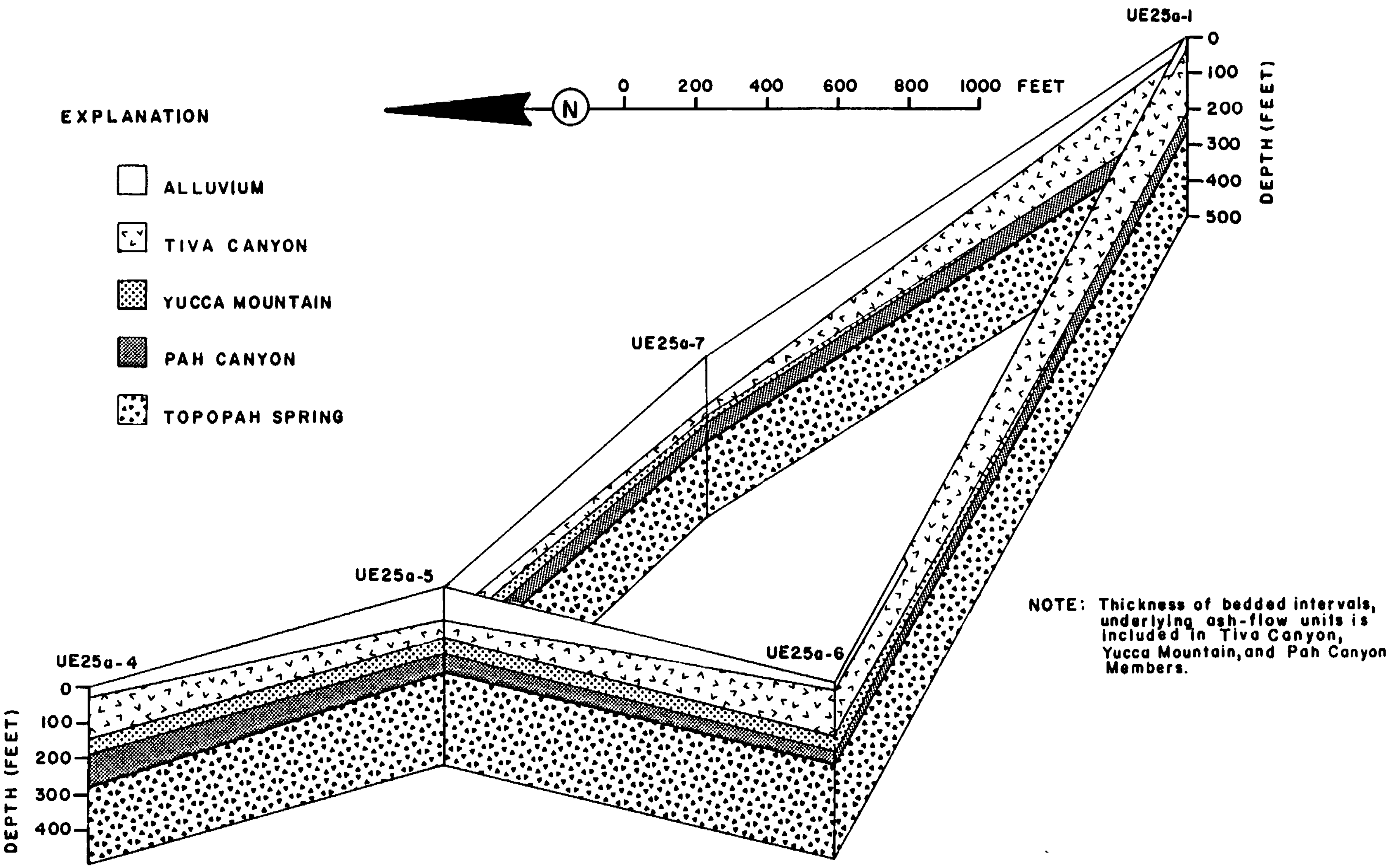

Figure 5.--Fence diagram showing thicknesses of alluvium and tuff members of Paintbrush Tuff in drill holes at Yucca Mountain.

N. 12° E. and a dip of 5.5° to the southeast with a correlation coefficient of 0.998. This regression and analysis indicates only a 5-percent probability that any additional elevations obtained to better define the base of the Tiva Canyon Member will deviate by more than 12 feet from the planar surface. Structurally, this implies that if a fault or combination of faults with vertical displacements of less than 12 feet are present, they would not significantly alter the attitude of the plane as defined by this computational technique.

Regression analysis on elevations at the top of the vitrophyre in the Topopah Spring Member in the five drill holes defines a plane striking N. 01° W. and dipping 4.4° E. with a correlation coefficient of 0.987. In this analysis, 95-percent-confidence limits are within 19 feet of the planar surface.

On the basis of new surface and subsurface data, a structure contour map was made of the base of the Tiva Canyon, which shows a change in direction of strike within the area of interest (fig. 6). In the northern part of the area the strike is dominantly northeast, as it is over a large area to the north and northwest, whereas, a northerly strike direction is dominant to the south. This shift in direction is probably a result of tilting of structural blocks as faulting increases in magnitude southward.

Although inadequate exposure of the Topopah Spring Member prevents a similar comparison of drill-hole data with that of outcrops in the area of interest, the planar surface defined by the drill holes appears atypical of the regional trends of the Topopah Spring. Foliation trends of the Topopah Spring are predominantly northeasterly in the northern part of Yucca Mountain near Prow Pass and in the Pinnacles Ridge area (Christiansen and Lipman, 1965; Lipman and McKay, 1965) (fig. 1). Near the southern end of Yucca Mountain foliation attitudes display a northerly trend. Even if one takes into account the apparent shift in strike direction, similar to the Tiva Canyon, the observed northerly strike of the Topopah Spring in the area of the drill holes appears to be a little inconsistent. A more detailed approach to this discrepancy is presented in the following section.

Structural Orientation of Topopah Spring Member

Measurements were made of the eutaxitic structure of foliation planes in core within the densely welded zone of the Topopah Spring, where the parallel alinement of flattened pumice is well developed. A total of 83 observations was made, some of which were reoriented using using paleomagnetic data as previously discussed. As shown on figure 7, the data define mean strikes of foliation of N. 9° W., N. 17° W., and N. 6° W. for drill holes UE25a-4, -5, and -7, respectively. The dips vary from 8° to 13° toward the east-northeast. These values are in fairly good agreement with the strike direction of N. 01° W. determined by planar analysis of the top of the vitrophyre within the same unit. The data also illustrate the relative accuracy of using foliation planes to determine the strike of ash-flow tuffs where the base is unexposed. Observations that deviate significantly from the mean direction in each drill hole are believed to be due to (1) errors of measurement, (2) minor slumping, and (3) nonuniform compaction of the ash-flow tuff following emplacement.

In marked contrast to the other drill holes, the mean strike of foliation in hole UE25a-6, located outside of the main wash, is N. 23° E. The average dip is 8° to the southeast. This

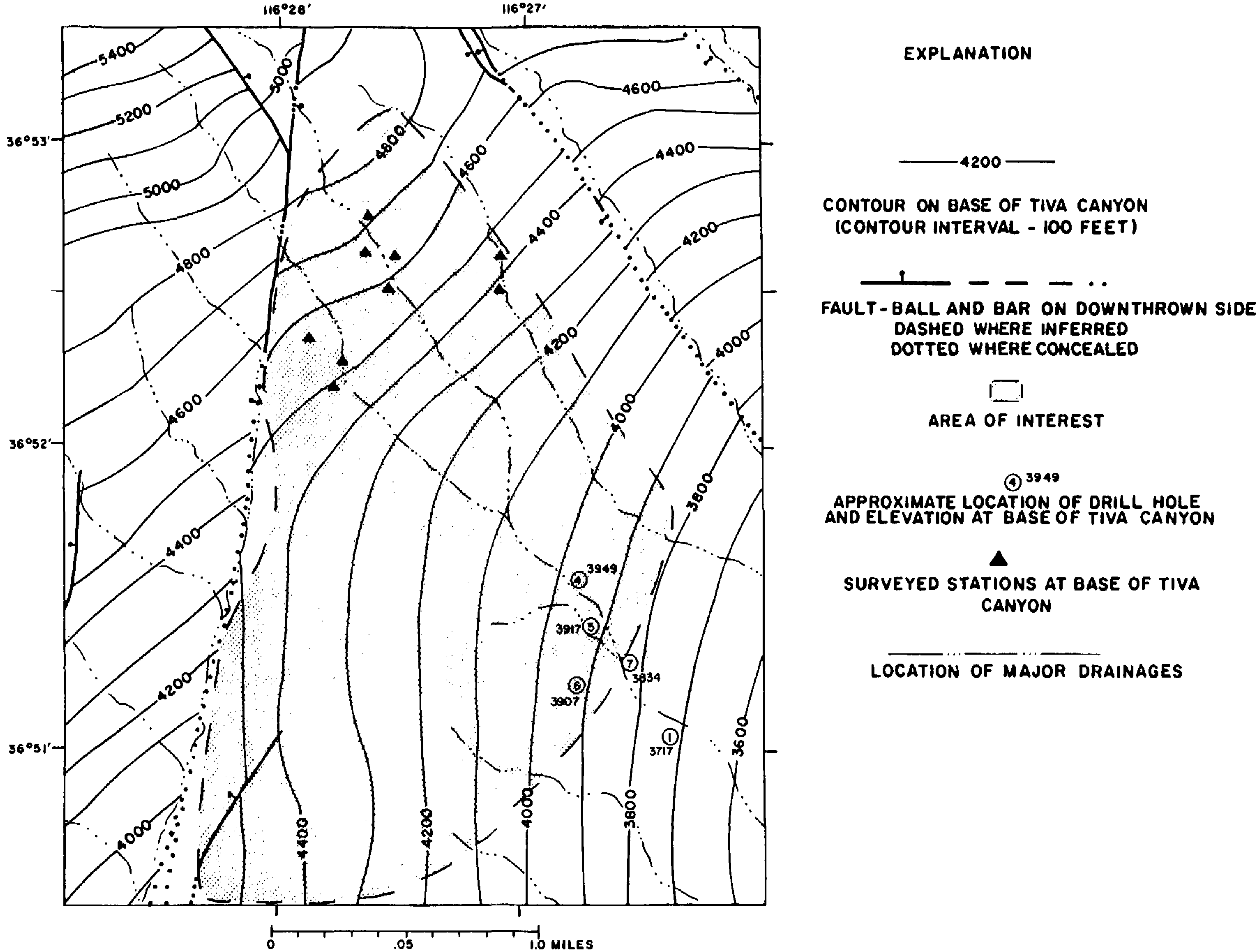

FIGURE 6-- STRUCTURE CONTOUR MAP OF BASE OF TIVA CANYON MEMBER AT NORTHERN YUCCA MOUNTAIN

(MODIFIED FROM W.J. CARR, WRITTEN COMMUN., 1979)

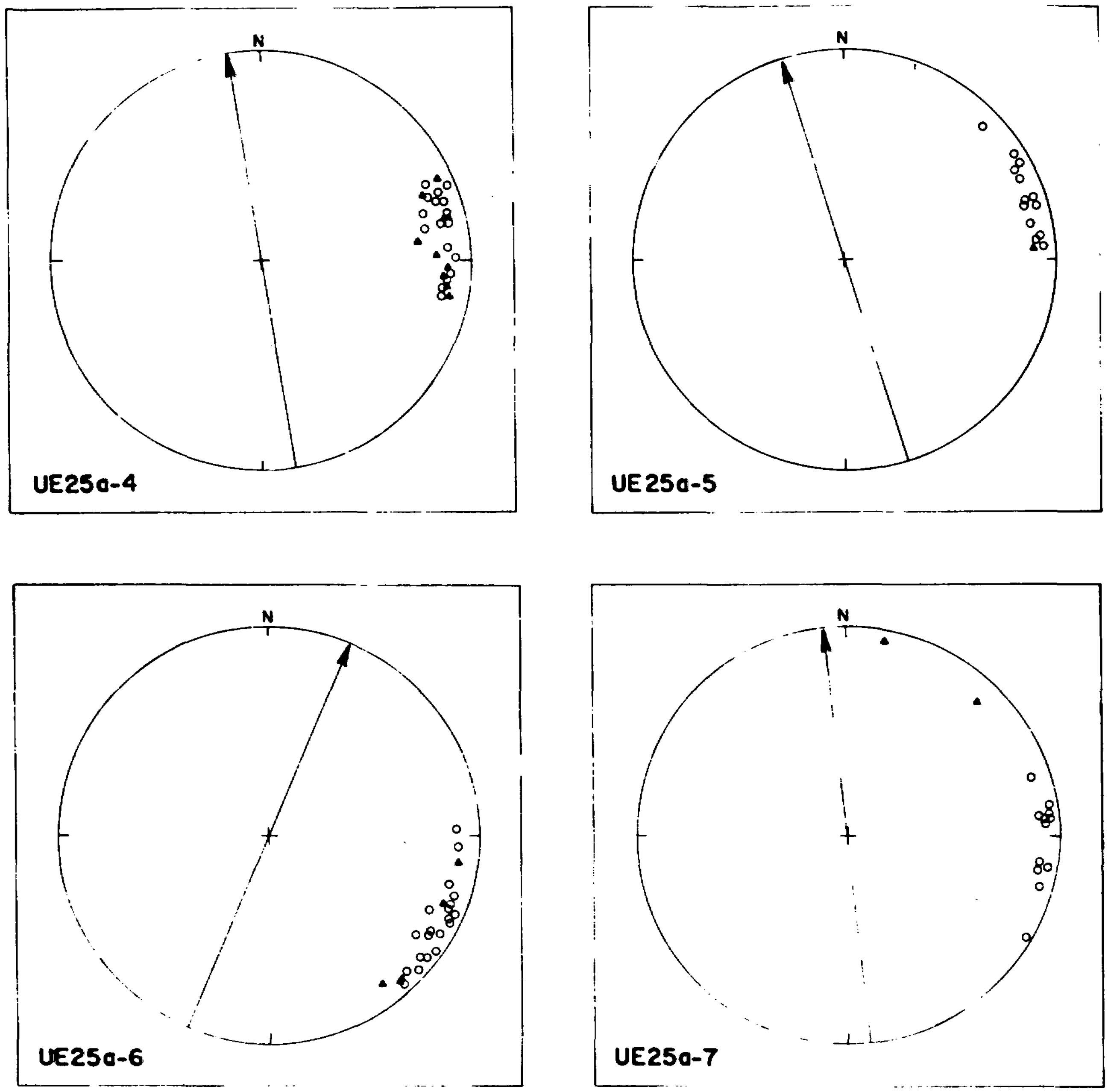

Figure 7.--Orientation of foliation in Topopah Spring Member in UE25a-4, -5, -6, and -7. (Amount and direction of dip plotted on lower hemisphere of equal-area projection. Shaded symbols indicate reorientation using magnetics; arrow indicates mean strike direction.)

discrepancy in the foliation attitudes could be due to local variations in the preeruptive topography. However, the mean paleomagnetic direction of the well-grouped samples from each drill hole indicates a similar discrepancy between UE25a-6 and the other drill holes (fig. 8). As the remanence is acquired at temperatures below 580°C (the Curie temperature of magnetite), it is unlikely that the magnetic directions would be significantly affected by movement or compaction of the flow. Therefore, the discrepancy is probably due to postemplacement rotation about a near-vertical axis.

This rotation implies the presence of a significant structural discontinuity located close to the southwestern edge of the wash (fig. 2), but the absence of any detectable vertical offsets between drill holes suggests that movement was for the most part of a strike-slip nature.

Joints

The most prevalent type of fractures recognized in core collected from drill holes UE25a-4, -5, -6, and -7 is described as "joints" and defined as planar fractures without detectable relative displacement of the walls. This definition eliminates many of the rough breaks presumably caused by coring and handling. Fracture frequencies, presented on figure 4, clearly indicate an association between fracture occurrence and lithology, as indicated by the dominance of fracturing in the lower half of the drill holes, particularly within the densely welded zone of the Topopah Spring Member. Therefore, the analysis of fracture frequency was devoted to the recognition of differences within this unit. No distinction in the compilations was made between open or closed fractures, nor between high or low angle. For instance, the high frequency of fractures recorded near the top of the Topopah Spring in UE25a-5 may be misleading, in that a large proportion of these fractures are closed calcite veinlets nearly parallel to foliation planes, and may not be tectonically significant. Nonetheless, comparison of fracturing in the drill holes indicates a relatively higher frequency in drill holes UE25a-1 and UE25a-4, located close to wash margins.

Within the units overlying the Topopah Spring Member, most of the joint surfaces are thinly coated with iron and manganese oxides. In contrast, most of the joint surfaces within the Topopah Spring are either partially or completed coated with calcite. Along some of the fracture faces both calcareous and siliceous coatings were recognized. One particular joint worthy of mention was found near the top of the densely welded zone of the Topopah Spring in UE25a-5. This fracture, the largest recorded in any of the drill holes, was near vertical, measured 10.4 feet in length, and 1.5-2 inches in width, and was completely filled with fine-grained calcite. For a more quantitative study of subsurface joint fillings, refer to Spengler and others (1979).

Shear Fractures

Although slickensides were not observed along fracture faces in any of the four shallow drill holes, several fractures, found only in UE25a-4 and -7, are classified as shear fractures. These fractures are nonplanar and appear to represent "crush zones," commonly less than 1 inch in width. Minor (<2 cm) offsets, both vertical and horizontal, were recognized in a few of these fractures and the parallel alinement of pumice is virtually destroyed within the zones due to the rotation of microscopic rock fragments. Fracture zones are conspicuously displayed by an abundance of en echelon calcite veinlets, some of which contain vugs lined with calcite. Near the margins of "crush zones" calcareous deposits display a braided pattern characterized by a network of veinlets that repeatedly merge and separate. Age dating of calcite coatings of fractures in the Topopah Spring in UE25a-1 was reported to be greater than 400,000 years (J. N. Rosholt, written commun., 1979, in Spengler and others, 1979).

Orientation of Fractures

A total of 63 measurements of fracture plane orientations in core samples was made within the densely welded zone of the Topopah Spring. At several depths, fracture occurrence did not coincide with the depths of orienting pictures; therefore, the magnetic reorientation method was employed to realine the azimuth of the reference groove. Figure 9 indicates the position of poles of fractures within the drill holes as plotted on the lower hemisphere of an equal-area projection.

Eight of the nine shear fractures recognized in UE25a-4 from 398.2 to 496.8 feet are tightly clustered in the northeast quadrant of the plot and indicate a strike direction ranging from N. 10° W. to N. 45° W. These fractures consistently dip steeply (70°-80°) toward the southwest and confirm the existence of a discrete structural demarcation along the northeast edge of the wash, whose strike corresponds with the wash trend.

It should be emphasized that the prominent fracture identified in UE25a-5 (previously described under "Joints") may not be accurately positioned on figure 9. As shown, the fracture dips 89° in a direction of N. 50° W. and represents the only magnetically reoriented fracture occurring within the quartz latitic caprock (table 2), a discrete depositional subunit of the Topopah Spring Member. Measurements taken in UE25a-5 to establish a mean magnetic direction were derived from samples in the rhyolitic portion of the ash-flow tuff and, thus, reorientation of the quartz latite portion of the tuff by this means may be inappropriate. There is no complete cooling break between the caprock and the more rhyolitic portion of the Topopah Spring, so it is unlikely that the caprock possesses a true remanent magnetization that deviates significantly from that of the rhyolite. Therefore, magnetic reorientation of this fracture based upon the mean magnetic direction is probably valid. Additional information concerning the remanent magnetization of the quartz latite is needed to resolve this question.

A contour diagram of pole concentration, derived from figure 9, shows two sets of steeply dipping fractures striking N. 12° W. and N. 37° E. (fig. 10). These complimentary sets of diagonal fractures form an acute angle of about 49° symmetrically about a N. 13° E. direction.

The 5-10 percent maximum situated close to the center of the diagram marks a prominant set of joints which parallel trends of the eutaxitic structure and, as stated previously, does not appear to have tectonic implications.

Core Index

The core index number represents a summation of the fracture frequency, core loss, and broken core (core less than 4 in. in length) into one significant number (J. R. Ege, written commun., 1975). This number reflects the relative engineering characteristics of the rock per cored interval (fig. 4).

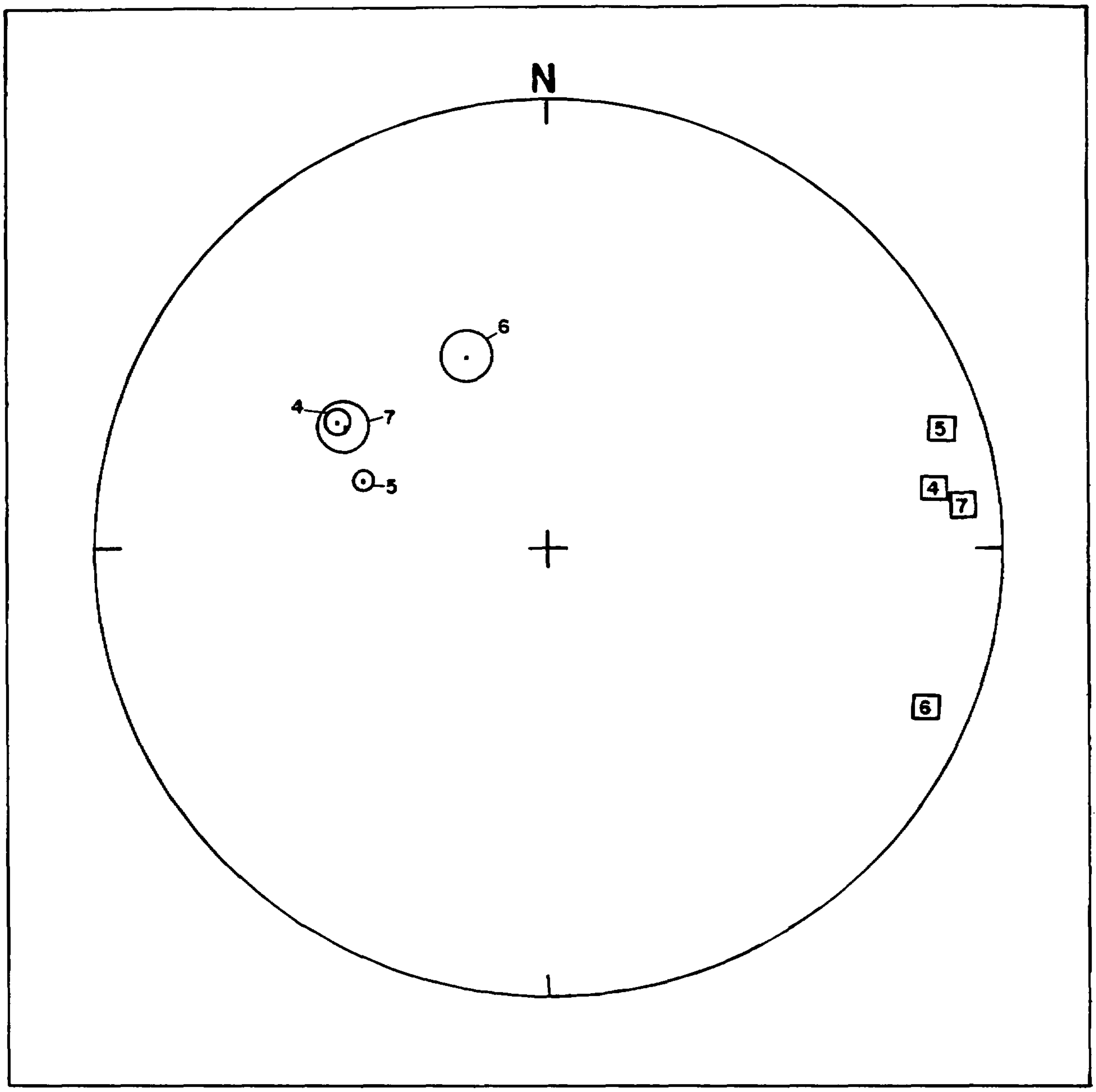

Figure 8.--Equal area projection of mean paleomagnetic directions of well-grouped samples ⊙ enclosed in cones of 95-percent-confidence limits and mean dip direction □ of samples in the Topopah Spring Member in drill holes UE25a-4, -5, -6, and -7.

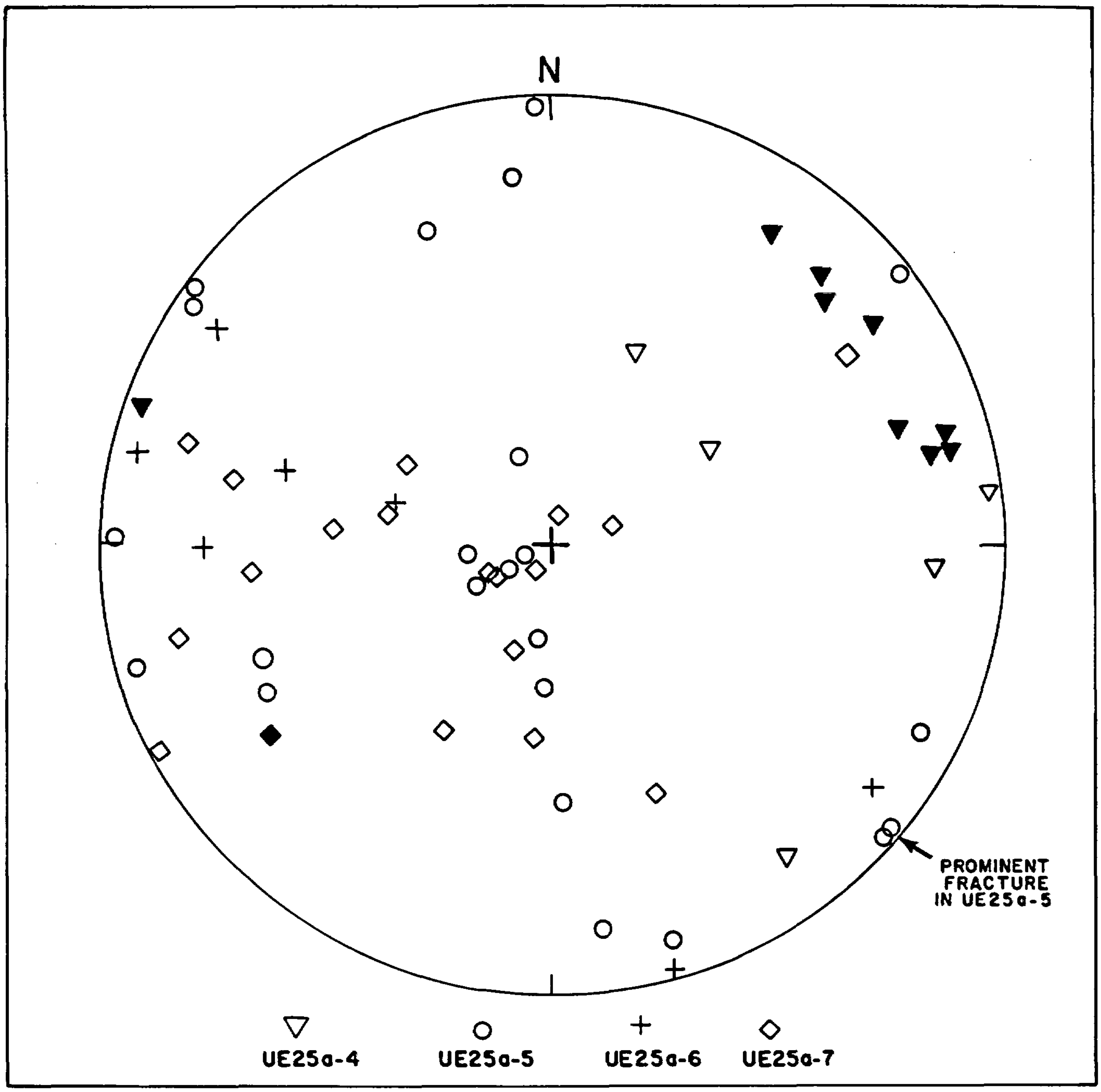

Figure 9.--Orientation of 63 fracture poles found in the Topopah Spring Member in drill holes UE25a-4, -5, -6, and -7. (Plotted on an equal area projection--shaded symbols represent shear fractures.)

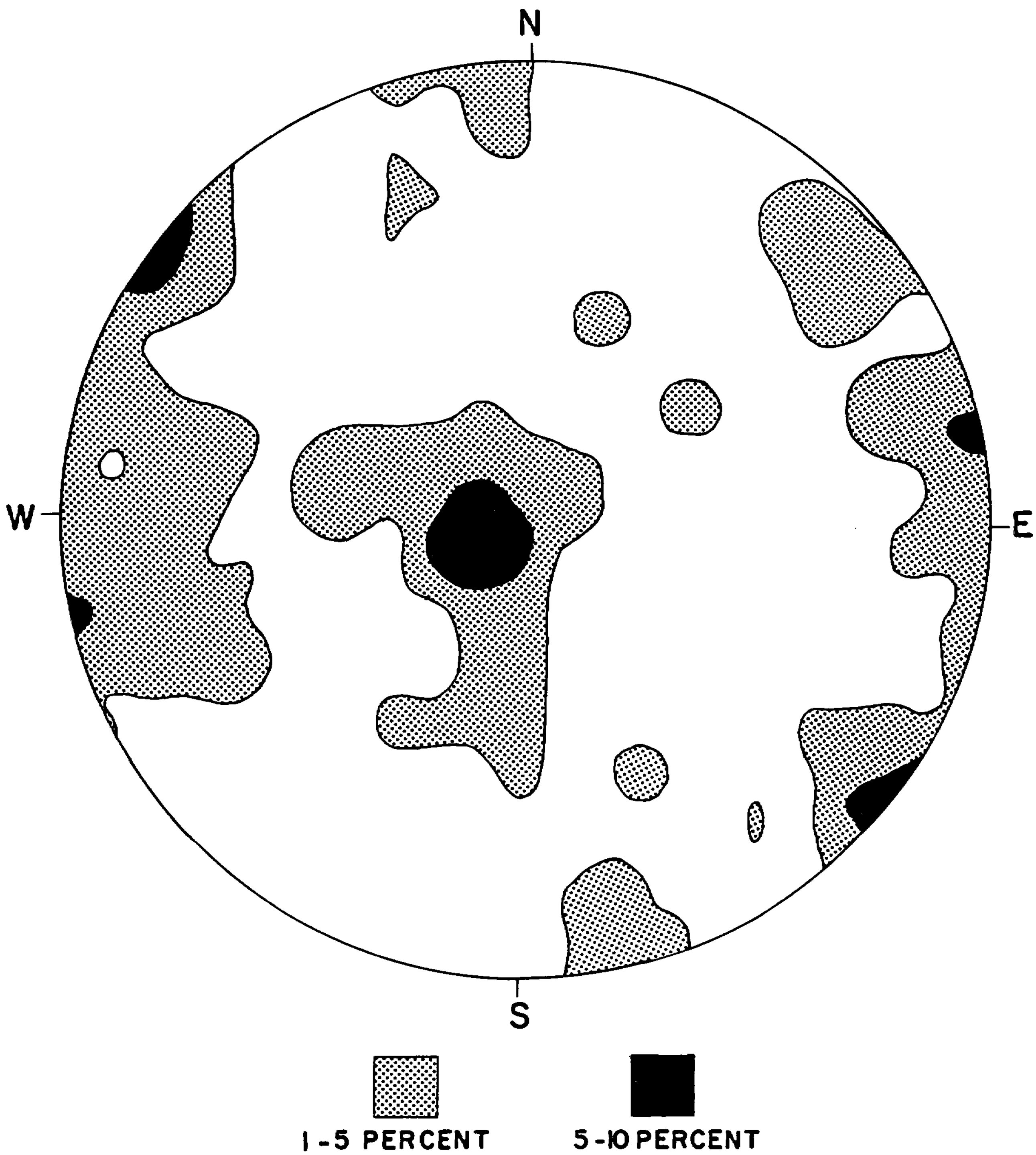

Figure 10.--Contour diagram of percentage of fracture poles (data on fig. 9). (Contours represent 5 and 10 percent of fractures per 1 percent of total area as plotted on an equal-area projection.)

The equation used to obtain the CI (core index) is expressed as:

$$CI = \frac{(\text{ft broken}) + (\text{ft core loss}) + (1/3\ \text{joints})}{(\text{drilled interval, ft})} \times 100$$

As graphically displayed in columns 4 and 6 of figure 4, the CI is greatly influenced in the upper nonwelded zones by core loss, whereas broken core and fractures dominate the densely welded zone in the Topopah Spring. In a relative sense, CI supports inferences made concerning the occurrence of fractures, in that the CI slightly decreases in drill holes UE25a-5, -6, and -7, positioned away from wash margins.

PRELIMINARY INTERPRETATIONS

Structural and stratigraphic analyses of core samples derived from drill holes UE25a-4, -5, -6, and -7 show evidence of at least one subtle structural discontinuity along the northeastern margin of the major northwest-trending wash. Another discontinuity is tentatively identified near its southwestern edge. Examination of core from UE25a-4 revealed a series of en echelon shear fractures, most of which trend in directions coincidental with the trend of the wash. No vertical displacements more than fractions of inches were recognized along any of the shears; nevertheless, the zone may have been a factor influencing the linear nature of the wash.

Analyses of both remanent magnetization vectors and foliation planes within the Topopah Spring Member strongly suggest an abrupt truncation of a northeasterly strike direction southwest of the main wash; within the wash, strikes of units are consistently north to north-northwest. This abrupt change in strike direction is believed indicative of block rotation about a near-vertical axis.

The absence of any notable vertical or horizontal displacements combined with the apparent horizontal block rotation suggest a wrenching effect within the wash bounded by minor faults along wash edges. These faults are either of a left-lateral strike-slip nature or normal with dominant components of lateral movement in opposite directions which caused a wedge-shaped segment of the wash to rotate (fig. 11).

This sense of displacement does not reflect the strong regional pattern of right-lateral northwest-trending structures at the NTS (Carr, 1974). Nevertheless, this small-scale rotation may represent an adjustment to the more conspicuous structures in the region. This hypothesis is tentative and must be confirmed with additional subsurface data, particularly from the area northeast of the wash.

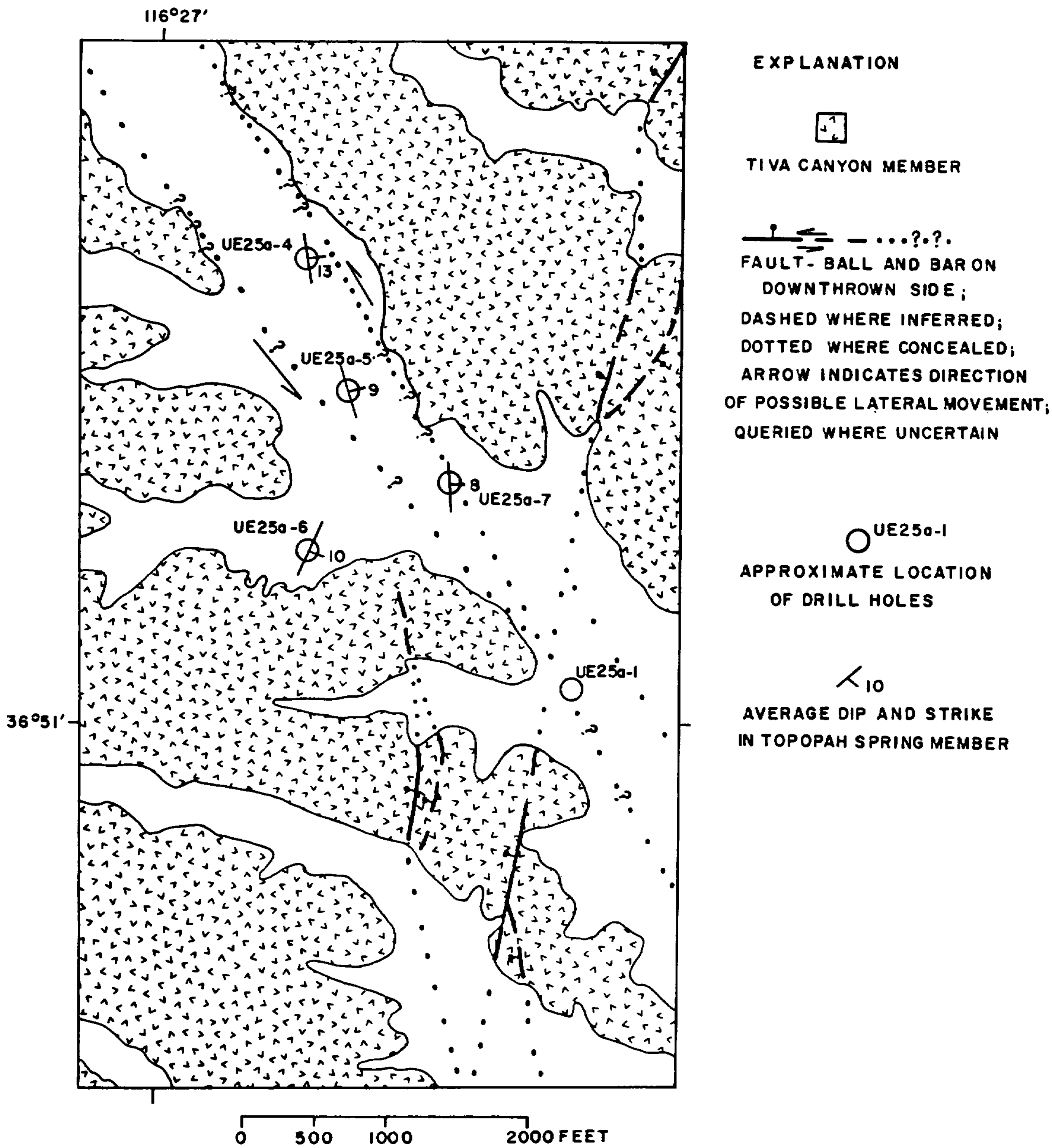

Figure 11.--Approximate location and sense of displacement inferred for faults in wash.

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