RESULTS OF GEOHYDROLOGIC TEST DRILLING IN THE EASTERN SNAKE RIVER PLAIN, GOODING COUNTY, IDAHO

By R. L. Whitehead and G. F. Lindholm

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[Plate in pocket at back of report]

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CONVERSION FACTORS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
foot (ft)	0.3048	meter
foot squared per day (ft^2/d)	0.0929	meter squared per day
inch (in.)	25.40	millimeter
mile (mi)	1.609	kilometer

Temperature in °C (degrees Celsius) can be converted to degrees °F (degrees Fahrenheit) as follows:

$$°F = (1.8)(°C) + 32$$

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ABSTRACT

A 1,123-foot test hole was core drilled near Wendell, Idaho, during 1981-82 as part of the Snake River Plain regional aquifer study. The test hole provided geologic and hydrologic information in the vicinity of Thousand Springs, the major discharge area for the eastern Snake River Plain. The hole penetrated an upper basalt unit from 1 to 403 feet, an intermediate unconsolidated sedimentary rock unit from 403 to 590 feet, and a lower basalt unit from 590 to 1,073 feet.

Drilling verified that the upper several hundred feet of high-resistivity material, as determined by surface electrical soundings, is basalt. Core examinations, laboratory analyses, and correlation with other drill holes indicated that the basalt is typical of Quaternary basalt of the Snake River Group.

Correlation with other drill holes and comparison with rock outcrops near the Snake River and in the Snake River canyon suggest that the underlying sediments and lower basalt unit are parts of the Tertiary and Quaternary Glenns Ferry Formation and Tertiary Banbury Basalt, both in the Idaho Group.

Water-level measurements in piezometers installed in the test hole verify upward movement of water, as expected in a ground-water discharge area. Hydraulic head in the bottom of the hole is about 155 feet higher than the water table.

Lithologic sequence in the test hole correlates well with sequences in deep drill holes at scattered locations on the plain.

INTRODUCTION

This report is one in a series resulting from the U.S. Geological Survey's Snake River Plain RASA (Regional Aquifer-Systems Analysis) study that began in 1979. One of the purposes of the study was to refine knowledge of the regional ground-water flow system (Lindholm, 1981, p. 1).

The main purpose of the test drilling (fig. 1) for this study was to help determine subsurface geology and its controls on water movement, particularly in the 40-mi reach of the Snake River from Twin Falls to Bliss, the major discharge area for the eastern Snake River Plain aquifer. In this reach, discharge from the aquifer is from springs that issue from the canyon wall above the river. In 1980, 4.3 million acre-ft of ground water discharged along the 90-mi reach of the river from Milner to King Hill (Kjelstrom, 1984).

Few drill holes penetrate the basalt aquifer more than a few tens of feet. A series of vertical electrical resistivity soundings were made (R. J. Bisdorf, U.S. Geological Survey, written commun., 1982) to gain a better understanding of aquifer thickness and areal extent of major rock types (figs. 2 and 3). Results of the resistivity study and a related gravity model study were summarized by Whitehead (1984).

To verify interpretations from these geophysical studies, to estimate hydraulic properties of rocks in the subsurface, and to determine variations of hydraulic head with depth, a 1,123-ft test hole was drilled in T. 7 S., R. 15 E., NE¼NW¼SW¼ sec. 12, Gooding County.

Acknowledgments

The assistance of employees of the U.S. Bureau of Land Management, Shoshone District Office, and local cattle association members in allowing access to the test site is gratefully acknowledged.

Additional thanks are given to Roger Jensen and Jeff Bagby of the U.S. Geological Survey, Idaho National Engineering Laboratory, who provided borehole geophysical logging services. Kim Bigadenetta, Idaho Department of Water Resources, Boise office, ran a water-temperature survey in the test hole. Contractor for the hole was R. P. Jones Core Drilling Company, Boise, Idaho. Eaton Drilling and Pump Service, Wendell, Idaho, subcontracted rotary drilling in the upper part of the hole. Mineralogic and chemical identifications of selected rocks from the test hole were made by P. P. Hearn and B. A. Scott, U.S. Geological Survey, Geologic Division; and W. W. Wood, U.S. Geological Survey, Water Resources Division, using a scanning electron microscope. Their assistance is greatly appreciated.

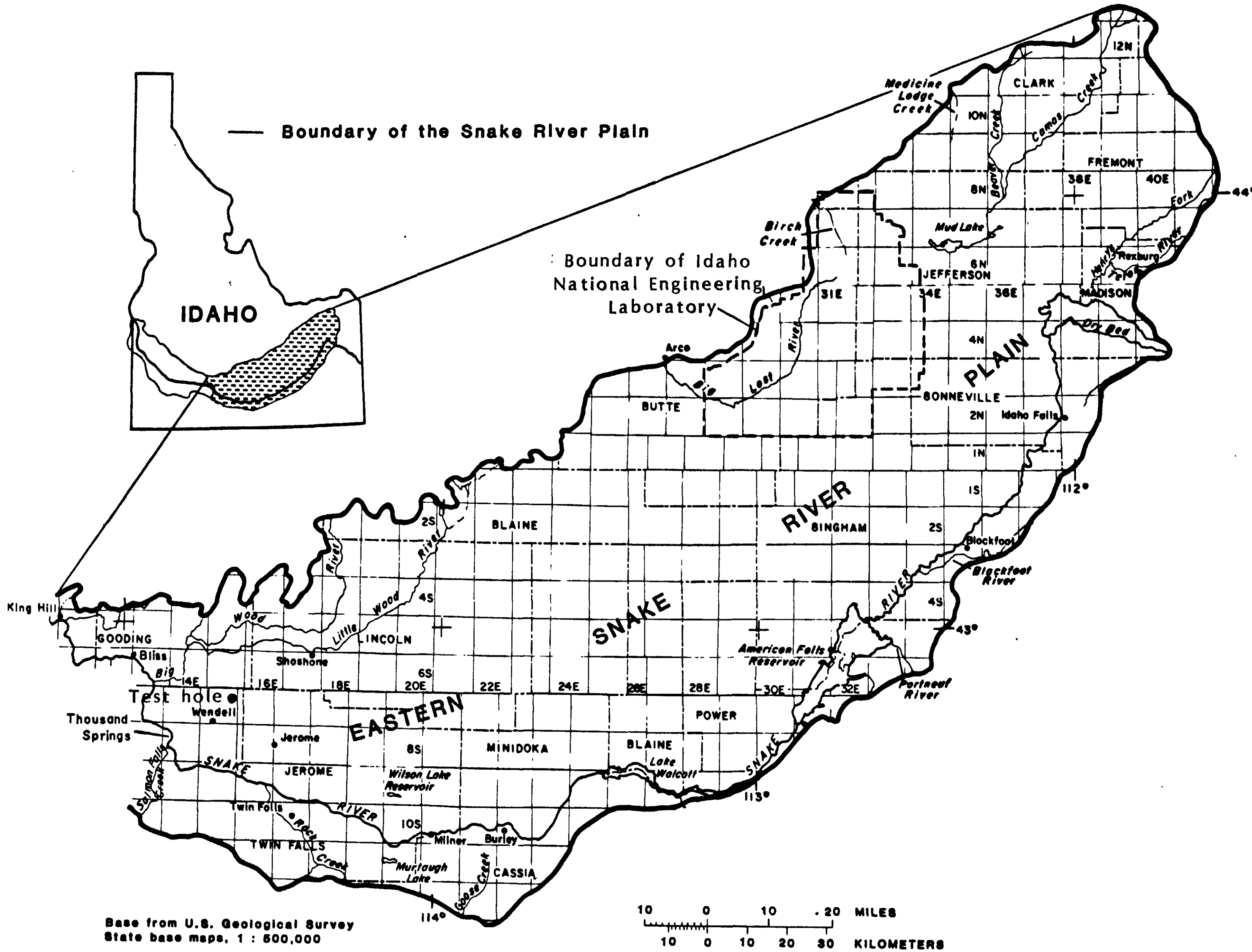


Figure 1.--Eastern Snake River Plain and location of test hole.

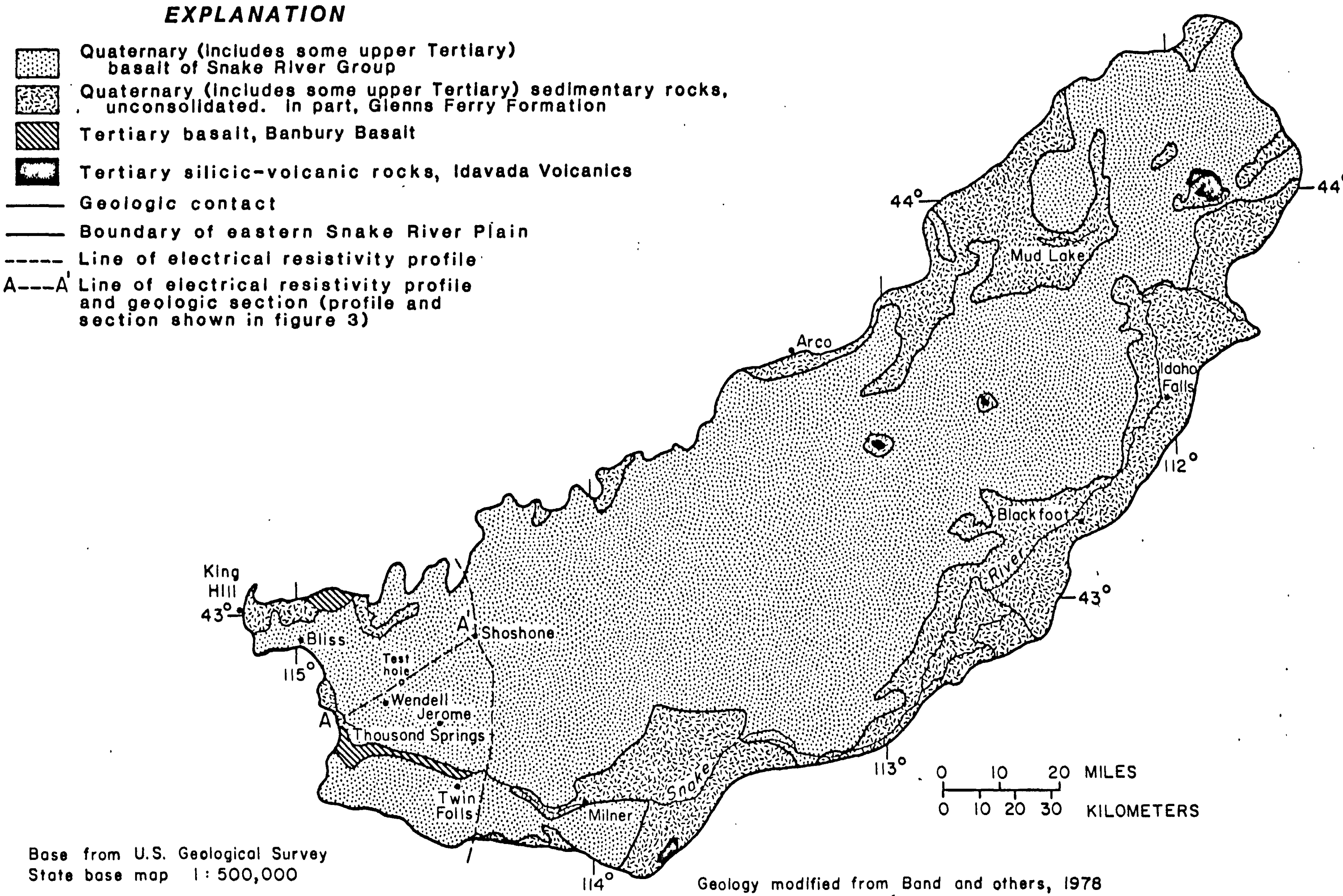
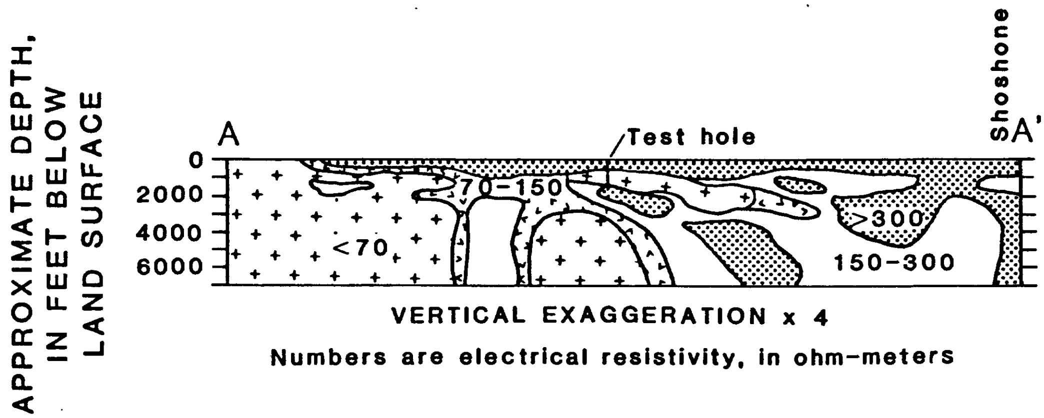


Figure 2.--Geology of eastern Snake River Plain, location of resistivity profiles, line of section, and test hole.



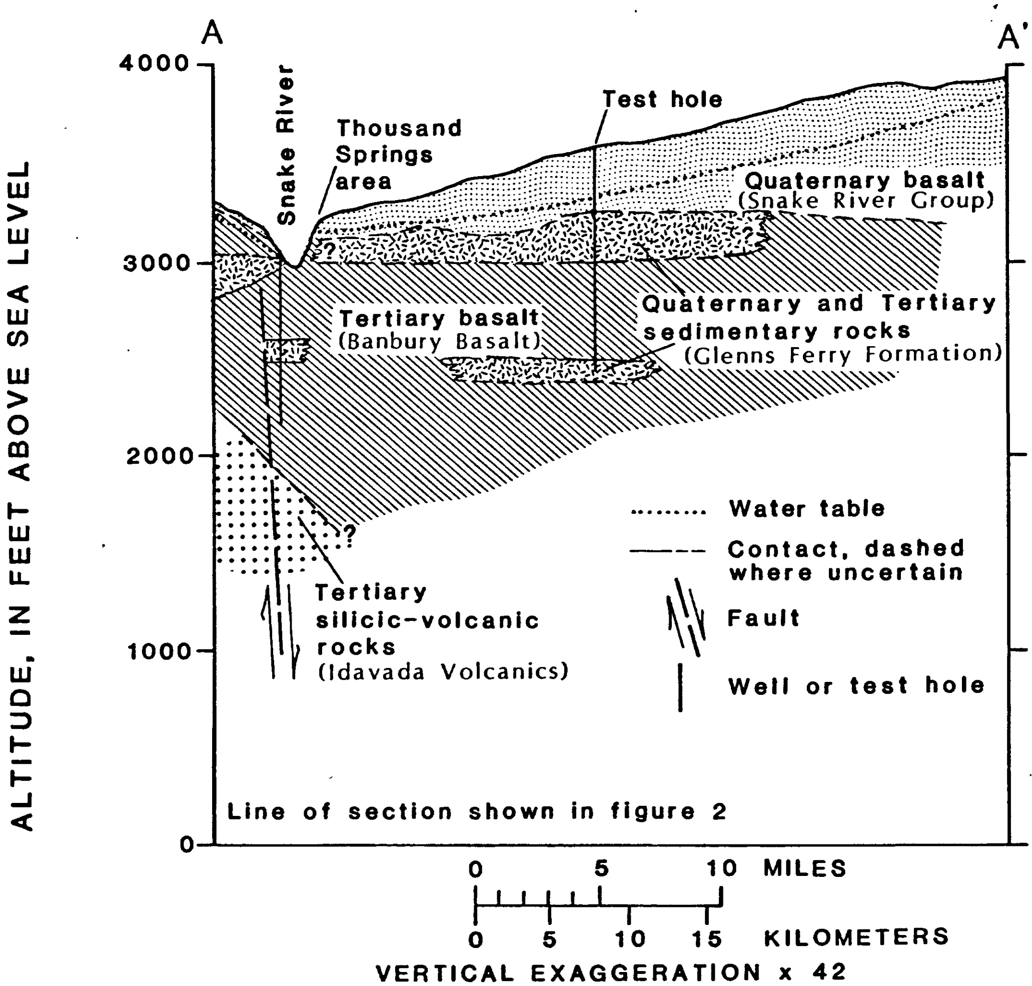


Figure 3.--Generalized electrical resistivity profile and geologic section A - A' from Shoshone to Thousand Springs area.

GEOLOGIC SETTING

Geology of the eastern Snake River Plain is dominated by Quaternary basalt of the Snake River Group (fig. 2). Quaternary basalt, which may include some upper Tertiary basalt, is estimated to be as much as 5,000 ft thick in the central part of the plain (Blaine, Power, and Minidoka Counties); as much as 3,500 ft may be saturated (Whitehead, 1984). The basalt has irregular to columnar jointing with zones of cinders and highly scoriaceous fragments. Thickness of individual flows underlying the plain is highly variable but averages about 20-25 ft (Mundorff and others, 1964, p. 143). Contacts between flows are commonly rubbly and have high porosities and hydraulic conductivities, which make interflow zones major avenues for horizontal movement of water.

Unconsolidated sedimentary rocks are intercalated with the basaltic rocks, chiefly along the plain's margins. Pre-Quaternary rhyolitic, basaltic, granitic, and sedimentary rocks are outside of and adjacent to the plain's boundary. Except in a few places, these older rocks have not been proven to underlie the plain. However, Tertiary basalt (Banbury Basalt of Idaho Group), exposed in the Snake River canyon wall between Twin Falls and King Hill (Covington, 1976; Malde and Powers, 1972), underlies basalt of the Snake River Group (fig. 2).

Subsurface geology of the plain is poorly defined. Thickness of basalt of the Snake River Group and of older rocks is not well known. Malde and Powers (1972) described the stratigraphic sequence in the Snake River canyon from near Twin Falls to King Hill. Malde's (1972, p. D11) descriptions of flood-plain and valley-border facies of the Glenns Ferry Formation were useful in tentatively identifying rocks penetrated by test drilling.

DRILLING AND COMPLETION METHODS

Drilling began in September 1981 and was completed in April 1982. A 10-in. diameter hole was air rotary drilled to 19 ft and permanent surface casing was installed. A 6-in. diameter hole was drilled to 277 ft. Foam was used to lubricate the drill bit and to aid in return of drill cuttings, which were collected every 10 ft. At the time of drilling, the water table was about 230 ft below land surface.

Basalt underlying the Snake River Plain commonly includes highly porous zones which, if saturated, often make return of rotary drill cuttings impossible. Therefore, to maximize geologic and hydrologic information return, consolidated rocks from 277 to 480 ft and from 610 to 1,072 ft were core drilled (3-in. diameter hole, 1.9-in. diameter core). Unconsolidated rocks from 480 to 610 ft were rotary drilled because core recovery was not possible. Drill cuttings were collected as described above. From 1,092 to 1,123 ft, core recovery was not possible. Drilling was stopped at 1,123 ft because sand under hydraulic head plugged the drill stem.

Piezometers (pl. 1) were installed in the test hole to: (1) Define hydraulic head changes with depth, (2) estimate the impedence of different rock types to vertical movement of water, and (3) monitor head changes over time. Piezometers are 3/4-in. (inside diameter) black iron pipe coupled every 21 ft. Openings near the end of each string of pipe, either a series of 1/8-in. drilled holes or an attached sand point, were isolated from the rest of the hole by concrete packers. The annular space opposite pipe openings was filled with sand or pea gravel, as was the drill hole between monitored intervals. Piezometers were numbered 1 to 5, from the shallowest to the deepest. A 2.4-in. diameter hole was cored (1.4-in. diameter core) to 262 ft to monitor the upper part of the aquifer (100 percent core recovery from 6 to 262 ft). Piezometer 1 was located in a nearby second hole because of installation problems; piezometers 2 through 5 were in the first hole. In this report, both holes are referred to collectively as the test hole.

A 4-ft square by 1-ft thick concrete slab was poured on the ground around the surface casings. Protective steel caps were fitted to the tops of the casings (fig. 4).

DESCRIPTION OF CORE AND GRAB SAMPLES

Core and grab samples (table 1, back of report) were described by using hand lenses and by testing with dilute hydrochloric acid. Individual flows were defined by visually identifying contacts between successive flows on core samples. Size and percentage of vesicular porosity were estimated visually from horizontal cross sections of the core. The estimates were based on comparison charts (Terry and Chilingar, 1955). The variability of vesicles in basalt is shown on plate 1 and is described in table 2.

Vesicularity and color of a typical Snake River Plain basalt flow as determined from visual inspection of the core are as follows: (1) The upper part is very vesicular to vesicular and is distinctively grayish-red purple, (2) the central part is generally much less vesicular and is mostly

A

B

Figure 4.--Completed test holes. A--test holes with locking caps installed; smaller cylinder welded to side of cap is the padlock protector. B--view into 10-in. casing (cap removed) showing piezometers 2, 3, 4, and 5.

Table 2.--Summary of vesicularity observed in core samples

Vesicularity, based on classification by Nace and others (1975, p. B43)	Basalt of Snake River Group (1 foot below land surface to 403 feet), as percentage of total 402-foot interval	Banbury Basalt of Idaho Group (590 to 1,073 feet), as percentage of total 483-foot interval
Very vesicular (more than 25 percent voids by volume)	4	17 (70 percent of upper 114 feet is very vesicular; may be part of Idaho Group)
Vesicular (10-25 percent voids by volume)	31	11
Slightly vesicular (1-10 percent voids by volume)	22	18
Minutely vesicular (ordinarily less than 5 percent voids by volume; diameter less than 0.04 inch)	15	1
Crystalline (less than 2 percent intercrystalline voids by volume)	28	53 (100 percent of lower 146 feet is crystalline)

gray, and (3) the lower part is crystalline and gray. Hydraulic conductivity of basalt depends on the degree of interconnection between vesicles and other fractures in a flow or series of flows.

Basalt of the Snake River Group is typically more vesicular than Banbury Basalt; secondary minerals fill many vesicles in the Banbury Basalt.

Lithologic Log

A lithologic log was compiled from examination of core and grab samples (pl. 1). Flow contacts or cooling unit boundaries are shown on the log as horizontal lines extending beyond the left side of the log. Most boundaries were readily identified by core examination, but some were less certain. Typical texture and color variations in individual flows, as described in the previous section, were not always apparent. Wide vertical spacing indicates high hydraulic conductivity; close spacing indicates low hydraulic conductivity. The spacing of vertical lines (basalt symbol) shows, in a general way, the relative hydraulic conductivity of basalt units. As shown on plate 1 and described in tables 1 and 2, the basalt ranges from very vesicular with high hydraulic conductivity to crystalline with little or no hydraulic conductivity.

Mineralogic and Chemical Analyses

Diagenetic minerals formed by the interaction of water with the rock matrix were identified on selected core samples by using scanning electron microscope-energy dispersive x-ray fluorescence techniques. Results of the analyses are summarized in table 3.

W. W. Wood and W. H. Low (U.S. Geological Survey, written commun., 1983) used data from these analyses to determine solute budgets for the regional basalt aquifer underlying the eastern Snake River Plain. Chemical analyses of basalts in the test hole are similar to those of basalt of the Snake River Group from other areas on the plain (table 4).

GEOPHYSICAL LOGS

Natural gamma, gamma-gamma, and neutron logs (pl. 1) were run in the drill stem to a depth of 986 ft. These geophysical logs helped determine lithology where samples were lacking and establish more accurately the depths of samples. Although each log provides some information about rock units penetrated, the suite of logs provides much additional information.

Table 3.--Mineralogic analyses of selected samples of basalt[1]
(Analyses by scanning electron microscope-energy dispersive x-ray fluorescence techniques)

Depth, in feet below land surface	Description	Modal proportions, in percent	
223.2-223.4	Vesicular, moderate alteration on vesicle rims, no fillings; olivine phenocrysts, medium to large, some iddingsite alteration; plagioclase phenocrysts, zoned and large, also small to medium unzoned laths; orthopyroxene microphenocrysts; matrix consists of altered opaques plus fibrous alteration products.	Olivine	17
		Plagioclase	38
		Orthopyroxene microphenocrysts	2
		Orthopyroxene, ophitic, altered	26
		Opaques	9
		Voids, unfilled	8
241.6-241.7	Highly vesicular, vesicles show fillings of both detrital material (possibly volcanic ash) and isotropic crystalline material (possibly halloysite), vesicle rims show minimal oxide alteration; plagioclase phenocrysts, medium, unzoned laths; orthopyroxene phenocrysts (hypersthene), medium, subhedral; matrix consists of small anhedral orthopyroxene and opaques and small to medium unzoned plagioclase laths; opaques mostly primary igneous phase.	Plagioclase phenocrysts	6
		Orthopyroxene phenocrysts	2
		Plagioclase matrix	13
		Orthopyroxene matrix	22
		Opaques	18
		Voids	34
		Void filling, isotropic	5
298.5-298.8	Vesicular, vesicle rims show iron-oxide alteration, vesicles filled with fine-grained material (possibly volcanic ash) of quartz, plagioclase, calcite, clays, and opaques; fillings altered (clay?, prehnite?, calcite?), possibly minor hydrothermal alteration after deposition; olivine microphenocrysts, subhedral; plagioclase laths, unzoned; orthopyroxene microphenocrysts, subhedral; matrix is devitrified glass, fibrous-brown alteration products (iron oxide and chlorite-serpentinite).	Olivine	8
		Plagioclase	32
		Orthopyroxene	9
		Opaques	39
		Voids, includes fillings	12
315.5-315.8	Highly vesicular, vesicle rims strongly altered to iron oxides, several vesicles lined with isotropic semicrystalline substance (possibly halloysite); olivine microphenocrysts; plagioclase microphenocrysts, medium laths, unzoned, pilotaxitic texture in some; orthopyroxene microphenocrysts; matrix is highly altered, opaque iron oxide and fibrous-brown chlorite-serpentinite, this material probably was ophitic orthopyroxene in primary basalt.	Olivine microphenocrysts	1
		Plagioclase microphenocrysts	41
		Orthopyroxene microphenocrysts	2
		Opaque matrix	35
		Voids, includes fillings	19
322.5-322.7	Vesicular, vesicle rims show minor alteration, no visible vesicle fillings, other vesicle rims strongly altered to iron oxide; plagioclase microphenocryst laths, unzoned; orthopyroxene microphenocrysts, small to medium grains (brownish-green hypersthene); matrix consists of altered ophitic orthopyroxene (fibrous chlorite-serpentinite) plus iron oxide secondary alteration.	Plagioclase microphenocrysts	27
		Orthopyroxene microphenocrysts	34
		Opaque matrix	23
		Voids	16
323.8-324.0	Vesicular, vesicle rims slightly altered, no void fillings; olivine microphenocrysts (altered to iron oxide and iddingsite); plagioclase microphenocrysts (altered slightly to iron oxide) anhedral, few are euhedral; orthopyroxene microphenocrysts (altered slightly to iron oxide), slightly pleochroic brown yellow green.	Olivine microphenocrysts	9
		Plagioclase microphenocrysts	30
		Orthopyroxene microphenocrysts	21
		Opaque matrix	20
		Voids	20

Table 3.--Mineralogic analyses of selected samples of basalt[1]-Continued

Depth, in feet below land surface	Description	Modal proportions, in percent	
355.0-355.2	Vesicular, vesicle rims altered to iron oxide, some vesicles filled with fragmental detrital material or ash; olivine microphenocrysts, iddingsite alteration; plagioclase microphenocrysts, altered; opaque matrix iron oxide secondary alteration, includes very small orthopyroxene aggregates.	Olivine microphenocrysts	11
		Plagioclase microphenocrysts	38
		Orthopyroxene matrix	5
		Opaque matrix	25
		Voids, includes fillings	21
363.6-363.8	Vesicular, vesicle rims altered to iron oxide, no fillings; olivine microphenocrysts, some alteration to iddingsite; plagioclase microphenocrysts, unzoned, euhedral to subhedral, some pilotaxitic areas; orthopyroxene microphenocrysts; matrix shows alteration to iron oxide and fibrous chlorite-serpentinite (possibly from original ophitic orthopyroxene).	Olivine microphenocrysts	11
		Plagioclase microphenocrysts	39
		Orthopyroxene microphenocrysts	1
		Opaque matrix, includes alteration products	27
		Voids	22
403.4-403.5	At contact with sedimentary rocks; plagioclase, euhedral to subhedral laths; orthopyroxene, ophitic (some alteration, deuteric); orthopyroxene microphenocrysts; isotropic phenocrysts, clear, high relief, few opaques.	Plagioclase microphenocrysts	30
		Orthopyroxene, ophitic	55
		Orthopyroxene microphenocrysts	7
		Isotropic phenocrysts	6
		Opaques	2
619.7-620.0	Vesicular, vesicles minor, no alteration on rims; olivine microphenocrysts, partly altered to iddingsite; plagioclase microphenocrysts, small to medium, euhedral to subhedral, show primary volcanic texture; orthopyroxene, ophitic; opaques show primary crystallization.	Olivine microphenocrysts	4
		Plagioclase microphenocrysts	44
		Orthopyroxene, ophitic	35
		Opaques	13
		Voids	4
627.4-627.6	Vesicular, vesicles filled with detrital material and isotropic clay; olivine microphenocrysts, some alteration to iddingsite; plagioclase microphenocrysts, small euhedral to subhedral laths; matrix highly altered to iron oxide, opaques from primary opaques plus ophitic orthopyroxene.	Olivine microphenocrysts	1
		Plagioclase microphenocrysts	22
		Orthopyroxene, ophitic, altered	5
		Opaque matrix	29
		Voids, includes fillings	43
1,067.2-1,067.5	Slightly vesicular, no alteration of the few vesicle rims, primary igneous texture; olivine microphenocrysts, some alteration to iddingsite; plagioclase microphenocrysts; orthopyroxene, ophitic texture; opaques appear as primary igneous phases.	Olivine microphenocrysts	4
		Plagioclase microphenocrysts	41
		Orthopyroxene microphenocrysts	46
		Opaques	9
		Voids	0

[1]Analyses by W. W. Wood and P. P. Hearn (U.S. Geological Survey, written commun., 1983), Reston, Va.

Table 4.--Comparison of chemical analyses of basalts from the test hole with basalt of the Snake River Group from other areas on the plain

	Test hole (depth, in feet below land surface)	Chemical analyses, in percent of total									
		SiO_2	Al_2O_3	FeO	MgO	CaO	TiO_2	Na_2O	P_2O_5	K_2O	MnO
Basalt of the Snake River Group[1]	223.2 - 223.4	46.3	13.8	14.67	6.79	9.60	3.36	2.8	0.84	0.74	0.21
	241.6 - 241.7	46.3	12.3	15.30	5.88	9.62	4.13	2.5	1.08	.75	.25
	292.7 - 298.0	46.3	14.8	12.87	8.63	9.98	2.53	2.5	.48	.59	.20
	[2]298.5 - 298.8	43.0	11.9	11.22	6.26	16.66	2.54	2.1	.51	.56	.16
	315.5 - 315.8	46.8	13.6	14.09	7.10	9.93	3.20	2.7	.56	.65	.21
	322.5 - 322.7	47.0	13.0	14.19	6.73	10.20	3.50	2.6	.60	.66	.21
	323.8 - 324.0	47.0	13.8	13.91	7.05	9.99	3.16	2.5	.55	.66	.21
	355.0 - 355.2	46.5	13.6	14.05	7.33	10.00	3.12	2.7	.61	.64	.21
	363.6 - 363.8	46.9	14.1	13.74	6.95	10.08	3.08	2.8	.60	.60	.20
	403.4 - 403.5	47.2	13.8	14.04	7.12	10.08	3.13	2.7	.61	.61	.21
	Average............	46.3	13.5	13.81	6.98	10.61	3.10	2.6	0.64	0.65	0.21
Banbury(?) Basalt[1]	619.7 - 620.0	47.4	14.3	12.67	7.75	10.64	2.51	2.9	0.37	0.50	0.20
	627.4 - 627.6	47.0	14.3	13.00	7.30	10.73	2.64	2.3	.39	.36	.20
	1,067.2 - 1,067.5	46.7	14.7	12.06	7.15	10.64	2.66	2.7	.47	.37	.18
	Average............	47.0	14.4	12.58	7.40	10.67	2.60	2.6	0.41	0.41	0.19
	Average of 17 analyses from central part of the plain[3]............	46.4	15.1	12.10	6.83	9.64	3.07	2.7	0.86	0.65	0.20
	Average of 38 analyses from other locations on the plain[4].........	46.8	14.8	10.29	7.59	9.87	2.97	2.4	0.68	0.62	0.17

[1] Chemical analyses by x-ray fluorescence method. Analysts, P. P. Hearn and B. A. Scott (U.S. Geological Survey, written commun., 1983).

[2] Percent of total analyses 94.91; percent of total analyses for other test-hole intervals ranges from 97.63 to 99.50. Anomalous values may be due to analytical error; analyses not adjusted to 100 percent.

[3] Kuntz and Dalrymple (1979, p. 19-20). Chemical analyses by x-ray fluorescence method.

[4] H. A. Powers (U.S. Geological Survey, written commun., 1963). Analytical methods unknown.

The gamma log was particularly helpful in distinguishing sedimentary rocks from basaltic rocks. Zones of sedimentary rock and ash exhibit marked positive deflections on the gamma log. The gamma log reacts positively in these zones because naturally occurring radioisotopes are more concentrated in fine-grained sediments and ash. The gamma log indicates that clay content increases with depth in the interval from 403 to 590 ft.

Positive deflections of the gamma-gamma log indicate that the interval from 620 to 700 ft is very porous. The scale shift above 80 ft is due to the absence of fluid in the drill stem to that depth, and the positive deflection to 230 ft indicates unsaturated material outside the drill stem.

The neutron log indicates moisture content in the unsaturated zone; below the water table strong positive deflections generally indicate dense basalt.

Many factors affect the response of different logging tools. Goldstein and Weight (1982, p. 8 and 9) discussed these factors as they apply to basalt underlying the plain. Keys and MacCary (1971) detailed the application of borehole geophysics to hydrologic investigations.

WATER LEVELS

Water levels in the piezometers were measured monthly to determine seasonal trends and head variations with depth. Hydrographs for piezometers 1, 4, and 5 (fig. 5) are assumed representative of aquifers penetrated by the test hole. Each hydrograph shows a similar response to recharge that is attenuated with increasing depth. Water levels are highest in the fall, owing to recharge from surface water used for irrigation, and lowest in early summer, at the start of the irrigation season.

Hydraulic head in the bottom of the hole is about 155 ft higher than the water table. Piezometer 2 malfunctioned, possibly because of installation problems; therefore, water levels in it were unusable.

Water levels in piezometer 3 were essentially the same as those in piezometer 4. Because zones monitored by piezometers 3 and 4 are separated by a fine-grained, apparently confining sediment zone, it seems reasonable to expect that water levels in piezometer 3 would be less than measured. Perhaps packers separating the two zones were ineffective or the water level in piezometer 3 reflects upward leakage from the underlying zone.

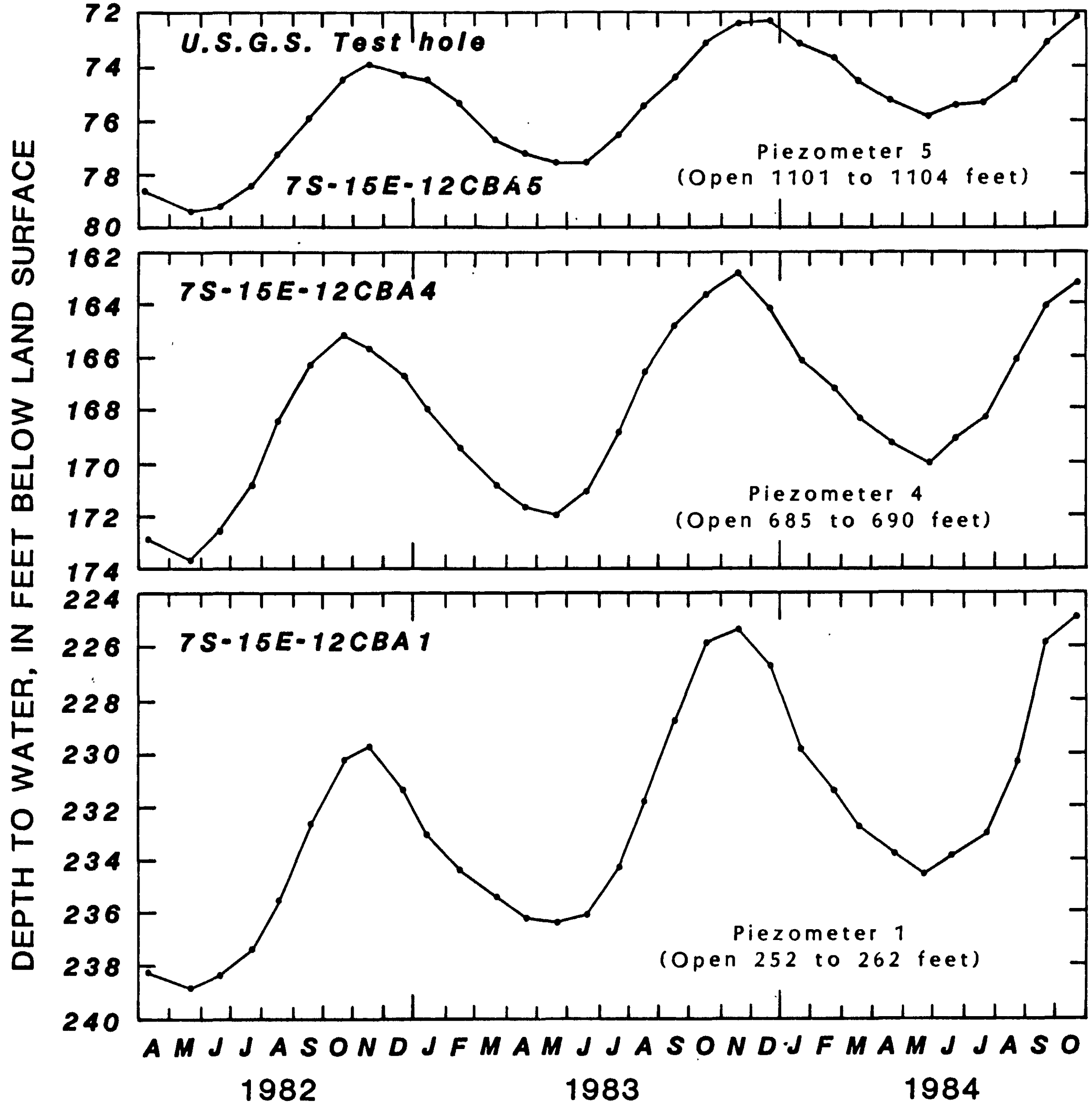


Figure 5.--Hydrographs of water levels in piezometers 1, 4, and 5.

WATER TEMPERATURE

A profile of water temperature to 1,086 ft in piezometer 5 (pl. 1) showed a gradual increase of about 1°C per 175 ft to a depth of about 950 ft. The sharper increase at 950 ft has been noted in other wells near the margins of the plain, particularly in Twin Falls County south of the Snake River (U.S. Geological Survey, unpubl. data, 1983). This change in temperature is probably near the contact between the cold-water system and the confining bed that separates it from the underlying geothermal system (Lewis and Young, 1982, p. 4). A flow meter in a well about 15 mi northwest of Twin Falls, indicated that water from a thermal system was flowing upward into the overlying cold-water system through the well bore (U.S. Geological Survey, unpubl. data, 1983).

GEOHYDROLOGIC SIGNIFICANCE OF TEST-DRILLING RESULTS

The test hole provided geologic and hydrologic information in the vicinity of Thousand Springs, the major discharge area for the regional aquifer underlying the eastern Snake River Plain. Drilling verified that the upper several hundred feet of high-resistivity materials, determined from surface electrical soundings, is basalt. Core examinations, laboratory analyses, and correlation with other drill holes indicated that the basalt is typical of Quaternary basalt of the Snake River Group. At the time of drilling, the water table was about 230 ft below land surface. Basalt composing the regional aquifer at the drill site is about 170 ft thick.

Regional ground-water flow modeling determined that transmissivity of the top 200 ft of the regional aquifer (including the 170-ft thick basalt interval mentioned above and 30 ft of underlying gravel) near the test hole is about 830,000 ft^2/d (Garabedian, 1984). Average hydraulic conductivity is about 4,150 ft/d, a high but reasonable value, considering the physical characteristics of Quaternary basalt of the Snake River Group.

The 187-ft thick interval of low electrical resistivity material that underlies the basalt consists of sediments that grade downward from gravel to clay. Correlation with other drill holes and comparison with outcrops near the Snake River suggest that the sediments are part of the Tertiary and Quaternary Glenns Ferry Formation.

The high-resistivity material underlying the sediments is another basalt unit about 480 ft thick. Eighty of the top 100 ft is a porous cinder zone with high hydraulic conductivity. If areally extensive, the cinder zone could be a good source of water. Clay fills the vesicles and thus greatly reduces porosity in the upper half of the remaining basalt; the lower half is crystalline basalt with few fractures and vesicles. Correlation with outcrops in the Snake River canyon and with drill holes near the canyon suggests that this basalt is part of the Tertiary Banbury Basalt. Sediments in the lowermost 48 ft (1,075-1,123 ft) of the test hole are believed to be the middle member of the Banbury Basalt.

Scant evidence from other drill holes, outcrops, and electrical resistivity data suggests that the lithologic sequence penetrated in the test hole may extend to the Snake River canyon. In places, sedimentary rocks of the Glenns Ferry Formation crop out in the north wall of the canyon and may be present beneath basalt talus slopes. If the sediment unit is areally extensive and extends to the canyon, it may be a major control on the elevation of springs and ground-water movement. Thinning of Quaternary basalt, where underlain by sediments of low hydraulic conductivity, helps explain the steepening water table in the western part of the eastern Snake River Plain (Lindholm and others, 1983).

Water-level measurements in piezometers installed in the test hole verify upward movement of water, as expected in a ground-water discharge area. Hydraulic head in the cinder zone of the lower basalt unit (piezometer 4) is about 65 ft higher than the water table (piezometer 1); fine-grained sediments are the confining material. Head in the sand zone in the bottom of the hole (piezometer 5) is about 155 ft higher than the water table; clay-filled vesicular basalt, crystalline basalt, and clay are the confining materials.

Lithologic sequence in the test hole correlates well with sequences in a few deep drill holes at (1) the Idaho National Engineering Laboratory site (J. T. Barraclough, U.S. Geological Survey, written commun., 1980); (2) south of the Snake River in Twin Falls County (U.S. Geological Survey, unpubl. data, 1980); and (3) other scattered places on the plain. Vertical electrical resistivity soundings also suggest that sediments may underlie Quaternary basalts in other parts of the plain (Whitehead, 1984).

Though not done for this study, age dating of coni-spiral gastropods and carbonized plant fragments present in slightly cemented siltstone near the bottom of the hole may aid in stratigraphic correlations.

Although much was learned from this test hole, additional strategically located and carefully drilled test holes are needed to improve the understanding of subsurface geology and its controls on occurrence, availability, and movement of ground water.

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Table 1.--Description of core and grab samples

Depth, in feet below land surface	Rock	Description[1]
0-1.0	Silt	Yellowish gray (5YR 7/2), windblown deposit (grab sample).
1.0-6.0	Basalt	No core sample, but determined from outcrop and grab samples to be similar to core sample from 6.0-9.0 ft.
6.0-9.0	Basalt	Medium gray (N5) dry sample, vesicular, vesicles 0.04-0.39 in. diameter compose 10 percent of the rock (cross-section of core); about 75 percent of the vesicles are less than 0.04 in. diameter; olivine, plagioclase, intergranular texture, some very small pyrite crystals in cavities.
9.0-11.5	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter compose about 10 percent of the rock; olivine, plagioclase, intergranular texture.
11.5-12.5	Basalt	Medium gray (N5), vesicular, vesicles 0.04-0.39 in. diameter compose 10 percent of the rock, about 75 percent of the vesicles are less than 0.04 in. diameter; olivine, plagioclase, intergranular texture; some very small pyrite crystals in cavities.
12.5		Flow boundary.
12.5-14.5	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.39 in. diameter compose 25 percent of the rock; weathering products include silt, iron staining, and weathered olivine (iddingsite), also a noncalcareous white mineral.
14.5-16.0	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter, only about 1-3 percent of vesicles are larger than 0.04 in. and compose 10 percent of the rock; olivine, plagioclase, intergranular texture.
16.0-19.5	Basalt	Medium gray (N5), vesicular, vesicles less than 0.04 in. diameter compose 10 percent of the rock; olivine, plagioclase, intergranular texture; silty-clay coating on broken surfaces.
19.5		Flow boundary.
19.5-22.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.39 in. diameter compose 25 percent of the rock; weathering products include silt, iron staining, and olivine, also a noncalcareous white mineral.
22.0-25.6	Basalt	Medium gray (N5), vesicular, vesicles 0.04-0.39 in. diameter compose 10 percent of the rock, many vesicles less than 0.04 in.; olivine, plagioclase, intergranular texture; clay coating on both surfaces of a 45° fracture.
25.6-29.0	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter compose about 10 percent of the rock; olivine, plagioclase, intergranular texture.
29.0-35.2	Basalt	Medium gray (N5), vesicular, vesicles less than 0.04 in. diameter compose 10 percent of the rock; olivine, plagioclase, intergranular texture; silty-clay coating on both surfaces of a horizontal fracture at 31.2 ft.
35.2-63.5	Basalt	Medium gray (N5), vesicular, vesicles less than 0.04 in. diameter compose 10 percent of the rock; olivine, plagioclase, intergranular texture; more vesicular with 0.04-0.20 in. vesicles at 40.4-40.7 ft and 43.5-44.0 ft; large plagioclase laths, some zeolites in cavities; small iridescent crystals.
63.5		Flow boundary.
63.5-71.2	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose about 25 percent of the rock; color changes to grayish red (5R 4/2) at 66.8 ft, silty-clay coating on surface of some fractures.
71.2-75.0		Void reported by driller.
75.0-76.2	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose about 25 percent of the rock.
76.2-80.9	Basalt	Medium gray (N5), vesicular, vesicles less than 0.04 in. to greater than 0.20 in. diameter; olivine, plagioclase, intergranular texture; calcareous silty-clay coating on surfaces of some fractures.

Table 1.--Description of core and grab samples--Continued

Depth, in feet below land surface	Rock	Description[1]
80.9-82.9	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter; olivine, plagioclase, intergranular texture.
82.9-92.3	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter; olivine, plagioclase, intergranular texture.
92.3		Flow boundary.
92.3-95.7	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose about 30 percent of the rock.
95.7-98.5	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter, many cannot be seen without hand lens; olivine, plagioclase, intergranular texture; some plagioclase laths 0.20 in. long.
98.5		Flow boundary.
98.5-100.5	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose about 25 percent of the rock; olivine, plagioclase, some iridescent crystals.
100.5-103.6	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter; olivine, plagioclase, intergranular texture.
103.6		Flow boundary.
103.6-106.0	Basalt	Grayish red (5R 4/2), vesicular, vesicles 0.04-0.39 in. diameter, very broken; olivine, plagioclase; intergranular texture; about 1 ft of core missing.
106.0-107.0	Basalt	Medium gray (N5), vesicular, vesicles 0.04-0.20 in. diameter compose 25 percent of the rock, grades to smaller vesicles less than 0.04 in. diameter; olivine, plagioclase, intergranular texture.
107.0		Flow boundary.
107.0-109.3	Basalt	Grayish red (5R 4/2), vesicular, vesicles 0.04-0.39 in. diameter, very broken; about 50 percent of core missing.
109.3-113.0	Basalt	Grayish red (5R 4/2), vesicular, vesicles 0.04-0.39 in. diameter, not broken, vesicles compose about 25 percent of the rock; olivine, plagioclase, intergranular texture.
113.0-117.0	Basalt	Brownish gray (5R 4/1), vesicular, vesicles generally less than 0.04 in. diameter; high-angle to vertical fractures; surfaces of fragments coated with noncalcareous silty clay.
117.0-121.0	Basalt	Medium gray (N5), vesicular, vesicles 0.04-0.39 in. diameter compose about 25 percent of the rock.
121.0-136.0	Basalt	Medium gray (N5), vesicular, vesicles 0.04-0.12 in. diameter compose about 7 percent of the rock; olivine crystals 0.12 in. long and magnetite crystals or zeolites(?) on walls of vesicles; from 131.8 ft to 136.0 ft, the vesicles are generally less than 0.04 in. diameter; intergranular texture; three high-angle fractures (60°-70°) at 128.5, 129.0, and 130.0 ft have a silty-clay coating on surfaces.
136.0		Flow boundary.
136.0-138.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose 25 percent of the rock, very broken; vertical and horizontal fractures, vesicles and fractures coated with calcareous clay.
138.0-141.8	Basalt	Medium gray (N5), vesicular, vesicles 0.04-0.39 in. diameter compose 10 percent of the first foot, vesicles grade to less than 0.04 in. diameter below; olivine and plagioclase; some clay coating in cavities and on surfaces of fractures.
141.8-162.0	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter, some 0.04-0.20 in. vesicles in places; crystal growth in many vesicles seems to be calcite and magnetite or zeolites 0.04-0.12 in. long; olivine and plagioclase.
162.0		Flow boundary.

Table 1.--Description of core and grab samples--Continued

Depth, in feet below land surface	Rock	Description[1]
162.0-170.6	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose about 25 percent of the rock; reddish oxidized coating on walls of cavities; vesicles become less than 0.04 in. with depth; olivine and plagioclase.
170.6-174.5	Basalt	Medium gray (N5), vesicular, vesicles less than 0.04 in. diameter.
174.5		Flow boundary.
174.5-181.8	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter; some crystal growth in cavities; vesicles decrease in diameter to less than 0.04 in. from 178.3-181.8 ft; color changes to medium gray (N5).
181.8-185.8	Basalt	Medium gray (N5) grading to grayish-red purple (5RP 4/2) with depth; vesicular, intergranular texture, ophitic texture in some cavities.
185.8		Flow boundary.
185.8-199.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.39 in. diameter near top composing about 15 percent of the rock and generally about 0.04 in. or less near the bottom.
199.0		Flow boundary.
199.0-209.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.12 in. diameter compose about 30 percent of the rock; from 200.0 to 202.0 ft, vesicles 0.04-0.39 in. compose about 7 percent of the rock; from 202.0 to 209.0 ft, vesicles range from 0.04-0.20 in. and compose about 25 percent of the rock; olivine and plagioclase, intergranular texture; mineral coating in some vesicles.
209.0-213.2	Basalt	Color changes to medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter.
213.2		Flow boundary.
213.2-217.2	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose about 15 percent of the rock, very broken.
217.2-222.7	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter; olivine, plagioclase laths less than 0.08 in. long, intergranular texture.
222.7		Possible minor flow boundary.
[2]222.7-223.8	Basalt	Medium gray (N5), vesicular, vesicles 0.04-0.12 in. diameter compose 25 percent of the rock; olivine, plagioclase laths up to 0.28 in. long, intergranular texture; vesicles coated lightly with minerals.
223.8-240.7	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles generally less than 0.04 in. diameter; olivine, plagioclase, intergranular texture; shades to medium gray (N5) and medium-dark gray (N4); lower part has glassy appearance.
240.7-241.4	Clayey sand	Pale yellowish brown (10YR 6/2), no apparent grain size gradation, contains quartz, basalt, and rhyolite fragments, angular to subrounded.
241.4		Top of flow.
241.4-251.2	Basalt	Medium-dark gray (H4), vesicular, vesicles 0.04-0.20 in. diameter compose 25 percent of the rock; olivine, plagioclase laths up to 0.28 in. long; clay coating on many fracture surfaces and in cavities; grades to smaller, less than 0.04 in. diameter cavities and shorter, 0.12 in. plagioclase laths.
251.2		Flow boundary.
251.2-262.0	Basalt	Medium-dark gray (N4), vesicular, vesicles 0.04-0.20 in. diameter compose 25 percent of the rock; olivine, plagioclase laths to 0.28 in. long, intergranular texture; clayey-sand coating in some cavities and on surfaces of fractures.

Table 1.--Description of core and grab samples--Continued

Depth, in feet below land surface	Rock	Description[1]
262.0-277.5	Basalt	Grab samples indicate basalt similar to that described from 277.5-403.5 ft.
		The following core description is from the main test hole.
277.5-292.5	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter, about 5 percent may be as large as 0.20 in.; all small vesicles below 280.0 ft; olivine, plagioclase; fractured surfaces coated with clay; no apparent crystal growth in most cavities; from 280.0-292.5 ft some smaller cavities contain olivine, calcite, and iridescent crystals.
292.5-293.0	Basalt	Medium-dark gray (N4), vesicular with calcareous clayey-sand filling; olivine, plagioclase; iridescent crystals in cavities.
293.0		Bottom of flow.
293.0-293.4	Sandstone	Light gray (N7), conglomeratic, lightly compacted, medium- to fine-grained matrix of basaltic, rhyolitic, and granitic rock fragments, noncalcareous; several large fragments (0.39 in. or less) angular to subrounded calcareous material; fragments related to layer below.
293.4-294.1	Claystone	White (N9), calcareous matrix, the white material may be a water-laid ash, which makes up most of this core section.
294.1-296.0	Sand	Light gray (N7), fine-grained semiconsolidated calcareous; a few very small oolites are present in the sand, visible only with hand lens; iron staining apparent.
296.0-297.8	Mudstone	Pinkish gray (5YR 8/1), lightly compacted, fine-grained to very fine-grained calcareous mud; basaltic, rhyolitic, and granitic fragments, angular to subrounded.
297.8		Top of flow.
[2]297.8-315.0	Basalt	Medium-dark gray (N4), vesicular, vesicles 0.04-0.28 in. diameter compose 7 percent of the rock; surface of fractures is coated with a calcareous clay; some olivine and calcite crystals in cavities; no clay filling after about 300 ft; color changes to light gray (N7), vesicles 0.04 in. or smaller; at 308 ft color darkens to medium gray (N5), percent olivine increases and number of vesicles decreases.
315.0		Flow boundary.
[2]315.0-317.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.39 in. diameter compose about 25 percent of the rock; olivine, no plagioclase laths apparent, aphanitic.
317.0-318.0	Basalt	Light gray (N7), dense, very few vesicles.
318.0		Flow boundary.
318.0-322.5	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.28 in. diameter compose about 25 percent of the rock; no large plagioclase laths, small laths are visible in cavities; highly permeable section.
322.5		Flow boundary.
[2]322.5-326.0	Basalt	Medium-dark gray (N4), vesicular, vesicles 0.04-0.39 in. diameter compose 5-7 percent of the rock; olivine, plagioclase, no plagioclase laths apparent; olivine less dominant than in intervals above; some cavities contain very small crystalline growths of calcite, olivine, hematite, and zeolites.
326.0-335.0	Basalt	Medium-dark gray (N4), vesicular, vesicles are all less than 0.04 in. diameter, very dense appearance; no plagioclase laths.
335.0		Flow boundary.
335.0-353.0	Basalt	Medium-dark gray (N4), vesicular, vesicles 0.04-0.20 in. diameter compose 25 percent of the rock; very broken; rock is glassy and aphanitic; olivine.

Table 1.--Description of core and grab samples--Continued

Depth, in feet below land surface	Rock	Description[1]
353.0-355.0	Basalt	Medium-dark gray (N4), vesicular, vesicles about 0.04 in. diameter or less, fewer than in previous zone; not broken; olivine.
[2]355.0-356.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.12 in. diameter compose 30 percent of the rock; mostly aphanitic, some iridescent crystals in cavities; very cindery and broken.
356.0-358.0	Basalt	Medium-dark gray (N4), vesicular, vesicles 0.04-0.20 in. diameter compose 7 percent of the rock; olivine.
358.0-359.5	Basalt	Medium-dark gray (N4), vesicular, vesicles much smaller, generally less than 0.04 in. diameter and fewer than in zone above.
359.5-362.5	Basalt	Medium gray (N5), vesicles less than 0.04 in. diameter; olivine.
362.5		Flow boundary.
[2]362.5-366.0	Basalt	Medium-dark gray (N4), vesicular, vesicles 0.04-0.39 in. diameter compose 30 percent of the rock; numerous iridescent crystals in cavities; very cindery and broken; olivine.
366.0-369.5	Basalt	Medium-dark gray (N4), very dense; olivine, no plagioclase laths.
369.5		Flow boundary.
369.5-374.5	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.39 in. diameter compose 25 percent of the rock, very cindery and broken; olivine.
374.5-380.0	Basalt	Medium-dark gray (N4), vesicular, vesicles 0.04-0.20 in. diameter compose 25 percent of the rock; cindery and broken; olivine.
380.0-382.0	Basalt	Medium-dark gray (N4), smaller and fewer vesicles than in zone above; olivine, a few small plagioclase laths, phaneritic to aphanitic.
[2]382.0-403.5	Basalt	Medium-dark gray (N4), vesicular, vesicles 0.04-0.12 in. diameter compose 3 percent of the rock; cindery zone; olivine, numerous plagioclase laths generally less than 0.04 in. long; surface contact with lower sediment zone is glassy.
403.5		Base of flow; basalt-sediment contact.
403.5-410.0	Gravel	Probable gravel zone; drilling actions indicate gravel, very little core recovery; a few fragments of basalt, serpentinized, color ranges from green to red on fragments, some iridescent.
410.0-430.0	Gravel	Probable gravel zone; very little core recovery; two well-rounded (water-worn?) rocks: (1) rhyolite, pinkish gray (5YR 8/1), (2) rhyolite, light brownish gray (5YR 6/1).
430.0-439.1	Gravel	Probable gravel zone; only 1 ft of core recovery; chiefly rhyolitic rock fragments; several calcareous siltstone fragments and one piece of quartz.
439.1-440.0	Siltstone	Pinkish gray (5YR 8/1), poorly cemented.
440.0-448.5	Conglomerate	Color ranges from a pinkish gray (5YR 8/1) to a greenish gray (5G 6/1); partial core recovery; grades from pebble gravel to clay; no distinct zonation; calcareous silty matrix, mostly volcanic rock fragments (rhyolitic and basaltic) with a few rounded to subrounded quartz fragments; largest fragment is 1.18x1.57x0.39 in.
448.5-450.0	Siltstone	Pinkish gray (5YR 8/1).
450.0-470.0	Conglomerate	Color ranges from a pinkish gray (5YR 8/1) to a greenish gray (5G 6/1), 4 ft of core recovered from 450-460 ft. One 2.36x1.57 in. rhyolitic fragment (rounded), brownish gray (5YR 4/1). About 5 ft of core recovered from 460-470 ft.
470.0		Coring stopped (grab samples only to 610.0 ft).

Table 1.--Description of core and grab samples--Continued

Depth, in feet below land surface	Rock	Description [1]
470.0-500.0	Gravel	No samples taken. Drilling action indicates probable gravel.
500.0-510.0	Sand	Pinkish gray (5YR 8/1), poorly sorted; basaltic, rhyolitic, and granitic rock fragments, angular to rounded; ranges from coarse to fine sand.
510.0-520.0	Sand	Pinkish gray (5YR 8/1), poorly sorted. Similar to 500.0-510.0 ft zone but, in general, coarser.
520.0-530.0	Clay and silt	Pinkish gray (5YR 8/1), well sorted, few angular volcanic rock fragments; some calcareous clay.
530.0-540.0	Clay and silt	Pinkish gray (5YR 8/1) well sorted, few angular volcanic rock fragments; some quartz fragments, some calcareous clay.
540.0-560.0	Clay and silt	Pinkish gray (5YR 8/1), well sorted but, in general, coarser than 530.0-540.0 ft zone; medium to coarse grains of volcanic rock fragments and quartz, angular to well rounded; some calcareous clay.
560.0-570.0	Clay, silt, and sand	Yellowish gray (5YR 7/2), sand, fine-grained, subrounded to rounded grains of basalt, rhyolite, and granite or quartz; some calcareous clay.
570.0-580.0	Clay, silt, and sand	Yellowish gray (5YR 7/2), some conglomeratic coarse-grained material grading to a medium-dark gray (N4); more angular basalt fragments; some calcareous clay.
580.0-590.0	Clay, silt, and sand	Yellowish gray (5YR 7/2), generally fine grained, some 0.08-0.12 in. diameter basalt fragments, well rounded; most sand grains are subrounded to rounded, clay is calcareous.
590.0		Top of basalt flow.
590.0-610.0	Basalt	Medium-dark gray (N4), slightly vesicular, vesicles much less than 0.04 in. diameter; fragments very angular; medium to coarse grained.
610.0		Coring started.
610.0-612.0	Basalt	Medium-dark gray (N4), vesicular, vesicles 0.04-0.20 in. diameter compose 20 percent of the rock; olivine, plagioclase laths; calcite crystals and lamellae in cavities.
[2]612.0-621.5	Basalt	Medium-dark gray (N4), vesicular, vesicles less than 0.04 in. diameter; unit appears dense to naked eye; high-angle fractures; olivine, small plagioclase laths; zeolites, magnetite or ilmenite, and calcite crystals in cavities.
621.5		Flow boundary.
[2]621.5-692.5	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.39 in. diameter compose about 50 percent of the rock; very permeable, no crystalline growth in cavities, minor amounts of calcium sulfate coating on some cavities; olivine, a few plagioclase laths, aphanitic in general; very cindery, pumaceous zone.
692.5-694.2	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.08 in. diameter compose about 5 percent of the rock; olivine, plagioclase, calcite, pyroxene.
694.2		Flow boundary.
694.2-702.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.12 in. diameter compose up to 50 percent of the rock; very broken cindery zone; olivine; no crystalline growth in cavities; appears to be a magnesium or calcium carbonate coating on some cavities in the lower part; reacts weakly with dilute hydrochloric acid; aphanitic and glassy in places.
702.0		Flow boundary.
702.0-703.5	Basalt	Medium gray (N5), vesicular; very permeable; olivine.
703.5-707.0	Basalt	Medium gray (N5), generally dense, some vesicles 0.04-0.39 in. diameter compose 3 percent of the rock; olivine; cavities filled with calcite crystals.

Table 1.--Description of core and grab samples--Continued

Depth, in feet below land surface	Rock	Description[1]
707.0-714.0	Basalt	Dark gray (N3), generally dense, vesicles 0.04-0.08 in. diameter compose about 3 percent of the rock; olivine; serpentinized; most vesicles wholly or partially filled with dark green to black serpentinized material.
714.0		Flow boundary.
714.0-718.0	Basalt	Color changes to brownish gray (5YR 4/1), vesicular, vesicles 0.04-0.12 in. diameter compose less than 10 percent of the rock; many vesicles filled with calcareous clay (water talc--local name), very pale yellowish orange (10YR 8/2).
718.0-725.0	Basalt	Medium-dark gray (N4), vesicular, vesicles 0.04-0.20 in. diameter; some larger compose about 10 percent of the rock; many vesicles filled with very pale yellowish orange (10YR 8/2) calcareous clay and some calcite crystals as long as 0.20 in.
725.0-742.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose 5-10 percent of the rock; most vesicles filled with very pale yellowish orange (10YR 8/2) noncalcareous clay.
742.0		Flow boundary.
742.0-743.9	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose 5-10 percent of the rock; olivine; most vesicles filled with noncalcareous clay that ranges from a very pale yellowish orange (10YR 8/2) to a moderate yellowish brown (10YR 5/4).
743.9-749.0	Basalt	Dark gray (N3), dense, a few vesicles composing about 1 percent of the rock are wholly or partially filled with noncalcareous grayish olive (10Y 4/2) clay.
749.0		Flow boundary.
749.0-754.9	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.39 in. diameter compose 25 percent of the rock; olivine, plagioclase laths; cindery zone at 749 ft; aphanitic in places.
754.9		Flow boundary.
754.9-758.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.39 in. diameter compose 15 percent of the rock; olivine; calcite and magnetite crystals in some cavities; most crystals are small, visible with hand lens only.
758.0-765.5	Basalt	Grayish-red purple (5RP 4/2), vesicles smaller and fewer than in zone above compose 3 percent of the rock; a white (N9) and very pale yellowish orange (10YR 8/2) clay coating on surfaces of fragments; some coatings are calcareous; some calcite crystals in cavities.
765.5		Flow boundary.
765.5-769.0	Basalt	Medium gray (N5), purplish tint, vesicular, vesicles 0.04-0.28 in. diameter compose 10 percent of the rock, a pinkish gray (5YR 8/1) noncalcareous clay coating covers walls of cavities and surface of fragments.
769.0-784.6	Basalt	Medium gray (N5), purplish tint, fairly dense, vesicles 0.04-0.20 in. diameter compose 5 percent of the rock; olivine; a few vesicles coated with calcite and olivine crystals.
784.6-791.6	Basalt	Grayish-red purple (5RP 4/2), dense, small vesicles generally less than 0.04 in. diameter; broken surfaces and cavities coated with calcite and olivine crystals.
791.6-823.0	Basalt	Dark gray (N3), dense, olivine rich; serpentinized in places; some calcareous coatings on surface of fragments.
823.0		Flow boundary.
823.0-823.5	Basalt	Grayish-red purple (5RP 4/2), dense but broken; noncalcareous clay in cavities and on surface of broken fragments ranges from moderate yellow-green (5GY 7/4) to white (N9); some clear calcite crystals.
823.5-825.0	Ash	Pale reddish brown (10R 5/4), fine grained, probably silicic in composition.

Table 1.--Description of core and grab samples--Continued

Depth, in feet below land surface	Rock	Description[1]
825.0		Flow boundary.
825.0-827.0	Ash and basalt	Pale reddish-brown ash (10R 5/4) and grayish-red purple basalt (5RP 4/2); ash fills vesicles and fractures in basalt; basalt is vesicular, vesicles 0.04-0.16 in. diameter compose 20 percent of the rock; olivine, plagioclase laths 0.04-0.12 in. long, intergranular texture; some white (N9) to clear calcareous coatings on cavity walls and on surface of fragments.
827.0		Flow boundary.
827.0-830.2	Ash and basalt	Pale reddish-brown ash (10R 5/4) about 0.20 in. thick on top of a grayish-red purple basalt (5RP 4/2); there is a 5° dip on the surface; the basalt is vesicular, vesicles 0.04-0.39 in. diameter compose 25 percent of the rock; some cavities contain small crystals (visible only with hand lens) of calcite, olivine, and fluorite; color grades to a medium-dark gray (N4) near the bottom at about 830 ft.
830.2-832.0	Basalt	Medium-dark gray (N4), at 831 ft color changes to brownish gray (5YR 4/1), at 832 ft to grayish black (N2); rock varies from slightly vesicular to dense; bluish white (5B 9/1) botryoidal crystals in some cavities.
832.0-836.5	Basalt	Grayish black (N2), dense, olivine rich, serpentinized; grayish olive (10Y 7/2) clay in amygdaloidal fillings, clay is soft with a greasy feel; some pyrite and iridescent crystals visible with hand lens; slickenside surface on 45° fracture at 833 ft.
836.5-837.0	Basalt	Grayish black (N2), less dense and more vesicular than unit above, changes to brownish gray (5YR 4/1) and to grayish-red purple (5RP 4/2).
837.0-840.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose 25 percent of the rock; very broken; olivine, plagioclase laths 0.04-0.16 in. long; noncalcareous cherty white (N9) filling on some surfaces of broken pieces and in some cavities; some iridescent crystals visible with hand lens.
840.0-843.0	Basalt	Grayish-red purple (5RP 4/2), dense, very few vesicles 0.04-0.28 in. diameter; olivine, plagioclase laths 0.04-0.12 in. long.
843.0		Flow boundary.
843.0-845.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, broken, vesicles generally less than 0.04 in. diameter compose 25 percent of the rock; highly weathered; noncalcareous clay filling, very pale yellowish orange (10YR 8/2) in vesicles and on surface of fragments.
845.0-847.0	Basalt	Grayish-red purple (5RP 4/2), dense, very few vesicles 0.04-0.28 in. diameter; olivine, plagioclase laths 0.04-0.12 in. long; one high-angle (about 80°) fracture at 845.5 ft is coated with a pale yellowish orange (10YR 8/6) ash about 0.04 in. thick.
847.0		Flow boundary.
847.0-849.5	Basalt	Grayish-red purple (5RP 4/2), vesicular, very broken, vesicles 0.04-0.20 in. diameter compose about 30 percent of the rock; surface of some fragments and some vesicles coated with a grayish yellow (5Y 8/4) clay; clay is noncalcareous and has cherty appearance where not badly decomposed.
849.5-854.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles fewer and larger than in zone above compose about 10 percent of the rock; moderately fractured; very little clay in openings.
854.0		Flow boundary.
854.0-860.9	Basalt	Grayish-red purple (5RP 4/2), vesicular in upper 0.5 ft, grades to a denser unit, vesicles generally less than 0.04 in. diameter; highly fractured; olivine, plagioclase laths, intergranular texture, laths 0.04-0.12 in. long, pyrite crystals visible with hand lens; some grayish-yellow (5Y 8/4) calcareous and noncalcareous clay coating on cavity walls and surface of fragments.

Table 1.--Description of core and grab samples--Continued

Depth, in feet below land surface	Rock	Description[1]
860.9		Flow boundary.
860.9-861.2	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose 25 percent of the rock; olivine, plagioclase laths 0.04-0.12 in. long; some white (N9) to grayish yellow (5Y 8/4) clay, noncalcareous cherty appearance in cavities and on surface of fragments.
861.2		Flow boundary.
861.2-864.2	Basalt	Medium gray (N5), vesicular, vesicles 0.04-0.12 in. diameter compose 15 percent of the rock; color changes to grayish-red purple (5RP 4/2); calcareous clay coating in vesicles and on surface of fragments, pinkish-gray (5YR 8/1); fewer vesicles near 864 ft.
864.2-864.7	Ash	Moderate reddish orange (10R 6/6), possibly silt, sand, very angular; poorly cemented; some pinkish gray (5YR 8/1) cherty pieces in matrix.
864.7		Flow boundary.
864.7-868.0	Basalt	Medium gray (N5), vesicular, vesicles generally less than 0.04 in. diameter but range to 0.20 in. compose 10 percent of the rock; noncalcareous white (N9) crystals in some larger vesicles.
868.0-876.0	Basalt	Medium gray (N5), dense, vesicles generally less than 0.04 in. diameter; olivine, plagioclase laths, intergranular texture; broken in places.
876.0		Flow boundary.
876.0-876.5	Basalt	Medium gray (N5), very broken, vesicular, vesicles 0.04-0.20 in. diameter compose 15 percent of the rock; olivine, plagioclase.
876.5-877.0	Basalt	Medium gray (N5), dense.
877.0		Flow boundary.
877.0-878.7	Basalt	Medium gray (N5), vesicular, vesicles 0.04-0.20 in. diameter compose 20 percent of the rock; olivine, plagioclase; a few small calcite crystals in cavities; color changes to grayish-red purple (5RP 4/2) then back to medium gray (N5); toward the bottom of this zone vesicles compose about 7 percent of the rock.
878.7		Flow boundary.
878.7-880.0	Basalt	Medium gray (N5), vesicular, vesicles 0.04-0.20 in. diameter compose about 25 percent of the rock; olivine, plagioclase laths 0.04-0.08 in. long; intergranular texture; both calcareous and noncalcareous bluish-white (5B 9/1) coating on some cavity walls.
880.0-881.2	Basalt	Medium gray (N5), dense, very few vesicles; olivine, plagioclase; some calcareous white (N9) clay cavity fillings and some noncalcareous dusky yellow (5Y 6/4) clay cavity fillings.
881.2		Flow boundary.
881.2-883.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, very broken, vesicles 0.04-0.12 in. diameter compose about 25 percent of the rock; olivine, plagioclase; grayish white (5B 9/1) coating on surfaces, some iridescent crystals visible with hand lens.
883.0-887.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.20 in. diameter compose 10 percent of the rock; dense zone 884-885 ft; olivine, plagioclase; some calcite crystals in cavities.
887.0-890.0	Basalt	Grayish-red purple (5RP 4/2), very dense, fractured; olivine, plagioclase; calcareous white clay (N9) in veins along fractures; calcite crystals in some cavities; olivine-rich area at 889 ft is serpentinized, grayish-olive (10Y 4/2).
890.0		Flow boundary.

Table 1.--Description of core and grab samples--Continued

Depth, in feet below land surface	Rock	Description[1]
890.0-892.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, vesicles 0.04-0.28 in. diameter compose about 25 percent of the rock; olivine, plagioclase; some cavities coated with very pale yellowish orange clay (10YR 8/2) and white (N9) clay; a bluish-white (5B 9/1) coating on some surfaces; calcite crystals in some larger cavities.
892.0-893.6	Basalt	Grayish-red purple (5RP 4/2), very dense; a few large vesicles (up to 0.12 in. diameter) contain calcite crystals; some very pale yellowish orange (10YR 8/2) silty-clay coating on surfaces of fragments; this clay seems to be an alteration product from white (N9) opalized cherty material.
893.6-899.0	Basalt	Medium-dark gray (N4), dense, vesicles generally less than 0.04 in. diameter; some white (N9) calcite on surfaces of fragments; also dusky yellow (5Y 6/4) noncalcareous clay in a few cavities.
899.0		Flow boundary.
899.0-901.0	Basalt	Grayish-red purple (5RP 4/2), vesicular, broken, vesicles 0.04-0.20 in. diameter compose 25 percent of the rock; olivine, plagioclase; light bluish-gray (5B 7/1) coating on some surfaces.
901.0-902.5	Basalt	Grayish-red purple (5RP 4/2), dense, vesicles less than 0.04 in. diameter; calcite crystals in some cavities.
902.5		Flow boundary.
902.5-907.4	Basalt	Grayish-red purple (5RP 4/2), vesicular, very broken, vesicles 0.04-0.39 in. diameter compose 20 percent of the rock; olivine, plagioclase; a noncalcareous bluish-gray (5B 7/1) coating on surface of fragments; also a noncalcareous yellowish-gray (5Y 7/2) clay on some surfaces; no noticeable crystalline growth in cavities.
907.4-911.1	Basalt	Medium gray (N5), slight purple tint, dense, vesicles less than 0.04 in. diameter; olivine, plagioclase; no noticeable crystalline growth in most cavities; a few contain small calcite crystals.
911.1		Flow boundary.
911.1-925.3	Basalt	Grayish-red purple (5RP 4/2), vesicular, very broken, cindery, vesicles 0.04-0.12 in. diameter compose about 25 percent of the rock; olivine, plagioclase; light bluish-gray (5B 7/1) and yellowish-gray (5Y 7/2) noncalcareous clay coats walls of some cavities and surfaces of broken pieces; from 915-916 ft, calcareous very pale yellowish-orange (10YR 8/2) clay forms a matrix for angular basalt fragments.
925.3		Flow boundary.
925.3-926.9	Basalt	Grayish-red purple (5RP 4/2), vesicular, very broken, vesicles 0.04-0.08 in. diameter compose 5 percent of the rock; olivine, plagioclase; very pale yellowish orange (10YR 8/2) calcareous fragments; calcareous clay coating on walls of cavities and surface of fragments ranges from white (N9) to moderate orange pink (5YR 8/4); light bluish-gray (5B 7/1) coating on some surfaces.
926.9-929.0	Basalt	Medium gray (N5), dense, vesicles generally less than 0.04 in. diameter.
929.0-936.0	Basalt	Medium gray (N5), dense, broken, vesicles generally less than 0.04 in. diameter; olivine, plagioclase; noncalcareous silty-clay vein and cavity filling, very pale yellowish orange (10YR 8/2).
936.0-945.7	Basalt	Medium gray (N5), dense, most vesicles less than 0.04 in. diameter; olivine, plagioclase; several large (0.04-0.39 in.) cavities filled with crystalline growths of black hexagonal crystals, platy and intertwined (magnetite?); several high-angle (70°) fractures are coated with noncalcareous very pale yellowish-orange (10YR 8/2) clay.
945.7		Flow boundary.

Table 1.--Description of core and grab samples--Continued

Depth, in feet below land surface	Rock	Description[1]
945.7-947.0	Basalt	Grayish-red purple (5RP 4/2), very broken, vesicles less than 0.08 in. diameter; very pale yellowish orange (10YR 8/2) clay coating on some fractures; calcite crystals in a few larger cavities.
947.0-985.5	Basalt	Grayish-red purple (5RP 4/2), dense, vesicles range from 0.04-0.78 in. diameter but generally less than 0.04 in.; olivine, plagioclase; very pale yellowish orange (10YR 8/2) noncalcareous clay coating on surface of some fragments and along high-angle fractures; sparse iridescent crystals visible with hand lens; some fractures coated with calcareous clay, light bluish gray (5B 7/1); some gradational color changes to dark gray (N3) basalt.
985.5		Flow boundary.
985.5-986.5	Basalt	Dark gray (N3), very broken, cindery zone, vesicles less than 0.04 in. diameter; a 2.3 in.-thick calcareous sediment zone may be freshwater limestone; some crystallization, color ranges from white (N9) to very pale yellowish orange (10 YR 8/2).
[2]986.5-1,072.7	Basalt	Dark gray (N3), dense, olivine, serpentinized; clay deposits along fractures range from moderate olive brown (5Y 4/4) to pale yellowish brown (10YR 6/2) to moderate reddish brown (10R 4/6); calcareous and noncalcareous; where highly serpentinized, the color is moderate olive brown (5Y 4/4); most fractures are high angle; some clay deposits resulting from serpentinization are as much as 2.0 in. thick and mostly a moderate reddish brown (5Y 4/4); calcite crystals in some fractures; rock changes to grayish black (N2) near base.
1,072.7		Base of basalt.
1,072.7-1,075.0	Basalt, mudstone	Color ranges from grayish-black (N2) basalt to light gray (N7) mudstone; sediment zone is noncalcareous with talc present along contact to about 1,075.0 ft; at 1,075.0 ft, sediment becomes calcareous.
1,075.0-1,082.0	Clay and silt	Light gray (N7), moderately to slightly cemented, fossiliferous, calcareous, numerous very delicate (friable) shell fragments, rock matrix and fossils are calcareous; some nearly complete fossils about 0.20 in. diameter appear to be conispiral gastropods; at 1,082.0 ft, carbonaceous leaf and grass stems are found in a very fine, slightly cemented siltstone matrix.
1,082.0-1,092.3	Silt and sand	Light gray (N7), nonfossiliferous; grades to fine sand having well-developed crossbedding; unit is only slightly cemented; sand grades to a nonfossiliferous, slightly cemented siltstone.
1,092.3-1,123.0	Sand	Dark gray (N3), medium grained, well sorted, angular to well-rounded grains; grains comprised of basalt, rhyolite, quartz, and feldspar minerals (grab samples).
1,123.0		Bottom of hole.

[1]Rock colors for dry samples conform to the Rock Color Chart of the Geological Society of America (Goddard and others, 1948). Texture descriptions conform to the National Research Council (1947) classification of grain size.
[2]Refer to table 3 for analysis by scanning electron microscope.