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A SUMMARY INTERPRETATION OF GEOLOGIC, HYDROLOGIC, AND GEOPHYSICAL DATA FOR YUCCA VALLEY, NEVADA TEST SITE, NYE COUNTY, NEVADA

By

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*Prepared on behalf of the U. S. Atomic Energy Commission.

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A SUMMARY INTERPRETATION OF GEOLOGIC, HYDROLOGIC, AND GEOPHYSICAL DATA FOR YUCCA VALLEY, NEVADA TEST SITE, NYE COUNTY, NEVADA

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INTRODUCTION

Scope of report

This report summarizes an interpretation of the geology of Yucca Valley to depths of about 2,300 feet below the surface, the characteristic features of ground water in Yucca and Frenchman Valleys, and the seismic, gravity, and magnetic data for these valleys. Compilation of data, preparation of illustrations, and writing of the report were completed during the period December 26, 1958 to January 10, 1959. Some of the general conclusions must be considered as tentative until more data are available.

This work was done by the U. S. Geological Survey on behalf of Albuquerque Operations Office, U. S. Atomic Energy Commission.

Source and limitations of data

The attached annotated bibliography contains titles of reports, available to the public, which are concerned with the geologic, hydrologic, and geophysical features of Yucca and Frenchman Valleys. The principal reports are those by Johnson and Hibbard (1957) and Piper (1952).
R. F. Brown supplied valuable lithologic

details on well 7. The geology of Yucca Valley is adequately known in the Jangle area from shallow trenches and pits and 4 test holes (maximum depth of 502 feet) but elsewhere information has been obtained from 2 wells, 1,800 and 2,272 feet deep, respectively. Geophysical surveys in the Jangle area in 1952 and recent gravity and aeromagnetic surveys have outlined some of the general subsurface features in Yucca Valley. However, much more geophysical work coordinated with deep drilling is needed before the subsurface geology of Yucca Valley can be adequately defined.

Physical features

Yucca Valley is a broad north-trending intermontane valley in the northeastern part of the Nevada Test Site (fig. 1). It is about 20 miles long and 7 miles wide and has an area of approximately 135 square miles. Yucca Playa, with an area of approximately 6 square miles, in the southern end of the valley, has an altitude of 3,925 feet above sea level, whereas along the northern and higher parts of the valley the altitude is about 4,500 feet. The average slope within Yucca Valley is about 23 feet per mile to the south. Many parts of Yucca Valley are accessible from Mercury by paved roads; however, for travel beyond main roads, 4-wheel-drive vehicles are generally necessary.

GEOLOGY OF YUCCA VALLEY

General statement

The geology of Yucca Valley has been described by Johnson and Hibbard (1957) and by Piper (1952). The central part of the valley consists of unconsolidated detrital material that is locally as much as 1,530 feet thick. Underlying the valley fill are tuffaceous rocks that, on the basis of drill-hole data, are as much as 1,325 feet thick; the total thickness of tuffaceous rocks is unknown. The mountains that surround Yucca Valley consist of complexly faulted tuffs of the Oak Spring formation of Tertiary age underlain by several thousand feet of faulted and folded interbedded carbonate rocks, siliceous shale, and quartzites of Paleozoic age (fig. 1). In the northern part of the valley, a granite mass has intruded and altered the Paleozoic carbonate rocks. Yucca fault, a north-trending normal fault downthrown on the east side, divides Yucca Valley (fig. 1). Results of gravity surveys indicate a deep trough which roughly parallels the fault; in the southern part of Yucca Valley the gravity low is on the downthrown side but it lies west of the fault in vicinity of the Jangle area (fig. 2).

Stratigraphy of valley fill

According to Johnson and Hibbard (written communication, 1953) the valley fill is composed of interfingering and lenticular beds of unconsolidated detrital material transported from the surrounding mountains by intermittent streams. In shallow excavations in the Jangle area in the northern part of Yucca Valley, the valley fill is characterized by thin lenticular beds that are as much as 5 feet thick and are traceable along the strike for as much as 1,000 feet. The lithologic logs of 4 test holes (table 1) in the Jangle area (fig. 1) are incomplete; however, the individual beds, as shown by change in texture, range from 1 to about 50 feet in thickness. At depths below 500 feet the thickness of the individual beds is unknown.

The valley fill is composed of detrital material that ranges from clay and silt (less than 0.05 mm diameter) to cobbles (64 to 256 mm diameter) and boulders (256 mm to 1 meter diameter). Quantitative data on grain size distribution have been obtained from 60 samples collected in trenches and pits at depths of 5 to 35 feet below the surface in the Jangle area (fig. 1). According to Johnson and Hibbard (written communication, 1953) 50 percent of the material ranged in grain size from 0.009 to 0.39 inch and averaged 0.082 inch in diameter. The fragments that passed through a 100-mesh screen (openings of 0.0058 inch) constitute from 3 to 31 and averaged 13 percent by volume of the sample. The largest particles ranged from 1 to 12 inches in diameter. Information on textures of the valley fill at depth is limited to logs of 4 test holes in the Jangle area and from the logs of wells 3 and 7 (tables 2 and 3) (fig. 1). The test holes range from 177 to 502 feet in depth. Logs of these holes (Piper, 1952, p. 60-61) show that sand (0.05 to 2 mm) fragments

Table 1.--Lithologic logs of test holes 1, 2, 3, and 4, Jangle area, Yucca Valley, Nevada Test Site, Nye County, Nevada 1/

Test hole 1

Material	Thickness (feet)	Depth (feet)
Sand and gravel, silty, lightly cemented	22	22
Sand and gravel, lightly cemented	253	275
Boulders (limestone)	3	278
Gravel, lightly cemented	22	300
Sand and gravel, lightly cemented	35	335
Sand, silty, lightly cemented	5	340
Sand, loose	25	365
Boulders	4	369
Sand	1	370
Gravel, cemented, medium hard	35	405
Gravel, cemented	44	449
Sand, cemented	53	502

Test hole 2

Material	Thickness (feet)	Depth (feet)
"Surface"	2	2
Gravel and boulders, cemented	16	18
Gravel, cemented	97	115
Gravel and boulders, cemented	22	137
Boulders, cemented	40	177

Test hole 3

Material	Thickness (feet)	Depth (feet)
Sand and gravel (limestone)	20	20
Sand and gravel, lightly cemented (coarse zones at 35 and 55 feet; limestone to about 60 feet, rhyolite and tuff below)	65	85
Gravel, lightly cemented (rhyolite and tuff to about 200 feet, tuff from 200 to 325 feet, and limestone from 325 to 345 feet)	271	356
Sand and gravel, cemented (rhyolite and tuff to about 400 feet, tuff below)	89	445
Sand and gravel, cemented, soft (tuff)	57	502

Table 1.--Lithologic logs of test holes 1, 2, 3, and 4, Jangle area, Yucca Valley, Nevada Test Site, Nye County, Nevada--Continued

Test hole 4		
Material	Thickness (feet)	Depth (feet)
Sand and gravel (limestone; coarse zone at bottom)	76	76
Gravel, cemented (tuff)	52	128
Boulders (rhyolite?)	2	130
Sand and gravel (tuff)	5	135
Gravel, cemented (tuff)	25	160
Sand and gravel (tuff)	15	175
Sand and gravel, cemented (coarse zone at top; limestone)	35	210
Sand and gravel (tuff)	30	240
Gravel, cemented (coarse zone at 365 feet; largely limestone but considerable tuff at 275 and below 380 feet)	175	415
Sand and gravel, cemented (limestone and tuff)	50	465
Sand, cemented (tuff and limestone)	35	500

1/ Driller's logs taken from report by A. M. Piper, 1952. Geologist's identification of predominant rock types and other interpretations given in parentheses.

Table 2.--Log of well 3, Yucca Valley, Nevada Test Site, Nye County, Nevada

Material	Thickness (feet)	Depth (feet)
Brown silty sand with medium and fine gravel - - -	340	340
Coarse sand and fine gravel- - - - - - - - - - - - -	6	346
Brown silty sand with fine gravel- - - - - - - - - -	14	360
Brown fine gravel and sand with streaks of silty sand -	330	690
Brown fine gravel and sand - - - - - - - - - - - - -	70	760
Brown sand and fine gravel with streaks of silty sand -	240	1000
Volcanic and sedimentary rock fragments in the size range of cobbles, gravel and sand, all of which occur in a matrix of reddish-brown silt and/or clay- - - - - - - - - - - - - - - - - - - -	445	1445
Coarse volcanic gravel and sand in volcanically derived silt and clay, finer textured at 1450 to 1520 feet - - - - - - - - - - - - - - - - - - -	75	1520
Transition from valley fill to soft, faintly reddish-brown volcanic tuff- - - - - - - - - - - -	10	1530
Tuff, hard, faintly reddish-brown- - - - - - - - - -	45	1575
Tuff, soft, with streaks of sand - - - - - - - - - -	110	1685
Sandstone- -	80	1765
Conglomerate -	35	1800

Table 3.--Sample log of well 7, Yucca Valley, Nevada Test Site, Nye County, Nevada 1/

Material	Thickness (feet)	Depth (feet)
Sand, fine to coarse, with fine to coarse granules and clay. Gravel consists mostly of felsite, pumice, tuff; sand is rounded to subangular quartz and felsite.	10	10
Sand, fine to coarse, with fine to coarse granules, pebbles, and cobbles. Gravel consists mostly of felsite, pumice, tuff, and limestone; sand is rounded to subangular quartz and felsite.	10	20
Sand, fine to coarse, with fine to coarse granules, pebbles, cobbles, and boulders. Gravel consists mostly of felsite, pumice, tuff, basalt, and limestone; sand is rounded to subangular quartz and felsite.	10	30
Granules, fine to coarse, with fine to coarse sand, pebbles, cobbles, and boulders. Gravel consists mostly of felsite, pumice, tuff, basalt, and limestone; sand is rounded subangular quartz and felsite.	73	103
Boulders, with cobbles, pebbles, granules and sand. Particles in sample consist of quartz, felsite, basalt, pumice, tuff, limestone, predominantly angular; sand is rounded to subangular quartz and felsite.	22	125
Granules, fine to coarse, with fine to coarse sand, pebbles, and cobbles. Gravel is mostly felsite, pumice, tuff, basalt, and limestone; sand is angular to subrounded quartz and felsite.	30	155
Granules, fine to coarse, with fine to coarse sand, pebbles, cobbles, and boulders. Gravel is mostly felsite, pumice, tuff, basalt, and limestone; sand is subrounded quartz and felsite.	62	217
Boulders, with cobbles, pebbles, granules, and sand. Particles in sample consist of quartz, felsite, pumice, basalt, and limestone.	39	256

1/ Log from Brown, R. F., written communication, 1956.

Table 3.--Sample log of well 7, Yucca Valley, Nevada Test Site, Nye County, Nevada--Continued

Material	Thickness (feet)	Depth (feet)
Core sample number 1. Granules, fine to coarse, with fine to coarse sand, pebbles, cobbles, and sections of boulders. Formation is very compact, slightly cemented, yellow-brown in color. Consists of felsite, limestone, some pumice and basalt; gravel is subangular to subrounded, sand is subrounded quartz and felsite. Material is poorly sorted. Core recovery about 3 feet. - - -	20	276
Granules, fine to coarse, with fine to coarse sand, pebbles, cobbles, and boulders. Gravel is mostly felsite, pumice, tuff, basalt, and limestone; sand is subrounded quartz and felsite. - - - - -	52	328
Sand, fine, with some coarse, and fine to coarse granules, pebbles, and cobbles. Gravel is mostly felsite, tuff, and limestone; sand is subrounded quartz and felsite. - - - - - - - - - - - - - - - -	27	355
Boulders, felsite. - - - - - - - - - - - - - - - - - -	3	358
Sand, fine to coarse, with fine to coarse granules, pebbles, and cobbles. Gravel is mostly felsite, tuff, and limestone; sand is subrounded quartz and felsite. - - - - - - - - - - - - - - - - - -	2	360
Boulders, felsite. - - - - - - - - - - - - - - - - -	5	365
Granules, fine to coarse, fine to coarse sand, pebbles, cobbles, and boulders. Gravel is mostly felsite and limestone; sand is subrounded to subangular quartz and felsite. One thin streak of arenaceous blue clay penetrated at 378 feet. -	156	521
Sand, fine to coarse, with fine to coarse granules, pebbles, and cobbles. Gravel is mostly felsite, tuff, and limestone; sand is subrounded to subangular quartz and felsite. - - - - - - - - - - -	10	531
Granules, fine to coarse, fine to coarse sand, pebbles, cobbles, and boulders. Gravel is mostly felsite, limestone, and basalt; sand is subrounded to subangular quartz and felsite. - - - - - - - -	48	579

Table 3.--Sample log of well 7, Yucca Valley, Nevada Test Site, Nye County, Nevada--Continued

Material	Thickness (feet)	Depth (feet)
Granules, fine to coarse, fine to coarse sand, pebbles, cobbles, and boulders; cemented with $CaCO_3$. Gravel is mostly felsite, limestone, and basalt; sand is subrounded to subangular quartz and felsite. -	53	632
Sand, fine to coarse, with fine to coarse gravel, pebbles, and cobbles. Gravel is mostly felsite, tuff, and limestone; sand is subrounded to subangular quartz and felsite. - - - - - - - - - - - - - -	285	917
Clay, light tan to brown, soft, plastic, arenaceous. Consists of weathered tuff; contains numerous pieces of volcanic debris intermixed with sand and gravel. -	30	947 2/
Tuff, light tan, hard; contains mica, felsite, quartz and hornblende. - - - - - - - - - - - - - - - - - -	74	1021
Tuff, reddish-pink and gray, hard; contains mica, felsite, quartz and hornblende. - - - - - - - - - - - - -	2	1023
Core sample number 2. Tuff, reddish-pink and gray, mottled, predominantly reddish-pink; hard; contains mica, felsite, quartz, and hornblende, up to coarse granule dimensions; material is not saturated. Core recovery 20 feet. - - - - - - - - - - -	20	1043
Tuff, reddish-pink and gray; hard; contains mica, felsite, quartz, and hornblende. Lost circulation at 1,059 feet, regained after thickening drilling fluid. -	36	1079
Tuff, brown, very hard, arenaceous; contains quartz, mica, felsite, and hornblende. - - - - - - - - - - - - -	40	1119
Tuff, brown, hard; contains quartz, mica, felsite, and hornblende. -	20	1139
Tuff, black, clayey, slightly softer than above; contains mica, quartz, hornblende and felsite. - - - -	10	1149

2/ Electric log indicates alluvium-tuff contact is at depth of 975 feet.

Table 3.--Sample log of well 7, Yucca Valley, Nevada Test Site, Nye County, Nevada--Continued

Material	Thickness (feet)	Depth (feet)
Tuff, light tan, hard to very hard, arenaceous; contains quartz, mica, and hornblende. - - - - -	123	1272
Tuff, black to gray, hard, arenaceous; contains quartz, mica, hornblende, and felsite. - - - - -	11	1283
Tuff, light tan to light gray, arenaceous, but more clay fraction than above; contains quartz, mica, hornblende, and felsite. - - - - - - - - - -	10	1293
Tuff, reddish-pink, arenaceous, hard. - - - - - - -	12	1305
Tuff, yellow-brown, arenaceous, very hard. - - - -	111	1416
Tuff, reddish-pink to gray, mottled, arenaceous, very hard. -	153	1569
Tuff, brown, argillaceous, hard. - - - - - - - - - -	15	1584
Tuff, brown to dark tan, arenaceous, very hard.- -	5	1589
Tuff, pink-gray to brown, mottled, argillaceous, ranges from hard to soft. - - - - - - - - - - -	122	1711
Core sample number 3. Tuff, gray to gray-green, argillaceous, hard, compact, saturated. Contains grains of mica, quartz, hornblende, felsite, and basalt. Core recovery 20 feet. - - - - - - - -	20	1731
Tuff, gray to gray-green, argillaceous, hard, compact. Ranges from very hard to soft; contains grains of mica, quartz, hornblende, felsite, and basalt. -	253	1984
Core sample number 4. Tuff, gray to gray-green and reddish-pink, mottled, argillaceous, ranges from hard to very hard and brittle. Badly fractured, mud-filled fractures up to 1 inch in width found in core; walls of some fractures are brittle to very hard, and glassy. Reddish-pink felsite(?) adjacent to fractures, very hard, brittle, glassy; green-gray, hard, brittle, glassy metamorphosed tuff adjacent to fractures, firm to tough 2 inches away from fractures, soft in some places. Core drilled without circulation; circulation lost in fractures in tuff. Core recovery 15½ feet. -	16	2000

Table 3.--Sample log of well 7, Yucca Valley, Nevada Test Site, Nye County, Nevada--Continued

Material	Thickness (feet)	Depth (feet)
No sample, no circulation. - - - - - - - - - - - - - -	252	2252
Core sample, number 5. Tuff, gray to gray-green and reddish-pink, mottled, argillaceous, generally tough to very hard and brittle, slightly fractured, with mud filled fractures up to three-eighths inch in width. Reddish-pink felsite adjacent to reddish-pink material, ranges from soft to hard elsewhere. Core drilled without circulation; all circulation lost in fractures. Core recovery 20 feet. - - - -	20	2272
Total depth -		2272

comprise 22 to 47 percent; gravel (2 to 256 mm) 51 to 76 percent and boulders (>256 mm) 1 to 3 percent of the valley fill. On the basis of these lithologic logs there is no apparent progressive change in texture of the fill with depth. The variability of the texture of the valley fill to a depth of 500 feet is well shown in the detailed logs of the 4 test holes. In general, the individual lithologies are not traceable between the test holes, which are a minimum of about 2,100 feet apart. In the wells (3 and 7) that penetrated the alluvium, the distribution of sand, gravel, and boulders is about the same as near the surface.

Silt and clay are the dominant components of Yucca Playa, the lowest part in the present Yucca Valley. Thickness of the Playa sediments is unknown but in the Frenchman Playa to the south (fig. 1) they are at least 175 feet thick (Johnson and Hibbard, written communication, 1953). Studies of seismic velocities made in Frenchman Playa indicate velocities of about 2,600 feet per second. From these data it is inferred that velocities in Yucca Playa are similar.

Composition of the valley fill has been determined from pebble counts made on the surface and from lithologic logs of the 4 test holes and the 2 wells. Pebble counts made by Johnson and Hibbard (written communication, 1953) in several parts of Yucca Valley have shown that there is a direct relation between the dominant lithic fragment in the valley fill and the bordering bedrock. Thus the fill of Yucca Valley is inferred to contain tuff, limestone, dolomite, and quartzite detritus along the western and eastern sides; granite fragments in the northern part;

and to consist mainly of tuff in the northeastern part. On the basis of lithologic logs of the test holes in the Jangle area (fig. 1) the valley fill is predominantly fragments of limestone and tuff; the absence of quartzite fragments is noteworthy in the fill in the Jangle area and indicates most of the lithic fragments were derived from the rocks exposed to the east of this area. The logs of wells 3 and 7 show that tuff, limestone, quartz, basalt, and felsite are the common fragments in the valley fill in the central part of Yucca Valley.

Calcium carbonate cement(caliche)is common in the fill exposed in trenches and pits in the northern part of Yucca Valley. According to Piper (1952, p. 18) caliche occurs as discontinuous and irregular beds as much as 2 feet thick; individual beds are traceable along strike for as much as 900 feet. More commonly the caliche occurs as thin veinlets and irregular masses scattered throughout the valley fill. As is indicated from stratigraphic sections measured in the surface cuts, caliche constitutes as much as 15 percent by volume of valley fill to a depth of 35 feet; however, this value should not be considered to be characteristic of the total valley fill. Lithologic logs (Piper, 1952, p. 60-61) of the 4 test holes in Jangle area indicate that the valley fill is "lightly to medium-hard" cemented to depths of 502 feet; the coarse-grained valley fill is better cemented than the silts and sands. However, the available logs of the test holes are not sufficiently accurate to define degree of cementation and thickness of the cemented beds. Seismic exploration in the test holes has defined a high-velocity layer, presumably due to calcium carbonate cement, at depths of 20 to 70 feet below the surface, and possibly another such layer at a depth of 465 feet in test hole 3 (Piper, 1952, p. 20). Information on cementation of valley fill below 500 feet throughout Yucca Valley is obtained from lithologic logs of wells 3 and 7 (tables 2 and 3). The only cemented fill was penetrated in well 7 between 579 and 632 feet below the surface.

Quantitative data on physical properties of the valley fill are limited to results of density measurements on 21 samples obtained at depths of 0.5 to 16 feet in trenches and pits in the Jangle area. Density of the samples was determined in the field and ranged from 1.30 to 1.81, averaging 1.46 for 7 samples between 0.5 and 2 feet below the surface; between 2 and 16 feet, the average density is 1.65 (Piper, 1952, p. 17). The caliche has density of 2.00 to 2.05 or about 25 percent greater than the uncemented valley fill (Piper, 1952).

Results of vertical wave velocity surveys made by United Geophysical Co., Inc., in the test holes are given in table 4. The velocities range from 1,430 to 13,350 feet per second, indicating a wide range in chemical and physical characteristics of the valley fill to a depth of 500 feet. The high velocities are probably due to caliche layers. The average velocity increases from 2,690 feet per second in the first 15 feet of fill to 5,220 feet per second at 460 feet below the surface. The higher velocities at depth are believed to indicate more compact

Table 4.--Vertical wave velocities in valley fill at test holes 1, 2, 3, and 4, Jangle area, Yucca Valley, Nye County, Nevada 1/

Depth (feet)	Velocity (feet per second) Mean 2/	Minimum	Maximum
0 - 15	2,690	1,430	3,030
15 - 40	3,050	1,630	3,380
40 - 100	3,240	1,960	12,500
100 - 150	4,000	2,750	5,820
150 - 300	4,300	3,790	5,560
300 - 350	4,710	4,170	8,060
350 - 460	5,220	3,590	8,060
460 - 500		4,500	13,350

1/ Data from Piper, 1952, p. 21.

2/ Mean values are for zones between the successive depths at which there is an appreciable change in velocity in one or more of the four holes.

and dense rocks than near the surface. Consequently the average density of 1.65 for valley fill near the surface probably represents a minimum value for the density of the valley fill. Data are insufficient to approximate the density of the valley fill at depth.

Thickness of valley fill

Thickness of the fill in Yucca Valley is known accurately at two localities, wells 3 and 7 (fig. 1). Some qualitative data have been obtained from the 4 test holes and seismic surveys in the Jangle area (fig. 1). The lithologic logs of wells 3 and 7 indicate that tuff was penetrated at depths of 1,530 and 947 feet, respectively, below the surface (tables 2 and 3). Well 3 is about 5 miles south of well 7 and on the upthrown side of Yucca Fault. The greater thickness of valley fill at well 3 and results of gravity surveys (fig. 2) suggest the presence of other faults in this area. In the Jangle area, the deepest test hole reached 502 feet below the surface and did not extend through the fill. According to Piper (1952, p. 19) the seismic refraction survey in the Jangle area indicates that the valley fill is 800 to 1,000 feet thick, thins eastward to a few feet at the edge of the valley floor; near test hole 3, the fill thins abruptly to about 600 feet over the crest of a buried bedrock "high." The fill apparently forms a thin layer not more than several feet thick along the valley margins, but toward the central part the fill is as much as 1,530 feet thick.

However, as shown by seismic work in the Jangle area, considerable differences in thickness were found over short horizontal distances, and to ascertain accurately the thickness of the valley fill seismic surveys accompanied by drilling would be required.

Several holes about 1 mile southeast of well 7 were drilled in 1958 to a maximum depth of 550 feet; the holes were entirely in valley fill.

Rocks beneath valley fill

The valley fill is underlain in the vicinity of wells 3 and 7 (fig. 1) by tuffaceous rocks that are as much as 270 feet thick in well 3 and 1,325 feet thick in well 7 (tables 2 and 3).

In vicinity of Rainier Mesa the contact between the tuff and valley fill, where exposed, has local relief of at least 100 feet. Presumably this buried surface exhibits comparable relief in Yucca Valley. Deep drilling would be required to verify the position of this surface in critical areas.

The tuffaceous rocks that underlie the valley fill have not been penetrated completely by drill holes and their thicknesses can only be approximated. In the vicinity of well 7 the contact between the lighter rocks, including valley fill and tuffaceous rocks, and the underlying dense rocks, presumably carbonates and quartzites of Paleozoic age, has been inferred from gravity surveys. Near well 7 this contact is estimated to be at a depth of at least 3,000 feet. This depth indicates that the tuffaceous rocks are nearly 2,000 feet thick, which is comparable to the thickness of the Oak Spring formation on Rainier Mesa. The variation in thickness of the tuffaceous rocks throughout other parts of Yucca Valley is unknown.

The contact between fill and tuffs is characterized by a gradation zone as much as 30 feet thick that contains intermixed detrital materials and weathered tuff fragments. Beneath this zone the tuffs are similar in composition and textural features to the tuffaceous rocks that comprise the Oak Spring formation. In general the tuffs are tan, reddish, brown, gray, and gray-green, and are predominantly hard, though some layers of tuff are rich in clay and are soft. Where coring was undertaken in well 7, the tuffs were compacted, fractured, and core recovery was good. Quartz, mica, hornblende, and felsite and basalt fragments are the principal constituents identified in the tuffs. Predominantly the tuffs are fine to coarse grained although conglomeratic layers as much as 35 feet thick were recorded in well 3.

Structure

Yucca Fault is the major structural feature of Yucca Valley. It is a north-trending normal fault that dips steeply eastward and has been traced along the strike from Yucca Pass northward for 20 miles (fig. 1). Vertical displacement along the fault at Yucca Pass is estimated to be about 1,000 feet (Johnson and Hibbard, 1957, p. 376). Recent movement on the fault is indicated in the northern part of Yucca Valley where unconsolidated fill on the east is faulted against consolidated fanglomerate on the west. A fault scarp in this area indicates a vertical displacement of at least 75 feet. Elsewhere in Yucca Valley structural features are unknown but on the basis of gravity and magnetic surveys the rocks which form the basement of Yucca Valley are believed to be structurally complex.

PRELIMINARY RESULTS OF THE GRAVITY SURVEY OF YUCCA AND FRENCHMAN VALLEYS, NEVADA

Purpose

The purpose of the gravity survey of the Nevada Test Site was to define some of the Cenozoic structural features of the basin areas. This information has two uses: 1) a knowledge of the bedrock configuration would be very useful in the study of the ground-water movement, and 2) the gravity data can also help define buried geologic structures that are important to the current geologic mapping program at the Nevada Test Site.

The average density of the tuff of the Oak Spring formation of Tertiary age is similar to the average density of the alluvial fan and playa deposits (valley fill) of Quaternary age. Therefore, in this section of the report which deals with the gravity survey, the Tertiary and Quaternary rocks are considered as one Cenozoic unit, and depth to bedrock means depth to the Paleozoic formations which are assumed to underlie the tuffaceous rocks in this area.

Field methods and reduction of data

The gravity survey of the Nevada Test Site is referred to the National Base control net, the actual tie being made at McCarran Field in Las Vegas, Nevada (Woollard, G. P., 1958).

The gravity stations on the Test Site, to date, have been established either at U. S. Coast and Geodetic Survey benchmarks or at points located by survey parties from Holmes and Narver, Inc. All the stations are considered to have a vertical accuracy of within one foot.

The standard corrections for free-air, Bouguer, latitude, and instrument drift have been applied to the data. The data were reduced to sea level using a combined free-air and Bouguer correction factor of 0.06 milligal/foot. The 0.06 milligal/foot factor is probably low and the anomalies as presented should be considered as minimum values. Terrain corrections to remove the effect of the rugged topography that surrounds Yucca and Frenchman Valleys have not been made in this preliminary report. This correction is less than 0.5 milligal in the center of the valleys but is 1 to 4 milligals near the mountains. In areas of high relief, such as the Rainier Mesa area, the terrain corrections may be as high as 9 milligals. Because most of the terrain corrections occur over the mountainous areas, the gravity data for the stations in and adjacent to the mountains are low by approximately 1 to 4 milligals. The terrain corrections would not alter the contouring appreciably but would increase the magnitude of the anomalies over the mountainous areas.

The U. S. Geological Survey is still in the process of accumulating gravity data in the area covered by this preliminary report. It is planned to complete the now sparse horizontal and vertical control by plane-table surveying to locate sites for additional gravity stations.

Three different gravity meters, having scale constants of 0.0871, 0.2672, and 0.5391 milligals per scale division, have been used in the gravity survey. The meters have been cross-checked against one another on a calibration loop and also by repeat readings on given stations. Agreement between the three meters has been found to be within 0.2 milligals on repeat readings of field stations.

Interpretation

In the Basin and Range Province, gravity lows are associated with the Cenozoic materials that fill the basin areas. This condition is true at the Nevada Test Site and the valleys are defined by gravity lows. In Yucca and Frenchman Valleys, valley fill overlies tuffaceous rocks of the Tertiary Oak Spring formation. Because the average density of rocks of the Oak Spring formation is similar to the average density of the alluvium, both are treated as valley fill in gravity computations.

The gravity data obtained to date in the vicinity of Yucca and Frenchman Valleys are sufficient to delineate only the major structural features; the definition of all the small anomalous areas would require more gravity stations.

The gravity data are superimposed on the geologic map of Johnson and Hibbard (1957). The Bouguer gravity map of Yucca and Frenchman Valleys (fig. 2) shows an overall north-northwest trend to the regional gravity.

Perhaps the most significant anomaly in Yucca and Frenchman Valleys is the gravity low which apparently extends from Frenchman Playa north through Yucca Valley to the junction of Butte and Yucca

Faults where the low swings to the northeast and continues into Groom Lake (Emigrant Valley). Between Frenchman and Yucca Valleys the gravity data are not sufficient for drawing accurate contours. However, the data from stations along the west side of the low indicate at least the -155 and possibly the -165 milligal contour continues across the full distance separating the basins. On the east side of this low the data suggest that the -160 and possibly the -165 milligal contour persists the full length of the low. A gravity saddle of undetermined magnitude may occur at some intermediate point between these two basins. Additional gravity stations are required in this area to solve this problem.

If the continuity of this gravity low proves to be real and Frenchman, Yucca and Emigrant Valleys all lie in the same structural trough, this information will be very important, especially in the interpretation of ground-water movement.

Across the southern part of Yucca Valley the gravity low parallels roughly the trace of the Yucca Fault. At the north end of the valley the low crosses the Yucca Fault and delineates a widened area of the valley. This widened area appears to be formed by a down-dropped block bounded by the southwestward extension of Butte Fault and perhaps by the fault which lies between the Butte and Yucca Faults. These data imply an extension of the Butte Fault west to the vicinity of the Eleana Range, where it probably intersects the Quartzite Mountain anticline. The subsidiary fault appears to extend into Yucca Valley at least several miles beyond the last exposed evidence.

The Mine Mountains and Syncline Ridge are expresssed as part of a large, northwest-trending gravity high which swings north over the Eleana Range and to the northeast over Quartzite Mountain.

At an intermediate position between Syncline Ridge and Yucca Fault is a gravity-high nose which roughly parallels Yucca Flat and continues into the central part of Yucca Valley. This nose is important for interpreting the structure of Yucca Valley because it probably represents a fault block which extends northward from the Paleozoic rocks exposed just west of Yucca Pass.

It is not possible to compute an accurate depth to bedrock in Yucca Valley because a depth-control point is not available with which to refer the gravity data. It is possible, however, to give an estimate of the minimum depths by using the formula for a semi-infinite slab. In an elongate basin such as Yucca Valley the end effects can be safely ignored. True depths are always greater than those found by using the semi-infinite slab formula, provided the density assumptions are correct.

A profile extending from north and west of Syncline Ridge to a point directly north of well 7 exhibits a gravity relief of 25 milligals and a vertical relief of about 940 feet. Assuming a density contrast of 0.5 gm/cm^3 between the Paleozoic bedrock and the Cenozoic tuff and valley fill, the indicated depth to bedrock at a point directly north of well 7 is at least 3,000 feet. Well 7 bottomed at 2,272 feet and was still in tuff of the Oak Spring formation. If the density contrast between the Paleozoic bedrock and the valley fill (including the tuff) is more than 0.5 gm/cm^3, the minimum depth will be less than indicated and, conversely, if it is less, the depths could be considerably greater. The factor of 0.5 gm/cm^3 is thought to be approximately correct for the density contrast between these media. However, as previously mentioned, this interpretation is conservative and the depth of 3,000 feet in Yucca Valley is probably too shallow by 50 percent or more.

A line of gravity stations up Nye Canyon (north of Frenchman Valley) shows a gravity relief of 26 milligals over a horizontal distance of 4 miles, and a difference in elevation of about 400 feet. These data, assuming a density contrast of 0.5 gm/cm^3, indicate that in Frenchman Valley bedrock is at least 3,600 feet below the surface at a point 3 miles north of the center of the playa. The gravity data show that the deeper part of the Frenchman Valley is about 2 miles north of the north edge of the present playa surface.

Here again the depth estimate is probably low by 50 percent or more; changing the assumed density contrast from 0.5 to 0.4 gm/cm^3 adds 1,000 feet to the indicated minimum depth of the basin.

Conclusions

This preliminary inspection of the gravity data, even though the reduction is not complete and the coverage is not sufficient to reach definite conclusions concerning the causes of anomalies, does point out several important features about the structural geology of the Nevada Test Site.

Frenchman Valley, Yucca Valley, and Groom Lake (Emigrant Valley) appear to lie along the same structural trough, although the magnitude of the gravity low connecting Yucca and Frenchman Valleys is not known at this time.

Yucca Valley is a narrow trough which widens at the north end. This basin appears to be caused by down-dropped blocks bounded by the Butte Fault and the fault to the east, and also by the termination of an inferred bedrock ledge that extends into the valley from the south.

Rough estimates of the depth to Paleozoic bedrock in the valleys give minimum depths of 3,000 in Yucca Valley and 3,600 in Frenchman Valley. These values must be considered as minimum because (1) terrain corrections have not been applied to the data, and this would add an average of 1 to 4 milligals to the magnitude of the anomalies; (2) the assumed density contrast of 0.5 gm/cm^3 between the Paleozoic formations and the Cenozoic tuffs and alluvial material may be high; (3) the thickness of a semi-infinite slab is always less than the equivalent depth of a structure of finite width.

An estimation of depth to the contact between the Quaternary alluvial valley fill and the Tertiary Oak Spring formation is not feasible because of the close similarity in densities of the two materials (Diment, 1958; Pakiser, L. C., personal communication).

PRELIMINARY RESULTS OF AEROMAGNETIC SURVEY OF PART OF YUCCA VALLEY

Introduction

An aeromagnetic survey of part of Yucca Valley was flown in 1952. The traverses were flown in an approximate east-west direction, 500 feet above the ground, with approximately 1/4-mile flight separation. The surveyed area is bounded approximately by latitudes 37°03' N and 37°07' N and by longitudes 115°57' W and 116°05' W. The area of this survey is somewhat smaller than that of the gravity survey but the data are more detailed.

In the western United States, particularly in the Basin and Range province in Nevada and California, aeromagnetic data serve to complement gravity information in determining the depth and areal distribution of subsurface volcanic rocks.

Description and interpretation of magnetic anomalies

The aeromagnetic data and generalized geology are shown in figure 3.

In the eastern part of the area small anomalies are located over tuff of the Oak Spring formation. To the west, approximately 2 miles east of Yucca Fault, a belt of positive and negative anomalies occurs. These anomalies are probably caused by lava flows buried at a shallow depth in a belt 1 mile wide paralleling the general northward geologic trend of the exposed bedrock.

The most significant anomaly on the map is a magnetic low elongated for several miles in a north-south direction, having a maximum amplitude of 200 gammas. This feature shows excellent correlation with the Yucca Fault which lies approximately along the line of maximum magnetic gradient on the east side of the anomaly. Immediately to the east of the fault is a series of positive anomalies which are probably associated with this elongated low. The west side of the low exhibits a gradient which is less steep than that on the east side. Here the line of maximum magnetic gradient correlates well with the eastern edge of the fault block extending northward from Yucca Pass (fig. 2) inferred from the gravity data.

This anomaly may be caused by a thin lava flow approximately 1/2 mile wide, bounded by the Yucca Fault on the east and by the edge of this fault block on the west. Interpretation of the magnetic data suggests that the flow is buried by only a few hundred feet of overlying alluvium on the Yucca Fault side and is deeper to the west.

It must be admitted that the general pattern of this linear anomaly is different from that of the flows farther east where the anomalies are much more irregularly distributed and display positive as well as negative amplitudes. Because of the linear magnetic trends of the anomaly, an intrusion into the buried Paleozoic rocks seems possible. Depth estimates based on the magnetic data near the Yucca Fault would place the mass causing the anomaly at probably no more than 500 feet below the surface. This postulated intrusion at such a shallow depth would produce a gravity anomaly of several milligals. Although the gravity data are sparse, nevertheless a gravity anomaly of several milligals probably would have some manifestation in the gravity contour map. To test this hypothesis, a detailed gravity survey in the area of this magnetic anomaly is highly desirable. If this hypothesis of intrusion is later verified, it would aid considerably in the understanding of the movement of ground water in Yucca Valley.

Because of the very useful information obtained from the aeromagnetic coverage of this small area, additional useful information could be obtained by extending the survey both to the north and south.

GROUND WATER

Occurrence beneath Yucca Valley

Basic information on ground water beneath Yucca Valley is limited to that obtainable from two wells, the locations of which are shown on figure 1. Other data on the two wells are given in tables 2, 3, and 5.

Well 3, which is in the southwestern part of the valley, was drilled originally to 1,575 feet and later deepened to 1,800 feet. A precise measurement of the depth to water is not available. The depth to water was reported originally as 1,530 feet; in 1952 it was reported as 1,545 feet; an airline measurement on December 2, 1958, indicates a depth to water of 1,575 feet. It is assumed that the 1,530-foot and 1,545 foot depths are airline measurements also, but the original depth may have been measured with cable on a drill rig. The three measurements suggest the possibility that the water table may be declining because of pumping, but the total pumpage from well 3 has been small and the possibility seem slight. However, the influence of prolonged pumping during September, October, and November is reflected in the December 1958 measurement because measurements on November 28, 29, 30, and December 1 indicate a steady rise. After a period of decreased pumping, the water level probably would recover further.

The non-pumping water level in well 3 is in the Oak Spring formation, near the contact with the overlying alluvial fill.

Although there may be perched water within the alluvial fill, none was reported in the driller's log of the well, and inasmuch as the hole was drilled with a cable-tool rig, it can be concluded safely that the alluvium does not contain perched water at this locality.

Table 5.--Data on wells in Yucca Valley, Nevada Test Site, Nye County, Nevada.

	Well 3	Well 7
Location (Nevada State Grid Central Zone)	N. 817794.96 E. 677761.73	N. 843100) Approx. E. 684700)
Altitude of land surface (ft)	3,967	4,063
Driller	S. R. McKinney and Son	Frontier Drilling Co.
Drilling date	11/15/50 to 2/10/51 Deepened 1952	4/18/54 to 6/27/54
Total depth (ft)	1,800	2,272
Casing record	12-inch 0-20 ft 10-inch 0-257 8-inch 0-1,209 6-inch 1,209-1,765	16-inch 0-40 ft 12-inch 0-2,017 9-inch 2,017-2,272
Perforations (ft)	1,535-1,765 slots	1,710-1,720 gun 1,900-2,272 slots
Depth to water (ft)	1,530-1,545	1,662.2 (Sept. 9, 1958)
Pump	38.5-hp Reda submersible at 1,726 ft	None
Discharge (max)	40 gpm	---
Drawdown	45.5 ft after pumping 22 hours at 30 gpm	

The altitude of the water level in well 3 is 2,437 feet if the depth to water is 1,530 feet, or 2,422 feet if the depth to water is 1,545 feet.

The depth to water in well 7 was 1,662 feet below land surface in September, 1958 (altitude 2,401 feet). This depth has been measured with an electric sounding line and was confirmed by successive measurements, and did not change measureably after the injection of 1,478 gallons of water.

The contact between the Oak Spring formation and the alluvial fill is 947 feet below the land surface in well 7, thus, the Oak Spring is the principal water-bearing formation. Inasmuch as this well was drilled with a hydraulic rotary rig, it cannot be proved that there is no perched water higher in the deposits penetrated, but this possibility seems unlikely.

It is impossible to determine the water-table gradient beneath Yucca Valley with data from only two wells. The fact that the altitude of the water surface in the wells differs by only 36 feet at the most, and probably by only 21 feet, suggests that the water-table gradient is very gentle assuming that there is hydraulic interconnection between the two wells. By inference, and by analogy with conditions in the Rainier Mesa, it is assumed that the water moves predominantly through secondary openings in the tuffaceous rock of the Oak Spring formation. Thus, hydraulic interconnection is to be suspected even though the logs of the wells cannot be correlated and a hydraulic connection cannot be demonstrated. The 2 wells are approximately 5 miles apart, indicating a component of the natural water-table gradient of less than 7 feet per mile toward the north-northeast. If the depth to water is 1,545 feet in well 3 (the mean of three reported depths) the component of gradient is about 4 feet per mile. The possibility that local artesian conditions may be present at either of the two wells cannot be ignored, particularly in view of the lithology and inferred structure of the tuff of the Oak Spring formation; therefore the difference in altitude may not be a true indication of the direction of flow.

The altitudes of water levels reported in wells in Frenchman Valley range from 2,386 to 2,409 feet. Because of mechanical difficulties it has been possible to measure the depth to water only in well 5A (fig. 1) in recent months. This measurement indicates an altitude of the water table of 2,390 feet. R. F. Brown (personal communication, 1955) made measurements in well 5C in April 1954 which indicated a water-table altitude of 2,388 feet. These two measurements appear to be the most accurate ones available for the wells in Frenchman Valley.

The foregoing indicates that the difference in altitude of the water table beneath the two valleys is a maximum of about 50 feet, but it is possible that the difference is only about 35 feet. Water levels in 2 wells in Jackass Flats, 18 and 24 miles west of the Frenchman Valley well field, stand at altitudes of 2,407 and 2,389 feet, respectively.

The meager data available indicates that the water table has unusually low gradients. Such gradients could result from low recharge, high permeability, or both. Because of the low annual precipitation, recharge undoubtedly is very low. Limited data from pumping tests indicate that the aquifer is of low to moderate permeability.

Figure 1 shows lines of equal depth to the main zone of saturation beneath Yucca Valley. These lines have been constructed by assuming a flat water table at an altitude of 2,400 feet and neglecting the possible existence of perched water. Thus, the lines are generalized and are subject to error because of the fact that the water table is not absolutely flat. Probably the water table is higher along the western and northern margins of the valley than elsewhere, because the mountains bordering the valley on the west and north are higher than the hills to the east and south and receive more recharge owing to greater precipitation. In the central part of the valley the possibility of perched water is unlikely, but near the valley margins water may occur at various depths, either in the alluvial fill or in the tuff of the Oak Spring formation.

Aquifer characteristics

The hydrologic characteristics of the tuff buried beneath Yucca Valley are inferred by analogy with those of the tuff in Rainier Mesa as observed in tunneling operations, from laboratory measurements of permeability, (the capacity of a rock to transmit a fluid), and from drilling and pumping-test data available for wells 3 and 7.

Ground water observed draining from units Tos_{2}, 3, 4, 5, and the basal part of unit Tos_{7} of the Oak Spring formation (Hansen and Lemke, 1957) in the U12b and U12e tunnels in Rainier Mesa emerge predominantly from joints, fractures, and faults in the tuff (Clebsch, A., and Winograd, I. J., written communication, 1958). Additional evidence of the movement of water through fractures in the tuff is indicated by the difficulty in maintaining mud circulation during the drilling of holes into the tuff underlying Rainier Mesa and well 7. On the Mesa, unit Tos_{8} was especially difficult to drill for this reason. According to excerpts from the daily drilling records of well 7, drilling mud containing more than 300,000 gallons of water was lost in the course of drilling from 1,042 feet to 2,272, the total depth. More than 80,000 gallons of fluid was lost in drilling from 2,060 to 2,250 feet, even though the hole was cased from

from the surface to 2,012 feet. This suggests that the aquifer is relatively permeable.

The average permeability to brine, of various subunits of the Oak Spring formation from the vicinity of Rainier Mesa, is extremely low (Diment and others, 1959, p. 3-7), ranging from 0.23 to 0.0004 gpd per sq ft (gallons per day per square foot). Fifty-two samples were analyzed.

The laboratory measurements of permeability and loss of drilling fluid would appear inconsistent except that some parts of the Oak Spring are highly fractured. Fractures were observed at many places in the tunnels in Rainier Mesa and are presumed to be characteristic of the tuff beneath Yucca Valley.

Typically, the transmissibility (permeability times thickness, in feet) of aquifers that yield water predominantly from fractures varies from place to place just as the intensity, spacing, and width of the fractures vary from place to place, accordingly, the transmissibility of the tuffs beneath Yucca Valley can be expected to vary within a wide range of values. No quantitative date are available on the transmissibility of the tuff in the vicinity of well 7. Furthermore,aquifer tests of well 7 probably would not give representative results because the large quantities of drilling mud lost in the hole, and the material pumped into the hole in attempts to regain the mud circulation, would have the effect of reducing the transmissibility by plugging the openings that could yield water to the well.

Data obtained during a short pumping test of well 3 in December 1958 provide the only basis for an estimate of the transmissibility of the aquifer, although the test was too short to obtain a reliable figure and methods of measurement did not provide the desired accuracy. Figure 4 and 5

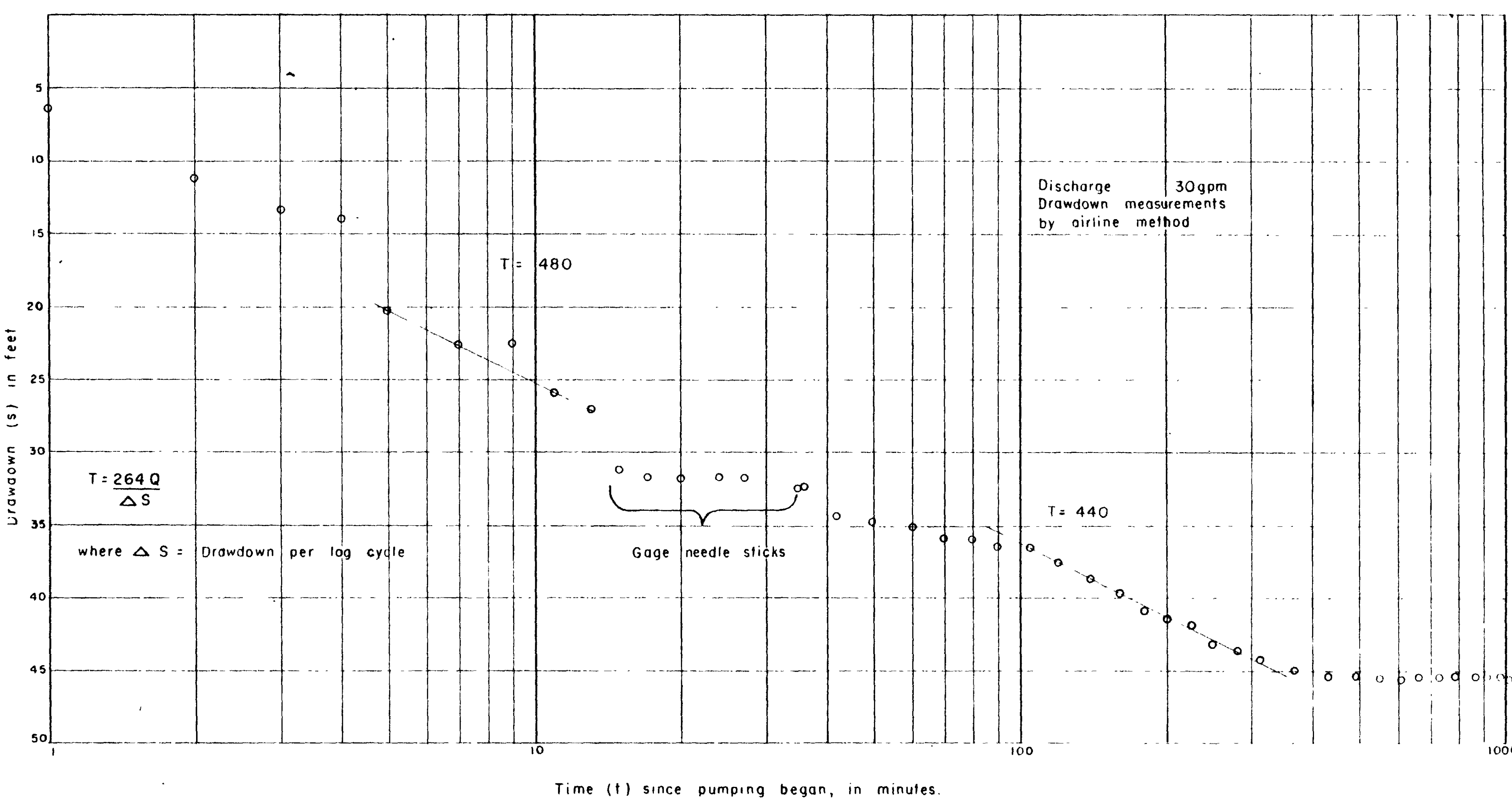

FIGURE 4 — DRAWDOWN DURING PUMPING OF WELL 3

(December 1 and 2, 1958)

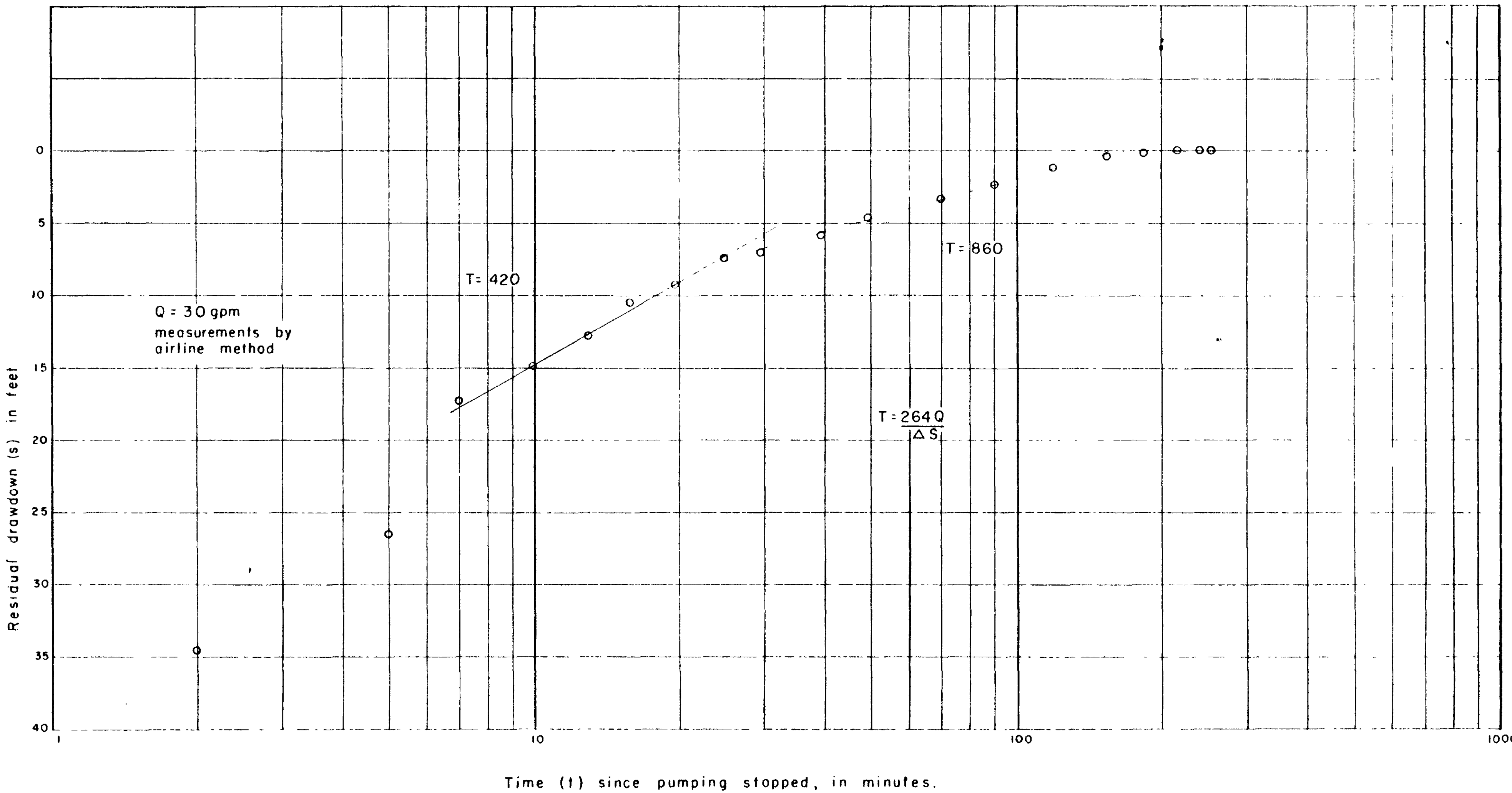

FIGURE 5 —RECOVERY OF WATER LEVEL AFTER PUMPING WELL 3 FOR 22 HOURS

(December 2, 1958)

present the results of this test. The well was pumped at a constant rate of 30 gpm for a period of 22 hours. Airline measurements of the drawdown were made periodically. After pumping was stopped, periodic measurements of water level were made during a 4-hour recovery period.

Measurements during the first few minutes of pumping are inacurate because of the time necessary for the airline gage to stabilize. Using techniques suggested by Ferris (1960) the data plot between t=105 minutes and t=310 minutes, an apparent coefficient of transmissibility of 440 gpd per ft (gallons per day per foot) was computed. It is emphasized that this is only a rough approximation. A longer test would be necessary for a better estimate of the transmissibility.

The recovery curve (fig. 5) shows two fairly well-defined straight-line segments which indicate apparent coefficients of transmissibility of 430 and 880 gpd per ft.

Whereas the Oak Spring formation is the water-bearing unit in both wells in Yucca Valley, the valley fill may be thick enough in parts of the valley to extend down into the zone of saturation. Well 3 penetrated more than 1,500 feet of valley fill. It seems likely that the fill is even thicker than this elsewhere in the southern part of the basin. If this is true, aquifer characteristics of the valley fill would differ from those of the tuff. The valley fill would probably have the characteristics of saturated granular material. The principal difference in these characteristics is the ability of granular material to hold more water in storage. A pumping test conducted by R. F. Brown (written communication, 1955) on well 5C in Frenchman Flat indicates that the coefficient of transmissibility of the alluvium in that area may be between about 700 and 3,400 gpd per ft, depending upon the interpretation of the data.

No data are available on which to base an estimate of the specific yield (the ratio of the volume of water which, after saturation, a rock will yield by gravity to its own volume) or coefficient of storage. The volume of the tuff that is occupied by open fractures in the Rainier Mesa area is extremely small--probably less than a tenth of a per cent and certainly not more than a few per cent. The tuff in the subsurface of Yucca Valley is inferred to be similar in this respect. Where the lower part of the valley fill is saturated, the specific yield of this material probably would be substantially higher. Because of the intergranular space is filled with cement, it may be appreciably less than that of the average valley-fill aquifer.

Possibility of hydraulic continuity between Yucca and Frenchman Valleys

The close agreement in altitude of the water table beneath Yucca Valley, as indicated by the water levels in 2 wells, and that beneath Frenchman Flat, as indicated by data from 4 wells, could be due to chance, or more likely to a hydrologic connection between the 2 basins. That such a connection may exist is inferred in part from an interpretation of gravity data; namely--that the range of hills separating the basins does not contain a "core" of dense, relatively impermeable Paleozoic rocks (see fig. 2). The drainage basin of Frenchman Valley occupies about 450 square miles. Yucca Valley receives surface drainage from about 300 square miles. However, about 22 square miles of the Yucca Valley drainage basin is above 6,000 feet and thus receives greater precipitation and has a more persistent snow cover in winter than the Frenchman Valley drainage basin, only 5 or 6 square miles of which is higher than 6,000 feet.

Thus, one might expect a higher water table in Yucca Valley than in Frenchman Valley because of the inferred higher recharge.

Ground-water conditions in other nearby basins may have a bearing on this question, inasmuch as the water table in these valleys stand much higher than in Yucca and Frenchman Valleys. Water levels in wells in Emigrant Valley indicate that the water table beneath that valley is 900 feet or more higher than the water table in Yucca Valley. In Kawich Valley, northwest of Yucca Valley, a reported depth to water indicates that the water table beneath that valley is more than 2,000 feet higher than that beneath Yucca Valley.

On the basis of the available evidence, it is inferred that the ground water beneath Yucca and Frenchman Valleys is in hydraulic continuity.

Additional arguments can be advanced along the lines, that if Yucca Valley were a tight, closed basin it would be saturated to an overflow level at its low point. The fact that the water table is 1,550 feet or more deep suggests that water is leaving the basin although not necessarily to Frenchman Valley.

Direction and rate of movement

The area of natural recharge for Yucca and Frenchman Valleys is inferred to be the highlands that form the northern and western border of Yucca Valley; the southern part of the Belted Range, the Eleana Range, and Shoshone Mountain. The area of natural discharge is unknown. Water-level data suggest movement toward the east, but beyond the confines of Yuccs and Frenchman Valleys this seems unlikely in view of the higher water levels in Indian Spring Valley (southeast of Frenchman Valley), at least near its southern end, in the northwestern end of Las Vegas Valley, and in Emigrant Valley. More work will be necessary to define the direction of movement. It is possible that some of the Paleozoic rocks, particularly limestones, transmit some water. If this is true, the direction of movement might be to the southwest into the Amargosa Desert--Ash Meadows--Fortymile Canyon area, and water levels in these areas are consistent with this hypothesis.

The gentle water-table gradients and low to moderate permeability of the water-bearing materials suggest that the ground water moves very slowly. Where fracture systems are open and well connected, the velocity might be several times the average. However, data are not available on which to base a quantitative estimate.

Radioactivity of ground water

The radioactivity of water from wells 3 and 7 in Yucca Valley, and from wells 5A, 5B, and 5C in Frenchman Flat between April 1957 and March 1958 is given in table 6.

If one considers the great depth to saturated rock beneath Yucca and Frenchman Valleys, the distance from the most probable source of recharge, and the low rate of recharge from surface waters, it seems safe to assume that the radioactivity of these samples is natural. A possible exception is analysis 2167 from well 5B; the conditions under which this sample was collected are not well known. The concentration of Alpha activity in this sample is inconsistent when compared to the uranium concentration, with that of samples collected in April 1957 and March 1958. The higher concentration of uranium and alpha activity in samples collected from well 5A, compared to other samples from the Frenchman Valley well field, presumably to the fact that well 5A is finished in Oak Spring tuff, whereas the other wells are finished in alluvium. The lithologic character of the Oak Spring formation exposed on the south side of Frenchman Valley is considerably different than in the vicinity of wells 3 and 7; this might account for the difference in radioactivity between water from well 5A and wells 3 and 7.

Table 6.--Radiochemical analyses of water samples from wells in Yucca and Frenchman Valleys 1/

Well	Date collected	Analysis number	Beta-gamma activity µµc/1	Radium (Ra) µµc/1	Uranium (U) µg/1	Alpha activity 2/ µg/1	Net extractable alpha activity µµc/1	Strontium-90 µµc/1
3	4/57	1836	<14	<0.2	3.1	4.4	<3	--
	9/57	2155	<15	0.5	3.6	<4	2	<5
	3/58	2442	<22	<0.1	7.1	<5	<1.6	<5
7	2/58	2329	<19	0.2	0.5	<4	<0.4	<6
5A	4/57	1837	25	<0.2	13	13	<3	--
	9/57	2154	22	<0.1	21	17	<4	<5
	4/58	2511	<25	<0.1	19	--	3 ±2	<5
5B	4/57	1838	35	<0.2	4.8	5.3	<2	--
	9/57	2167	27	<0.1	4.2	13	<1	<5
	3/58	2441	18	0.1	6.7	<5	<1.6	<5
5C	4/57	1839	<17	<0.2	4.3	4.2	<2	--
	9/57	2165	<19	0.1	4.9	<4	<3	<5
	3/58	2444	<16	<0.1	7.4	11 ±5	<1.7	<5

1/ Analysis by U. S. Geological Survey, Denver Laboratory

2/ Uranium equivalent

REFERENCES CITED

Diment, W. H. and others, 1958, Properties of Oak Spring formation in area 12 at the Nevada Test Site, U. S. Geol. Survey TEI-672 (prelim. draft), open-file report.

An extensive physical-properties study presenting basic data on petrography, chemistry, porosity, density, permeability, water content, thermal conductivity, melting temperatures, and velocity measurements of the tuffaceous rocks of the Oak Spring formation in Ranier Mesa.

Diment, W. H. and others, 1959, Geologic effects of the Rainier underground nuclear explosion: U. S. Geol. Survey TEI-355 (prelim. draft), open-file report.

The effects are presented of the underground Rainier nuclear test upon the physical, chemical, thermal, seismic, gravitational, and hydrologic properties of the tuff of the Oak Spring formation near the chamber. A brief section on economic implications of nuclear explosions is included.

Ferris, John G., Knowles, Doyle B., Brown, R. H., and Stallman, R. W., 1960 "Theory of aquifer test; a summary of lectures", U. S. Geol. Survey Water Supply Paper 1536 - . In press.