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GROUND WATER TEST WELL C, NEVADA TEST SITE, NYE COUNTY, NEVADA

By M. S. Garber and William Thordarson

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GROUND WATER TEST WELL C, NEVADA TEST SITE, NYE COUNTY, NEVADA*

A summary of lithologic data, aquifer tests, and well construction

By

M. S. Garber and William Thordarson

1962

Report TEI-818

This report is preliminary and has not been edited for conformity with Geological Survey format.

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

CONTENTS

CONTENTS

ILLUSTRATIONS

TABLES

GROUND WATER TEST WELL C

NEVADA TEST SITE, NYE COUNTY, NEVADA

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ABSTRACT

Ground-water test well C was drilled to a depth of 1,701 feet with rotary and cable-tool drilling equipment. It penetrated 215 feet of valley fill of Quaternary and Tertiary (?) age, 1,140 feet of tuff of Tertiary age, and 346 feet of limestone of Paleozoic age.

The static water level is about 1,544 feet below the land surface, or 2,377 feet above sea level. Water occurs only in the limestone and is yielded chiefly from fractures. The well was pumped at rates of 60, 62, and 212 gallons per minute for protracted periods, and apparently could yield much more. The drawdown created by pumping was largely obscured by barometric-pressure and possibly by earth-tide effects, but probably was no more than 0.5 foot, and the specific capacity therefore may be about 450 gallons per minute per foot of drawdown.

Water from test well C is of the sodium bicarbonate type with a relatively high percentage of calcium and sulfate.

INTRODUCTION

The U.S. Geological Survey is appraising the possibility, however slight, that the ground water beneath the Nevada Test Site, possibly contaminated by nuclear detonations, may carry radioactive fission products to places where they may constitute a public hazard. The U.S. Atomic Energy Commission is sponsoring this work, which deals with the ground-water hydrology of the Nevada Test Site, and especially the hydrology beneath Yucca Flat. Test wells penetrating 100 feet or more below the water table provide a major part of the information needed for the study and also yield much information that cannot be incorporated in the final report. This information, however, can be recorded and preserved in interim reports, of which this report is one of a series.

Purpose and scope

In detail, the objectives sought through the drilling and testing of wells are:

1. To determine the lithology, distribution, structure, and water-bearing properties of the rocks and sediments from the surface downward into the zone of saturation.

2. To sample these rocks and sediments for laboratory analysis and study.

3. To determine the location, depth below the surface, quantity, temperature, and chemical and radiochemical quality of the ground water.

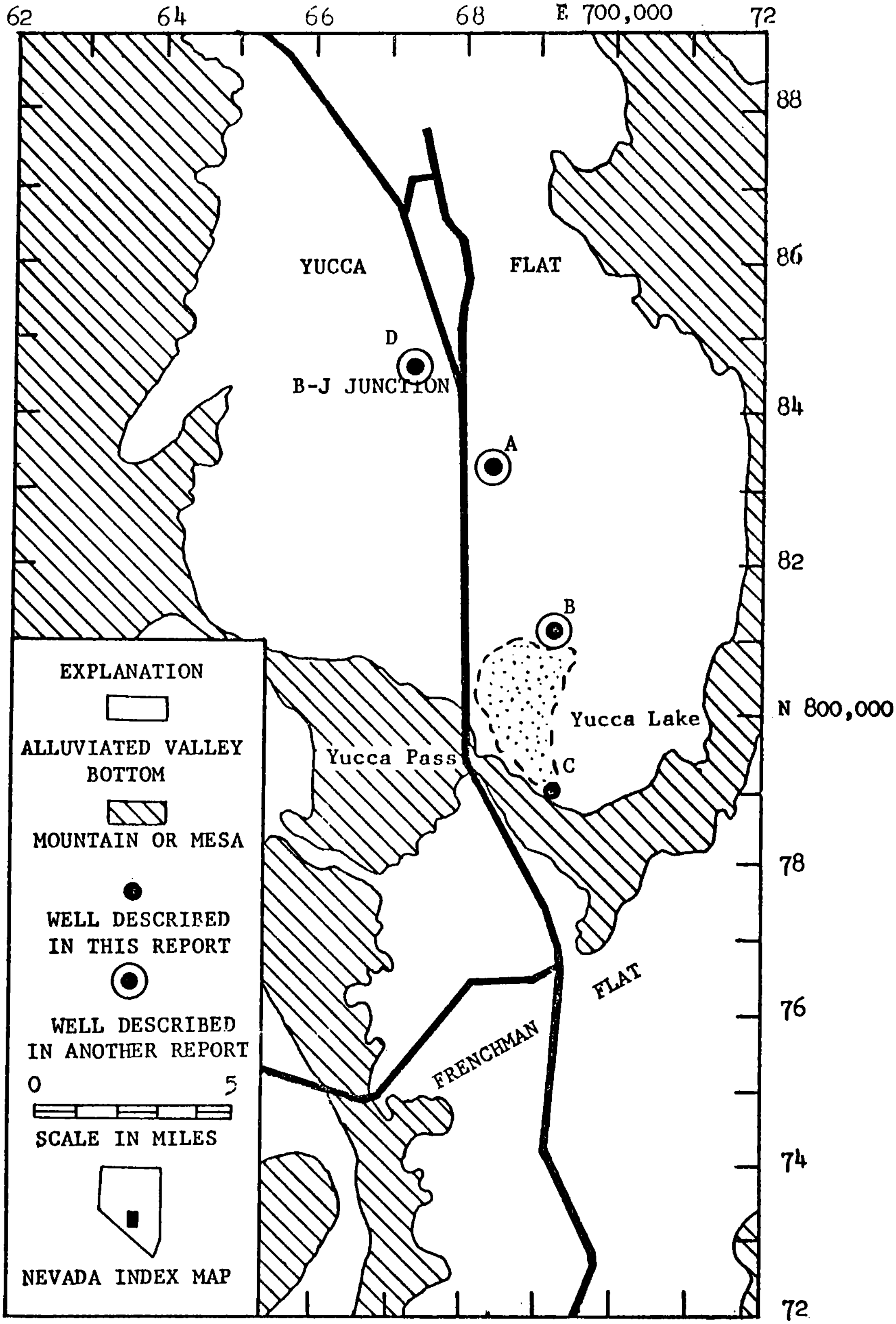
4. To determine the configuration of the piezometric surface as one step in ascertaining the direction and rate of movement of the ground water.

5. To establish a network of wells in which observation of water-level fluctuations can be made and from which water samples can be taken for chemical and radiochemical monitoring.

Specifically, test well C is one of six wells that were drilled to find the direction and rate of ground-water movement beneath Yucca Flat. This report describes the drilling, the casing, and the geophysical logging of the strata penetrated, the hydraulic tests that were made in the well, and the chemical quality of the water. The report is largely a compilation of data with little interpretation because valid interpretations must await the accumulation of data from other test wells.

Location

Ground-water test well C is in the Nevada Test Site, which is about 70 miles northwest of Las Vegas, Nev. The well is in the southern part of Yucca Flat, an enclosed intermontane valley about 20 miles long and 7 miles wide. The well is about 2 miles east-southeast of the control point at Yucca Pass (fig. 1). The Nevada State coordinates of the well site are N 790,082 and E 692,061. The altitude of the land surface at the well is about 3,921 feet.



Coordinates: Nevada State
System, central zone.

FIGURE 1.--MAP SHOWING LOCATION OF TEST WELL DESCRIBED IN THIS REPORT

Previous investigations

Johnson and Hibbard (1957) mapped and described the geology of the Nevada Test Site. Clebsch and Winograd (in Wilmarth and others, 1959, p. 36-49) have given a preliminary description of the hydrology of Yucca Flat, including a discussion of the possibility of hydraulic connection between Yucca and Frenchman valleys. Moore (1961) tabulated records of wells, test holes, and springs in the Nevada Test Site and surrounding areas. Hood (1961) described the water wells in Frenchman and Yucca valleys, provided lithologic logs of these wells and analyzed hydraulic tests made in them. Price and Thordarson (1961), Thordarson, Garber, and Walker (1962), Moore and Garber (1962) discussed the drilling, lithology, and hydrology of test wells A, D, and B respectively. Schoff and Winograd (1961) summarized the hydrology of the carbonate rocks of Paleozoic age, based on six core holes. Walker (1962) described the occurrence of ground water in the Climax stock.

General geology

The mountains surrounding Yucca Flat are composed of sedimentary rocks of Paleozoic age and extrusive and sedimentary rocks (Oak Spring Formation) of Tertiary age, which have been intruded by granitic rocks and by mafic dikes. Intrusion of the granitic rocks probably occurred in Permian to middle Mesozoic time (Houser and Poole, 1961), and intrusion of the dikes in Miocene time or later. The rocks are folded, and they are cut by thrust faults and normal faults (Johnson and Hibbard, 1957, p. 366-367, 369). The valley floor is underlain by alluvial and lacustrine sediments, the upper part of which is of Quaternary age; the lower part, however, may be of Tertiary age. The greatest thickness of alluvial sediments thus far penetrated is 1,870 feet.

Methods of investigation

Field work for this report consisted principally of observations of drilling operations and of hydraulic testing by bailing water from the well. Samples of drill cuttings were collected by drill crews according to instructions of the contracting officer.

The cuttings first were washed free of drilling mud on a 0.59-millimeter screen and then they and the cores were examined under a binocular microscope for determination of mineralogy, texture, size, roundness, and color of individual constituents. Colors of the samples were compared with the standard colors of the National Research Council rock color chart (Goddard and others, 1951).

Selected samples of tuff and limestone were studied by the X-ray powder method for mineral identification, using a goniometer diffractometer. The samples first were ground slightly and then were sieved through a 0.074-millimeter screen in order to remove most of the phenocrysts. The screened product was placed in an aluminum slide and X-rayed through a 2 Θ angle of 30° (2° to 32°). In addition, several oriented-aggregate slides were X-rayed to determine the clay-mineral composition.

All measurements to determine depth to water in the well were made using a device consisting of a bronze-magnesium "potential" cell suspended on a coaxial (armored) wire. The sheath serves as a ground conductor; the length of cable in the hole is measured by a producti-meter wheel; and contact with water is indicated by a deflection registered on a voltmeter. All components of the device are mounted on a steel frame for mobility.

The smallest division on the depth indicator built into the instrument equals 0.2 foot of depth, but the accuracy of the instrument was extended by inscribing additional divisions on the circumference of the measuring shieve. Each of these divisions is equal to 0.01 foot of depth. Without this increased accuracy, it would not have been possible to detect the small changes in water level that took place in the pumping tests in well C.

Periodic checks against a steel tape show the instrumental error usually is not greater than 0.002 foot per foot. At a depth of 1,500 feet, therefore, the depth reading from this instrument may be as much as 3.0 feet too great. The principal causes of instrumental error appear to be the elasticity of the coaxial wire, slippage of this wire as it passes over the measuring shieve, and possibly progressive wear of the measuring shieve with continued use.

The second of the above causes of error, slippage of the wire over the shieve, is to a certain extent controllable by the operator and for this reason, it may be the major factor in operator error. Operator error, introduced each time the self-potential cell is lowered in a well, is variable, is not linear, and if identifiable can be expressed only as an overall figure for the maximum depth measured. Although it is believed not to exceed 0.5 foot in most measurements, it probably is the reason why measurements of static water level at depths of 1,500 feet are not readily reproducible.

Unless otherwise indicated, the water levels recorded in this report are referred to the land surface but have not been adjusted for the errors discussed above. The instrumental and operator errors affect the determination of the absolute depth to the water table below the land surface and the altitude of the water table. They are not believed to invalidate the measurements of relative changes in water level made during hydraulic tests.

Acknowledgments

The authors wish to express their gratitude for the cooperation and assistance given by James L. McBride and W. R. McNinch of the Mac Exploration Co., Kyle Cheney of the Layne-Franklin Co., and H. B. Woodworth and J. Haught of Holmes and Narver, Inc.

CONSTRUCTION RECORD

Well C was constructed in 115 days in accord with specifications set forth in AEC invitation 292-60-21, Feb. 1960 and under contract AT(29-2-989). The prime contractor, Mac Exploration Co., Milford, Utah, did the hydraulic-rotary drilling but subcontracted the cable-tool work to the Layne-Franklin Co., Houston, Tex. Engineering inspection was provided by Holmes and Narver, Inc., Los Angeles, Calif., whose records show the cost to have been $53,960, or slightly less than $32 per foot (appendix A).

The machines used in drilling the well were a Failing holemaster hydraulic-rotary combination drill, a custom-made hydraulic-rotary drill assembled by the Cardwell Manufacturing Co., and a Bucyrus-Erie 36-L cable-tool drill. These same machines were used in drilling test well D and have been described in detail by Thordarson, Garber, and Walker (1962, p. 44-46).

The well was to be drilled by the hydraulic-rotary method to a depth about 100 feet, or less, above the water table. The well then was to be completed into the saturated zone by the cable-tool method because with this method no drilling mud or other additives would be required. Thus, the possibility of plugging the aquifer with drilling fluid and cuttings would be minimized. In addition the collection of water samples uncontaminated by drilling fluid and the recognition of zones of differing head might be possible.

Rotary drilling

Drilling by the rotary-hydraulic method began on April 14, 1960. When the hole was 753 feet deep the swivel atop the kelly locked and after repairs had been effected it was discovered that the drilling string was stuck. Various unsuccessful attempts were made to free the drilling string.

These included simply pulling on the drill rod with the drawworks, running a washover string alongside the stuck tools, and exploding charges of dynamite in the hole. After 13 days the upper 674 feet of drill pipe was retrieved by breaking it off by dynamiting. About 20 feet of drill rod, a 58-foot drill collar, and one Hughes drill bit 7 7/8 inches in diameter were left in the hole.

Drilling at a new location about 100 feet northeast of the site was begun on May 20, 1961, and a 6-inch pilot hole 1,548 feet deep was completed without unusual difficulty in 33 days. The actual work required only 15 days. A total of 41,600 gallons of water, 26,900 pounds of bentonite, 30 pounds of quicklime, and 2,170 pounds of various other materials were used in drilling the pilot hole (appendix B). About 18,000 gallons of mud was discarded during three sump-cleaning operations.

The rate of penetration during the drilling of the pilot hole, recorded by a geolograph, ranged from 2 to 9 minutes per foot and averaged about 4.5 minutes per foot (fig. 2). The rate of penetration in rotary drilling depends principally upon the character of the strata being penetrated, but also upon the size, suitability, and sharpness of the bits used, the weight of the tools, the speed of rotation, and the condition of the drilling fluid. The drillers often reduced the rate of penetration when drilling in soft strata so as to minimize the liklihood of making the hole crooked and to ensure flushing of cuttings from the hole.

Reaming of the pilot hole by the rotary-hydraulic method was begun on August 18, 1960, and was continued intermittently for 4 months. The

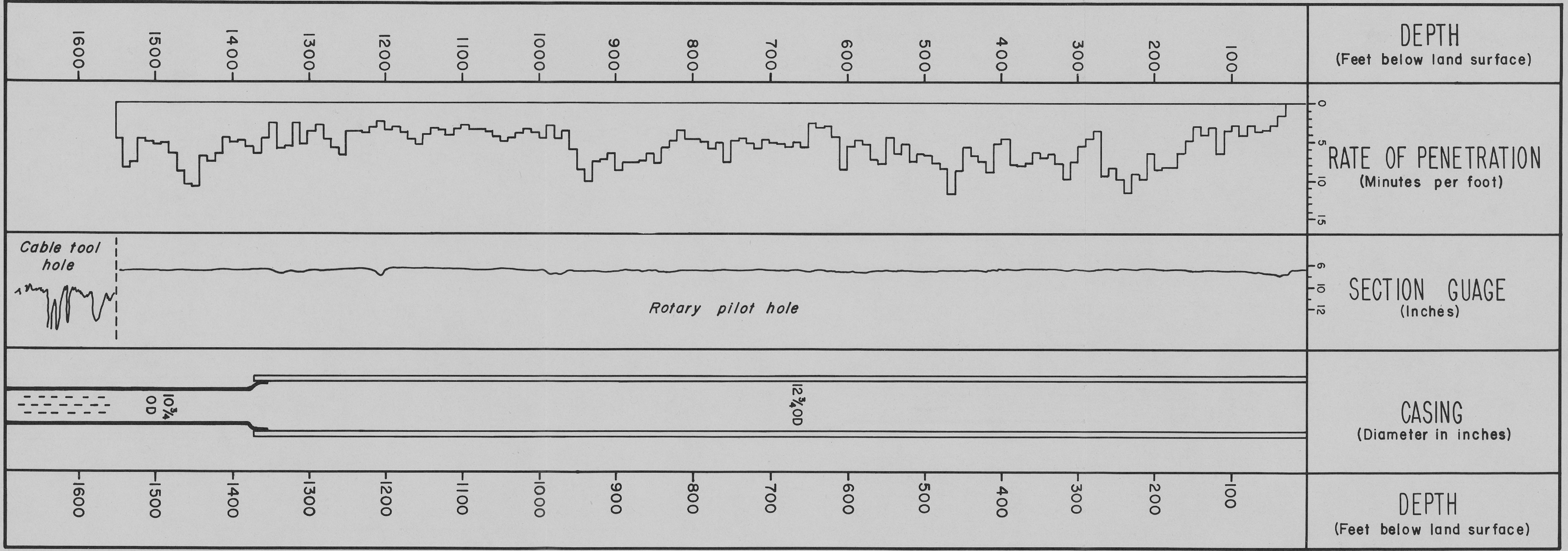


Figure 2.--Rate of rotary drilling penetration and section-gauge log for pilot hole, and casing record for completed well C.

reaming was done in two principal stages by two different machines and to two different diameters. First, the Failing drill rig was used for reaming to a diameter of 15 inches and depth of 1,000 feet, and to a diameter of 9 inches from that depth to 1,244 feet. Then, after an interruption of 68 days, the custom-built drill rig was used to continue the reaming. The reamed hole was to be 15 inches in diameter to a depth of 1,500 feet, but the contractor elected to abandon reaming by the rotary method and to change to cable-tools because the reaming was progressing very slowly. The slow drilling was due in part to serious losses of drilling fluid into the rock. At the end of the rotary reaming, the hole was 15 inches in diameter to a depth of 1,364 feet, and 9 inches in diameter from that depth to 1,460 feet. No enlargement of the lowermost 88 feet of the pilot hole had been accomplished.

Cable-tool drilling and casing installation

Reaming of the pilot hole to a diameter of 15 inches was resumed by the cable-tool method after an interruption of about 2 months. The reaming operation was completed to a depth of 1,500 feet in 7 days. However, the hole was too crooked for casing, and 48 hours of additional work was spent in straightening it. A section of the casing, 12 3/4 inches in outside diameter, was successfully lowered to 1,500 feet as a test of straightness. When the full string of casing was being lowered it became stuck at 1,369 feet, and the mast of the drill rig became bent in attempts to free the casing. After replacement of the mast further attempts were made to install the casing; however, it could not be lowered below 1,373 feet. The lower 127 feet of the reamed hole therefore was left uncased at this stage.

Work was interrupted for about a month, and then the hole was deepened in 7 days to 1,701 feet by cable-tools with a 12-inch bit. The 12 3/4-inch OD casing already in the well was cemented in place at the top with 6 sacks of cement and at the bottom with 20 sacks of cement (appendix C). When cement had set, the plug was drilled out and 345 feet of 10 3/4-inch OD casing was landed on the bottom of the well. The 10 3/4-inch casing was swaged out against the 12 3/4-inch casing at 1,356 feet. It is slotted in the interval from 1,571 to 1,679 feet (fig. 2). Work on test well C was terminated on March 30, 1961.

Condition of well

Well C contains a large quantity of foreign objects, all below a depth of 1,650 feet, which fell into the well when on April 2, 1961, an attempt was made to install a submersible turbine pump.

The pump was submersible turbine at the bottom of a string of discharge pipe 3 1/2 inches in diameter. Electric cable 1 3/4 inches in diameter was held to the discharge pipe by steel bands at 9-foot intervals. The cable weighed 2.6 pounds per foot and was fed into the well from a cable spool 4.5 feet in diameter.

The 1-inch tubing was intended as an access line in which measurements of water level were to be made. It was clamped to the discharge pipe at 20-foot intervals by means of wrought-steel straps, each 3/16 by 1 inch.

When the pump had been lowered to a depth of about 1,475 feet, the electric cable and the 1-inch tubing broke loose from the discharge pipe and fell into the well.

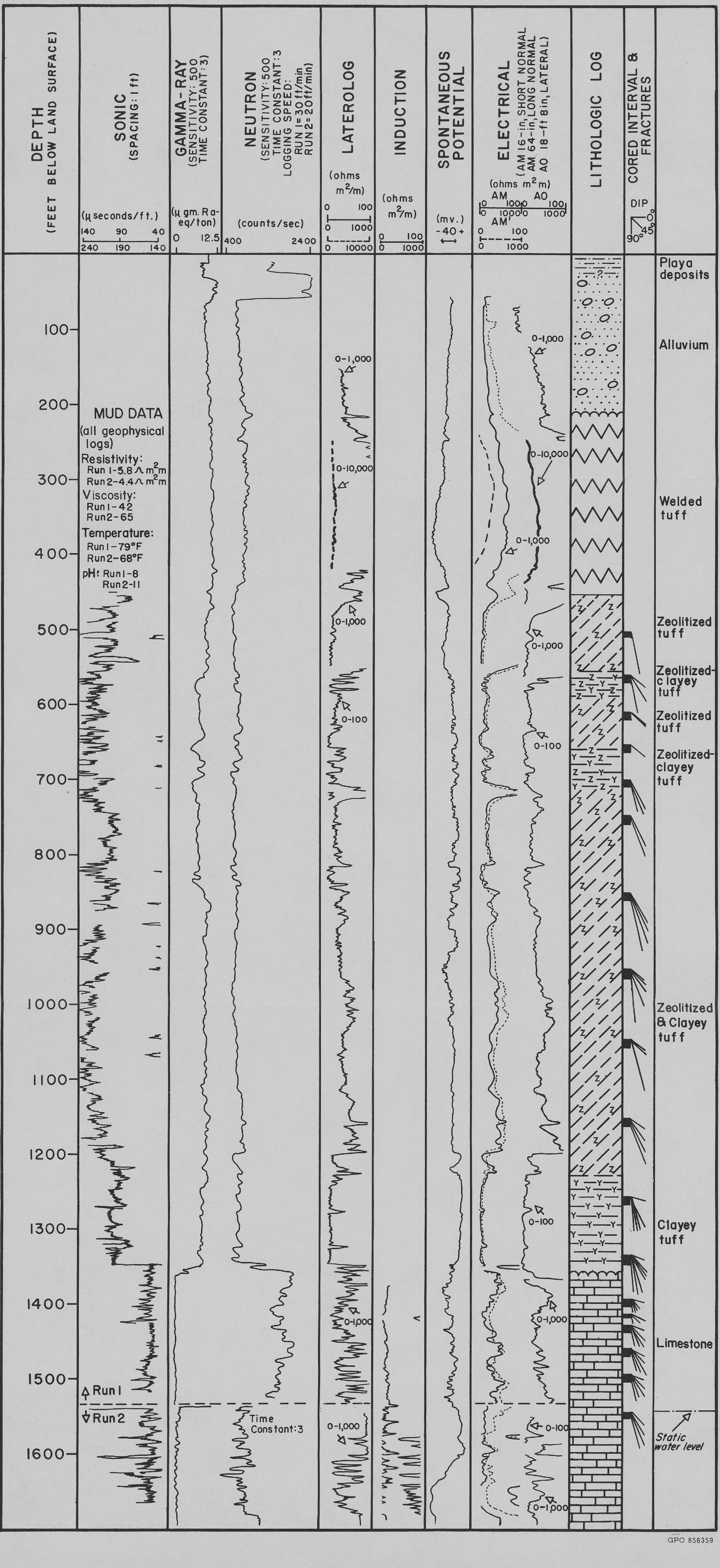
The pump, discharge pipe, all the electric cable, and part of the 1-inch tubing were recovered from the well. All bands and clamps used to hold the cable and tubing to the discharge pipe had been broken from the pipe. Only part of them were recovered with the electric cable. It was estimated that 900 feet of 1-inch tubing, 75 clamps, about 80 bands, and 140 saddles remained in the hole when the attempt to recover them was abandoned after a week of fishing.

LITHOLOGY OF STRATA PENETRATED

Test well C penetrated valley fill of Quaternary and Tertiary(?) age from 0 to 215 feet, tuff of the Oak Spring Formation of Tertiary (Miocene (?) or younger) age from 215 to 1,355 feet, and limestone of Paleozoic age from 1,355 to 1,701 feet.

A lithologic log (appendix D) gives in detail the character of the formations penetrated. In the preparation of this log, cores where available were used in preference to cuttings because the reliability of cuttings is affected by crushing and disaggregation by the bit, contamination by caving from the upper part of the hole, delay in arriving at the surface, and density separation of the grains in the drilling fluid. The cores show many lithologic details (fracture angles, orientation of pumice, size of pumice fragments, etc.) that cannot be seen in cuttings. The cores from this hole are excellent both in quality and quantity (appendix E). A total of 141 feet of core was obtained. In those intervals where cores were not available cuttings are described. The various lithologies in the tuff are classified on the basis of 4 major tuff constituents as follows: pumice, glass, crystals, and lithic fragments. This classification is similar to one given by Pettijohn (1956, p. 338). In order to keep the log as brief as possible, the general characteristics of tuffs are described as follows: quartz and feldspar crystals are clear, euhedral, and less than 2 millimeters in diameter; biotite, hornblende, and magnetite are black, euhedral, and less than 1 millimeter in diameter. A graphic log of the well is shown in figure 3.

Figure 3.--Lithologic and geophysical logs of test well C.



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The first hole for well C, abandoned at a depth of 753 feet, penetrated strata differing in some respects from those in this well and affords cores for intervals not cored in the completed well. A lithologic log of the hole is given in appendix F.

Valley fill

The valley fill, consisting of playa and alluvial deposits, was penetrated from the surface to 215 feet. The playa deposits were penetrated from the surface to 25 feet and consist of clay and fine silt with some sand and gravel. The alluvium penetrated from 25 to 215 feet contains poorly sorted silt, sand, and gravel. The major constituent of the gravel portion of the alluvium is welded tuff.

Oak Spring Formation

Several varieties of tuff identified as part of the Oak Spring Formation were penetrated from 215 to 1,355 feet. Two members of the Oak Spring Formation were distinguished and they are briefly described as follows: The Topopah Spring Member consists of 240 feet of welded to partly welded tuff and 55 feet of zeolitized tuff. The welded tuff is mottled red, brown, orange, and pink, and contains abundant flattened fragments of pumice and minute spherulites together with minor amounts of quartz and feldspar crystals and quartz veinlets. The lower 90 feet of this member contains abundant altered glass shards, has the same colors as the rock above, and grades downward from partly welded to nonwelded.

The lower member of the Oak Spring Formation consists of 845 feet of zeolitized and clayey pumiceous tuff. The upper 452 feet of it consisting of variegated bedded tuff altered to zeolite or clay contains abundant fragments of pumice and crystals of quartz and feldspar. Red and pink strata are abundant and many of the red ones are laminated. Individual layers in this subdivision of the member range in thickness from 5 to 40 feet. The middle 248 feet of the member consists of massive strata of zeolitized-pumiceous tuff mottled yellowish gray and pink. The lowermost 145 feet of the member consists of red pumiceous tuff which has been altered to clay and zeolite.

The dip in the tuff beds, believed to represent the initial dip of the strata plus tilting caused by gravity faulting, ranges from 0° to 60°. Fractures dip from 15° to 90°.

Limestone

Limestone, Paleozoic in age, was penetrated from 1,355 to 1,701 feet. The bottom of the formation was not penetrated in the well. The limestone is laminated and fine-grained, and contains abundant white calcite veinlets and stylolites coated with red clay. The limestone is generally light gray to medium-dark gray, but some of it in the upper 183 feet is olive gray, brownish gray, brown, and pink, and much of it in the next lower 163 feet is red and brownish gray. Parts of it are both variegated and mottled. The mottling in places is highly irregular and, although the colors generally parallel the laminae, they in places cut across the laminae.

The limestone recovered in the cores from test well C is highly fractured. Fractures of at least two ages are represented. The older fractures are as much as 152 millimeters wide. Some of them are filled with breccia and yellowish-gray to pale brown calcite. Among them are high-angle fractures having displacements of as much as 10 millimeters. Some of the high-angle fractures have red clayey slickensides and some contain calcite like that in the breccia.

The younger fractures dip in all directions and at all angles, intersecting each other in a pattern whose intricacy is emphasized by fillings of white to clear calcite. These fillings constitute veinlets, most of which are less than 1 millimeter wide. Some of the high-angle fractures in this set, however, are as much as 25 millimeters wide and contain vugs as much as 152 millimeters long and 5 to 10 millimeters wide. These vugs are lined with calcite and at places are interconnected.

The dip of the limestone, as indicated by laminae in the cores from well C, is constant in the upper part but irregular in the lower part of the well. The dip is 35° in cores from the depth interval between 1,390 and 1,465 feet, but is irregularly between 10° and 40° in the interval from 1,490 to 1,548 feet. The irregularity in dip in the lower part of the well is believed to be due to faulting.

MINERALOGY

X-ray mineralogical analyses were made by John E. Moore of 9 samples of limestone and 17 samples of tuff. In each sample only the fraction finer than 0.074 millimeter was studied. The results are detailed in table 1.

The limestone samples contain 32 to 100 percent calcite and 0 to 68 percent dolomite. In only one sample did the percentage of dolomite exceed the percentage of calcite. On the basis of mineralogical composition the carbonate rocks from this test well can be classified as limestone and dolomitic limestone (Pettijohn, 1956, p. 417).

The general order of abundance of minerals in the tuff matrix is as follows: welded tuff contains quartz, feldspar, and cristobalite; zeolitized-clayey tuff contains heulandite, montmorillonite, quartz, and feldspar; and clayey tuff contains montmorillonite, quartz, and feldspar. A large percentage of calcite was present in two samples of tuff taken at 751 and 1,339 feet. The predominant zeolite in the tuffs is heulandite, but analcite was predominant in a sample taken at 1,050 feet.

GEOPHYSICAL LOGS

Geophysical logs were made in test well C by the Schlumberger Well Surveying Corp. when the hole was 1,548 feet deep, was uncased, and was filled with drilling fluid. A second set of geophysical logs was made by the same company when the well was 1,701 feet deep, was cased to 1,373 feet, and was filled with formation water to about 1,540 feet. The geophysical logs made for both sets include electrical, laterolog, gamma-ray, neutron, sonic, and section gauge. In addition a directional survery was made in

Table 1.--X-ray diffraction analyses of samples (<0.074mm) from test well C (analyses in percent based on peak height)--Continued

Sample depth	Lithology	Clay minerals	Mica	Zeo-lite	Quartz	Cristo-balite	Feld-spar	Cal-cite	Dolo-mite
1,331	Clayey tuff	53	--	--	31	--	16	--	--
1,339	..........do...........	7	--	--	57	--	14	22	--
1,340	..........do...........	51	--	--	40	--	9	--	--
1,390	Limestone	--	--	--	--	--	--	100	--
1,399	..........do...........	--	--	--	--	--	--	100	--
1,412	Dolomitic limestone	--	--	--	--	--	--	70	30
1,434	..........do...........	--	--	--	--	--	--	51	49
1,455	Calcitic dolomite	--	--	--	--	--	--	32	68
1,463	Limestone	--	--	--	--	--	--	100	--
1,493	Dolomitic limestone	--	--	--	--	--	--	55	45
1,536	Limestone	--	--	--	--	--	--	100	--
1,548	..........do...........	--	--	--	--	--	--	100	--

[a]Zeolite is analcite, other samples contain heulandite.

the first set and an induction log was included in the second set. A comparison of the geophysical logs and the lithologic log is shown in figure 3. The section-gauge log is given in figure 2.

The sonic, gamma-ray, neutron, lateral, and electrical logs show several pronounced changes in character, which are believed to be related to the major lithologic breaks.

The contacts of the welded tuff with the overlying alluvium and underlying zeolitized tuff are characterized by gradual increases in resistivity. The clayey tuff is shown on the electrical logs by low resistivity (20 ohm meters), by lack of separation of the short- and long-normal curves, and by linearity of the trace of the curves. The contact of the clayey tuff and dolomite is shown on the sonic, gamma-ray, neutron, and electrical logs. These and other changes are summarized in table 2.

Table 2.--Correlation of geophysical logs with changes in lithology

Lithologic contact	Sonic log (feet)	Gamma-ray neutron logs (feet)	Lateral log (feet)	Electrical log (feet)
Alluvium/welded tuff	--	--	250	240
Welded tuff/zeolitized tuff	--	440	420	430
Zeolitized tuff/clayey tuff	--	--	1,205	1,200
Clayey tuff/dolomite	1,350	1,350	1,350	1,350

The section-gauge log shows that the pilot hole was uniform in bore to 1,550 feet (fig. 2). The log below that depth shows several abrupt increases in diameter of the hole, which may be due to caving.

The directional survey illustrates that the hole deviates from the vertical. The difference between the measured depth and the true vertical depth at 1,540 feet is 1.03 feet and the position at this depth is 11.5 feet north and 42.4 feet west of the origin (fig. 4 and table 3).

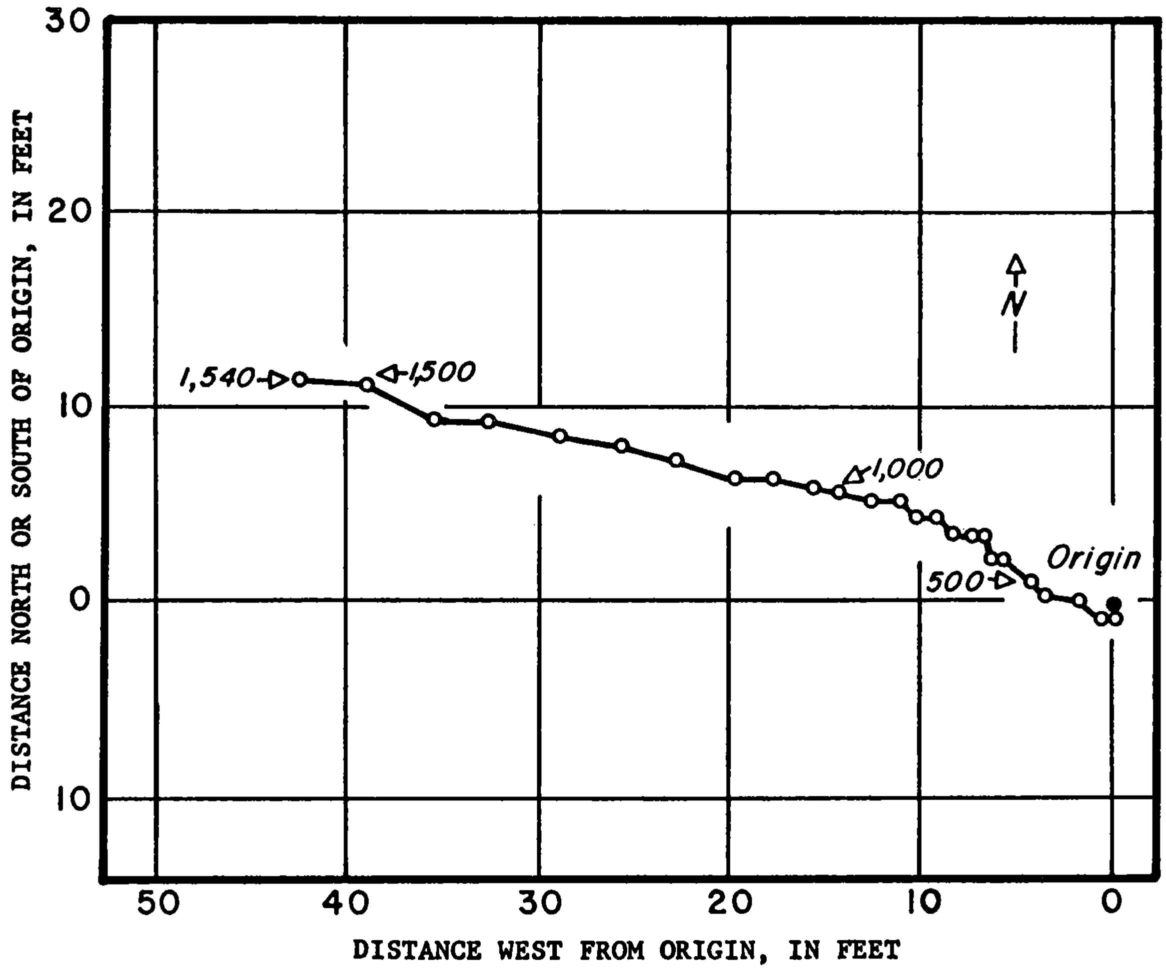

Figure 4.--Graph of directional survey in pilot hole for well C.

Table 3.--Directional log of test well C

Depth (feet)	Drift angle	Deflection: True bearing	Deflection: Horiz. footage	Deflection: Vert. footage	Latitude: N	Latitude: S	Departure: E	Departure: W	Coordinates: N	Coordinates: S	Coordinates: E	Coordinates: W
50	0°15'	S34E	.22	50.00	-	.18	.12	-	-	.18	.12	-
100	0°15'	S49E	.22	100.00	-	.14	.17	-	-	.32	.29	-
150	0°15'	S	.22	150.00	-	.22	-	-	-	.54	.29	-
200	0°35'	S57W	.44	200.00	-	.24	-	.36	-	.78	-	.07
250	0°45'	N70W	.65	250.00	.22	-	-	.61	-	.56	-	.68
300	1°00'	N62W	.87	299.99	.41	-	-	.77	-	.15	-	1.45
350	0°45'	N53W	.65	349.99	.39	-	-	.52	.24	-	-	1.97
400	0°30'	W	.44	399.99	-	-	-	.44	.24	-	-	2.41
450	1°15'	N61W	1.09	449.98	.53	-	-	.95	.77	-	-	3.36
500	1°15'	N58W	1.09	499.97	.58	-	-	.92	1.35	-	-	4.28
550	1°00'	N49W	.87	549.96	.57	-	-	.66	1.92	-	-	4.94
600	1°00'	N59W	.87	599.95	.45	-	-	.75	2.37	-	-	5.69
650	1°00'	N62W	.87	649.94	.41	-	-	.77	2.78	-	-	6.46
700	0°45'	N46W	.65	699.94	.45	-	-	.47	3.23	-	-	6.93
750	0°45'	N55W	.65	749.94	.37	-	-	.53	3.60	-	-	7.46
800	1°00'	N65W	.87	799.93	.37	-	-	.79	3.97	-	-	8.25
850	1°15'	N63W	1.09	849.92	.49	-	-	.97	4.46	-	-	9.22
900	1°15'	N73W	1.09	899.91	.32	-	-	1.04	4.78	-	-	10.26
950	1°15'	N66W	1.09	949.90	.44	-	-	.99	5.22	-	-	11.25
1,000	1°45'	N77W	1.52	999.88	.34	-	-	1.49	5.56	-	-	12.74
1,050	1°45'	N76W	1.52	1,049.86	.37	-	-	1.48	5.93	-	-	14.22
1,100	2°00'	N85W	1.74	1,099.83	.15	-	-	1.74	6.08	-	-	15.96
1,150	2°15'	N80W	1.96	1,149.79	.34	-	-	1.93	6.42	-	-	17.89
1,200	2°15'	N83W	1.96	1,199.75	.24	-	-	1.95	6.66	-	-	19.84
1,250	3°15'	N77W	2.84	1,249.67	.63	-	-	2.76	7.29	-	-	22.60
1,300	3°30'	N76W	3.05	1,299.58	.74	-	-	2.96	8.03	-	-	25.56
1,350	4°00'	N77W	3.49	1,349.46	.78	-	-	3.40	8.81	-	-	28.96
1,400	3°45'	N79W	3.27	1,399.36	.62	-	-	3.21	9.43	-	-	32.17
1,450	3°30'	N81W	3.05	1,449.27	.48	-	-	3.01	9.91	-	-	35.18
1,500	4°30'	N72W	3.92	1,499.12	1.21	-	-	3.73	11.12	-	-	38.91
1,540	5°00'	N83W	3.49	1,538.97	.42	-	-	3.46	11.54	-	-	42.37

GROUND-WATER HYDROLOGY

The static water level in test well C on September 13, 1961, adjusted for vertical deviation of the hole, was 1,544 feet below the land surface. Subtracting the vertical depth to water from the land-surface altitude (3,921 feet) gives the altitude of the water table at the well as 2,377 feet. Perched zones of saturation were not detected during the reaming of the hole by the cable-tool method. No change in water level was detected when the zone of saturation was entered and no change in head was observed as the hole was deepened through the saturated zone.

Description of the aquifer

The aquifer in test well C is limestone which yields water chiefly from fractures, although possibly also from cavities. Fracturing of the limestones is demonstrated by the condition of the core that was recovered, by the sonic log and by the caliper log. A detailed description of the limestone is given on pages 18 and 19 and in appendix D.

Aquifer tests

Three aquifer tests of the limestone were made by bailing water from well C at three different depths while the well was being deepened into the saturated zone. However, these tests failed to achieve their purpose because the drawdown that could be created by bailing was obscured by fluctuations due to barometric-pressure and possible earth-tide effects.

Three pumping tests were made in the well (appendix G) At the time of these tests the well was 1,701 feet deep and was cased to the bottom. Casing in the interval from 1,571 to 1,679 was slotted.

In the first two tests by pumping the discharge rate was 62 gpm (gallons per minute) for 45 hours and 60 gpm for 23 hours, respectively. There was no measurable drawdown in either of these tests. The water-level fluctuations that occurred in the well during pumping may be attributed principally but not entirely to response of the water level to changes in atmospheric pressure. Figure 5A shows the water-level fluctuations as they were observed during pumping test 2, and figure 5B shows the barometric fluctuations recorded by a microbarograph at a site 3 miles away. For comparison the barometric fluctuations have been converted to the water equivalent of mercury and have been inverted. The similarity of these two curves is apparent, but even if the barometric efficiency of the well is assumed to be 100 percent and the barometric effect is eliminated from the water-level measurements there remain residual fluctuations. The cause of these fluctuations has not been determined, though it is suggested that they were caused by earth tides.

In the third test well C was pumped at a rate of 212 gpm. Again it appeared that the drawdown created by pumping was largely obscured by atmospheric pressure and earth-tide effects. For this reason the

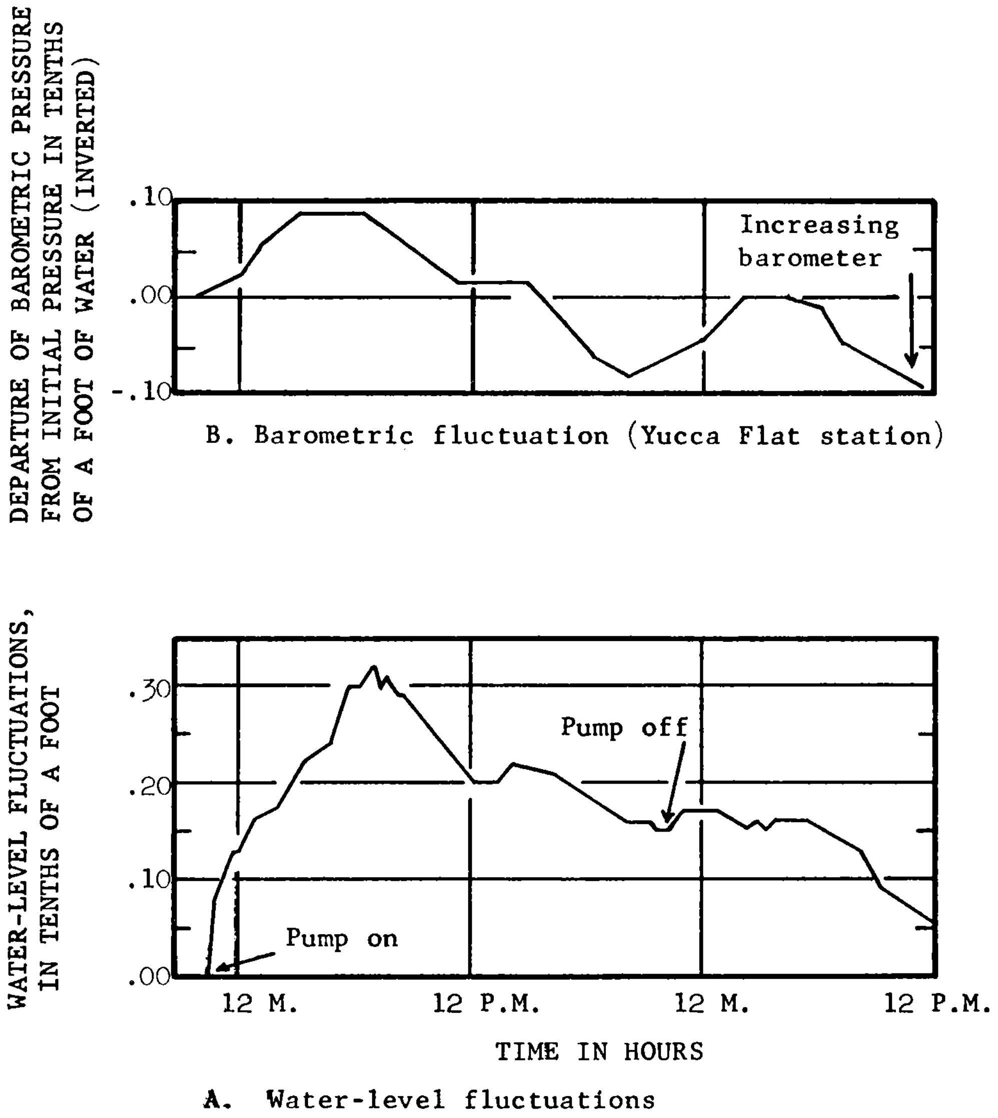

Figure 5.--Relation of changes in atmospheric pressure to water-level fluctuations in the second pumping test, September 13 and 14, 1961.

pumping was suspended after only about 5 hours. However, a careful inspection of the water-level measurements after correction for barometric effects suggests that no more than 0.5 foot of drawdown had been created by pumping. Although the exact amount of drawdown is in doubt it is clear that the specific capacity for the well is at least 450 gallons per minute per foot of drawdown and, further, that the coefficient of transmissibility is very high, perhaps as much as 1,000,000 gallons per day per foot.

PHYSICAL PROPERTIES OF TUFF AND LIMESTONE

The physical properties of 11 samples of tuff from cores taken between depths of 563 and 1,340 feet in well C were measured in the Hydrologic Laboratory of the Geological Survey and are summarized in table 4. The porosity of the zeolitized and zeolitized-clayey tuff ranges from 27 to 39 percent, but the porosity of the clayey tuff is lower, ranging from 20 to 21 percent. The coefficients of permeability for both the zeolitized and clayey tuffs are low, ranging from 0.00003 to 0.6 gallons per day per square foot. Their specific gravities range from 2.39 to 2.62.

The dry bulk density of 10 core samples of limestone from the interval 1,390 to 1,497 feet ranged from 2.59 to 2.75 grams per cubic centimeter and averaged 2.68 grams per cubic centimeter (Frank Byers, oral communication). Because not all the open spaces (vugs) of certain cores were included in the bulk density measurements, Byers recalculated the bulk densities assuming additional fracture or vugular porosity of 1 to 4 percent. For 1 percent additional porosity, the calculated bulk density is 2.65 grams per cubic centimeter; for 2 percent, 2.63; for 3 percent, 2.60; and for 4 percent, 2.57.

Table 4.--Laboratory analyses of samples of tuff from test well C, determined by the U.S. Geological Survey Hydrologic Laboratory

Depth (feet)	Lithology	Specific gravity of solids	Dry unit weight (g/cc)	Specific retention (percent)	Porosity (percent)	Specific yield (percent)	Coefficient of permeability (gpd/sq ft)
563	Zeolitized tuff	2.66	1.62	23.76	39.1	15.3	---
653	Zeolitized-clayey tuff	2.64	1.87	28.99	29.2	.20	0.002
702	Zeolitized-clayey tuff	2.39	1.57	---	34.3	---	---
750-751	Zeolitized tuff	2.40	1.71	---	28.8	---	.6
851-852	Zeolitized-clayey tuff	2.41	1.77	23.41	26.6	3.2	.0008
959-960	Zeolitized-clayey tuff	2.42	1.68	23.02	30.6	7.6	.3
1,050	Zeolitized-clayey tuff	2.52	1.55	30.68	38.5	7.8	.0004
1,153	Zeolitized tuff	2.55	1.86	25.06	27.1	2.0	.003
1,256	Clayey tuff	2.67	2.10	---	21.3	---	.00003
1,332	Clayey tuff	2.62	2.10	---	19.8	---	.04
1,340	Clayey tuff	2.60	2.05	19.77	21.2	1.40	.01

CHEMICAL AND RADIOCHEMICAL QUALITY OF WATER

A water sample collected from test well C after 30 hours of pumping was analyzed in the Geological Survey laboratory, Denver, Colo. The water is of the sodium bicarbonate type with a relatively high percentage of calcium and sulfate. The sample had a hardness expressed as $CaCO_3$ of 296 parts per million and a specific conductance of 1,080 micromhos per centimeter. The temperature of the water at the time of collection was 98° F. The results of this analysis is given in table 5.

CONCLUSIONS

Test well C taps water in limestone of Paleozoic age and will yield water more abundantly than any other well thus far drilled at the Nevada Test Site. The static water level in it is 10 to 170 feet lower than water levels in all wells tapping Cenozoic rocks or Paleozoic clastic rocks within a 25-mile radius.

Pumping tests show that the well can yield at least 212 gallons per minute, but the maximum yield is probably much greater. Only slight drawdown was detected during pumping, indicating that the transmissibility of the aquifer is much higher than those thus far determined at other wells tapping alluvium, tuff, or clastic rocks at the Nevada Test Site.

The water from test well C is a hard, sodium bicarbonate water usable for some purposes, and was being used by the U.S. Atomic Energy Commission at the time this report was completed.

Table 5.--Chemical and radiochemical analyses of water from test well C, Nevada Test Site, by the U.S. Geological Survey

		Field determinations	
Date collected:	September 1, 1961.	Temperature:	98°F.
Collected by:	M. S. Garber.	pH:	7.2
		Appearance:	clear.

Chemical components, Parts per million (ppm)		Physical characteristics and computed values	
Silica (SiO_2)	30	Dissolved solids (ppm) Res. on evap. at 180°C.	624
Aluminum (Al)	.3		
Iron (Fe)	1.0	Hardness as $CaCO_3$ (ppm) Total	296
Manganese (Mn)	.00	Non-carbonate	0
Calcium (Ca)	74	Specific conductance (μmhos at 25°C.)	1,080
Magnesium (Mg)	27		
Sodium (Na)	142	pH	7.0
Potassium (K)	15	**Radiochemical data**	
Bicarbonate (HCO_3)	577		
Carbonate (CO_3)	0	Alpha activity (μg/l as uranium equivalent) as of 11/21/61	< 32
Sulfate (SO_4)	71		
Chloride (Cl)	34	Beta activity (pc/l) as of 11/21/61	21 ± 3
Flouride (F)	.9	Radium (Ra) (pc/l)	1.3 ± 0.3
Nitrate (NO_3)	1.0	Uranium (U) (μg/l)	7.5 ± 0.8
Phosphate (PO_4)	.07	Extractable alpha activity (net) (pc/l)	5.1 ± 1.7
		Strontium 90 (pc/l)	[a]< 0.4

[a]None detected; limit of accuracy in determination was 0.6.

REFERENCES CITED

Goddard, E. M., and others, 1951, Rock color chart: Geol. Soc. America (2d printing).

Hood, J. W., 1961, Water wells in Frenchman and Yucca Valleys, Nevada Test Site, Nye County, Nevada: U.S. Geol. Survey TEI-788, 59 p.

Houser, F. N., and Poole, F. G., 1961, Age relations of the Climax composite stock, Nevada Test Site, Nye County, Nevada: U.S. Geol. Survey Prof. Paper 424-B, p. B176-B177.

Johnson, M. S., and Hibbard, D. E., 1957, Geology of the Atomic Energy Proving Grounds Area, Nevada: U.S. Geol. Survey Bull. 1021-K, p. 333-384, 2 pls., 1 fig.

Moore, J. E., 1961, Records of wells, test holes, and springs in the Nevada Test Site and surrounding area: U.S. Geol. Survey TEI-781, 22 p.

Moore, J. E., and Garber, M. S., 1962, Ground-water test well B, Nevada Test Site, Nye County, Nevada: U.S. Geol. Survey TEI-808, 39 p.

Pettijohn, F. J., 1956, Sedimentary rocks: Harper and Brothers, New York, 718 p.

Price, C. E., and Thordarson, William, 1961, Ground-water test well A, Nevada Test Site, Nye County, Nevada: U.S. Geol. Survey TEI-800, 59 p.

Schoff, S. L., and Winograd, I. J., 1961, Hydrologic significance of six core holes in carbonate rocks of the Nevada Test Site: U.S. Geol. Survey TEI-787, 97 p.

Thordarson, William, Garber, M. S., and Walker, G. E., 1962, Ground-water test well D, Nevada Test Site, Nye County, Nevada: U.S. Geol. Survey TEI-803, 58 p.

Walker, G. E., 1962, Ground water in the Climax stock, Nevada Test Site, Nye County, Nevada: U.S. Geol. Survey TEI-813, 48 p.

Wilmarth, V. R., Healy, D. L., Clebsch, Alfred, Winograd, I. J., Zeitz, Isodore, and Oliver, H. W., 1959, A summary interpretation of geologic, hydrologic, and geophysical data for Yucca Valley, Nevada Test Site, Nye County, Nevada: U.S. Geol. Survey TEI-358.

Appendix A.--Contract cost

The itemization of costs for the drilling in test well C is divided according to the drilling method employed.

A. Cost of work with hydraulic-rotary drilling equipment.

Description	Amount
Move-in and set-up at first test well site	$ 2,000.00
Rotary drilling in alluvium and Oak Spring Formation	8,438.50
Rotary reaming in alluvium and Oak Spring Formation	8,438.50
Rotary drilling in basement rock	1,386.60
Rotary reaming in basement rock	98.00
Coring in Oak Spring Formation	3,607.50
Coring in basement rock	1,802.00
Logging truck mileage	400.00
Electrical log - upper section	450.00
Laterolog - upper section	300.00
Section gage - upper section	350.00
Gamma ray-neutron log - upper section	300.00
Sonic log - upper section	300.00
Directional survey - upper section	300.00
Subtotal	$ 28,171.10

Appendix A.--Contract cost--Continued

B. Cost of work with cable-tool drilling equipment.

Description	Amount
Move drilling rig to test-hole site	$ 60.00
Dismantle drilling rig and set-up next test hole site	300.00
Reaming in basement rock	1,242.00
Drilling in basement rock	2,065.50
Furnish 12 3/4-inch OD steel casing	8,931.00
Install 12 3/4-inch OD steel casing	2,404.00
Cementing 12 3/4-inch OD steel casing	1,250.00
Furnish 10 3/4-inch OD slotted casing	756.00
Install 10 3/4-inch OD slotted casing	189.00
Furnish 10 3/4-inch OD blank casing	1,185.00
Install 10 3/4-inch OD blank casing	403.75
Logging truck mileage	400.00
Electrical log - lower section	500.00
Laterolog - lower section	350.00
Induction log - lower section	450.00
Gamma ray-neutron log - lower section	350.00
Sonic log - lower portion	350.00

Appendix A.--Contract cost--Continued

Description		Amount
Bailing		$ 51.00
Standby - ready (for bailing tests)		208.00
Furnishing pumping test and equipment		1,785.90
Furnishing 1-inch access pipe		686.25
Installation of submersible pump		1,200.00
Test pumping		672.00
	Subtotal	$ 25,789.40
	Grand total	$ 53,960.50

Appendix B. Record of water and additives used in drilling the pilot hole of test well C

Depth interval (feet)	Water added (gallons)	Bentonite (pounds)	Other additives (name)	Other additives (pounds)
0- 18	500	400	Flocele	25
--- ---	1,700	200	None added	0
21- 95	0	1,400	Quicklime	15
151- 257	0	0	----do----	3
257- 302	1,000	400	----do----	2
302- 425	2,000	700	----do----	3
425- 566	3,000	1,400	----do---- Tann Athin	7 10
566- 662	1,000	0	None added	0
662- 758	[a] 7,500	6,300	Celocel Magcofiber	100 80
758- 903	4,000	1,000	Flocele Fiber seal	100 100
903-1,080	1,700	0	None added	0
1,080-1,242	[a] 8,600	7,100	Beet pulp	500
1,242-1,361	3,500	2,200	----do---- Magcofiber	150 100
1,361-1,415	2,500	1,300	None added	0
[b] 1,415-1,458	[a] 2,300	4,500	Fiber seal Beet pulp	350 650
1,458-1,531	1,500	0	Sodium hexa- metaphosphate	5
1,531-1,548	800	0	None added	0
Total	41,600	26,900		2,170

[a] Drilling mud discarded; replaced by fresh supply.

[b] Lost circulation in this interval.

Appendix C.--Record of casing and cementing in test well C

Depth interval (feet)	Casing and cementing
0-1,373	12 3/4-inch OD casing; casing shoe is 1-foot piece of the same casing split and welded to the outside at the bottom; casing reportedly cemented at top by plugging annular space 10 feet below land surface with burlap and paper and adding a slurry of 6 sacks of portland cement and water on top of it. Casing reportedly cemented at bottom by first plugging the hole at about 1,375 feet with wood, brush, dirt, and rocks, and tamping with drill bit for 30 minutes. A slurry consisting of 20 sacks of commercial portland cement and water was dumped into the hole, and was squeezed up the annular space by a Halliburton plug plus weight of the bit and 1,200 gallons of water.
1,356-1,571	10 3/4-inch OD casing, top 17 feet annealed and swaged out against 12 3/4-inch OD casing.
1,571-1,679	10 3/4-inch OD casing with saw-cut vertical slots, 1/8 inch by 3 inches, in rows of 16 slots per row, staggered so that alternate rows are aligned; rows separated by 3 inches of blank casing.
1,679-1,701	10 3/4-inch OD casing, without casing shoe.

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores

	Thickness (feet)	Depth (feet)
Valley fill		
Playa deposits		
Clay and silt; light to pale yellowish brown; with some silty sand having sparse to abundant calcite cement and some gravel made up of welded tuff (light gray, pale red, and grayish red) and small amounts of fragments of grayish-orange pumice; sparse black coatings of dendritic manganese oxide on gravel	25	25
Alluvium		
Sand, silty, and gravel, with some clay; pale yellowish brown to grayish orange; gravel is predominantly welded tuff (very light gray, some gray to pale red), with small amounts of light brown glass, fragments of grayish-orange pumice, and a trace of black vitrophyre, and has grayish-orange coatings of calcium carbonate and black dendrites of manganese oxide	190	215

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Oak Spring Formation		
Topopah Spring Member		
Tuff, welded; pale red, mottled light brown in lower 10 feet; abundant flattened pumice containing spherulites; quartz and feldspar crystals, 5-10 percent; traces of biotite, magnetite and quartz veinlets <1mm wide	25	240
Tuff, welded; grayish-orange pink; flattened pumice, difficult to distinguish from matrix; spherulites <2mm in diameter, 20 percent; quartz and feldspar crystals, 5-10 percent; traces of biotite and magnetite	35	275
Tuff, welded; pale brown, in part mottled grayish red; very pale orange spherulites 1 mm in diameter, 20 percent; quartz and feldspar crystals, 5 percent; trace of biotite.	50	325
Tuff, welded; mostly grayish red mottled pale and light brown; composition similar to unit above	15	340

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Tuff, welded; pale red, in part mottled grayish-orange pink to very pale orange; flattened pumice (very pale and grayish orange, completely filled with spherulites < 2 mm in diameter), 60 percent; spherulites also abundant in matrix (< 2 mm across); quartz and feldspar crystals < 5 percent; trace of biotite; abundant quartz veinlets (< 2 mm wide); many manganese-oxide veinlets from 400-405 feet (< 1 mm thick), abundant manganese-oxide stains	65	405
Tuff, welded; pale brown, with grayish orange to very pale orange spherulites < 1 mm in diameter; flattened pumice, very pale to grayish orange, 20-50 percent; quartz and feldspar crystals, < 5 percent; traces of biotite, quartz veinlets < 2 mm wide, grayish-red spots, and manganese-oxide coatings	15	420

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Tuff, partly welded; pale red, in part mottled grayish orange to very pale orange; spherulitized glass shards and pumice fragments <2 mm across; grayish-orange pumice, slightly to well flattened, 40 percent; quartz and feldspar crystals, <5 percent; quartz veinlets <1 mm wide, <5 percent; traces of biotite, magnetite and lithics	15	435
Tuff, partly welded; pale yellowish brown, in part mottled white to very pale orange and grayish orange; altered glass shards, pumice, slightly to well flattened, white to very pale orange, 30 percent; quartz and feldspar crystals, <5 percent; traces of biotite, lithic fragments, quartz veinlets <2 mm wide and agate veinlets <1 mm wide	20	455
Tuff, zeolitized, incipiently welded to non-welded; mostly light brown, in part grayish-orange pink; dark yellowish-orange		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
zeolite mineral <1 mm across, 25 percent; abundant pumice and glass shards, slightly flattened, <4 mm across; quartz and feldspar crystals, <5 percent; magnetite, <5 percent; traces of biotite; quartz veinlets <4 mm wide	30	485
Tuff, zeolitized; grayish-orange pink; pumice and glass shards <4 mm across, grayish-orange pink, 20 percent; included are hollow zeolite spheres <0.25 mm in diameter, partly altered to white, grayish yellow and moderate yellowish green; quartz and feldspar crystals <0.5 mm across, <5 percent; traces of biotite, magnetite, and lithic fragments; manganese oxide in pumice and oval masses <7 mm long, <5 percent; matrix altered to zeolite spheres (white to moderate yellowish green, <0.25 mm in diameter, hollow		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
to solid, in clusters and rows); core, 503-509 ft, shows flattened lapilli pumice and suggests bedding nearly horizontal; 3 possible fractures dip 80°	25	510
Lower member		
Tuff, zeolitized, pumiceous; grayish-orange pink; pumice mostly grayish-orange pink, <4 mm across, with sparse lapilli, 60 percent; quartz and feldspar crystals, 5 percent (15 percent in lower 15 ft); traces of biotite and magnetite; brown and red lithic fragments, 5 percent; manganese oxide at 545-550 ft; matrix altered to zeolite, 20 percent of it as zeolite spheres (grayish-yellowish green, <0.25 mm across, hollow)	45	555
Tuff, zeolitized, pumiceous; moderate orange pink to moderate reddish orange; pumice, grayish-orange pink, <1 mm across, 50 percent; quartz and feldspar crystals, 20		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
percent; biotite, 5 percent, magnetite; < 5 percent; brown and red lithic fragments, 5 percent.	5	560
Tuff, zeolitized, crystal; mottled moderate orange pink to moderate reddish orange near fractures; quartz and feldspar crystals < 2.5 mm across, 60 percent; pumice grayish pink to white, < 5 mm across, 5 percent; biotite < 2.5 mm across, < 10 percent; hornblende, < 0.5 mm across, < 5 percent; trace of lithic fragments, moderate red, < 2.5 mm across; core, 560-567 ft, shows hollow pores < 5 mm across, 1 quartz veinlet 2.5 mm wide, and dips 80°	7	567
Tuff, interbedded zeolitized and clayey in layers about 5 ft thick. Zeolitized tuff is pumiceous, grayish-orange pink to pale reddish brown; pumice, pink to white, < 0.5 mm across, 30-50 percent; quartz and feldspar crystals, 20 percent; biotite,		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
<10 percent; hornblende, <5 percent; traces of magnetite and red and brown lithic fragments. Clayey tuff, represented by core, 567-570 ft, pumiceous, in part altered to zeolite; matrix, very pale orange to pale yellowish brown; pumice, grayish pink, clayey, <10 mm across, 50 percent; biotite <2.5 mm across, <25 percent; quartz and feldspar crystals, <2 mm across, 15 percent; trace of moderate yellowish-green halos around crystals; trace of red lithic fragments <1.5 mm across; crude bedding dips about 10°, quartz veinlet 2.5 mm wide dips 40°, possible fracture dips 60°.	28	595
Tuff, zeolitized, pumiceous-crystal; moderate reddish orange to moderate orange pink; pumice, pink,30-50 percent, quartz and feldspar crystals, 25 percent; biotite, 5 percent; magnetite, <5 percent; red and brown lithic fragments, 15-20 percent . .	15	610

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Tuff, zeolitized and clayey, crystal; pale reddish brown; contains interbedded laminated siltstone strata, 0.02-0.4 ft thick, and a greenish-gray vitric bed with abundant glass from 620-625 ft; pumice, white, <8 mm across, 10-20 percent; quartz and feldspar crystals, 40 percent; clayey yellowish-green mineral with red halos, 5-10 percent; biotite <2.5 mm across, 4 percent; trace of magnetite; red lithic fragments, 5-15 percent; core, 610-620 ft, shows beds dip 19°; 2 fractures dip 45° (one contains white gouge and slickensides, the other displaces strata by 10 mm)	20	630
Tuff, zeolitized, crystal; mostly laminated and very fine grained; moderate to dark reddish brown; quartz and feldspar crystal <0.1 mm across, 25-60 percent; biotite, <5 percent; traces of magnetite and yellowish-green mineral; red lithic fragments, <5 percent.	10	640

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Tuff, zeolitized and clayey, pumiceous; light yellowish gray to white; contains interbedded pale brown, fine-grained laminated crystal tuff from 654-655 ft; pumice 2.5-12 mm across, 50 percent; quartz and feldspar crystals, 5-20 percent; biotite, 10-20 percent; trace of magnetite; red lithic fragments, 3-20 percent; core 652-659 ft shows beds dip 10°, 1 fracture with possible slickenside dips 40°	19	659
Tuff, zeolitized and clayey, crystal; mostly fine grained and laminated; pale reddish brown; quartz and feldspar crystals <0.5 mm across, 20-50 percent; pumice, white, 10-25 percent; biotite, <5 percent; red lithic fragments, 5 percent	36	695
Tuff, zeolitized and clayey, pumiceous; some interbedded fine-grained crystal-tuff laminae, 2.5-25 mm thick; pinkish gray to white, some light yellowish gray; pumice		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
<10 mm across, 50-70 percent; quartz and feldspar crystals, 10 percent; biotite, <5 percent; trace of magnetite; brown and red lithic fragments, <0.5 mm in diameter, 2-10 percent; core, 700-707 ft, shows fault breccia, 0.2 ft wide containing open spaces and cracks <2.5 mm wide; 10 small faults dip 65°-80° and displace beds by <45 mm, some contain quartz veinlets 0.5-12 mm wide; beds generally dip 14° but near faults dip 10°-20°; yellowish-green alteration near faults	15	710
Tuff, very densely zeolitized, pumiceous; yellowish gray to grayish yellow; pumice, mostly >1 mm across, 80 percent; quartz and feldspar crystals, 10 percent; biotite, <5 percent; lithic fragments, 3-10 percent	20	730
Tuff, zeolitized and clayey, pumiceous; grayish-orange pink to moderate orange pink;		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
pumice, white, mostly <2.5 mm across but some as much as 10 mm across, slightly to moderately calcareous, 30 percent; quartz and feldspar crystals, 5-10 percent; traces of biotite and magnetite; red lithic fragments, <48 mm across, many with red halos, 5-25 percent; core, 748-758 ft, shows fault with slickensides dipping 70° and pale reddish-brown gouge, 2.5-13 mm wide; 3 fractures dip 65°-70° (1 contains quartz veinlet, 0.25 mm wide)	28	758
Tuff, zeolitized, pumiceous; mottled white and grayish-orange pink; pumice white, <5 mm across, a small part altered to a yellowish-green mineral, with abundant lapilli, 50 percent; quartz and feldspar crystals, 10 percent; traces of biotite and magnetite; red, brown, and gray lithic fragments, 5-10 percent	7	765

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Tuff, zeolitized, pumiceous; white to very pale orange; pumice white, <5 mm across, 50-75 percent; quartz and feldspar crystals, 5 percent; traces of biotite, magnetite, and an olive-gray mineral with grayish-red halos; red and brown lithic fragments, 5 percent	20	785
Tuff, zeolitized, pumiceous; moderate orange pink and light red; pumice white, <2 mm across, 20-30 percent; quartz and feldspar crystals, 5-10 percent; traces of biotite and magnetite; red and brown lithic fragments, <5 percent	15	800
Tuff, zeolitized, pumiceous; grayish-orange pink; pumice white, <2 mm across, 30 percent; quartz and feldspar crystals, 5 percent; traces of biotite and magnetite; red and brown lithic fragments, <5 percent	10	810
Tuff, zeolitized, pumiceous; light red; white pumice, <1 mm across, 30-50 percent; quartz		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
and feldspar crystals, 5 percent; traces of biotite and magnetite; red and brown lithic fragments, <5 percent.	10	820
Tuff, zeolitized, pumiceous; white; pumice with abundant lapilli <5 mm across, 75 percent; quartz and feldspar crystals, 5 percent; traces of biotite and magnetite; red and brown lithic fragments, 5 percent	5	825
Tuff, very densely zeolitized, crystal; moderate red; quartz and feldspar crystals, 50 percent; pumice white <0.25 mm across, 5 percent; biotite, <5 percent; trace of magnetite; red and brown lithic fragments, <5 percent.	5	830
Tuff, pumiceous; white; abundance of quartz and feldspar crystals and lack of matrix in cuttings indicate matrix possibly altered to clay, which was washed away during drilling	10	840

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Tuff, zeolitized, pumiceous-crystal, fine grained; moderate, dusky, and light red; quartz and feldspar crystals <0.25 mm across, 30-40 percent; traces of biotite, magnetite, and lithic fragments	10	850
Tuff, zeolitized and clayey (very densely zeolitized from 870-885 ft), pumiceous; moderate orange pink with pale red layer from 853-853.7 ft; pumice (mostly grayish yellow, some white and yellow green, some pink halos) mostly <4 mm across, with abundant lapilli <15 mm across, 30-60 percent; quartz and feldspar crystals, 10 percent; traces of biotite and magnetite; manganese-oxide at 856.5 ft; red and brown lithic fragments, <7.5 mm across with yellow-green halos, <5 percent; sparse calcite in specks from 856-859 ft; core, 850-859 ft, shows beds dip 55°-60°; 6 fractures intersecting at right angles in lower half of core dip 61°-79°, red		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
coatings on some, white clay coating on one and manganese-oxide coating on one; 4 steeply dipping intersecting fractures at 853-853.7 ft, stained moderate red	35	885
Tuff, zeolitized, pumiceous; grayish yellow, with small amount greenish yellow; pumice with abundant lapilli, 50 percent; quartz and feldspar crystals, 10 percent; traces of biotite and magnetite; brown and gray lithic fragments, <5 percent	10	895
Tuff, zeolitized (very dense, 900-905 ft); grayish-orange pink with much greenish yellow in lower half; pumice white, some altered greenish yellow, 20 percent; quartz and feldspar crystals, 10 percent; traces of biotite and magnetite; lithic fragments, <5 percent.	10	905
Tuff, zeolitized; moderate orange pink to light red; pumice white, 20 percent; quartz and feldspar crystals, 10 percent;		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
biotite, <5 percent; lithic fragments, mostly pale brown, <5 percent; trace of magnetite	10	915
Tuff, zeolitized, pumiceous; white, very light gray (very densely zeolitized), some grayish-yellow alteration; pumice, 70 percent; quartz and feldspar crystals, 10-15 percent; biotite, <5 percent; trace of magnetite; brown and red lithic fragments, <5 percent	37	952
Tuff, zeolitized; grayish-orange pink; pumice white, <5 mm across, 20 percent; quartz and feldspar crystals with light red halos, 20 percent; biotite, <5 percent; two irregular masses of manganese oxide < 33 mm across; traces of magnetite and red lithic fragments <7.5 mm across; core, 952-958 ft, shows beds dip 53°; fault with thin clayey gouge displaces beds by 30 mm, dips 70°; 20 fractures, one stained with iron		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
oxide, dip 40^{o}-60^{o} in interval 952-955 ft, and 70^{o}-90^{o}in interval 955-958 ft	6	958
Tuff, zeolitized and clayey; light gray to light brownish gray; pumice, very pale orange, mostly <4 mm across but some as much as 7.5 mm across, 15 percent; quartz and feldspar crystals with some with pink halos, 20 percent; traces of biotite and magnetite; red lithic fragments, <5 percent; core, 958-962 ft, shows several fractures, some with grayish-red slickensides dip 40^{o}-45^{o} at 959 ft and 53^{o}-60^{o} (maximum 90^{o}) at 961.5 ft	4	962
Tuff, zeolitized, pumiceous; between pinkish gray and light gray at top, grading to pinkish gray at bottom, top 3 ft mottled yellowish gray; pumice <5 mm across, 50 percent; quartz and feldspar crystals, 10 percent; traces of biotite, magnetite, a		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
grayish orange and yellowish-green mineral, and brown and gray lithic fragments; matrix contains many hollow zeolitic spheres, <0.5 mm across.	63	1,025
Tuff, zeolitized and clayey, pumiceous; mottled yellowish gray, pinkish gray, and pale red; pumice yellowish gray to grayish-orange pink, contains abundant hollow zeolitic spheres, <0.5 mm across, 50 percent; quartz and feldspar crystals, some with red halos (locally 40 percent of rock), 10-30 percent; biotite, <5 percent; brown specks, possibly iron-oxide, <0.25 mm across, 5 percent; traces of magnetite, manganese oxide, and yellowish-green specks, <1 mm across; red and brown lithic fragments, some with red halos, <5 percent; black to dark gray lithic fragments or concretions from 1,085-1,095 ft, 10 percent; core, 1,046-1,056 ft, shows 2 fractures dip 35° with red slickensides,		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
1 fracture dips 76° with red gouge, 2 fractures dip 70° and displaced 4 mm by 3 fractures with red gouge which dip 50°, several other fractures dip 35°-50°, 1 dips 90°	120	1,145
Tuff, zeolitized (very densely zeolitized from 1,175-1,210 ft), pumiceous and pumiceous-crystal; yellowish gray to very pale orange, mottled with moderate pink in upper half and reddish purple in lower half; pumice, <5 mm across, 50 percent; quartz and feldspar crystals with some red halos, 10-25 percent; biotite, <5 percent; traces of magnetite, manganese oxide, and olive-brown mineral <2 mm across; red, pink, and gray lithic fragments <15 mm across, some olive halos, <5 percent; abundant minute zeolite spheres in matrix from 1,145-1,175 ft; abundant calcite veinlets at 1,160 and 1,200 ft; core, 1,150-1,160 ft, shows		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
beds dip 25°; several faults with red to brown slickensides displace bedding 15 mm and dip 35°, 55° and 70°; some small fractures near base dip 0°-90° and are filled with manganese-oxide veinlets <1 mm thick	65	1,210
Tuff, clayey and zeolitized, pumiceous; between moderate red and dusky red; pumice, mostly white, some grayish-orange pink, <1 mm across, 20-30 percent; quartz and feldspar crystals, 20 percent; biotite and magnetite, each <5 percent; red and gray lithic fragments, < 5 percent	20	1,230
Tuff, clayey and very densely zeolitized, pumiceous; moderate red to pale red; pumice, moderate pink, 30 percent; quartz and feldspar crystals, 5-10 percent; traces of biotite and magnetite; lithic fragments, <5 percent; white to clear calcite veinlets <3 mm wide . . .	5	1,235

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Tuff, clayey and zeolitized, pumiceous; moderate red to dusky red; pumice grayish yellow, very light gray, pink, and white, <13 mm across, some calcareous, 25 percent; quartz and feldspar crystals, 10-20 percent; traces of biotite, magnetite, manganese oxide, and lithic fragments; some calcite veinlets and masses, <2 mm in width and diameter, respectively; core, 1,255-1,265 ft, shows 10 fractures dip 15°, 44°, 60°, 65°, 75°, and 70°-90°, some with pale reddish brown clay and slickensides, some filled with calcite veinlets <2.5 mm thick, one 75°-fracture displaces a 44°-fracture by 5 mm; many small fractures filled with dusky-yellow clay dip 10° at 1,262 ft. . .	30	1,265
Tuff, clayey and zeolitized, pumiceous; dusky red; similar to tuff in interval 1,235-1,265 ft	20	1,285

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Tuff, very densely zeolitized, pumiceous; light red; pumice, white to grayish yellow, 30 percent; quartz and feldspar crystals, 10-20 percent; biotite, and magnetite, each <5 percent; trace of red iron-oxide stains; gray, black, and brown lithic fragments, <5 percent; many small calcareous specks, <0.5 mm across	35	1,320
Tuff, clayey, pumiceous; pale to dark reddish brown; similar to interval 1,255-1,265 ft, but pumice all altered to calcareous clay; core, 1,331-1,337 ft shows 7 fractures dip 20°, 42°, 53°, 60°, 74°, 80°, and 90°, some intersect, most filled with calcite veinlets, one contains red-clay slickensides; 10 fractures at 1,333 ft contain manganese oxide	17	1,337
Tuff, clayey, crystal; pinkish gray; quartz and feldspar crystals, 60-70 percent;		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
pumice, white to yellowish gray, altered to clay, <2.5 mm across, 15 percent; biotite, <5 percent; traces of magnetite, small manganese-oxide masses, and red lithic fragments with grayish-olive halos; core, 1,337-1,341 ft, shows 3 fractures dip 45°, 45°, and 65°, filled with calcite veinlets or clay, 0.25-5 mm wide	18	1,355
Limestone of Paleozoic age		
Limestone, very fine grained; mostly medium gray but ranging from very light gray to medium dark gray; white to clear calcite veinlets, 5 percent.	35	1,390
Limestone (cored interval), very fine grained; laminated, dip 35°-40°; medium dark gray to dark gray, mottled grayish-orange pink and light brown parallel to bedding; includes two fault breccias <150 mm wide cemented by yellowish-gray and pale brown calcite, intersected by both high- and low-angle veinlets 1-25 mm wide;		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
veinlets total <5 percent, consist of white to clear calcite and a little quartz, three have pale red slickensides; a few styolites with moderate red clay coatings; elongate vugs, not interconnected, <10 percent	9	1,399
Limestone, very fine grained; light gray to medium dark gray, mottled grayish-orange pink; white, clear, and yellowish-gray calcite veinlets, 10 percent; some styolites coated with moderate reddish-brown clay	11	1,410
Limestone, dolomitic (cored interval); very fine grained, laminated, dip 35°; very irregularly mottled, light gray and medium dark gray with some light brownish gray; one older breccia next to slickensided fracture dipping 25°, 20 mm wide, cemented by grayish-orange pink calcite; white to clear calcite veinlets, 5 percent; abundant elongate		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
vugs in veinlets range from minute to as much as 5 mm wide by 125 mm long; some styolites coated with pale reddish-brown clay.	5	1,415
Limestone, dolomitic, very fine grained; light gray to medium dark gray, some light olive gray; core, 1,425-1,434 ft, shows mottling both irregularly and parallel to laminae; dip 45°; white to clear calcite veinlets <10 mm wide, most at high angles to bedding, <15 percent; veinlets contain vugs ranging from minute to as much as 25 mm wide by 125 mm long; five older fractures coated with pale reddish-brown slickenslides and dipping 40°-60° themselves contain calcite veinlets; abundant styolites along and across laminae. . . .	30	1,445
Limestone, dolomitic, very fine grained; mostly light gray, some medium gray; white,		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
clear, and grayish-pink calcite, probably from veinlets, 50-70 percent.	5	1,450
Limestone, dolomitic, very fine grained; between light gray and medium light gray, with some light brownish gray; white to clear calcite from veinlets, <5 percent. .	5	1,455
Limestone, dolomitic (cored interval) very fine grained; laminated, dip 35°; upper half medium dark gray with some grayish-orange pink, lower half medium light gray with mottling parallel to laminae; breccia in middle of core cemented with white to clear calcite containing two elongate vugs 125 mm long; abundant white to clear calcite veinlets, in upper half chiefly at high angles and <1 mm wide, in lower half <35 mm wide and containing many elongate vugs; possible slickensides in fractures parallel to bedding; styolites,		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
sparse and coated with pale reddish-brown clay in upper half, abundant in lower half.	10	1,465
Limestone, very fine grained; medium light gray to light gray; white to clear calcite from veinlets, 10 percent; some red stained clay-coated styolites or fractures	5	1,470
Limestone, very fine grained; mostly medium gray; white to clear calcite from veinlets, 5-10 percent	20	1,490
Limestone, dolomitic (cored interval) very fine grained; laminated, dip 3°-10°; upper part between light gray and medium gray with light brownish gray along laminations; lower part, very light gray with yellowish gray to very pale orange laminations; some mottling parallel to laminae; abundant white to clear calcited-filled fractures <25 mm wide in at least two		

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
intersecting sets, 5 percent; some fractures in upper half dip 65° and show displacements as much as 4 mm, one has slickensides; calcite fillings contain abundant interconnected vugs as much as 150 mm long in lower half, vug at bottom caused core to crumble, one vug contains some quartz crystals; abundant styolites coated with reddish-brown clay both parallel and across bedding	10	1,500
Limestone, very fine grained; mostly medium gray, some light brownish gray, sparse light olive gray and between pale red and medium gray; white to clear calcite from veinlets, 10 percent	20	1,520
Limestone, very fine grained; mostly medium dark gray to light gray, some very pale orange, sparse pale red; white to clear calcite from veinlets, 10 percent	18	1,538

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Limestone, (cored interval) very fine grained; dip 20° above vuggy calcite-filled fault at 1,541 ft and 40° below; upper part mostly very light gray to medium gray with some light brownish gray to pale red; lower part mostly medium gray to dark gray with part between grayish orange and light olive gray; abundant white to clear high-angle calcite veinlets in at least two sets, 5 percent; veinlets dipping 55°-60° displace laminae by as much as 10 mm; calcite vein fillings contain abundant vugs ranging from minute to 5 mm wide by 150 mm long; abundant styolites coated with pale reddish-brown clay, many parallel to bedding.	10	1,548
Limestone, very fine grained; medium gray, brownish gray, light brownish gray, and pale red; white to clear calcite from veinlets, 5 percent	22	1,570

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Limestone, very fine grained; mostly pale reddish brown and medium gray with sparse grayish-orange pink; white to clear calcite from veinlets, 5-10 percent. . . .	20	1,590
Limestone, very fine grained; mostly medium dark gray, pale reddish brown, and pale red, some yellowish gray; white to clear calcite from veinlets, 5 percent.	10	1,600
Limestone, very fine grained; medium gray to medium dark gray, 60-70 percent; pale red to pale reddish brown, 30-40 percent; white to clear calcite from veinlets, 10 percent.	30	1,630
Limestone, very fine grained; similar to unit above but contains 10 percent yellowish-gray limestone	10	1,640
Limestone, very fine grained; mostly medium light gray to medium gray; some medium dark gray and light brownish gray; white to clear calcite from veinlets, 10 percent. .	10	1,650

Appendix D.--Log of test well C, based on microscopic examination of drill cuttings and cores--Continued

	Thickness (feet)	Depth (feet)
Limestone, very fine grained; medium dark gray, 70 percent; pale red to pale reddish brown, 30 percent; white to pinkish gray-calcite from veinlets, 10 percent	10	1,660
Limestone, very fine grained; mostly medium light gray and light brownish gray with pale red; white to clear calcite from veinlets, <10 percent	20	1,680
Limestone, very fine grained; mostly medium light gray with light olive gray and pale red; white to clear calcite from veinlets, 5 percent	21	1,701

Appendix E.--Cored intervals in test well C

Depth interval (feet)	Length of cored interval (feet)	Length of core recovered (feet)	Percent recovered
503- 509	6	1.6	27
562- 570	8	8	100
610- 620	10	9	90
652- 662	10	10	100
700- 707	7	3.6	52
748- 758	10	10	100
850- 860	10	9.2	92
952- 962	10	10	100
1,046-1,056	10	10	100
1,150-1,160	10	6.2	62
1,255-1,265	10	10	100
1,331-1,341	10	10	100
1,390-1,399	9	5	56
1,410-1,415	5	3	60
1,425-1,434	9	9	100
1,455-1,465	10	10	100
1,490-1,500	10	7	70
1,538-1,548	10	9	90
Average recovery	---	---	86

Appendix F.--Log of initial pilot hole for test well C, based on microscopic examination of drill cuttings and core

	Thickness (feet)	Depth (feet)
Valley fill		
Playa deposits		
Clay and silt, light brown to pale yellowish brown	25	25
Alluvium		
Sand, silty, and gravel, pale yellowish brown to grayish orange	174	199
Oak Spring Formation		
Topopah Spring Member		
Tuff, welded, spherulitic; pale red, some grayish red; flattened pumice, 70 percent; quartz and feldspar crystals, 15 percent; traces of biotite and magnetite; quartz veinlets <1 mm wide; core, 204-205 ft, shows flattened pumice dips 20°, fractures dip 70°, 80°, and 90°; one 90° fracture filled with quartz, <0.5 mm wide	36	235
Tuff, welded, spherulitic; pale to grayish red with some very pale orange.	35	270
Tuff, welded, spherulitic; between pale brown and pale red.	45	315

Appendix F.--Log of initial pilot hole for test well C, based on microscopic examination of drill cuttings and core--Continued

	Thickness (feet)	Depth (feet)
Tuff, welded, spherulitic; between grayish orange and pale yellowish brown, mottled grayish red; flattened pumice mottled white to very pale orange, mostly <4 mm across but maximum 15 mm, 15-30 percent; quartz and feldspar crystals, <5 percent; traces of biotite, magnetite, and manganese oxide; cores, 334-344 ft, 349-351 ft, and 356-366 ft, show flattened pumice dips 7^{o}-10^{o}; most fractures in upper core dip 20^{o}-45^{o} but some are vertical; one quartz veinlet	60	375
Tuff, welded to partially welded; grayish orange, mottled grayish red to grayish brown.	10	385
Tuff, partially to incipiently welded; light brown; abundant altered glass shards and pumice fragments	15	400
Tuff, zeolitized; light brown to grayish-orange pink; abundant altered glass shards and pumice fragments; minute		

Appendix F.--Log of initial pilot hole for test well C, based on microscopic examination of drill cuttings and core--Continued

	Thickness (feet)	Depth (feet)
spherical zeolites, white to grayish orange, <0.5 mm across, some hollow. . . .	44	444
Lower member		
Tuff, zeolitized, pumiceous; very pale orange to white; pumice, 50 percent; quartz and feldspar crystals, 10 percent	16	460
Tuff, zeolitized, pumiceous; grayish-orange pink; pumice 50 percent; quartz and feldspar crystals, 15 percent	20	480
Tuff, zeolitized, pumiceous; light red, pale red, and moderate reddish orange; pumice 50 percent; quartz and feldspar crystals, 15 percent; biotite, 5 percent. .	20	500
Tuff, zeolitized, pumiceous; mostly white to very light gray with some light yellowish gray; pumice, 50 percent; quartz and feldspar crystals, 10 percent	55	555
Tuff, zeolitized, crystal; fine grained, laminated; most is pale reddish brown with a little moderate reddish brown and moderate reddish orange; pumice, 15 percent;		

Appendix F.--Log of initial pilot hole for test well C, based on microscopic examination of drill cuttings and core--Continued

	Thickness (feet)	Depth (feet)
quartz and feldspar crystals in sizes ranging from silt to fine sand, 20-60 percent; sparse calcite cement and veinlets	60	615
Tuff, similar to unit above but moderate orange pink to pale reddish brown[1] . . .	35	650
Tuff, zeolitized, pumiceous; white; pumice, 50 percent; quartz and feldspar crystals, 15 percent	5	655
Tuff, zeolitized and clayey, pumiceous; light yellowish gray; pumice, 60 percent; quartz and feldspar crystals, 10 percent. . . .	19	674
Tuff, zeolitized, pumiceous; white; pumice, 50 percent; quartz and feldspar crystals, 15 percent	11	685
Tuff, zeolitized, pumiceous; light yellowish gray; pumice 60 percent; quartz and feldspar crystals, 10 percent.	15	700
Tuff, zeolitized, pumiceous; moderate orange pink; pumice, moderate orange pink to white		

[1] Vermiculite, golden to black, was added to the well at a depth of 650 ft and contaminates samples below this depth.

Appendix F.--Log of initial pilot hole for test well C, based on microscopic examination of drill cuttings and core--Continued

	Thickness (feet)	Depth (feet)
<1 mm across, 40 percent; quartz and feldspar crystals, 5 percent	25	725
Tuff, zeolitized, pumiceous; light red to moderate orange pink; pumice, <2 mm across, 40 percent; quartz and feldspar crystals, 5 percent	28	753

Appendix G.--Equipment for pumping tests

The pump and other equipment used in the pumping tests in well C are summarized below:

Pumping tests 1 and 2

Pump assembly:

Pump: Reda submersible turbine, model 95D47E, 95 stages; rated at 50 horsepower at 3,450 rpm; intake set at 1,633 feet below land surface.

Check valves: at 850 and 1,620 ft below land surface.

Power: Uni-control AC generator, driven by an Allis Chalmers diesel engine.

Discharge rate: measured with 10-gal can in test 1, and with 55-gal barrel in test 2.

Water levels: measured by 2-conductor cable with bronze-magnesium "potential" cell.

Pumping test 3

Pumps: Winthroath 27-stage submersible turbine; rated at 50 horsepower at 1,800 rpm; intake set at 1,590 ft below land surface.

Winthroath 46-stage submersible turbine booster; rated at 100 horsepower at 1,800 rpm; set at depth 918 ft below land surface.

Check valves: at 495, 886, and 1,571 ft below land surface.

Discharge rate: measured with Hersey-Sparling meter K325.

Water levels: measured by electrical water-level indicator consisting of cable, battery, milliameter, and electrode.