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Revised Volcanic Stratigraphy of Drill Hole J-13, Fortymile Wash, Nevada, Based on Petrographic Modes and Chemistry of Phenocrysts

F. M. Byers, Jr.*
Richard G. Warren

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*Visiting Staff Member at Los Alamos. 125 Everett St., Lakewood, CO 80226.

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

REVISED VOLCANIC STRATIGRAPHY OF DRILL HOLE J-13, FORTYMILE WASH, NEVADA, BASED ON PETROGRAPHIC MODES AND CHEMISTRY OF PHENOCRYSTS

by

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ABSTRACT

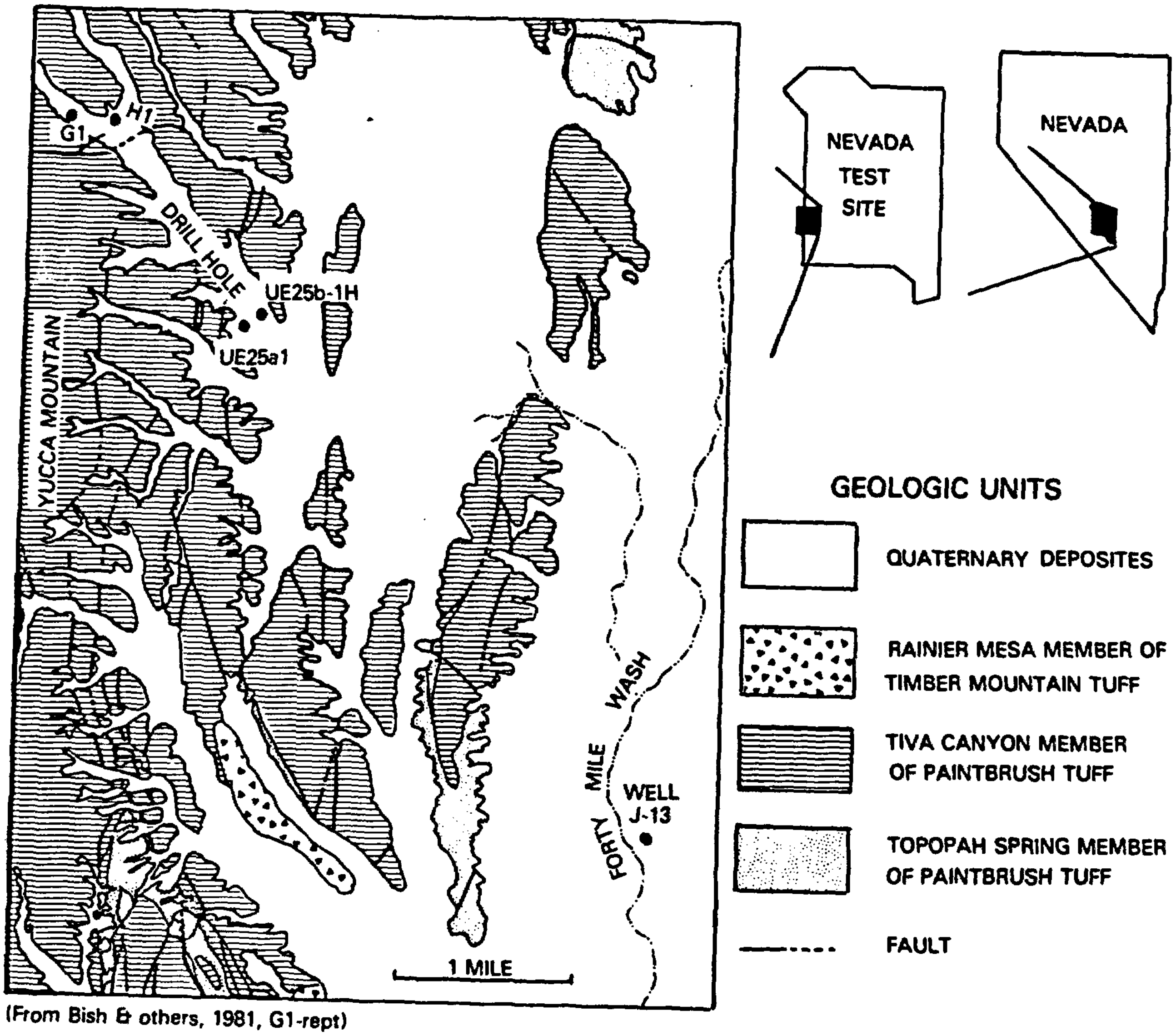
The core and cuttings of water well J-13 below the lower contact of the Paintbrush Tuff at 1475 ft (449.6 m) to the total depth of 3498 ft (1066.2 m) have been reexamined in the light of recent core drilling at Yucca Mountain sponsored by the Nevada Nuclear Waste Storage Investigations of the U.S. Department of Energy. An updated stratigraphic log is presented, showing the position of cored intervals and sample locations. The tuffs of Calico Hills were penetrated from 1475 to 1740 ft (449.6 to 530 m), a thickness of 265 ft (80.8 m). All three units of the Crater Flat Tuff were penetrated: the Prow Pass from 1740 to 1956 ft (530.4 to 596.2 m), the Bullfrog from 2015 to 2320 ft (614.2 to 707.1 m), and the Tram unit from 2350 to 3200 ft (716.3 to 975.4 m). The lowermost ash-flow tuff penetrated from 3220 ft (981.5 m) to the bottom of the hole at 3498 ft (1066.2 m) is the tuff of Lithic Ridge, also penetrated in hole USW-G1. The units were identified by thin-section modal analysis and by electron microprobe analyses of the feldspar and biotite phenocrysts.

I. INTRODUCTION

This revised stratigraphic log of well J-13 is based on recent studies of cuttings and core samples of the pre-Paintbrush volcanic rocks penetrated between 1475 ft (449.6 m) and 3498 ft (1066.2 m), the bottom of the hole. We believe this information is timely, because participants in the Nevada Nuclear Waste Storage Investigations (NNWSI) of the U.S. Department of Energy (DOE) at nearby Yucca Mountain, a few miles to the west (Fig. 1), have identified stratigraphic units below the Paintbrush Tuff as possible candidate media for storage of high-level nuclear waste. Earlier U.S. Geological Survey (USGS) reports by Doyle and Meyer (1963) and by Young (1972) did not identify stratigraphic units below the Paintbrush Tuff other than to call them "older tuffs." This was understandable at the time, because the Topopah Spring Member of the Paintbrush Tuff is the principal aquifer penetrated by well J-13. The well was drilled in 1963 as test well 6 of the USGS, but was redesignated well J-13 shortly thereafter by the Nevada Operations Office (NVOO) when the hole became a producing water well.

More recently, Heiken and Bevier (1979) of the Los Alamos National Laboratory issued a report entitled "Petrology of Tuff units from the J-13 drill site, Jackass Flats, Nevada" based on core samples from well J-13. Their report emphasizes the ground-water alteration and depth zonation of secondary mineral assemblages. Additional USGS data (Table A-I, Appendix) confirms the finding of Heiken and Bevier of clinoptilolite at 3491 ft (1064.1 m) near the bottom of the well. The stratigraphy below the Paintbrush Tuff in Heiken and Bevier (1979) was based on the incomplete information then available for the Crater Flat Tuff, obtained primarily by communication with geologists of the Special Projects Group, USGS, and from Byers et al. (1976). Since 1979, renewed interest in the older units penetrated by well J-13 resulted because deep holes [4000 to 6000 ft (1200 to 1800 m)] were drilled in the Yucca Mountain area for NNWSI, including USW-G1, USW-H1, and UE25b-1H (Fig. 1). Well J-13, which is 3498 ft (1066.2 m) deep, has provided a convenient southeasternmost anchor for southeast-northwest geologic cross sections through Yucca Mountain drill holes, but unfortunately knowledge of the older units has been incomplete.

The basis for this report is mainly from the logging and sampling of intermittent core runs by Paul P. Orkild of the USGS in 1977, starting with the core run from 1340.5 to 1341.3 ft (408.58 to 408.83 m) down to the core run in the bottom 8 ft (2.4 m) of J-13 (Fig. 2). Orkild first recognized the existence of an older ash-flow tuff underlying units of the Crater Flat Tuff in the lower part of well J-13 and provided an initial log of the hole.



(From Bish & others, 1981, G1-rept)

Fig. 1.
Generalized geologic map of a portion of Yucca Mountain-Fortymile Wash area, showing location of well J-13 and other drill holes (geology after Lipman and McKay, 1965).

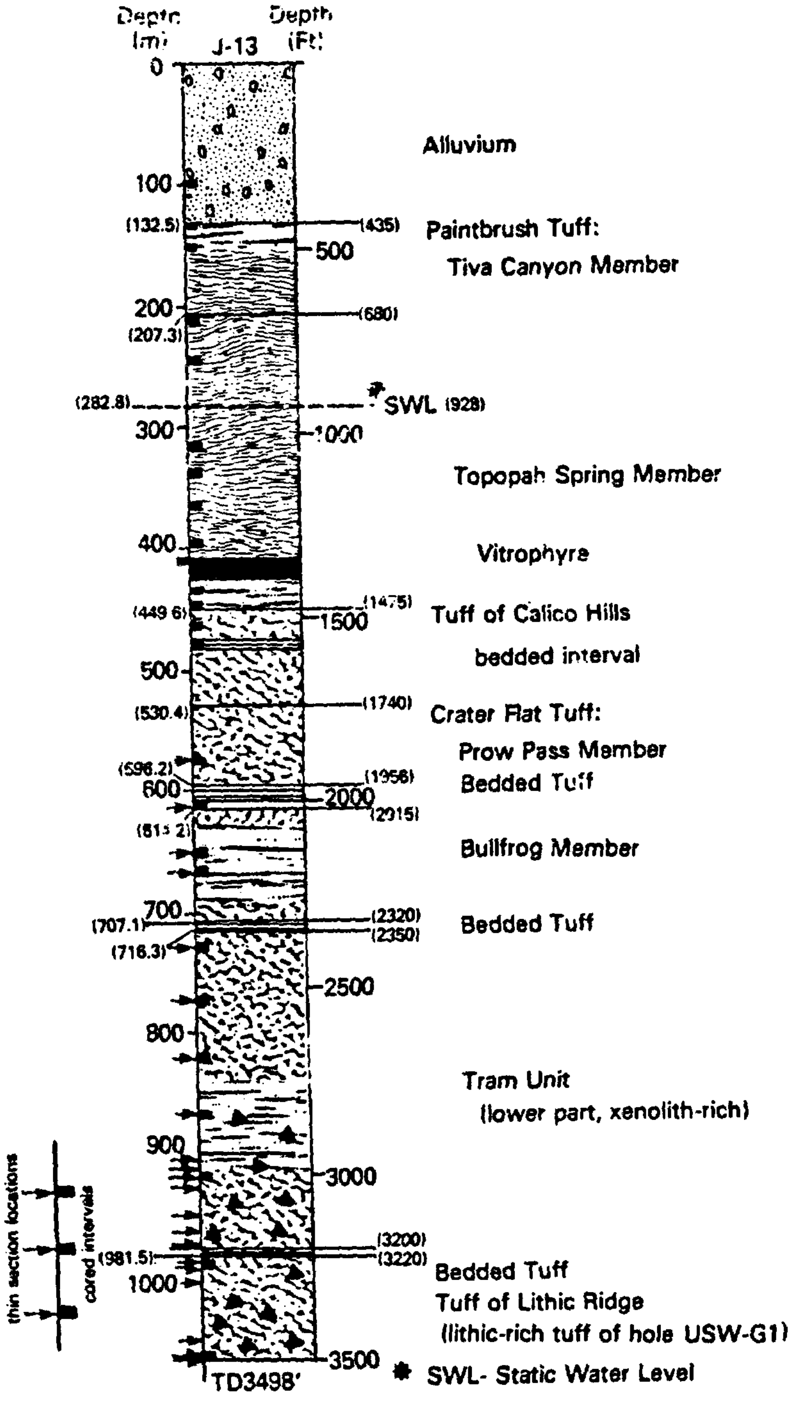


Fig. 2.
Graphic log of well J-13; density of pattern is roughly proportional to density of welding; solid triangles represent zones enriched in lithic fragments.

Both core and cuttings were examined and sampled below 2820 ft (859.5 m) by Byers in 1980. Well J-13 has good cuttings samples taken at 10-ft (3-m) intervals. The geophysical logs are useful for interpreting stratigraphic contacts down to about 2900 ft (884 m), but below that depth, pervasive alteration products result in featureless geophysical logs, so that it is impossible to pick stratigraphic contacts. The drill cuttings, however, are consistent with the three cored intervals starting at about 3000 ft or 915 m (see Fig. 2), despite minor contamination. The cuttings samples were mounted in epoxy, thin sectioned, and studied petrographically like the drill cores. The cuttings samples between 2900 and 3200 ft (884 and 975 m) not only match the core at 3000 ft (915 m) fairly well, but the cuttings samples from 3000 to 3200 ft (915 to 975 m) in J-13 show progressively less welding and less quartz (Fig. 3 and Table A-II, Appendix) typical of the lower part of the Tram unit of the Crater Flat Tuff. The cuttings between 3200 and 3220 ft (975 and 981.5 m) are a mixture of zeolite tuff, suggestive of a bedded interval, but the cuttings between 3220 and 3498 ft (981.5 and 1066.2 m) closely match the cores taken at 3245 and 3490 ft (989.1 and 1063.8 m) in J-13 (see Fig. 3 and Table A-II, Appendix).

No detailed lithologic log is included in this report because 1) our main purpose is stratigraphic correlation, 2) we have not routinely logged the hole as we would a new drill hole, and 3) there are three prior reports on J-13 with lithologic information (see references). The main conclusion presented here is that the tuff of Lithic Ridge (lithic-rich tuff of G-1) was penetrated in J-13 from 3220 ft (981.5 m) to 3498 ft (1066.2 m) instead of the lower part of the Tram unit through this interval (W. J. Carr, USGS, personal communication, 1980; Bish et al. 1981).

Thin sections of the core and cuttings were examined by Byers during 1978 - 1981, while employed by the USGS. Modal analyses of the J-13 samples are compared with those of drill hole USW-G1 on Yucca Mountain, because this hole has the most complete section for the purpose of stratigraphic correlation. Warren contributed electron microprobe analyses of feldspar phenocrysts in selected thin sections of the Crater Flat Tuff and the tuff of Lithic Ridge. Helpful comments of USGS geologists W. J. Carr, G. L. Dixon, Florian Maldonado, Paul P. Orkild, and R. W. Spengler are gratefully acknowledged.

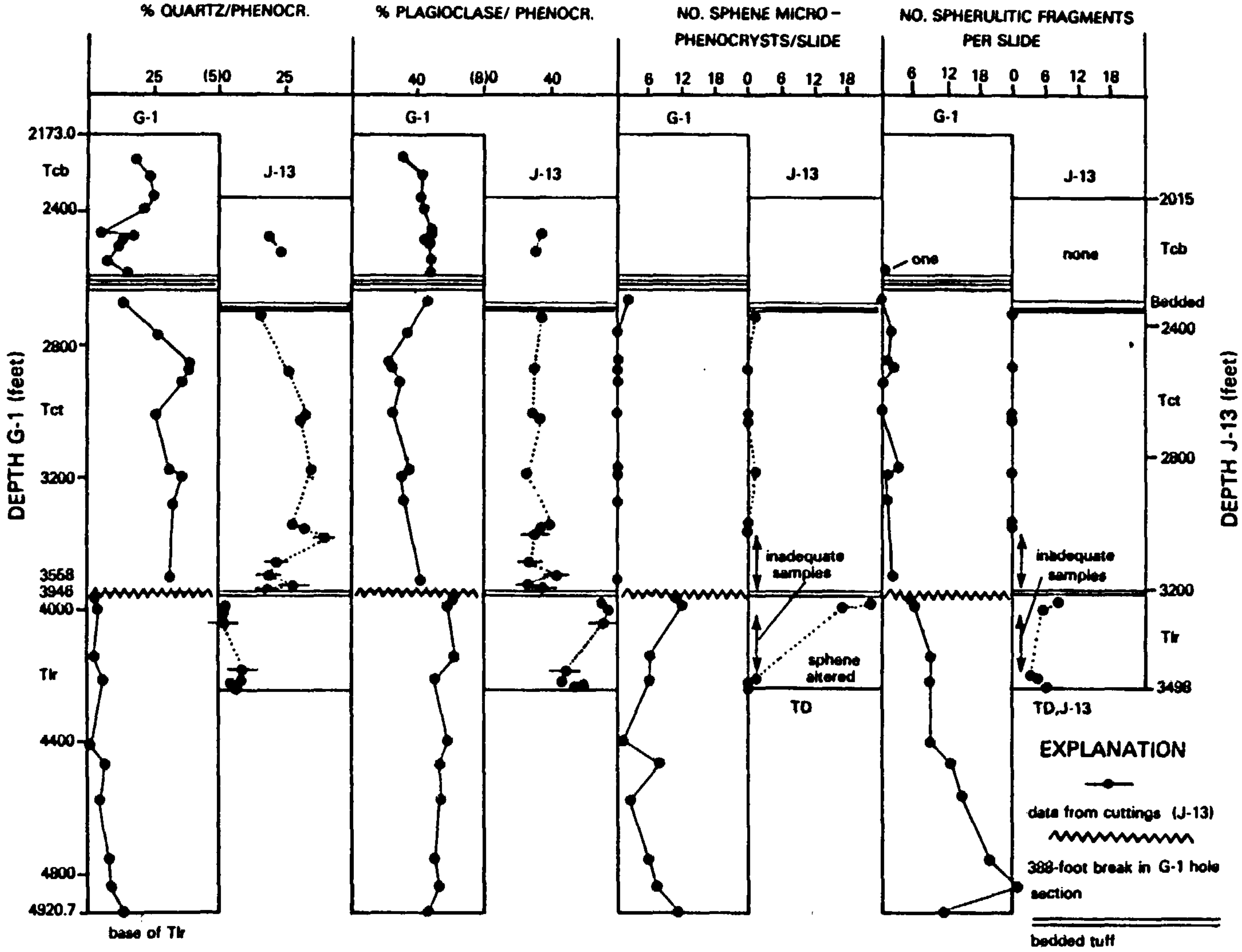


Fig. 3.

Thin-section modal comparison of well J-13 with drill hole USW-G1, showing modal contrast of Bullfrog (Tcb) and Tram (Tct) with Lithic Ridge Tuff (Tlr). G1 hole section is broken between 3558 and 3946 ft (1084 and 1203 m) to cut out dacite flow breccia which is missing in J-13, and also to juxtapose ash-flow units for comparison between holes.

II. STRATIGRAPHIC UNITS IN J-13

A summary stratigraphic log of well J-13 is presented in Table I and a graphic log is shown in Fig. 2. Thin bedded intervals occurring between the ash-flow tuff units are not considered part of any ash-flow unit. These bedded units are shown equal in rank to the members where the units occur within a formation, for commonly, they contain a phenocryst assemblage typical of the overlying or underlying member.

The stratigraphic units in the middle part of the drill hole between 1475 ft (449.6 m) and 2015 ft (614.2 m) include the tuffs of Calico Hills, and the Prow Pass Member of the Crater Flat Tuff (Fig. 2). The tuffs of Calico Hills include both bedded intervals and thin nonwelded ash flows, pervasively

TABLE I

SUMMARY STRATIGRAPHIC LOG, WELL J-13 (USGS TEST WELL 6), JACKASS FLATS, NEVADA [from USGS data, (elevation, 1011.3 m; SWL,[a] 728.5 m)].

Stratigraphic unit	Depth to base of unit m	Depth to base of unit ft	Thickness of unit m	Thickness of unit ft	Elevation of base of unit m	Elevation of base of unit ft
Alluvium	132.5	435	132.5	435	878.8	2883
Paintbrush Tuff						
Tiva Canyon Member	207.3	680	74.8	245	804.0	2638
Topopah Spring Member	449.6	1475	242.3	795	561.7	1843
Tuffs of Calico Hills	530.4	1740	80.8	265	480.9	1578
Crater Flat Tuff						
Prow Pass Member	596.2	1956	65.8	216	415.1	1362
Bedded Tuff	614.2	2015	18.0	59	397.1	1303
Bullfrog Member	707.1	2320	92.9	305	304.2	998
Bedded Tuff	716.3	2350	9.2	30	295.0	968
Tram Unit	975.4	3200	259.1	850	35.9	118
Bedded Tuff	981.5	3220	6.1	20	29.8	98
Tuff of Lithic Ridge	>1066.2	>3498(TD)[b]	>84.7	>278	<-54.9	<-180

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[a] Static water level elevation (Nuclear Hydrology Group, USGS).

[b] Total depth.

zeolitic, and are similar to the same unit penetrated in USW-G1 (Bish et al. 1981; Spengler et al. 1981). The Prow Pass Member is non- to partially welded, and is largely devitrified; the uppermost and lowermost nonwelded parts are zeolitic (Heiken and Bevier 1979). The Prow Pass is identified in thin section by its orthopyroxene pseudomorphs (characterized by rectangular prismatic sections and rounded terminations), and by Eleana (?) mudstone lithics and strongly resorbed quartz phenocrysts. The underlying Bullfrog also contains strongly resorbed quartz but has hornblende instead of orthopyroxene phenocrysts (Table A-II, Appendix). The Prow Pass has sparse hornblende in the upper part, and when both units are sufficiently altered to have completely destroyed the mafic phenocrysts, distinguishing the Prow Pass from the Bullfrog on the basis of thin section petrography is almost impossible. The Prow Pass was first mistaken for Bullfrog in drill hole USW-G2 from two thin sections taken in the upper 50 ft.

To provide further support for the stratigraphic assignments, five samples from well J-13 available from a previous study (Heiken and Bevier 1979), were selected for electron microprobe analysis of feldspars and biotites. Previously, it was shown that each member of the Crater Flat Tuff of USW-G1 has a distinct composition for its feldspar (Bish et al. 1981). The alkali feldspar composition is invariant from top to bottom of each unit in USW-G1, within the precision of the analyses (about 1 mol% orthoclase molecular end member). The alkali feldspar composition for units of the Crater Flat Tuff is also laterally invariant over distances exceeding 30 miles. This work also confirms a similar constancy in alkali feldspar compositions for the tuff of Lithic Ridge and many additional units, and extends the results to include mafic minerals. Alkali feldspar compositions can be utilized to determine the genetic source of bedded units; for example, alkali feldspar compositions indicate that the bedded unit between the Bullfrog and Prow Pass Members of the Crater Flat Tuff in USW-G1 is genetically related to the Bullfrog (Bish et al. 1981).

The Prow Pass Member is distinguished from the underlying Bullfrog by the orthoclase (Or) plus celsian (Cn) content in the alkali feldspar (sanidine) and the anorthite (An) content of the plagioclase, as shown by the frequency distribution diagrams in Fig. 4. (See also Table A-III, Appendix.) The frequency modes of Or+Cn in alkali feldspar of the J-13 subset matches the same class interval as the parent population, mainly from USW-G1, and a

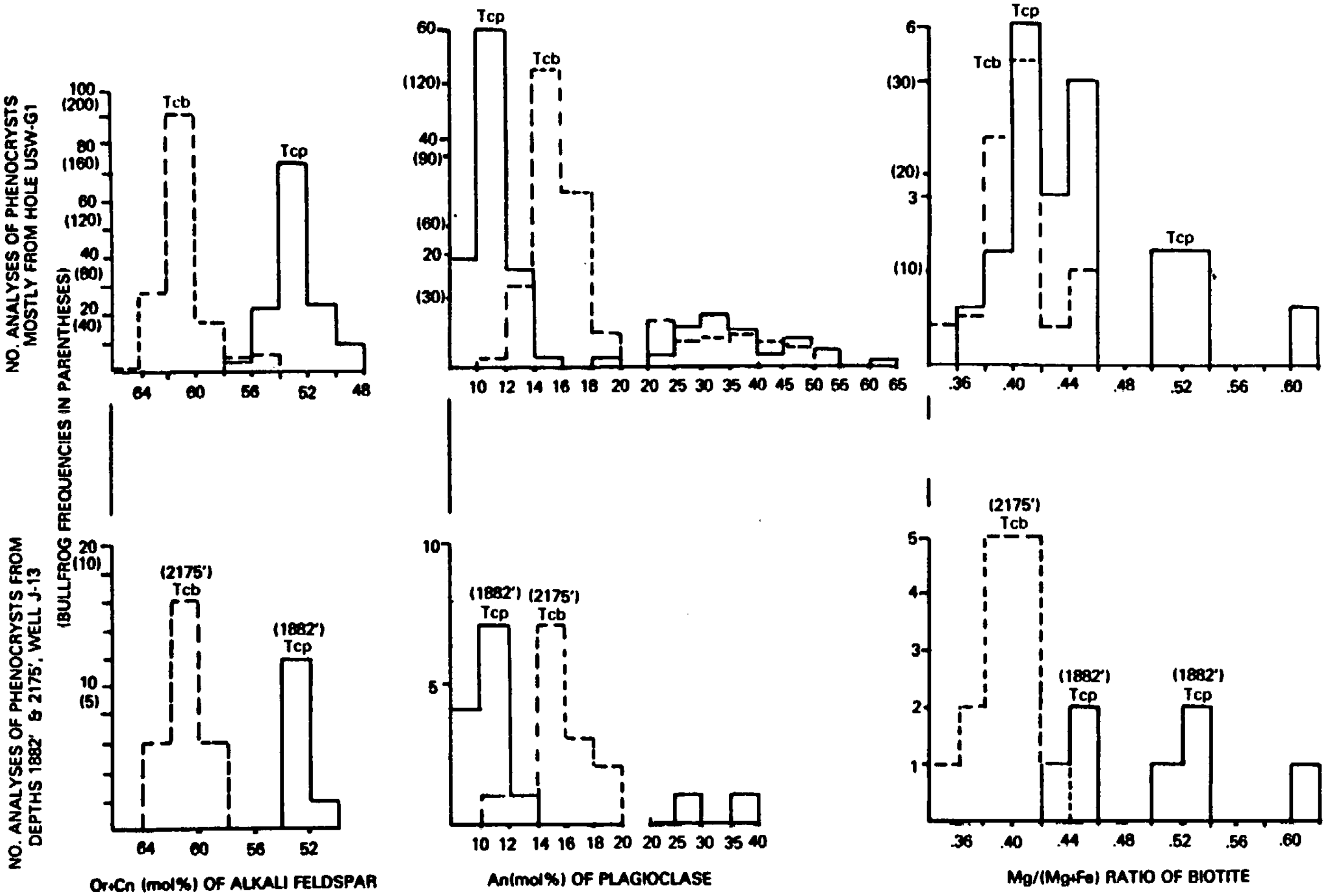


Fig. 4.

Percentages of selected end member constituents in feldspar, and Mg/(Mg+Fe) atomic ratio in biotite for phenocrysts of the Prow Pass (Tcp, solid lines) and Bullfrog (Tcb, dashed lines) Members, comparing frequency distributions of analyses mostly from drill hole USW-G1 with those from J-13. Some outside intervals in the upperdiagrams include a few values beyond the class interval.

similar relation holds between the parent population and the J-13 subset in the case of plagioclase. Visually, it is quite apparent from Fig. 4 that the Prow Pass Member can be distinguished from the petrographically closely similar Bullfrog Member by comparison of their feldspar chemistry. The magnesium-to-magnesium plus iron molecular ratios (Mg/Mg+Fe) in the biotites of the Prow Pass and the Bullfrog Members are not significantly different. Mafic mineral compositions are very similar among members of each formation defined within the Nevada Test Site (NTS).

The petrographic data used to identify the lower stratigraphic units penetrated below the Prow Pass Member in well J-13 are compared between drill holes J-13 and USW-G1 in Fig. 3. These units are the Bullfrog Member and the Tram unit of the Crater Flat Tuff and the tuff of Lithic Ridge (lithic-rich tuff in USW-G1 of Spengler et al. 1981). The 388-ft-thick dacite flow breccia, which is not present in J-13, was eliminated from the USW-G1 columns in Fig. 3 to allow easy comparison of unit thicknesses between the two holes.

Plots of the diagnostic modal constituents of the Bullfrog Member and the Tram unit of the Crater Flat Tuff (Fig. 3) indicate a generally higher content of quartz in the Tram except in the uppermost part of both G-1 and J-13. Also, quartz in the Bullfrog is highly resorbed in contrast with quartz phenocrysts in the Tram.

Feldspar compositions are highly distinctive among all units of the Crater Flat Tuff, even though biotite compositions usually are not. Feldspar and biotite compositions of samples from J-13 are compared with compositions for the appropriate unit in Figs. 5 and 6. (See also Tables A-IV and A-V, Appendix.) Samples for each unit were obtained primarily from USW-G1 and supplemented by samples from widely scattered outcrops. A slightly, but significantly, higher Mg/(Mg+Fe) for Tram at 2382-ft (726-m) depth in J-13 compared to the sample of Tram at 2980 ft (909 m) (Fig. 6) parallels a similar magnesium enrichment for biotite within the uppermost 60 ft (18 m) of the Tram Member in drill hole USW-G1 (Bish et al. 1981) and thus conveniently fingerprints the uppermost portion of the unit.

The five cuttings samples taken between 3000 and 3200 ft (915 and 975 m) closely resemble the core taken in the Tram unit at 3000 ft (915 m) (Figs. 2 and 3; Table A-II, Appendix), and all five samples yielded precentages of the felsic constituents that were consistent with those of the core at 3000 ft (915 m). Because mounts prepared from cuttings offer considerably less area

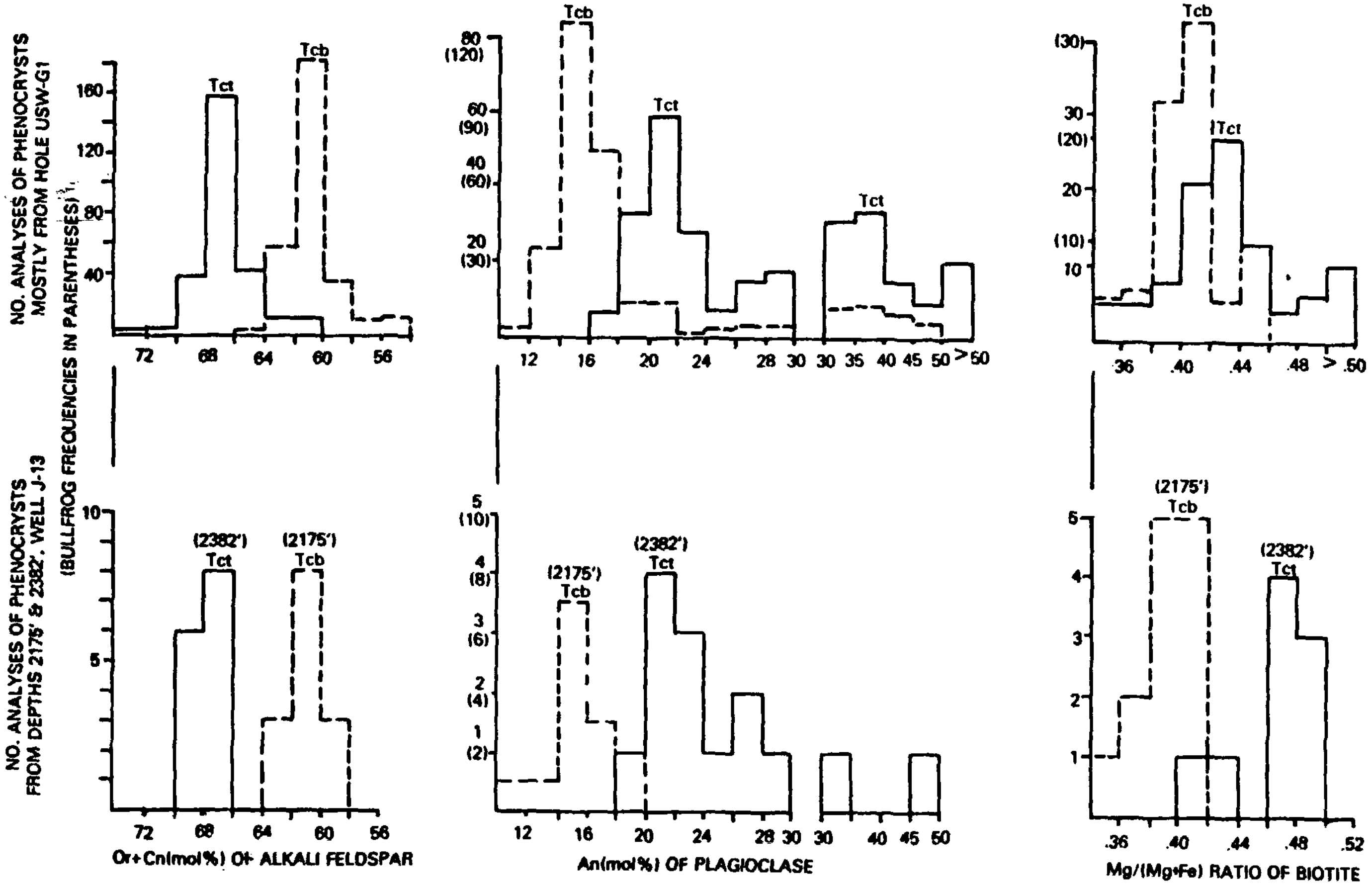


Fig. 5.

Percentages of selected end member constituents in feldspar and Mg/(Mg+Fe) atomic ratio in biotite for phenocrysts of the Tram (Tct, solid line) and Bullfrog (Tcb, dashed line) Members, comparing frequency distributions of analyses mostly from drill hole USW-G1 with those from J-13. Some outside intervals in the upper diagrams include a few values beyond the class interval.

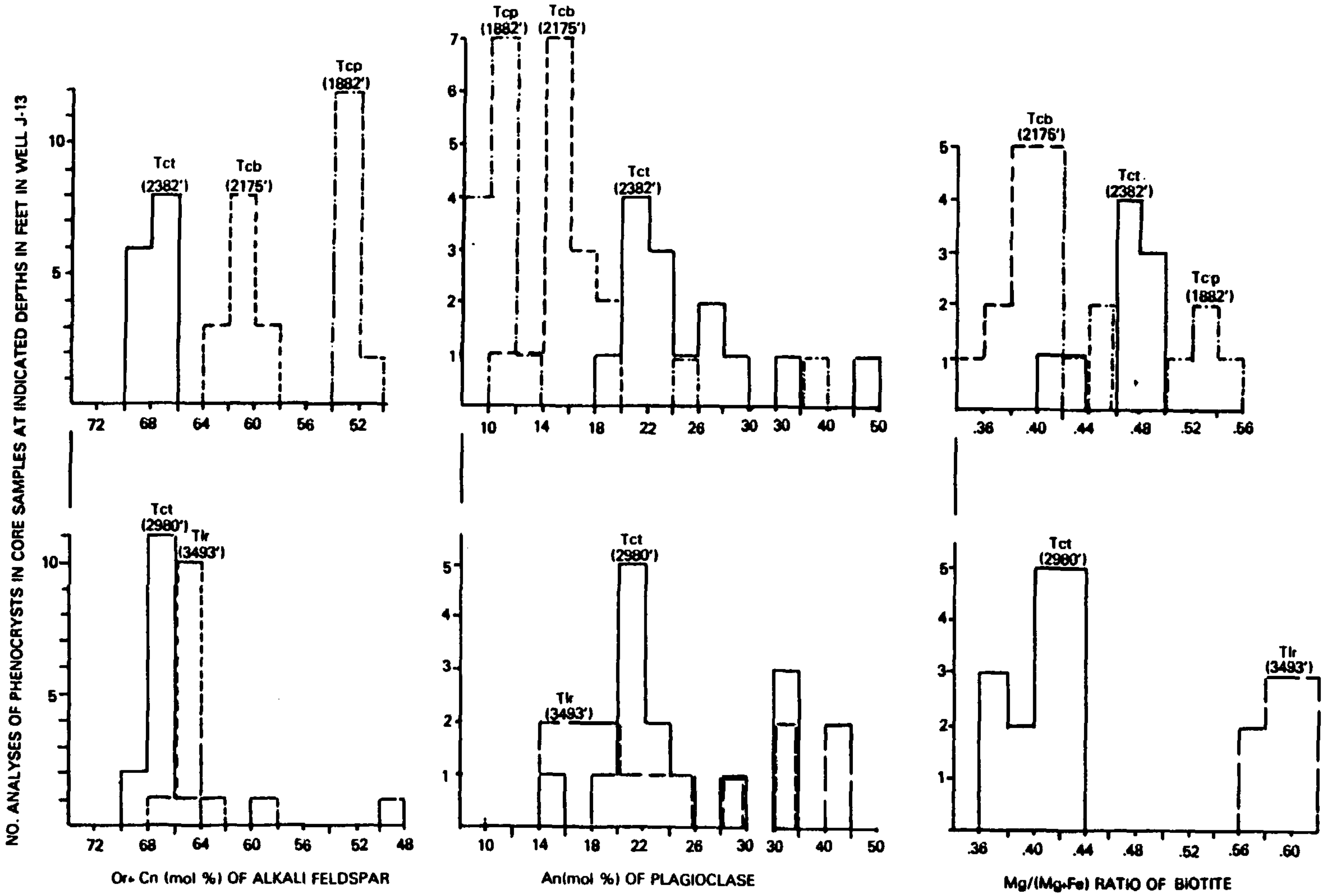


Fig. 6.
Percentages of selected end member constituents in feldspar and Mg/(Mg+Fe) atomic ratio in biotite, showing comparisons between phenocryst compositions of Tram (Tct, solid lines), Bullfrog (Tcb, dashed lines), and Prow Pass (Tcp, dot-dash lines) in upper diagrams and between phenocryst compositions of tuff of Lithic Ridge (Tlr), long dashed line) and Tram Member of Crater Flat Tuff (lower diagrams) in well J-13.

for modal counts than do full thin sections prepared from core, only 500 to 1000 points were counted for cuttings contrasted with 3000 to 4000 for core. Consequently, counting statistical errors are considerably larger for cuttings and therefore modal data on mounted cuttings (Table A-II, Appendix) are rounded to the nearest whole percent.

The cuttings from 3200 ft (975.4 m) to 3220 ft (981.5 m) are a mixture of varicolored zeolitic (?) tuff, unlike the predominantly monolithologic cuttings above and below this interval. This interval, therefore, presumably is the bedded interval between the Tram unit and tuff of Lithic Ridge. The upper contact of the underlying tuff of Lithic Ridge is placed at 3220 ft (981.5 m) because of the first appearance of green ash-flow tuff like that to be described from cuttings and core below that depth.

The tuff of Lithic Ridge represented by core and cuttings below 3220 ft (981.5 m) in J-13 (Figs. 2 and 3) is largely greenish-gray, lithic-rich, and whereas it does somewhat resemble the lithic-rich lower Tram unit in USW-G1, it differs in color and presumably in alteration from the overlying Tram unit, which in J-13 is very light gray, typical of the lower, partially welded zone of the Tram unit with minimum alteration. The modal analyses of the two core runs in the tuff of Lithic Ridge and those of the two cuttings samples between 3244 ft and the total depth of 3498 ft (988.8 and 1066.2 m) are markedly different from the overlying Tram unit in containing much less quartz and more plagioclase. The tuff of Lithic Ridge also contains sparse sphene microphenocrysts and more spherulitic, high-silica rhyolite lithics. In the lower core run at the bottom of J-13, the sphene is altered. The cuttings from 3230 to 3244 ft (984.5 to 988.8 m) are more than 80% green ash-flow tuff, essentially identical to the subjacent core run and for that reason were not sampled. The slight decrease in quartz content upward in the tuff of Lithic Ridge in G-1 is believed to be significant, for a quartz-rich unit underlies the tuff of Lithic Ridge in G-1, and in both G-1 and G-2, a thin quartz-free zone occupies the uppermost several feet of the tuff of Lithic Ridge and suggests a slight compositional zonation toward a more mafic caprock.

The feldspar compositions of the tuff of Lithic Ridge and the Tram unit are very similar though not quite identical (Fig. 7). (See also Table A-VI, Appendix.) The difference between alkali feldspar compositions (65 mol% Or+Cn for the tuff of Lithic Ridge in contrast to 67 mol% for the Tram unit) is not sufficient to distinguish individual samples from each unit. However, biotite

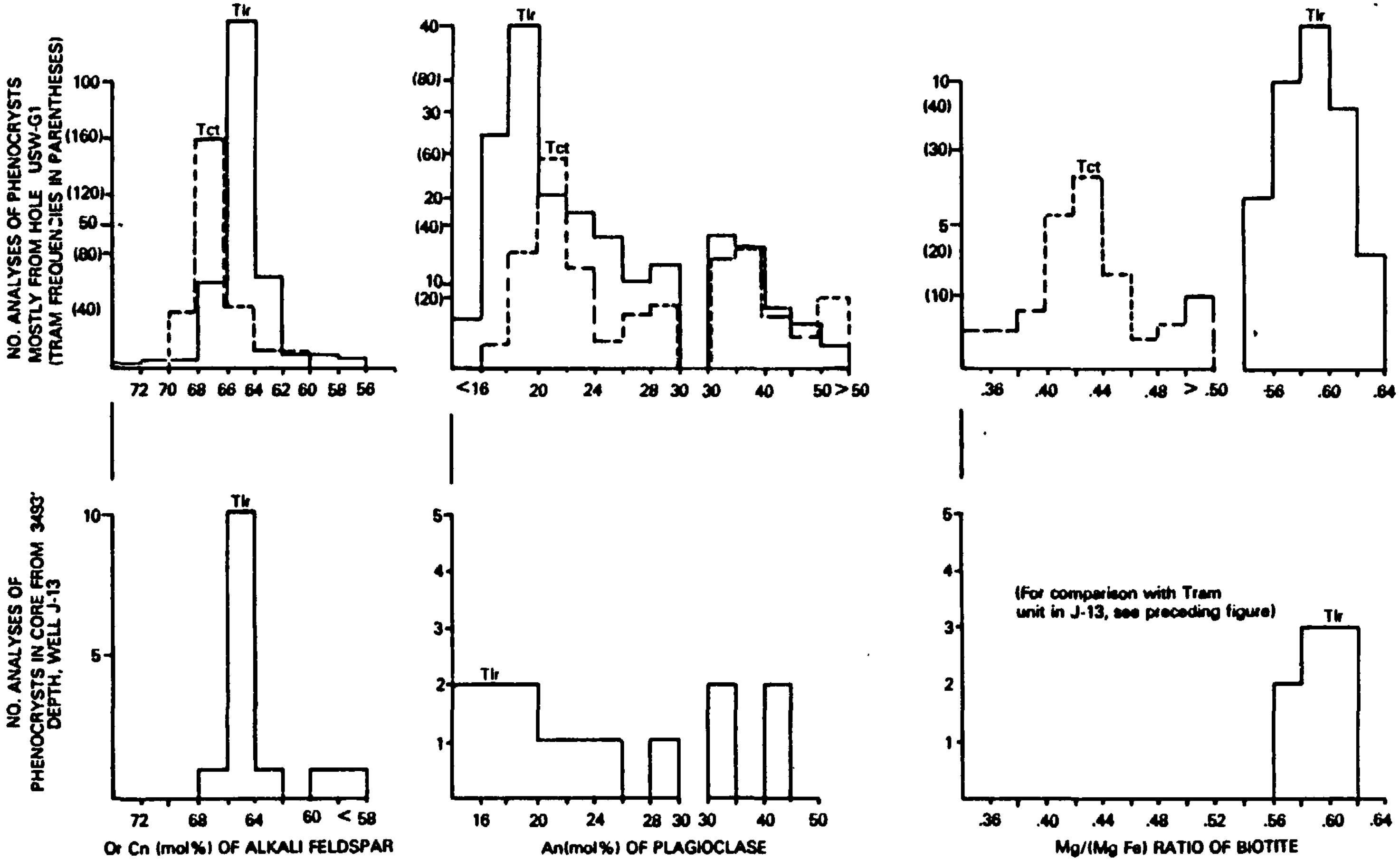
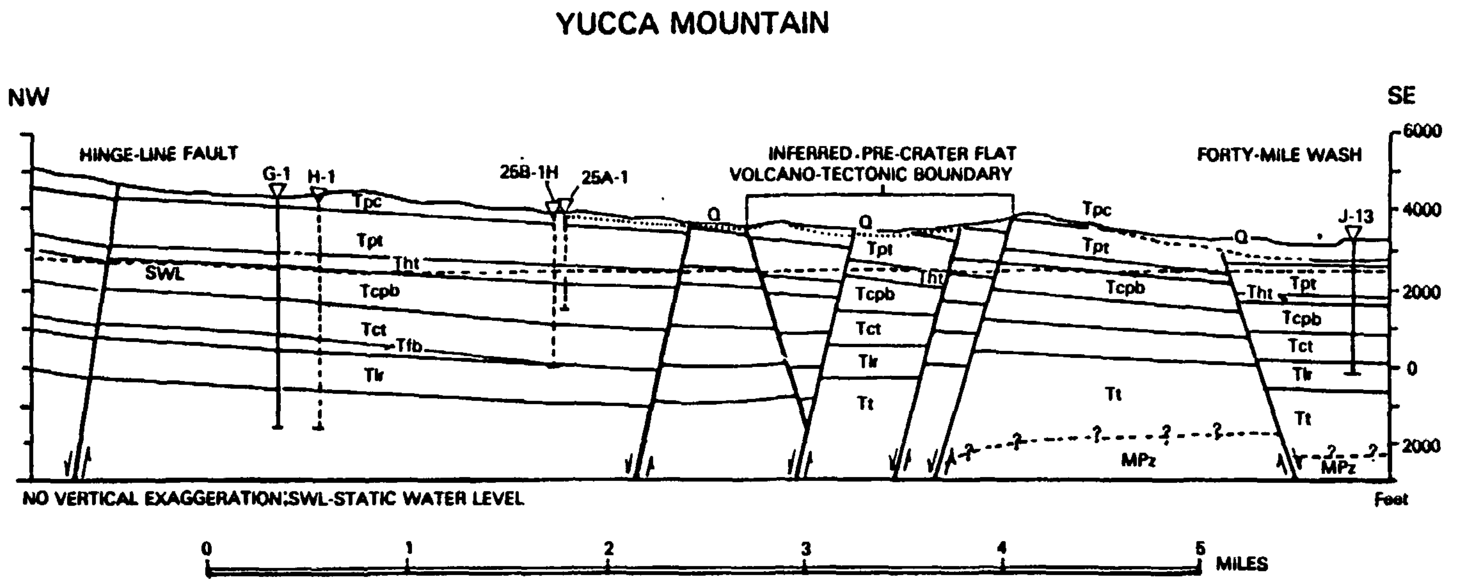


Fig. 7.

Percentages of selected end member constituents in feldspar and Mg/(Mg+Fe) atomic ratio in biotite, comparing phenocryst compositions of tuff of Lithic Ridge (Tlr, solid lines) and those of Tram unit (Tct, dashed lines) in upper diagrams and comparing tuff of Lithic Ridge phenocryst compositions between general population (upper diagrams) and well J-13 subset (lower diagrams). Some of the outside intervals include a few extreme values beyond the class interval, as indicated by > or <.

compositions readily allow distinction of the units, and the samples from J-13 that have probe analyses are seen to match biotite compositions of the appropriate unit (Figs. 6 and 7).

A generalized areal cross section (Fig. 8) between drill hole USW-G1 on Yucca Mountain and well J-13 in Jackass Flats is shown here to help visualize subsurface stratigraphic correlation. Minor faults, especially those in the vicinity of UE25a-1 and UE25b-1H, are not shown, and the location and displacement of the major faults may be revised in the future. In preparing this cross section we received help from geologists of the USGS; mainly, W. J. Carr, G. L. Dixon, and Florian Maldonado.



Q	Alluvium	
Tpc	Tiva Canyon Member (incl. Pah C. and Yucca Mtn. Mbrs.	Paintbrush Tuff
Tpt	Topopah Spring Member	
Tht	Rhyolite Tuff of Calico Hills	
Tcpb	Prow Pass and Bullfrog Members	Crater Flat Tuff
Tct	Tram Unit	
Tfb	Dacite Flow Breccia	
Tlr	Tuff of Lithic Ridge	
Tt	Older Tuffs (may include tuff of Yucca Flat)	
MPz	Mesozoic and Paleozoic Rocks	

Fig. 8.
Geologic cross section between drill holes USW-G1 and J-13 (modified from Maldonado, personal communication, 1981).

REFERENCES

Byers, F. M., Jr., W. J. Carr, Paul P. Orkild, W. D. Quinlivan, and K. A. Sargent, 1976, "Volcanic Suites and Related Cauldrons of Timber Mountain-Oasis Valley Caldera Complex, Southern Nevada," U.S. Geol. Surv. Prof. Paper 919, 70 p.

Bish, D. L., F. A. Caporuscio, J. F. Copp, B. M. Crowe, J. D. Purson, J. R. Smyth, and R. G. Warren, 1981, "Preliminary Stratigraphic and Petrologic Characterization of Core Samples from Yucca Mountain, Nevada," A. C. Waters and P. R. Carroll, eds., Los Alamos National Laboratory report LA-8840-MS, 66 p.

Doyle, A. C. and G. L. Meyer, 1963, "Summary of Hydraulic Data and Abridged Lithologic Log of Ground-Water Test Well 6 (J-13), Jackass Flats, Nevada Test Site, Nye County, Nevada," U.S. Geol. Surv. Tech. Lett. NTS-50, 11 p,(USGS-474-314).

Heiken, G. H. and M. L. Bevier, 1979, "Petrology of Tuff Units from the J-13 Drill Site, Jackass Flats, Nevada," Los Alamos Scientific Laboratory report LA-7563-MS, 55 p.

Lipman, P. W., and McKay, E. J. 1965, "Geologic map of the Topopah Spring SW quadrangle, Nye County, Nevada," U.S. Geol. Surv. Quad. Map GQ-439.

Spengler, R. W., F. M. Byers, Jr., and J. B. Warner, 1981, "Stratigraphy and Structure of Volcanic Rocks in Drill Hole USW-G1, Yucca Mountain, Nye County, Nevada," U.S. Geol. Surv. Open-file Report 81-1349, 50 p.

Young, R. A., 1972, "Water Supply for the Nuclear Rocket Development Station at the U.S. Atomic Energy Commission's Nevada Test Site," U.S. Geol. Surv. Water Supply Paper 1938, 19 p.

APPENDIX

MINERALOGICAL AND MICROPROBE DATA

TABLE A-I

MINERALOGICAL ANALYSES OF J-13 CORES (TUFF OF LITHIC RIDGE) BY X-RAY DIFFRACTOMETER (Paul D. Blackmon, analyst, USGS).

Minerals/Depth	3246 ft (parts in ten)	3491 ft (parts in ten)
Montmorillonite	1+	1+
Illite-mica	tr	tr
Chlorite	tr	nf
Clinoptilolite	nf	<1
Quartz	2+	3+
Feldspar	4	3
Calcite	<1	tr
Cristobalite-opaline silica	tr	nf
Amorphous	<1	<1

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tr = trace, <5%
nf = none found
<1 = 5 to 9%

TABLE A-II

MODAL ANALYSES OF THIN SECTIONS FROM WELL J-13.

(Blank spaces due to inadequate sample; data from cuttings and core at 3490 are semiquantitative.)

				Phenocrysts as volume percent of total crystals						Grains per thin section			
Stratigraphic unit	Depth (C = cuttings) sample (ft)	Lithic fragments (volume percent)	Phenocrysts (volume percent)	Quartz (percent)	Alkali feldspar (percent)	Plagioclase (percent)	Biotite (percent)	Hornblende pseudomorphs (percent)	Opaque Oxides	Zircon[a]	Sphene	Allanite	Spherulitic lithics
Prow Pass Mbr.	1883	1.6	12.5	10.5	54.3	32.1	0	2.5[b]	0.6	2	0	0	0
Bullfrog Mbr.	2132	0.5	18.6	18.5	39.6	36.5	2.7	1.9	0.8	c	0	0	0
do.	2183	0	18.9	22.7	36.4	32.6	4.9	1.9	1.5	c	0	0	0
Tram Unit	2382.5	0.7	8.6	17.0	40.7	36.3	5.0	0	0.9	12	1	0	0
do.	2532.1	0.9	10.7	25.5	34.8	29.8	8.7	0.6[d]	0.6	4	0	0	0
do.	2684	3.4	12.3	32.0	32.0	29.3	5.4	0.7[d]	0.7	3	0	0	0
do.	2685.2	1.4	13.9	30.8	26.4	34.1	7.2	0.5[d]	1.0	6	1	0	0
do.	2843	0.8	14.9	34.8	31.7	25.4	5.8	1.8[d]	0.4	5	1	0	0
do.	2998	13.5	7.9	27.1	30.5	39.8	1.0	0.8[d]	0.8	3	0	0	0
do.	3005	8.4	8.5	32.1	27.0	34.0	5.4	0	1.6	6	0	0	0
do.	3030-C	7	13	39	26	30	3	0	2				
do.	3110-C	2	9	20	52	26	1	0	0				
do.	3150-C	2	7	18	35	44	3	0	0				
do.	3190-C	4	5	27	38	27	8	0	0				
do.	3200-C	2	4	18	36	36	5	0	4				
Lithic Ridge	3246	8.7	9.2	2.5	21.7	71.2	0.6	1.2	2.8	41	22	3	8
do.	3251	8.4	12.5	1.1	14.4	76.5	3.2	<1	4	20	17	2	5
do.	3290-C	5	15	1	18	74	<1	<1	<5				
do.	3450-C	23	11	8	39	49	2	0	2				
do.	3490	20	>7	7	<41	>47	3	<1	2				
do.	3491	13.4	9.9	4.9	29.2	60.4	4.9	0	0.6	16	e		4
do.	3497	10.8	6.9	5.6	34.7	54.9	2.6	0	2.2	6	e		6

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[a] excludes grains within opaque oxides

[b] orthopyroxene pseudomorphs

[c] not counted

[d] mafic pseudomorph unidentifiable

[e] sphene mostly altered beyond recognition

TABLE A-III

PHENOCRYST COMPOSITIONS DETERMINED BY ELECTRON MICROPROBE ANALYSIS FOR PROW PASS MEMBER FROM DRILL HOLE J-13 AT 1882 FT DEPTH.

Alkali Feldspar

Mol% Or+Cn	Analyses Averaged	SiO_2	Al_2O_3	Fe_2O_3	CaO	BaO	Na_2O	K_2O	Total
52-54	12	67.2	18.7	0.12	0.26	0.14	5.29	9.18	100.9
50-52	2	68.0	18.8	0.10	0.28	0.21	5.38	8.93	101.7

Plagioclase

Mol% An	Analyses Averaged	SiO_2	Al_2O_3	Fe_2O_3	CaO	BaO	Na_2O	K_2O	Total
8-10	4	66.4	20.6	0.15	2.00	0.04	9.52	1.83	100.5
10-12	7	66.2	20.9	0.13	2.34	0.00	9.55	1.62	100.7
13	1	64.7	21.3	0.17	2.75	0.01	9.40	1.57	99.9
26	1	63.3	23.7	0.26	5.51	0.06	8.24	0.75	101.8
39	1	58.9	26.0	0.09	8.18	0.18	6.75	0.38	100.5

Biotite

Mg/(Mg+Fe)	Analyses Averaged	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	BaO	Na_2O	K_2O	Total
0.43	1	36.8	5.11	14.3	19.8	8.63	0.01	1.48	0.69	8.59	95.3
0.44-0.46	2	38.4	4.81	14.2	19.1	8.50	0.01	1.31	0.69	8.63	95.7
0.51	1	37.6	5.00	13.9	17.4	10.6	0.13	1.12	0.65	8.07	94.5
0.52-0.54	2	38.7	5.29	14.0	16.6	10.1	0.04	1.53	0.70	8.43	95.5
0.61	1	39.3	4.91	15.0	13.9	12.1	0.05	1.06	0.61	8.70	95.6

TABLE A-IV

PHENOCRYST COMPOSITIONS DETERMINED BY ELECTRON MICROPROBE ANALYSIS FOR BULLFROG MEMBER FROM DRILL HOLE J-13 AT 2175 FT DEPTH.

Alkali Feldspar

Mol% Or+Cn	Analyses Averaged	SiO_2	Al_2O_3	Fe_2O_3	CaO	BaO	Na_2O	K_2O	Total
62-64	3	64.9	18.8	0.06	0.19	0.58	4.15	10.7	99.4
60-62	8	65.3	18.8	0.10	0.20	0.39	4.39	10.5	99.7
58-60	3	65.2	19.0	0.06	0.22	0.64	4.54	10.0	99.7

Plagioclase

Mol% Or+Cn	Analyses Averaged	SiO_2	Al_2O_3	Fe_2O_3	CaO	BaO	Na_2O	K_2O	Total
11	1	65.9	21.3	0.19	2.48	0.00	9.63	1.60	101.1
13	1	64.1	21.7	0.25	2.79	0.00	9.28	1.43	99.5
14-16	7	64.6	21.8	0.18	3.25	0.00	9.30	1.32	100.5
16-18	3	64.1	21.9	0.14	3.50	0.00	9.21	1.21	100.1
18-20	2	63.2	22.6	0.23	3.99	0.00	8.81	1.00	99.8

Biotite

Mg/(Mg+Fe)	Analyses Averaged	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	BaO	Na_2O	K_2O	Total
0.35	1	35.5	4.73	12.6	25.8	8.12	0.00	0.23	0.18	8.97	96.1
0.36-0.38	2	35.4	4.75	13.2	25.3	8.43	0.00	0.49	0.45	8.80	96.8
0.38-0.40	5	35.8	4.78	13.3	24.3	8.68	0.00	0.60	0.46	8.67	96.6
0.40-0.42	5	36.3	4.67	13.2	24.1	9.30	0.00	0.42	0.56	8.89	97.4
0.43	1	36.4	4.39	12.8	23.7	9.73	0.00	0.00	0.57	8.91	96.5

TABLE A-V

PHENOCRYST COMPOSITIONS DETERMINED BY ELECTRON MICROPROBE ANALYSIS FOR TRAM UNIT FROM DRILL HOLE J-13 AT 2382 AND 2980 FT DEPTHS (COMBINED RESULTS).

Alkali Feldspar

Mol% Or+Cn	Analyses Averaged	SiO_2	Al_2O_3	Fe_2O_3	CaO	BaO	Na_2O	K_2O	Total
68-70	8	64.6	18.6	0.11	0.18	0.76	3.51	11.6	99.4
66-68	19	65.1	18.7	0.08	0.18	0.58	3.65	11.5	99.8
65	1	66.2	18.0	0.04	0.17	0.15	3.75	11.3	99.6

Plagioclase

Mol% Or+Cn	Analyses Averaged	SiO_2	Al_2O_3	Fe_2O_3	CaO	BaO	Na_2O	K_2O	Total
15	1	64.3	22.2	0.15	3.46	0.00	9.43	1.10	100.6
18-20	2	63.4	22.6	0.10	4.12	0.00	8.92	1.17	100.3
20-22	9	62.6	22.9	0.16	4.60	0.00	8.81	1.01	100.2
22-24	5	62.2	23.2	0.20	5.00	0.00	8.51	1.05	100.2
24-26	2	61.7	23.7	0.08	5.25	0.00	8.47	0.79	100.0
26-28	2	60.7	24.2	0.18	6.02	0.00	8.29	0.76	100.2
28-30	2	60.5	24.3	0.36	6.27	0.00	7.84	0.89	100.2
30-35	4	59.7	24.9	0.21	7.04	0.00	7.61	0.62	100.1
47	1	56.1	27.1	0.19	9.91	0.00	6.20	0.37	99.9

Biotite

Mg/(Mg+Fe)	Analyses Averaged	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	BaO	Na_2O	K_2O	Total
0.36-0.38	3	34.9	4.94	12.8	25.3	8.52	0.01	0.20	0.61	8.72	96.0
0.38-0.40	2	35.7	4.99	13.2	23.8	9.02	0.05	0.19	0.64	8.87	96.5
0.40-0.42	6	35.2	4.92	13.2	23.7	9.25	0.03	0.70	0.56	8.72	96.3
0.42-0.44	6	36.1	4.92	13.2	22.9	9.63	0.03	0.26	0.56	8.88	96.5
0.46-0.48	4	35.7	4.79	13.8	20.5	10.3	0.03	1.07	0.41	8.82	95.4
0.48-0.50	3	35.8	4.66	13.8	20.9	11.1	0.02	0.78	0.40	8.98	96.4

TABLE A-VI

PHENOCRYST COMPOSITIONS DETERMINED BY ELECTRON MICROPROBE ANALYSIS FOR TUFF OF LITHIC RIDGE FROM DRILL HOLE J-13 AT 3493 FT DEPTH.

Alkali Feldspar

Mol% Or+Cn	Analyses Averaged	SiO_2	Al_2O_3	Fe_2O_3	CaO	BaO	Na_2O	K_2O	Total
67	1	65.9	18.4	0.16	0.18	0.14	3.69	11.2	99.7
64-66	10	65.8	18.5	0.15	0.21	0.50	3.87	11.0	100.0
63	1	65.7	18.8	0.11	0.25	0.51	4.09	10.9	100.4
59	1	65.8	18.7	0.12	0.24	0.49	4.59	10.0	99.9
49	1	66.4	18.8	0.11	0.22	0.49	5.76	8.45	100.2

Plagioclase

Mol% Or+Cn	Analyses Averaged	SiO_2	Al_2O_3	Fe_2O_3	CaO	BaO	Na_2O	K_2O	Total
14-16	2	65.6	21.3	0.20	3.24	0.18	8.27	2.21	101.0
16-18	2	64.6	21.9	0.15	3.74	0.00	8.86	1.46	100.7
18-20	2	63.4	22.1	0.19	4.04	0.07	8.91	1.09	99.8
21	1	64.3	22.5	0.19	4.44	0.00	8.82	1.05	101.3
23	1	62.2	23.2	0.24	5.06	0.00	8.46	0.84	100.0
25	1	63.4	23.1	0.27	5.29	0.17	8.19	0.87	101.3
29	1	61.2	24.3	0.13	6.28	0.00	7.72	0.59	100.2
30-35	2	59.9	24.6	0.09	6.45	0.11	7.44	0.60	99.1
40-45	2	57.7	26.8	0.16	8.95	0.17	6.47	0.35	100.6

Biotite

Mg/(Mg+Fe)	Analyses Averaged	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	BaO	Na_2O	K_2O	Total
0.56-0.58	2	35.9	5.30	14.0	17.4	12.9	0.10	2.33	0.52	8.46	96.9
0.58-0.60	3	36.3	4.96	13.6	16.9	13.5	0.00	1.07	0.48	8.78	95.6
0.60-0.62	3	37.7	4.61	12.9	16.2	14.2	0.00	0.83	0.49	8.74	95.7