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TEST DRILLING FOR GROUND WATER IN HUDSPETH, CULBERSON, AND PRESIDIO COUNTIES IN WESTERNMOST TEXAS

By

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U.S. Geological Survey

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TEST DRILLING FOR GROUND WATER IN HUDSPETH, CULBERSON, AND PRESIDIO COUNTIES IN WESTERNMOST TEXAS

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ABSTRACT

From November 1973 to October 1974, the U.S. Geological Survey drilled four deep test holes to supplement hydrologic and geophysical studies evaluating fresh ground water in the basins of westernmost Texas. For each test, samples of drill cuttings were collected, borehole geophysical logs were run, and water samples were collected from specific zones.

The Leopold Guerra No. 1 test hole penetrated sand and gravel to 1,100 feet (335 m), and logs and water samples indicated fresh ground water to that depth. Below 1,100 feet (335 m), the material probably has low permeability. The Clay Evans No. 1 test penetrated sand, gravel, and clay to 555 feet (169 m), sand and thin volcanic flows to about 1,250 feet (381 m), and volcanic flows and tuffs to 2,006 feet (611 m). Logs and water samples indicated fresh ground water to about 1,250 feet (381 m); below that, permeability is probably low. The Culberson County Airport test was drilled through sand, gravel, and clay to 1,145 feet (349 m), conglomerate to 1,205 feet (367 m), and the Lower Cretaceous Cox Sandstone to 1,306 feet (398 m). Logs and water samples indicated fresh water in the alluvial fill and in the Cox Sandstone to about 1,265 feet (386 m); below that depth, permeability is probably low. The Davis test was drilled through clay with some thin beds of sand and gravel containing fresh water to a depth of 2,012 feet (613 m).

Borehole temperature data indicated above-normal gradients in the Guerra and Culberson County Airport tests. Temperature gradients in the Evans and Davis tests were near normal.

INTRODUCTION

During 1971-75, the Geological Survey evaluated the quantities of fresh ground water stored in the alluvial fill of the basins in Texas west of the Pecos River and northwest of the Big Bend country. These studies, which were made in cooperation with the Texas Water Development Board, will provide data for a continuing assessment of water availability in Texas.

The first phase of the investigation included an inventory of all major irrigation, municipal, and industrial water wells, selected stock and domestic wells, and selected springs; collection and chemical analyses of water samples from representative wells and springs; and a rough estimation of pumpage in the major irrigated areas. The second phase of the investigation included an estimation of the thickness of the alluvial fill in the basins by using geophysical surveys, primarily earth-resistivity but also seismic, gravity, aeromagnetic, and airborne-electromagnetic methods. The quality of water in the basin fill was estimated by using samples from wells, earth-resistivity data, and resistivity information obtained from airborne-electromagnetic data.

The final phase of the investigation was a test-drilling program in selected areas to determine the thickness of the alluvial fill and the quality of the water at various depths. The drilling sites were selected in areas (1) where available data indicated significant thicknesses of fill saturated with fresh water, (2) where ground-water data were sparse, and (3) where future development of ground water is likely to occur. On the basis of these criteria, test holes were drilled at four sites with the highest priority--Leopold Guerra No. 1 in Red Light Draw, 20 miles (32 km) southeast of Sierra Blanca; Clay Evans No. 1 on Ryan Flat, 5 miles (8.0 km) south of Valentine; Culberson County Airport No. 1 on Wildhorse Flat, 4 miles (6.4 km) northeast of Van Horn; and J. C. Davis No. 1 on Eagle Flat, 10 miles (16 km) southwest of Van Horn. The locations of the test holes and selected wells are shown on figure 1. This report presents a compilation and interpretation of the data collected from these test holes.

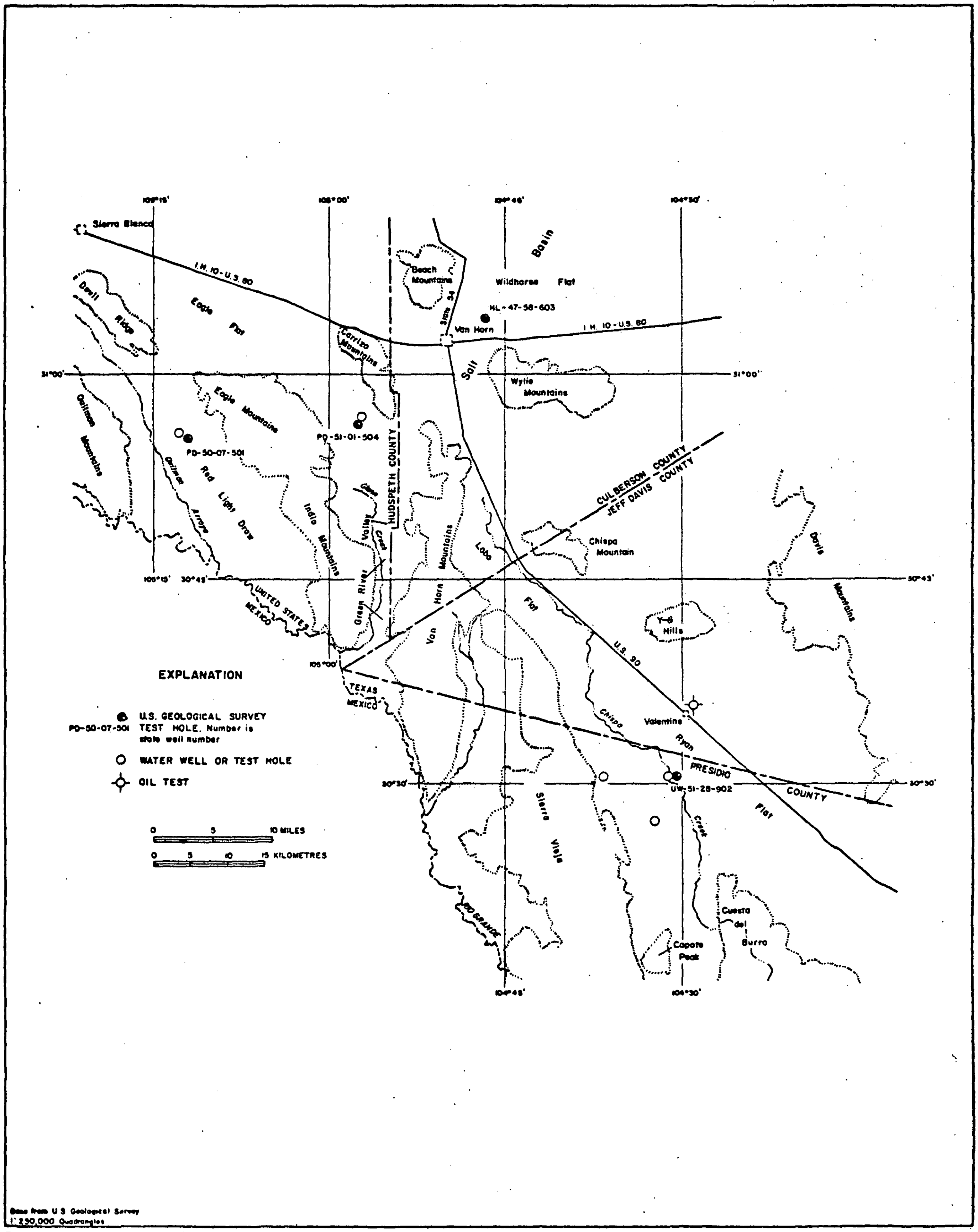

FIGURE 1.-Locations of test holes and selected wells

METRIC CONVERSIONS

For those readers interested in using the metric system, the metric equivalents of English units of measurements are given in parentheses. The English units used in this report may be converted to metric units by the following factors:

From		Multiply by	To obtain	
Unit	Abbreviation		Unit	Abbreviation
feet	--	0.3048	metres	m
feet per second	ft/s	.3048	metres per second	m/s
gallons per minute	gal/min	.06309	litres per second	l/s
inch	--	2.54	centimetres	cm
miles	--	1.609	kilometres	km

GENERAL GEOLOGY

The basins of westernmost Texas are in the southeastern part of the Basin and Range physiographic province, in which late Tertiary and Quaternary normal faulting formed isolated mountain ranges surrounded by flat basins. The relatively depressed basins or "flats" commonly are filled with thick deposits of unconsolidated alluvial and lacustrine clay, silt, sand, and gravel eroded from the mountain blocks. These deposits are the major source of ground water in the Basin and Range Province, and in many basins are the only significant source of water.

A prominent structural feature that crosses the project area along the northern side of Eagle Flat is the Texas lineament (Muehlberger and Wiley, 1970), which has been considered by some geologists as part of a transcontinental fracture zone. At Eagle Flat, the lineament coincides with the boundary between the Diablo Plateau, a structurally high area underlain by a relatively thin section of flat-lying Paleozoic and Mesozoic rocks, and the Chihuahua Trough, a structurally low area underlain by thick deposits, mostly of Cretaceous age. South of Eagle and Wildhorse Flats, extrusive volcanic rocks of Tertiary age are common, while to the north they are rare. The occurrence of these volcanic rocks, which cap many of the highlands in the Quitman, Eagle, and Van Horn Mountains south of Eagle and Wildhorse Flats and Davis Mountains (fig. 1), and form the hills south of the Wylie Mountains and the Sierra Vieja, may be related to the Texas lineament. Much of the alluvial fill in the basins between these highlands is composed of grains and pebbles of volcanics. In contrast, the alluvial fill of the Salt Basin, north of Van Horn, includes more grains and pebbles of limestone, sandstone, and quartzite.

PROCEDURES USED IN COLLECTING DATA

All test holes were drilled by rotary methods. The Guerra test hole was drilled with mud and air mist as the circulating fluids; the other three holes were drilled with mud. Drilling rates were measured with a stopwatch or were recorded on a geolograph. Drilling-time logs, which were prepared from these measurements or records are shown on figures 2-5.

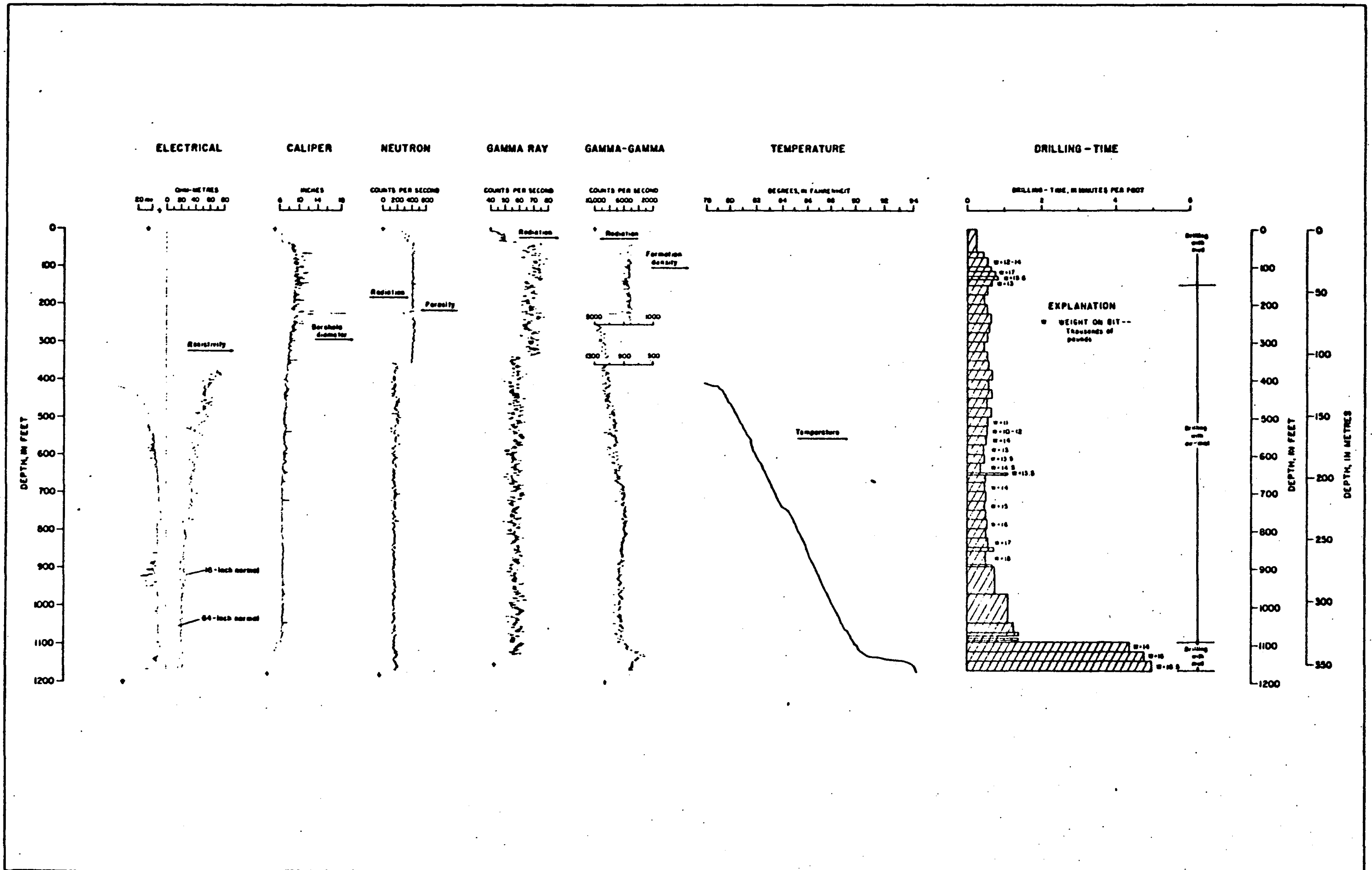

FIGURE 2.-Geophysical and drilling-time logs for Leopold Guerra No. 1 test hole (PD-50-07-501) in Red Light Draw

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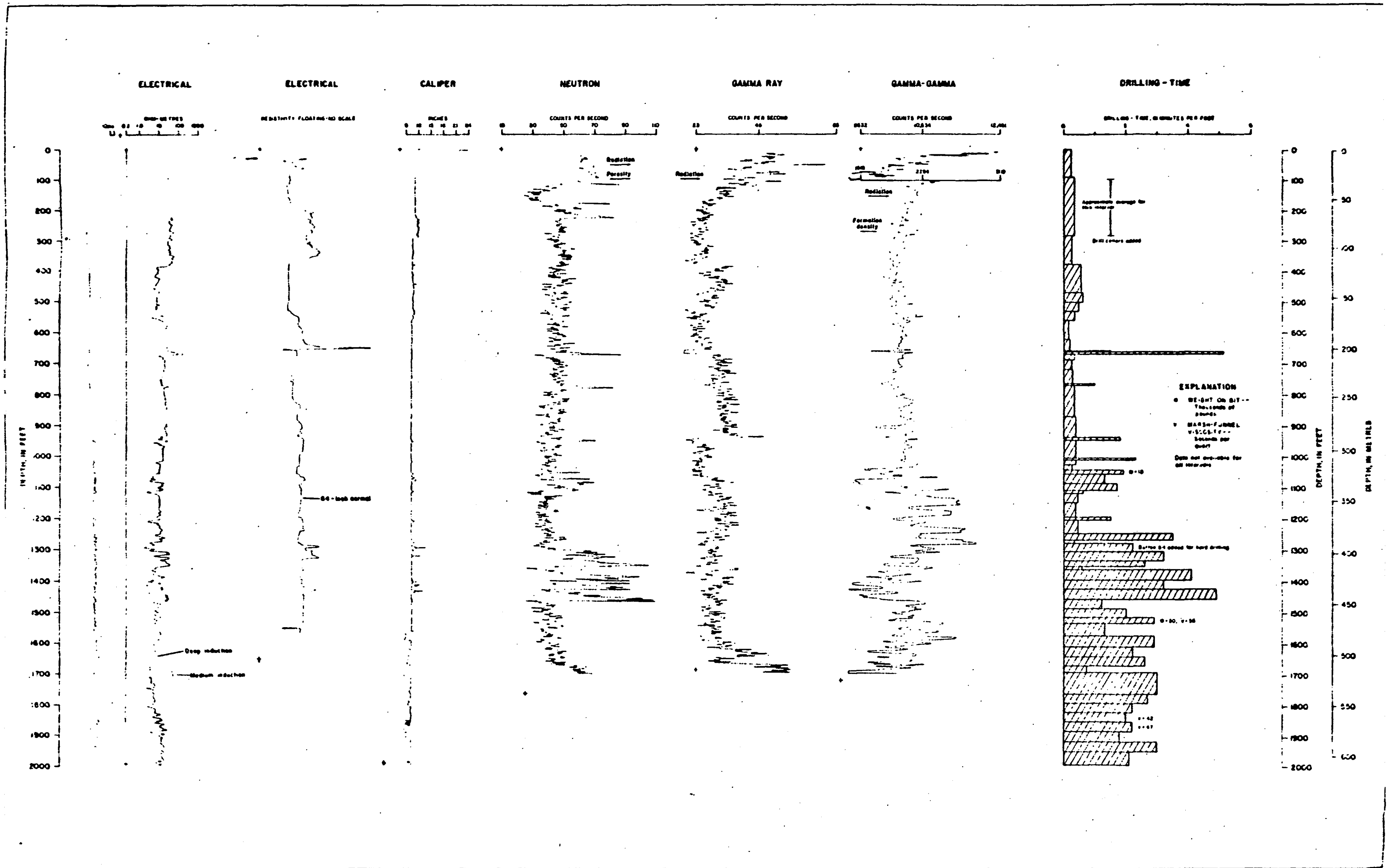

IGURE 3.-Geophysical and drilling-time logs for Clay Evans No. 1 test hole (UW-51-28-902) on Ryan Flat

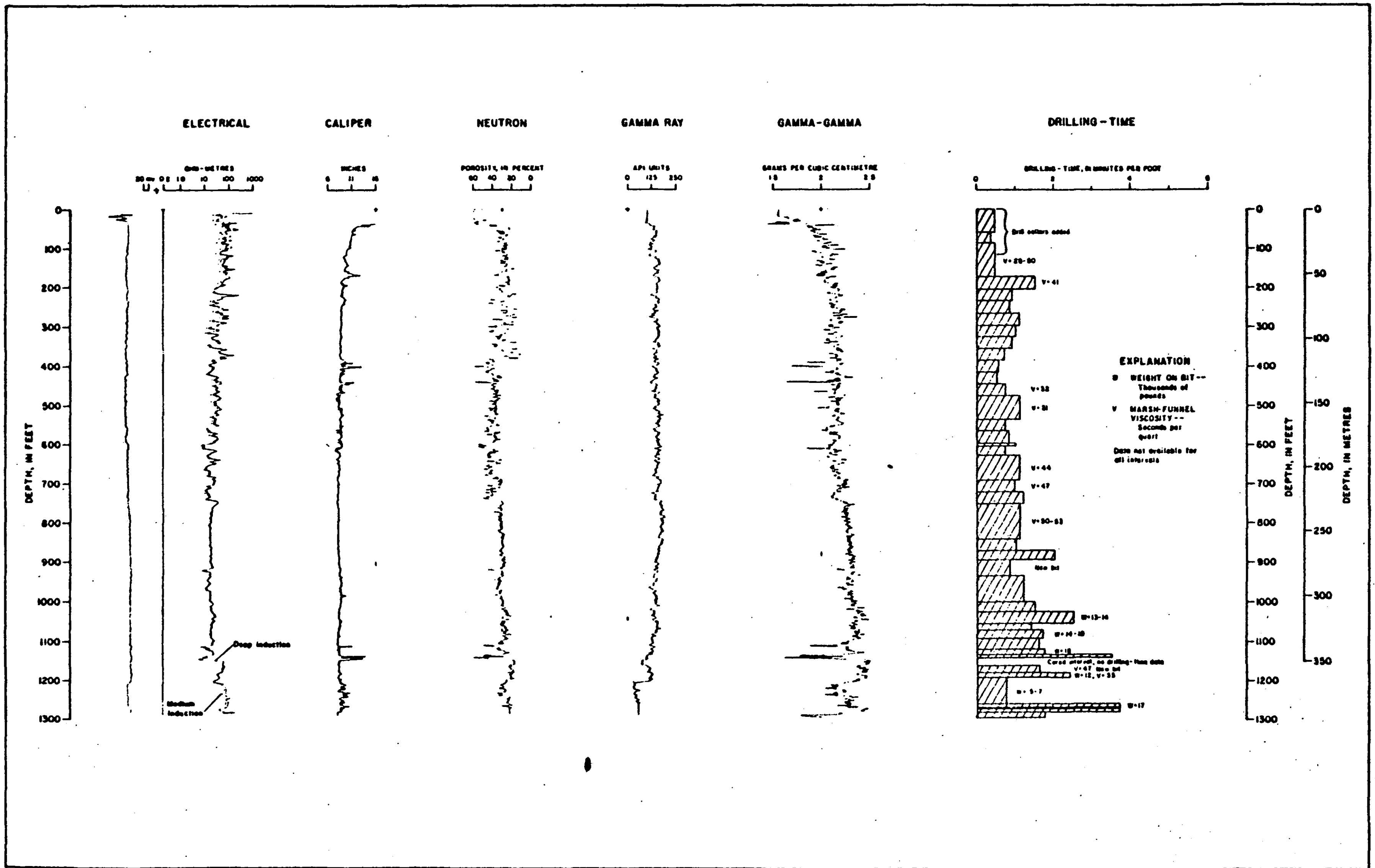

FIGURE 4.-Geophysical and drilling-time logs for Culberson County Airport No. 1 test hole (HL-47-58-603) on Wildhorse Flat

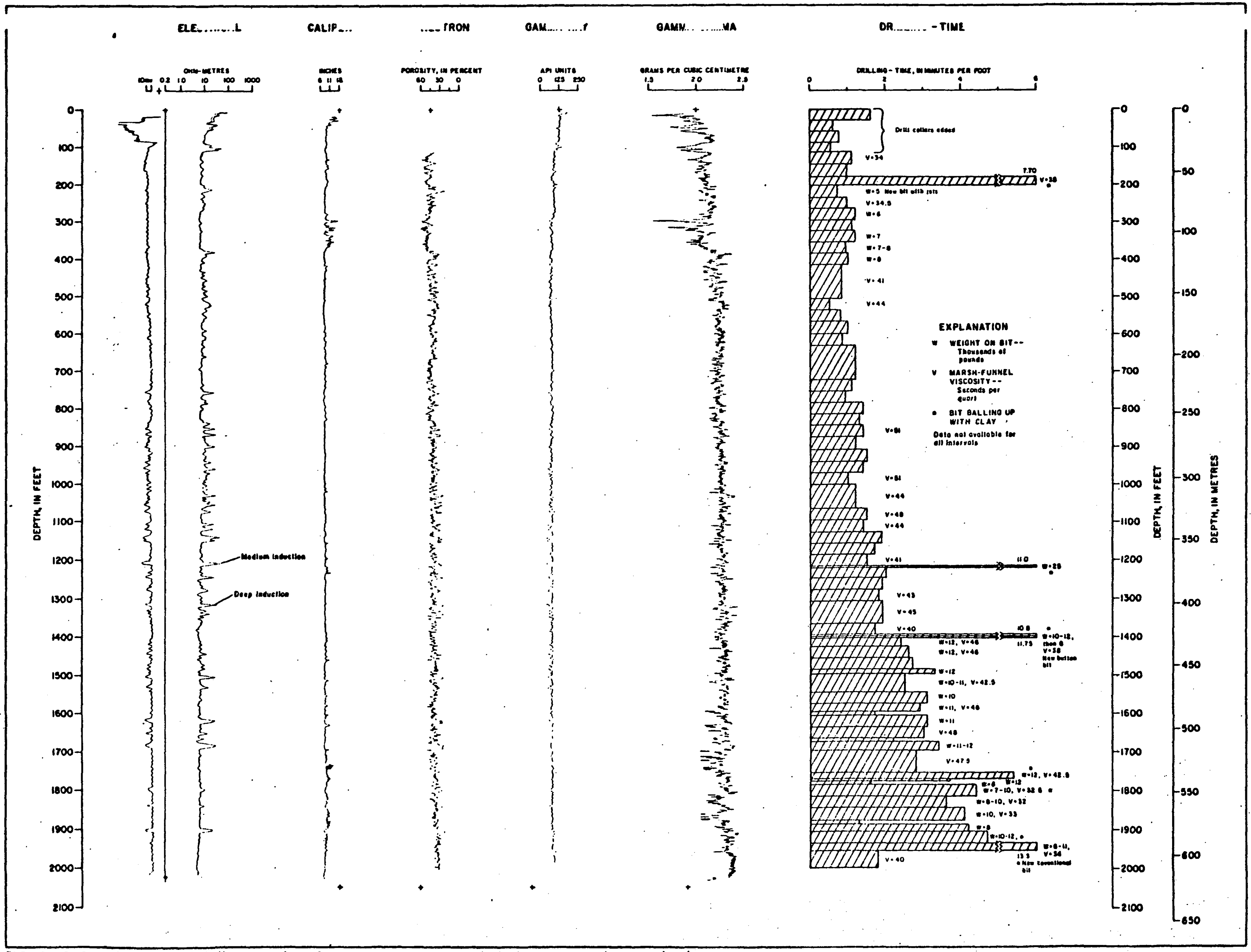

FIGURE 5.-Geophysical and drilling-time logs for J.C. Davis No. 1 test hole (PD-51-01-504) on Eagle Flat

Samples of drill cuttings were collected every 10 feet (3.0 m), and additional samples were collected when a change in lithology was noted, during periods of fluid circulation while drilling was stopped, and when bits were replaced. One core sample was taken in the Culberson County Airport test hole. Samples were examined briefly when collected, and selected samples were studied in more detail with a hand lens or binocular microscope.

Because the test holes were drilled primarily to determine the thickness of the alluvial fill, to evaluate water-bearing zones, and to select zones for the collection of water samples, the drill cuttings were not all examined in the same manner. Samples of the material in the lower part of each hole were examined in detail to determine the base of the alluvial fill and to estimate the degree of cementation of the fill. Samples of well-sorted sand and gravel beds below the water table were examined closely to evalute their water-bearing potential. All samples from the Evans test hole were examined with a binocular microscope because this hole was drilled into a complex sequence of alluvial and volcanic deposits. The sample logs of the test holes are given in tables 1, 3, 5, and 7. The log for the Evans No. 1 test hole is a detailed log, while the logs for the other holes include short entries for samples examined briefly during collection.

The test holes were drilled to the base of the alluvial fill or to a maximum depth of about 2,000 feet (610 m). The drilling program included provisions for coring the bedrock below the alluvial fill in each hole, but the only core obtained was in the Culberson County Airport test. Coring in the Guerra test was unsuccessful, and coring was not attempted in the Evans and Davis tests because they bottomed in tuff and clay, respectively. Cores of these materials would not have yielded useful hydrologic or stratigraphic information.

Geophysical logs were run in each test hole. In the Guerra test, electrical, radioactivity, caliper, and temperature logs (fig. 2) were made by the Geological Survey. In the Evans test, radioactivity and electrical logs were made by the Geological Survey, and electrical and caliper logs (fig. 3) were made by commercial companies. In the Culberson County Airport and Davis tests, electrical, radioactivity, and caliper logs (figs. 4 and 5) were made by a commercial company. All logs made by commercial companies can be purchased from the West Texas Electrical Log Service, 105 W. Wall Avenue, Midland, Texas 79701.

The geophysical and sample logs were used to select zones for water sampling. Attempts were made to obtain samples from four water-bearing zones in each hole--one from near the bottom of the hole, one from near the water table, and two in between. The chemical analyses of the water samples are given in tables 2, 4, 6, and 8. Most of the samples were collected by a method used by local drilling contractors and by El Paso Water Utilities in testing new wells. This method consists of using compressed air to jet a water sample from gravel-packed, perforated tubing (fig. 6).

The procedure is to position a 20- or 30-foot (6.1- or 9.1-m) joint of perforated tubing in the borehole, which is filled with drilling mud, opposite the lowest zone to be sampled. If the drilling mud contains fibrous "lost-circulation" material added to counteract loss of mud to permeable zones, it should be replaced with clean mud. If not, the fibrous material will clog the perforations in the tubing during sampling. Enough uniform, rounded gravel (1/8-1/4 inch; 0.3-0.6 cm) is poured into the borehole to fill the space below the perforated tubing, around the tubing, and to a level of about 100 feet (30 m) above the top of the perforations. A caliper log is used to estimate the volume of gravel needed. A small-diameter jet line is placed inside the tubing with one-third to one-half its length below the fluid level. Compressed air, which is blown through the jet line, returns to the surface bringing first the mud that was in the tubing and then water from the formation. The water is sampled when it is reasonably clear and its specific conductance is constant.

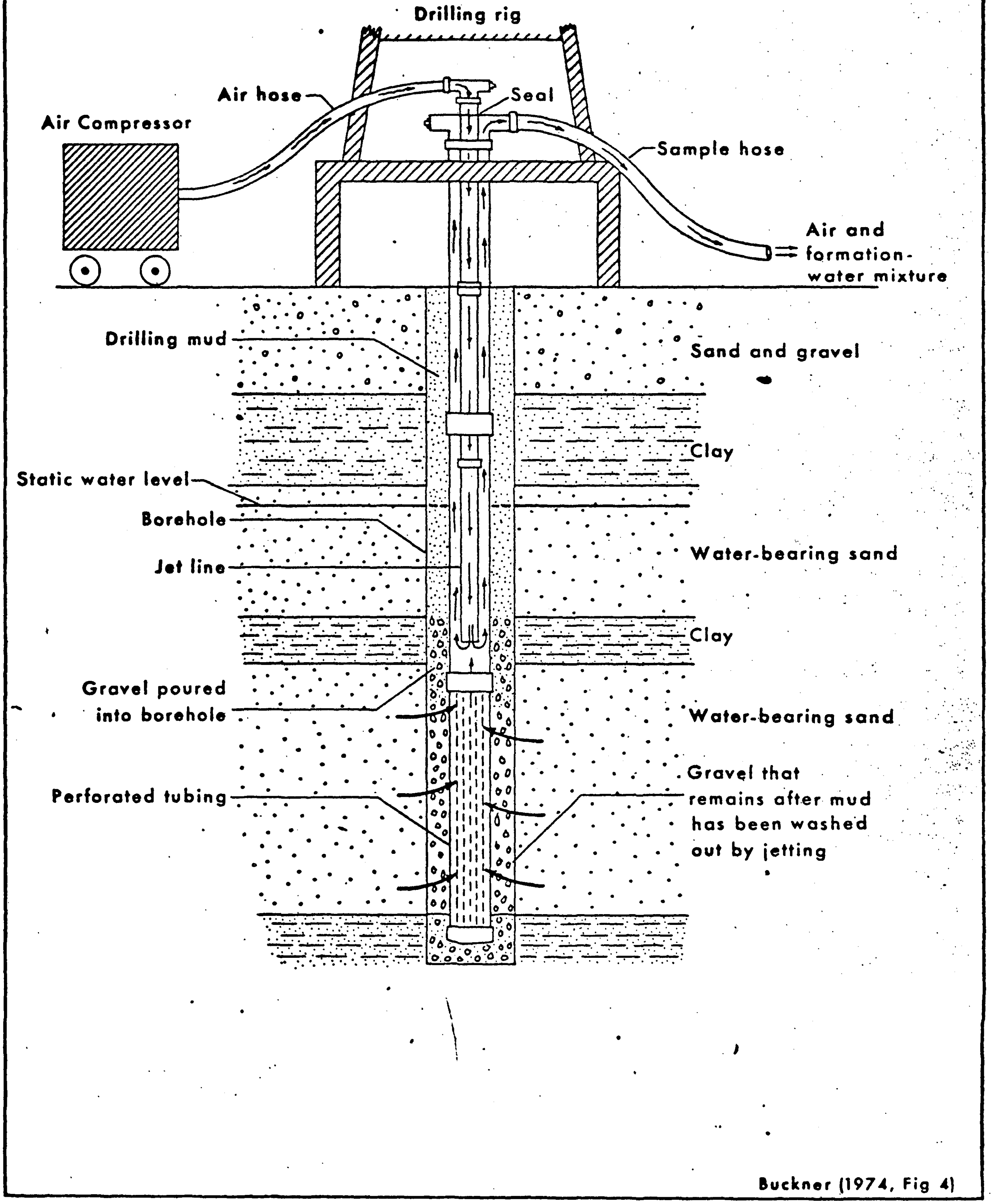

FIGURE 6.-Method of water sampling in an open hole

Subsequent samples are obtained by raising the tubing so that the perforated interval is opposite the next zone to be sampled. Additional gravel is added and the zone is jetted. Contamination of the water by mud moving upward or downward through the gravel pack is minimal because the hydraulic conductivity of the gravel with respect to the mud is about 5 percent of the hydraulic conductivity of the gravel with respect to water. The hydraulic conductivity of a material is inversely proportional to the viscosity of the fluid moving through it, and drilling mud commonly has a viscosity about 20 times greater than the viscosity of water.

The 100-foot (30-m) thickness of gravel in the borehole has been found by experience to be sufficient to minimize vertical movement of drilling mud. A lesser thickness might not be sufficient because the hydraulic gradient from the top of the gravel to the jetted zone would be steep enough so that significant amounts of mud could migrate downward through the gravel. The drop in head for this interval is reasonably constant--the head at the top of the gravel is the mud level in the open borehole, and the head at the jetted zone is the "pumping" fluid level in the tubing during jetting. The thicker the gravel interval in the borehole, the less is the rate of head drop through the gravel, and the less is the volume of mud moving downward. Thicknesses exceeding 100 feet (30 m) increase the possibility of sticking the tubing in the borehole.

After jetting a water sample, water-level recovery can be measured in the tubing and used to estimate relative permeabilities of sampled zones. The data generally are not adequate to compute hydraulic conductivities because the thickness of the producing zone, the degree of development, and the condition of the perforations in the tubing are not known.

This sampling method avoids some of the problems encountered in the use of a packer--principally that the samples are taken after the test hole is drilled to its total depth so that the zones to be sampled can be selected on the basis of geophysical logs, rather than being selected during drilling. In addition, this method eliminates the difficulty of setting a packer so that the zone between the packer and the bottom of the hole is isolated.

There are, however, three major disadvantages to the method of jetting from gravel-packed, perforated tubing: (1) Zones below 1,000 feet (305 m) are difficult to sample because proper emplacement of the gravel is difficult, especially where the gravel tends to form bridges between the borehole and the tubing; (2) for jetting efficiency, the jet line should be one-third to one-half submerged in water (Anderson, 1971, p. 121); therefore, if water levels are deep, it is difficult to jet samples from near the water table or even from the bottom of a test hole that is not almost twice as deep as the static water level; and (3) the water samples are contaminated to some extent by dissolved minerals from the drilling mud, either from mud or mud filtrate that has invaded the water-bearing zone, from mud continually being washed from the gravel around the perforations, or from small quantities of mud migrating vertically through the gravel pack. The less freely formation water can move into the borehole, the more mud from the gravel around, above, and below the perforations will be in the jetted fluid, and the more serious the contamination. A long period of jetting will lessen the amount of contamination, but will increase the danger of the tubing becoming stuck in the borehole.

In the Evans No. 1 test hole, hydraulically-inflatable straddle packers were used to sample three zones. Sampling was successful in one zone, but in the other two zones, the packers ruptured as they were being inflated. The rest of the water samples from the Evans test were collected by using gravel-packed, perforated tubing. In the Guerra No. 1 test hole, two water samples were collected while drilling with air mist, essentially by using the drill pipe as a jet line and the borehole as the perforated tubing. Therefore, the depth of the zones contributing water to the borehole was unknown.

In this report the term fresh water is used if water contains less than 1,000 mg/l dissolved solids; slightly saline water contains from 1,000 to 3,000 mg/l; moderately saline water contains 3,000-10,000 mg/l; very saline water contains 10,000-35,000 mg/l; and brine contains more than 35,000 mg/l dissolved solids.

LEOPOLD GUERRA NO. 1 TEST HOLE

The Leopold Guerra No. 1 test hole (State well No. PD-50-07-501) was drilled in November and December 1973 in Red Light Draw in Hudspeth County, 20 miles (32 km) southeast of Sierra Blanca (fig. 1). This site was selected because: (1) Few ground-water data were available; (2) the few water samples collected in the area were fresh; and (3) preliminary interpretation of earth-resistivity and seismic data indicated the occurrence of alluvium and volcanic rocks to depths of as much as 2,000 to 4,000 feet (610 to 1,219 m) on the eastern side of the draw. Consolidated sedimentary or volcanic rocks are within about 500 feet (152 m) of the land surface at the northern end of the draw and within about 400 feet (122 m) on the western side. The test hole is located about 3 miles (4.8 km) west of the Eagle Mountains on the youngest of three gravel terraces of Quaternary age (Underwood, 1963). The terraces are underlain by bolson fill of alluvial clay, silt, sand, and gravel of Quaternary and late Tertiary age. At some locations, a cemented gravel underlies the bolson fill or is equivalent to its lower part.

Prior to the late Tertiary faulting that formed the basin and range topography, volcanic rocks were emplaced by erruptions in the Eagle Mountain area, and some of these rocks probably underlie the bolson fill at the test-hole site. Underwood (1963) divided the volcanic rocks, from bottom to top, into a lower rhyolite, a trachyte porphyry, an upper rhyolite, and the Eagle Peak Syenite of Tertiary age. These rocks provided much of the material that makes up the older gravel, bolson fill, and terrace gravels at the test-hole site. The thickness of this volcanic sequence is variable, but from several hundred to several thousand feet (tens of hundreds of metres) of volcanic strata could underlie the test site. Limestone and sandstone of Cretaceous age probably underlie the volcanic rocks.

A later interpretation of the resistivity and seismic data indicates that at the test-hole site, about 300 to 900 feet (91 to 274 m) of alluvium is underlain by older and more cemented alluvium and volcanics that extend to depths of from 1,200 to 3,200 feet (366 to 975 m). Below this depth, other volcanics, probably flows that are more massive and coherent with higher resistivities and higher seismic velocities, extend to unknown depths (W. D. Stanley, written commun., Aug. 1, 1974).

The seismic data indicate that in the area of the test hole, the material between depths of about 300 to 500 feet (91 to 152 m) and 1,200 to 2,000 feet (366 to 610 m) had a seismic velocity of about 8,400 ft/s (2,560 m/s). This velocity is higher than the 5,000-ft/s (1,524-m/s) average that has been established for saturated alluvium (Zohdy, Eaton, and Mabey, 1974, p. 80), and suggests that the material is at least partly cemented. Below depths of 1,200 to 2,000 feet (366 to 610 m), the velocity is about 11,400 ft/s (3,475 m/s), indicating the occurrence of volcanic rocks or well-cemented alluvium.

Drilling and Sampling

The sample logs (table 1) indicate that the test hole was drilled to a total depth of 1,175 feet (358 m) in alluvial-fan deposits, primarily composed of siliceous volcanic rock and small amounts of limestone. Some chips and broken fragments of volcanic rock were observed in samples collected below a depth of 1,100 feet (335 m), but they appeared to be from at least three different types of rock, which suggests the occurrence of volcanic gravel rather than solid volcanic rock.

The drilling-time log (fig. 2) shows relatively slower drilling below 900 feet (274 m) and very slow drilling below 1,100 feet (335 m), which indicates that the fill was more cemented between 900 and 1,100 feet (274 and 335 m) and that the material below 1,100 feet (335 m) was well-cemented gravel or solid volcanic rock. The slower drilling rate below 1,100 feet (335 m) may have resulted, however, from a change in the drilling fluid from air mist to mud. Attempts to obtain a core from a depth of 1,175 feet (358 m) were unsuccessful; therefore, no positive identification was made of the material at the bottom of the hole. The static water level in the test hole is from about 540 to 580 feet (165 to 177 m) below land surface.

Borehole Logging

Six geophysical logs were made in the test hole--caliper, gamma ray, gamma gamma, neutron, electrical, and temperature (fig. 2). The caliper log shows a smaller, more uniform borehole below a depth of about 660-680 feet (201-207 m), which suggests the occurrence of harder material below this depth. Below 1,100 feet (335 m), the caliper tool did not operate properly, probably because of the viscous drilling mud in the hole. The gamma-ray log shows a uniform range of fluctuation from the fluid level at 340 feet (104 m) to a depth of 1,132 feet (345 m), indicating the occurrence of alternating beds of sand, gravel, and clay. The lack of a shift at the bottom of the hole suggests that the material below 1,100 feet (335 m) is either sand and gravel that is more cemented than the material above this depth or volcanic rock that is similar in composition to much of the sand and gravel.

The gamma-gamma log shows denser material, indicating greater cementation, below a depth of about 690 feet (210 m), and a sharp increase in density below 1,100 feet (335 m), indicating well-cemented gravel or solid volcanic rock. Within a limited range in density, with other factors (primarily borehole diameter) being equal, the bulk density of the rocks is linearly related to the logarithm of the count-rate on the gamma-gamma log (Keys and MacCary, 1971, p. 70-71). The count-rate in the zone of highest density at 1,120-1,140 feet (341-347 m) is about 675 counts per second, while the rate in the less dense zone from 900 to 1,100 feet (274 to 335 m) is about 950 counts per second.

Although the diameter of the borehole below 1,100 feet (335 m) is not known, it is probably close to the diameter of the hole between 900 and 1,100 feet (274 and 335 m), which is slightly larger than the diameter of the drill bit. By using the ratio of the logarithms of the count-rates and assuming that the particle density of the gravel and the density of solid rhyolite is about 2.5, the material between 1,120 and 1,140 feet (341 and 347 m) could be solid rhyolite; and the material between 900 and 1,100 feet (274 and 335 m) could be cemented gravel with a porosity of about 8 percent. However, if the material between 1,120 and 1,140 feet (341 and 347 m) is cemented gravel with a porosity of 5 percent, then the upper material could be gravel with a porosity of 13 percent. The data are insufficient to determine which of these alternatives is true.

The neutron log of this test hole exhibits very little change over its entire depth, although it does indicate a slight decrease in porosity below 1,120 feet (341 m). The electrical logs indicate a decrease in resistivity from about 550 feet (168 m), which is near the static water level, to about 780 feet (238 m), then a further decrease from 780 to 1,170 feet (238 to 357 m). The electrical logs show little change below 1,100 feet (335 m), although the 16-inch (41-cm) normal curve indicates a slightly higher resistivity between 1,120 and 1,130 feet (341 and 344 m). Lower porosity and permeability resulting from greater cementation may restrict the circulation of ground water below 780 feet (238 m). The restricted circulation could in turn result in the occurrence of water of poorer quality and lower resistivity.

The temperature log shows an increase in the thermal gradient at 1,104 feet (336 m), followed by a sharp increase between 1,132 to 1,150 feet (345 to 351 m). The high gradient at the bottom of the hole indicates that the denser material at this depth has a low thermal conductivity, which is the opposite of the expected conditions because unconsolidated alluvium normally has a lower conductivity than solid rock or cemented alluvium. However, some data on the thermal conductivities of rocks (Birch and Clark, 1940, table 6) indicate that rocks composed primarily of aggregates of feldspar such as many volcanic rocks, have lower thermal conductivities than sandstones composed primarily of quartz.

The steep thermal gradient at the bottom of the hole also could be caused by a change in permeability at the boundary of the bolson fill and consolidated rock. Temperature logs commonly show a steep gradient at the bedrock surface because active ground-water circulation above decreases the gradient, which must then steepen abruptly to continue the gradient in the consolidated rock below (C. A. Swanberg, oral commun., March 1, 1976).

Water Sampling

Water samples were collected periodically while the hole was being jetted clean prior to adding a new joint of drill pipe, and as much as 50-90 gal/min (3-6 l/s) of water was discharged during jetting below 1,000 feet (305 m). The conductance of the water samples ranged from 440 to 830 micromhos per centimetre (μmho/cm), which corresponds to a dissolved-solids content of 250-600 mg/l (milligrams per litre). The samples were contaminated to some degree by the 1,050-μmho/cm water injected into the compressed air to form the air-mist circulating fluid. The results of the analyses of samples collected while jetting at 1,000 and 1,100 feet (305 and 335 m) are given in table 2. These samples had a dissolved-solids content of 284 and 326 mg/l, which compares closely with the 312 mg/l of dissolved solids in water from a 510-foot (155-m) stock well 0.85 mile (1.4 km) northwest. The exact depth of occurrence of the water in these jetted samples is not known, but is probably from 540 to 780 feet (165 to 238 m), where the permeability of the alluvium is relatively high.

Attempts were made to obtain water samples from depths of 1,044 to 1,064 feet (318 to 324 m), 858 to 878 feet (262 to 268 m), and 702 to 722 feet (214 to 220 m) by using gravel-packed perforated tubing. A small amount of water was obtained from 858 to 878 feet (262 to 268 m), but the sample was contaminated with drilling mud and the dissolved-solids content of 838 mg/l (table 2) probably includes soluble material derived from the mud. No samples were obtained from the other two zones.

Summary

The Guerra No. 1 test hole penetrated sand and gravel in an alluvial-fan deposit that was increasingly cemented below depths of about 680 to 780 feet (210 to 238 m). At a depth of 1,100 feet (335 m) the hole penetrated either well-cemented gravel or volcanic rock. The electrical logs indicate that all of the ground water in the alluvium is fresh, and all water samples collected from the test hole were fresh. Of the strata penetrated, the porosity and permeability is highest in the alluvium. The potential for ground-water development is greatest between the depth of the water table at 540 to 580 feet (165 to 177 m) and depths of 680 to 780 feet (207 to 238 m).

Table 1.--Lithologic log of the Guerra No. 1 test hole (PD-50-07-501)

Interval (feet)	Description
0-40	Sand and gravel, coarse
40-50	Sand, fine to very coarse, and gravel, poorly sorted; most grains and gravel are angular to subangular, white, gray, yellowish-brown and reddish-brown volcanics; fine grains are subangular to rounded; little cementing material
50-90	Sand and gravel
90-100	Sand, very fine to very coarse, predominantly fine, and gravel; most coarse grains and gravel are angular, white, yellow, brown, orange, and gray volcanics; fine grains are subangular with some subrounded; little cementing material
100-140	Sand and gravel
140-150	Sand, very fine to very coarse, and gravel; most coarse grains and gravel are angular, pinkish-brown, dark brown, white, and gray volcanics with some orange and reddish brown; fine grains are subangular to subrounded, some sanidine(?); little cementing material
150-190	Gravel and sand
190-200	Sand, very fine to very coarse, mostly medium, and gravel; coarse grains and gravel are angular, pinkish and reddish-brown volcanics with some white and yellowish orange, some fresh chips present; fine grains are subangular with some subrounded, some sanidine(?); minor calcareous cementing material
200-220	Gravel
220-225	Clay(?)
225-240	Gravel
240-250	Sand, very fine to very coarse, gravel, and silt; coarse grains and gravel are angular, yellowish-orange, gray, reddish-brown, and white volcanics, some fresh chips; fine grains are subangular to subrounded, some sanidine(?); minor calcareous cementing material
250-290	Gravel
290-300	Sand, fine to very coarse, and gravel; coarse grains and gravel are angular to subangular, yellowish-orange, reddish-brown, pink, and white volcanics; minor fine grains are angular to subrounded; a few grains are cemented
300-340	Gravel
340-350	Sand, fine to very coarse, and gravel; coarse grains and gravel are angular, whitish-gray, yellow, orange, reddish-brown, and brown volcanics, some fresh chips; fine grains are subangular to subrounded, many fine grains of sanidine(?); minor calcareous cementing material
350-390	Gravel

Table 1.--Lithologic log of the Guerra No. 1 test hole (PD-50-07-501)--Continued

Interval (feet)	Description
390-400	Sand, very fine to very coarse, and gravel (very fine to fine pebbles) with coarse material predominating; coarse grains and pebbles are angular to subangular, yellowish-orange, red, pink, and gray volcanics with some green and mottled black, some fresh chips; fine grains more rounded, many fine grains of sanidine(?); little cementing material
400-440	Gravel
440-450	Sand, coarse to very coarse, and gravel, moderately well sorted; coarse grains and gravel are subangular with some subrounded, yellowish-orange, pink, gray, reddish-brown, white, and clear volcanics; some fresh chips, fine grains more rounded; little cementing material
450-490	Gravel and sand
490-500	Sand, mostly coarse to very coarse, and gravel, moderately well sorted; mostly angular to subangular, brown, orange-brown, yellowish-orange, reddish-brown, gray, and white volcanics, some fresh chips; pebble count showed 15 percent of grains have calcareous cement coating
500-540	Sand and gravel
540-550	Sand, mostly coarse to very coarse, and gravel (very fine to fine pebbles); coarse grains and pebbles are angular to subangular, yellowish-orange, gray, and reddish-brown volcanics with some white; minor fine grains are more rounded, some sanidine(?), minor calcareous cementing material
550-590	Sand and gravel
590-600	Sand, very fine to very coarse, and some gravel (very fine pebbles); coarse grains and pebbles are angular to subangular, brown, reddish-brown, yellowish-orange, white, and gray volcanics with some green and clear, some fresh chips; fine grains more rounded, some sanidine(?); little cementing material
600-640	Sand and gravel
640-650	Sand, mostly very coarse, and gravel (very fine to medium pebbles); angular to subangular, reddish-brown, brown, grayish-white, yellow, and yellowish-orange volcanics; minor fine grains are subangular to rounded, yellowish tan and clear (sanidine?); minor calcareous cementing material
650-690	Sand and gravel
690-700	Sand, mostly coarse to very coarse, and gravel (very fine to medium pebbles); angular to subangular, mostly reddish brown and brown, with white, gray, yellowish-orange, pink, and clear volcanics with some green, some fresh chips; fine grains are subangular to rounded, mostly clear (sanidine?); some calcareous cement on coarse grains
700-740	Sand and gravel

Table 1.--Lithologic log of the Guerra No. 1 test hole (PD-50-07-501)--Continued

Interval (feet)	Description
740-750	Sand, very coarse, and gravel (very fine to medium pebbles); angular to subangular, brown, reddish-brown, pinkish-brown, pink, yellowish-orange, white and gray volcanics, a few fresh chips; minor fine grains, more rounded, mostly clear (sanidine), several grains have calcareous cement coating
750-790	Sand and gravel
790-800	Sand, mostly coarse to very coarse, and gravel (very fine to fine pebbles); coarse grains and pebbles are angular to subangular, reddish-brown, brown, and yellowish-orange volcanics with some white, gray, and pink, a few fresh chips; minor fine grains are more rounded, clear (sanidine?), white, and yellowish; little to no cementing material
800-840	Sand and gravel
840-850	Sand, very coarse, and gravel (very fine to fine pebbles); angular to subangular, brown, reddish-brown, yellowish-orange, white, gray, pink, and tan volcanics, some fresh chips; pebble count shows 20-25 percent of grains have calcareous cement coating
850-890	Sand and gravel
890-900	Sand, mostly medium to very coarse, and gravel (very fine to fine pebbles); coarse grains and pebbles are angular to subrounded, reddish-brown, brown, yellowish-orange, white, gray, and pink volcanics, some fresh chips, fine grains are more rounded, clear and yellow, several grains have calcareous cement coating and calcareous material
900-940	Sand and gravel
940-950	Sand, medium to very coarse, and gravel (very fine to medium pebbles); coarse grains and pebbles are angular to subrounded, brown, reddish-brown, yellowish-orange, pink, white, and gray volcanics with rare green, some fresh chips; fine grains are more rounded, clear (sanidine?), white, and yellow; little calcareous cement coating the pebbles, some fine calcareous material
950-990	Sand and gravel
990-1,000	Sand, mostly coarse to very coarse, and gravel (very fine to medium pebbles); coarse grains and pebbles are angular to subrounded, mottled pink and white, reddish-brown, brown, yellow-orange, white, and gray volcanics with some clear grains (sanidine?), a few fresh chips; fine grains are more rounded, clear; some calcareous cementing material
1,000-1,025	Sand and gravel, mostly volcanics with a few fragments of limestone
1,025-1,040	Sand and gravel, poorly sorted

Table 1.--Lithologic log of the Guerra No. 1 test hole (PD-50-07-501)--Continued

Interval (feet)	Description
1,040-1,050	Sand, coarse to very coarse, and gravel (very fine to medium pebbles); coarse grains and pebbles are angular to subrounded, brown, reddish-brown, and yellowish-brown volcanics with some yellowish-orange, pink, white, and gray; minor fine grains are mostly clear (sanidine); some calcareous cement coatings and calcareous material
1,050-1,090	Sand, medium to very coarse, and gravel
1,090-1,100	Sand, mostly coarse to very coarse, and gravel (very fine to medium pebbles); coarse grains and pebbles are angular to subrounded, reddish-brown, brown, gray, yellowish-orange, and white volcanics with some pink, some fresh chips; minor fine grains are more rounded, clear (sanidine?) and yellow; little calcareous coating on grains but calcareous material in the fines
1,100-1,120	Sand and gravel, angular, poorly sorted
1,120-1,140	Sand and gravel
1,140-1,150	Sand, very fine to very coarse, and some gravel (very fine to fine pebbles); coarse grains and pebbles are angular to subrounded, reddish-brown, brown, yellowish-orange, white, gray, and clear volcanics with rare green; fresh chips are common, tan, reddish brown, pinkish gray, and white; fine grains are more rounded, clear (sanidine?) and yellow; little calcareous coating on grains, but calcareous material common in the fines
1,150-1,165	Sand and gravel
1,165-1,175	Sand, medium to very coarse, and gravel (very fine to coarse pebbles); coarse grains and pebbles are angular to subrounded, reddish-brown, brown, yellowish-orange, pink, gray, and white volcanics; fresh chips common, tan, reddish brown, pink, yellowish orange, gray, and brown; minor fine grains are more rounded; some grains and one fresh chip have calcareous coatings

Table 2.—Chemical analyses of water from the Guerra No. 1 test hole

SAMPLE DESCRIPTION	DATE	DIS-SOLVED SILICA (SIO_2) (MG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAGNE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED POTAS-SIUM (K) (MG/L)	BICAR-BONATE (HCO_3) (MG/L)	CAR-BONATE (CO_3) (MG/L)	DIS-SOLVED SUL-FATE (SO_4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED NITRITE PLUS NITRATE (N) (MG/L)	DIS-SOLVED ORTHO PHOS-PHORUS (P) (MG/L)	DIS-SOLVED BORON (B) (UG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	HARD-NESS (CA,MG) (MG/L)	PER-CENT SODIUM	RE-SIDUAL SODIUM CAR-BONATE (RSC)	SODIUM AD-SORP-TION RATIO (SAR)	SPECIFIC CONDUCT-ANCE (MICRO-MHOS)	PH (UNITS)	TEM-PERA-TURE (°C)
Guerra No. 1 while drilling with air at 1,000 feet.	11/28/73	24	740	--	14	2.6	82	2.4	158	.0	45	28	1.6	1/1.5	--	100	284	46	79	1.68	5.3	447	8.1	--
Guerra No. 1 while drilling with air at 1,100 feet.	11/29/73	23	--	--	10	2.2	2/110	--	206	0	40	33	2.4	1/1.5	--	--	326	34	87	2.70	8.1	508	8.3	30
Guerra No. 1 at 658-678 feet. (Sample very contaminated with drilling mud.)	12/13/73	4.1	--	--	16	4.4	2/290	--	344	12	290	54	2.7	1/ .5	--	--	838	58	92	4.88	16	1,320	8.4	--

1/ Dissolved nitrate (N).
2/ Shown as dissolved sodium + dissolved potassium.

CLAY EVANS NO. 1 TEST HOLE

The Clay Evans No. 1 test hole (State well No. UW-51-28-902) was drilled in April 1974 on Ryan Flat in Presidio County, 5 miles (8.0 km) south of Valentine (fig. 1). The area of Ryan Flat is underlain by a structural depression, which has some of the features of a caldera. The depression is filled with a thick sequence of volcanic deposits and associated sediments of Eocene and Oligocene age. The O. W. Killam Cole A. Means No. 1 oil test, 1 mile (1.6 km) northeast of Valentine, reportedly (Woodward, 1954, p. 15) penetrated alluvium to a depth of 528 feet (161 m) and volcanic rocks from 528 to 6,560 feet (161 to 1,999 m). Vertical electrical soundings and seismic refraction profiles indicate volcanic deposits to depths of about 1,700 to almost 5,000 feet (518 to 1,524 m), and gravity data show a pronounced low over most of Ryan Flat (W. D. Stanley, written commun., Sept. 22, 1972 and Aug. 1, 1974).

The volcanics are mostly thick flows north and east of Ryan Flat in the Davis Mountains, Y-6 Hills, and Chispa Mountain and thinner ash-flow tuffs and flows interbedded with thick tuffs around Ryan Flat.

Walton (1975, fig. 2) published the most recent stratigraphic section of the Tertiary volcanics of the Ryan Flat area. In descending order, the upper part (rocks of Oligocene age) includes the Petan Basalt, the Mitchell Mesa Ignimbrite (the Brite Ignimbrite of Twiss, 1970, fig. 8), the Capote Mountain Formation, the Bracks Rhyolite, the Chambers Formation, and the Buckshot Ignimbrite. The Mitchell Mesa and Buckshot are ash-flow tuffs, and the Capote Mountain and Chambers Formations are predominantly fine-grained tuffaceous sediments, but include nonmarine limestone and conglomerate. Twiss (1970, fig. 8) gives an approximate thickness of 300 feet (91 m) for the Petan, 50 feet (15 m) for the Mitchell Mesa, 1,800 feet (549 m) for the Capote Mountain, 150 feet (46 m) for the Bracks, 600 feet (183 m) for the Chambers, and 50 feet (15 m) for the Buckshot. A preliminary interpretation of a vertical electrical sounding 0.5 mile (0.8 km) north of the test-hole site indicated alluvium to about 660 feet (201 m) and tuff below. At the test-hole site, the nearest outcrop of the Petan Basalt is 4 miles (6.4 km) to the northwest, and the nearest outcrop of the Mitchell Mesa Ignimbrite and Capote Mountain Formation is 2 miles (3.2 km) west (P. C. Twiss, written commun., June 20, 1973).

The test hole on Ryan Flat was drilled to test the ground-water potential of the alluvial fill and the upper part of the volcanics.

Ground water in the Ryan Flat area is uniformly fresh, but is used mostly for domestic and livestock supply. Only a few large-capacity wells have been drilled for irrigation. A driller's report filed with the Texas Water Development Board indicates that an irrigation well 4 miles (6.4 km) southwest of the test hole (fig. 1) yielded about 1,500 gal/min (95 l/s) from a fine to medium sand between depths of 450 to 750 feet (137 to 229 m). The driller's log was not sufficiently detailed to determine whether the producing sand was part of the alluvial fill or part of the volcanic sequence. Six wells near Marfa, 35 miles (56 km) southeast of Valentine, yield from 400 to 1,200 gal/min (25 to 76 l/s) from reworked tuff and associated sediments, ash-flow tuff, and basalt (Davis, 1961, table 3). At Lobo Flat, northwest of Valentine, several large-capacity irrigation wells withdraw at least part of their water from basalt or andesite. Most wells drilled on Ryan Flat, however, have low yields. A test hole drilled by the U.S. Army to a depth of 1,001 feet (305 m), mostly through tuff and associated sediments 6 miles (10 km) west of the Evans No. 1 test hole (fig. 1), yielded only 10-15 gal/min (0.6-0.1 l/s). Several other shallow tests for stock water in the area were unsuccessful.

Drilling and Sampling

The Evans test hole was drilled to a depth of 2,006 feet (611 m). The sample log (table 3) and the drilling-time log (fig. 3) indicate that the upper 1,250 feet (381 m) of the deposit is unconsolidated sand and gravel with a few thin volcanic flows. The interval from 1,250 to 2,006 feet (381 to 611 m) is mostly tuff with some volcanic flows, and volcanic flows(?) predominate from 1,250-1,480 feet (381-451 m). The deposits are altered (clayey) tuff from 1,480 to 1,840 feet (451 to 561 m) and less altered tuff from 1,840 to 2,006 feet (561 to 611 m). The sample and drilling-time logs indicated a volcanic flow of dark porphyritic rock with white phenocrysts at about 670 feet (204 m), correlating with a high-resistivity zone from 662 to 672 feet (202 to 205 m) on the electrical log. Another flow at 1,700 feet (518 m), from 1,685 to 1,705 feet (514 to 520 m) on the electrical log, appears to be an altered tan to brown porphyritic rock with clear and black phenocrysts. No other flows were distinguished in the samples, but were suggested by slow drilling on the drilling-time log and by high resistivities on the electrical log at about 770, 950 and 1,050-1,115 feet (235, 290, and 320-340 m). A zone of alternating flows and tuffs was indicated from 1,255 to 1,465 feet (383 to 447 m). The slow drilling at 1,015 and 1,210 feet (309 and 369 m) does not correlate with high-resistivity zones on the electrical log and probably does not indicate volcanic flows.

The static water level in the test hole, measured after water sampling was completed and while the perforated section of the tubing was at 345-375 feet (105-114 m), was about 223 feet (68 m) below the land surface.

Borehole Logging

The geophysical logs obtained at the Evans test hole (fig. 3) are as follows: (1) Electrical, gamma-ray, gamma-gamma, and neutron logs made with use of Geological Survey equipment; (2) an electrical log run by Schlumberger Well Services; and (3) a caliper log run by Worth Well Surveys. The electrical logs obtained with Geological Survey equipment included 16- and 64-inch (41- and 163-cm) normal, single-point resistance, and spontaneous potential. The electrical log made by Schlumberger Well Services was a dual-induction laterolog and spontaneous potential log.

The electrical logs indicate the occurrence of clay from 40 to 210 feet (12 to 64 m), sand and gravel from 210 to 383 feet (64 to 117 m), and clay or tuff from 383 to 555 feet (117 to 169 m). The logs show moderately high resistivity (15-20 ohmmetres) from 555 to 935 feet (169 to 285 m), with zones of high resistivity (up to 90 ohmmetres) from 662-672 and 771-776 feet (202-205 and 235-237 m). This interval appears to be mostly fine to medium, fairly well-sorted sand with two thin volcanic flows. These beds probably correlate with the thick, fine to medium sand reported from 270 to 750 feet (82 to 229 m) in the irrigation well 4 miles (6.4 km) to the southwest.

From 935 feet to about 1,250 feet (285 to 381 m) the resistivity is low to moderately high (10-15 ohmmetres) with zones of higher resistivity (up to 25 ohmmetres) from 946-953 and 1,082-1,112 feet (288-290 and 330-339 m). This interval includes fine to medium sand, possibly including clay, and two volcanic flows.

From about 1,250 to 1,463 feet (381 to 446 m), the electrical logs show an interval of alternating high and low resistivity (from 2 to 40 ohmmetres), which probably indicates alternating volcanic flows and tuffs. From 1,463 to 1,825 feet (446 to 556 m) the resistivities are low (6-10 ohmmetres) and probably indicate an interval of altered (clayey) tuff. A zone of high resistivity (up to 55 ohmmetres) from 1,685 to 1,705 feet (514 to 520 m) is a volcanic flow. From 1,825 to 2,000 feet (556 to 610 m) the resistivities are moderately high (15 ohmmetres) and probably indicate unaltered or slightly altered tuff. The radioactive logs, especially the gamma-gamma and neutron logs, correlate with the electrical logs and show the volcanic flows distinctly.

The gamma-gamma log shows the upper volcanic flows as high-density zones at 658-663 feet (201-202 m), 760-768 feet (232-234 m), 935-940 feet (285-287 m), and 1,040-1,125 feet (317-343 m). The log also suggests a volcanic flow from 900 to 910 feet (274 to 277 m), of which there is only slight indication on the electrical log. Below 1,125 feet (343 m), the log shows alternating high-density and low-density zones, indicating interbedded flows and tuffs. The flow at 1,700 feet (518 m) is shown as a pronounced high-density zone.

The neutron log shows the upper volcanic flows as zones of low porosity at 665-670 feet (203-204 m), 768-773 feet (234-236 m), 942-949 feet (287-289 m), and 1,047-1,110 feet (319-338 m). The interval from 1,295-1,460 feet (395-445 m) shows alternating low- and high-porosity zones, corresponding to alternating flows and tuffs. The flows from 1,295-1,347 feet (395-411 m), 1,375-1,420 feet (419-433 m), and 1,445-1,460 feet (440-445 m), which are especially distinct, correlate with high-resistivity zones on the electrical logs.

In general, the geophysical logs indicate that the alluvial fill is composed mostly of clay to 210 feet (64 m) and sand and gravel from 210 to 385 feet (64 to 117 m). The zone from 385 to 555 feet (117 to 169 m) is probably clay, but could be altered tuff. From 555 to about 1,250 feet (169 to 381 m) the material is alluvial sand composed mostly of volcanic material and some thin volcanic flows. The sand is probably a reworked tuff.

Samples of sand pumped with the water from the irrigation well 4 miles (6.4 km) southwest of the test hole and samples of a semiconsolidated tuff or tuffaceous sandstone, which was obtained from a shallow excavation about 1 mile (1.6 km) north of the irrigation well, were analyzed by the Geological Survey. The sand pumped from the well, which probably represents the material from the interval perforated between depths of 450 and 750 feet (137 and 229 m), is composed of plagioclase feldspar and potash feldspar (mostly sanidine) with some magnetite, hornblende, and quartz. The semiconsolidated tuff was identified as a slightly reworked vitric crystal tuff, and such rock could have been the source of the unconsolidated sand.

The interval from about 1,250 feet to 1,465 feet (381 to 447 m) is mostly volcanic flows and interbedded tuffs; the interval from 1,465 to 1,825 feet (447 to 556 m) is altered tuff, with a flow at 1,700 feet (518 m); and the interval from 1,825 to 2,006 feet (556 to 611 m) is tuff.

The reworked deposits of volcanic material and thin volcanic flows in the interval from 555 to about 1,250 feet (169 to 381 m) are probably younger than the volcanic sequence defined by Twiss (1970) and Walton (1975); although they may be included in or equivalent to the Petan Basalt and Mitchell Mesa Ignimbrite. The volcanic flows and tuffs from about 1,250 to 2,006 feet (381 to 611 m) are probably equivalent to at least part of the interval from the Petan Basalt through the Capote Mountain Formation.

Water Sampling and Water-Level Recovery Tests

Water samples were obtained from 1,135-1,165 feet (346-355 m), 971-1,001 feet (296-305 m), 850-880 feet (259-268 m), and 345-375 feet (105-114 m). The attempt to obtain a sample at 1,255 to 1,335 feet (383 to 407 m) was unsuccessful because the inflatable packers ruptured. All water samples were fresh; the dissolved-solids content ranged from 430 to 490 mg/l and the specific conductances ranged from 583 to 680 μmho/cm (table 4). The samples were contaminated with drilling mud and the indicated dissolved-solids content therefore may not be accurate. The actual dissolved-solids content may be similar to that in water from the 320-foot (98-m) stock well about 1 mile (1.6 km) west (fig. 1), which had a specific conductance of about 360 μmho/cm (approximately 270 mg/l dissolved solids).

Water-level recovery was measured after jetting water samples from 971-1,001 feet (296-305 m), 850-880 feet (259-268 m), and 345-375 feet (105-114 m). These data probably are adequate only to indicate that the two upper zones are several times as permeable as the zone from 971-1,001 feet (296-305 m).

Summary

The Evans test hole was drilled through alluvial fill, alluvial sands of volcanic origin, and volcanic rocks. The interval from the surface to 555 feet (169 m) is equivalent to the bolson fill in other basins in the area. The sands from 555 to about 1,250 feet (169 to 381 m) are mostly reworked and redeposited volcanic material that may be older than the typical bolson fill. Below about 1,250 feet (381 m), the deposits are volcanic rocks. The alluvial fill and the reworked volcanic sands contain fresh ground water. The coarse alluvium from 210-385 feet (64-117 m) is probably the most permeable; the volcanic sands to about 900 feet (274 m) are probably intermediate in permeability; and the volcanic sands from 900 to about 1,250 feet (274 to 381 m) have the lowest permeability.

Table 3.--Lithologic log of the Clay Evans No. 1 test hole (UW-51-28-902)

Interval (feet)	Description
0-15	Sand, very fine to medium, well sorted, subangular to rounded, clear (sanidine or quartz), and brown, black, and red volcanics
15-30	Sand, very fine to coarse, as above, with rounded, black heavy minerals
30-40	Sand, fine to very coarse, rounded and clear (sanidine or quartz), angular and tan tuff grains, black heavy minerals, and brown and pink volcanics; gravel, fine, brown, black, pink, and white volcanics
40-75	Sand, fine to very coarse, poorly sorted, mostly angular to subangular tan tuff grains; gravel, fine to medium, brown, red, black, and white volcanics, with some pebbles of green volcanics from 60-75 feet
75-90	Sand, mostly coarse to very coarse, moderately sorted, subangular to rounded, black and dark brown volcanics with some gray, pink, and white
90-100	Sand, fine to very coarse, and fine gravel; coarse grains and gravel are subangular to rounded, black and dark brown volcanics with some red; fine grains are red volcanics and heavy minerals
100-120	Sand, mostly medium to coarse, subangular to subrounded, brown, red, black, gray, and white volcanics with some red chips; some fine gravel from 110-120 feet
120-130	Gravel, (very fine to medium pebbles), pink, dark brown, and black volcanics
130-150	Sand, fine to very coarse, and fine gravel; coarse grains and gravel are dark brown volcanics with some black, red, white, and clear; fine grains are red volcanics, rounded clear sanidine, and black heavy minerals; drilling mud or clay in sample, especially from 140-150 feet
150-180	Clay and/or drilling mud with some sand and gravel, volcanics
180-200	Clay and/or drilling mud with some sand, coarse, and gravel, fine to medium, gray, black, and red volcanics
200-210	Clay and/or drilling mud; sand, coarse to very coarse; fine gravel; sand and gravel are subangular to subrounded, green, brown, and red volcanics and altered tuff(?)
210-230	Sand, fine to very coarse, and some fine gravel; coarse grains and gravel are subangular to subrounded, black, brown, red, and green volcanics with some white; fine grains are mostly drilling mud with some rounded sanidine, red volcanics and rounded black heavy minerals

Table 3.--Lithologic log of the Clay Evans No. 1 test hole (UW-51-28-902)--Continued

Interval (feet)	Description
230-285	Sand, very fine to very coarse, and some gravel (very fine to fine pebbles); coarse grains and pebbles are angular to subrounded, tan, black, and brown volcanics with some red and green, some black basalt(?), and altered tuff(?) (especially common from 240-285 feet) which is angular to subangular, coherent, with a tan matrix of clayey material around rounded sanidine, dark volcanic grains, and black heavy minerals; fine grains are rounded sanidine, subrounded brown and red volcanics, and rounded heavy minerals
285-335	Sand, very fine to very coarse, and minor gravel from 325-335 feet (very fine to fine pebbles); coarse grains and pebbles are angular to subrounded, mostly altered tuff(?), and angular to subrounded mostly black volcanics with dark brown and red; minor fine grains are rounded sanidine with some subrounded brown and red volcanics, and rounded black heavy minerals
335-380	Sand, medium to very coarse, and some gravel (very fine to fine pebbles); coarse grains and pebbles are angular to rounded, black, brown, red, and pink volcanics with some white and altered tuff(?); fine grains are rounded sanidine with subrounded to rounded black and red volcanics and black heavy minerals
380-410	Sand, medium to very coarse, well sorted, coarse grains are angular to subrounded, black volcanics with some red and brownish orange and some vesicular red volcanics; fine grains are rounded sanidine with subangular to subrounded red and black volcanics and rounded heavy minerals
410-440	Sand, very fine to very coarse, with minor fine gravel; coarse grains and gravel are angular to subrounded black, brown, and red volcanics with some white; fine grains are tan clay and/or drilling mud with rounded sanidine, black and brown volcanics, and black heavy minerals
440-490	Sand, fine to very coarse, mostly coarse to very coarse from 440 to 450 feet and medium to coarse from 480-490 feet, and some fine gravel; coarse grains and gravel are angular to subrounded, dark brown, black, gray, red, and pink volcanics, some vesicular; fine grains are mostly rounded sanidine with tan altered clay(?) or drilling mud, subangular to subrounded black, red, and orange volcanics and rounded, black heavy minerals
490-500	Sand, fine to very coarse, poorly sorted; coarse grains are angular to rounded, dark brown, black, gray, red, and yellow volcanics, some vesicular, with a few white grains; fine grains are mostly rounded sanidine with subangular to subrounded brown, black, gray, and yellow volcanics and some rounded black heavy minerals

Table 3.--Lithologic log of the Clay Evans No. 1 test hole (UW-51-28-902)--Continued

Interval (feet)	Description
500-540	Sand, fine to very coarse, and some fine gravel; poorly sorted; coarse grains and gravel are angular to subrounded, black, dark brown, red, and yellow volcanics; fine grains are rounded sanidine with rounded green grains, subangular to subrounded red and brown volcanics and subrounded to rounded heavy minerals
540-560	Sand, very fine to very coarse, poorly sorted; coarse grains are black, dark brown, red, yellow and gray volcanics; fine grains are mostly rounded sanidine, subangular to rounded brown and red volcanics, and rounded heavy minerals, with some tan grains of clay, drilling mud, or tuff; some calcareous material present
560-600	Sand, mostly fine to medium with some coarse and very coarse, fairly well sorted; mostly rounded sanidine with rounded to subrounded yellow, red, and brown volcanics and some clay or drilling mud, and with abundant rounded heavy minerals from 590-600 feet; coarse grains are subrounded to subangular black and brown volcanics
600-610	Sand, fine to coarse, mostly medium, well sorted, mostly rounded sanidine and subangular to rounded red, black, and brown volcanics, with some fine-grained, rounded heavy minerals
610-620	Sand, fine to very coarse, fairly sorted; of angular to rounded dark brown, black, red, and green volcanics, fine to medium rounded sanidine, fragments of altered tuff(?), and fine rounded heavy minerals; some calcareous material present
620-670	Sand, fine to very coarse, fairly sorted; half-rounded sanidine and half-subangular to subrounded black, brown, red, and yellow volcanics, some vesicular, with some tuffaceous sandstone with calcareous cement and some rounded, black heavy minerals; some fine gravel from 660 to 670 feet
670-690	Sand, fine to very coarse, and fine gravel; mostly coarse to very coarse basalt(?) especially at 670-680 feet, fine crystalline with some clear to white phenocrysts, angular to subangular, black; some fine to very coarse, angular to rounded, gray, red, brown, and black volcanics, with rounded sanidine and clay or drilling mud
690-700	Sand, fine to very coarse, rounded sanidine and subangular to subrounded red, black, tan, and yellow volcanics with some cemented tuff(?), fine, rounded heavy minerals, and many grains of black basalt(?)
700-740	Sand, very fine to coarse with some very coarse, fairly sorted; mostly rounded sanidine with angular to rounded volcanics, much of which is black basalt(?), and some heavy minerals and fragments of cemented tuff(?); calcareous material present
740-780	Sand, very fine to very coarse, mostly medium to coarse, fairly sorted; of rounded sanidine and subangular to rounded, red, brown, black, and yellow volcanics with some white grains, and some cemented tuff(?), black basalt(?), and rounded, black, heavy minerals

Table 3.--Lithologic log of the Clay Evans No. 1 test hole (UW-51-28-902)--Continued

Interval (feet)	Description
780-810	Sand, very fine to very coarse; fine grains are rounded sanidine, with subrounded to rounded red, black, and brown volcanics, and rounded heavy minerals; coarse grains are angular to subangular, red volcanic chips, some vesicular, and black, brown, and green volcanics, with white grains, some calcareous
810-820	Sand, very fine to very coarse, mostly medium to coarse, fairly sorted; fine grains are mostly rounded sanidine and subangular to rounded red, orange, pink, yellow, and black volcanics with some rounded heavy minerals; coarse grains are brown, red, black, and gray volcanics and white grains, some calcareous
820-870	Sand, very fine to coarse, mostly medium, well sorted; rounded sanidine and subrounded to rounded, red, brown, black, and yellow volcanics with some rounded heavy minerals and cemented tuff(?); abundant coarse to very coarse angular to subangular, black volcanics from 850-870 feet
870-920	Sand, fine to coarse, mostly medium, well sorted; mostly rounded sanidine and subangular to rounded, red, brown, black, yellow, and green volcanics, with some rounded heavy minerals and with fine tan grains of calcareous clay or drilling mud from 910-920 feet; a few coarse grains of black volcanics, white chert, and cemented tuff(?)
920-940	Sand, very fine to coarse, mostly medium to coarse, fairly sorted; mostly rounded sanidine and subangular to rounded, red, brown, black, and yellow volcanics, with angular cemented tuff(?), grains of tan calcareous clay and/or drilling mud, and rounded heavy minerals
940-960	Sand, very fine to very coarse; fine grains are rounded sanidine and subangular to subrounded, red, brown, and black volcanics, with rounded heavy minerals and subangular tan grains of drilling mud or clay, about half calcareous; coarse grains mostly tan mud or clay, cemented tuff(?), and angular to subangular, black, brown, and red volcanics, and white chert; the coarse angular volcanics are more abundant from 950-960 feet
960-980	Sand, fine to very coarse, mostly medium, fairly sorted; fine grains are rounded sanidine and subrounded to rounded, red, brown, and black volcanics and fine, rounded, heavy minerals; coarse grains are angular to subangular, black, brown, and red volcanics; some tan grains of clay and/or drilling mud and cemented tuff present from 970-980 feet
980-1,000	Sand, fine to very coarse, poorly sorted; fine grains are rounded sanidine and subangular to rounded, black, brown, and red volcanics with some white grains and rounded heavy minerals; coarse grains are angular to subangular black, brown, and red volcanics, and some tan grains of drilling mud or calcareous clay, more abundant from 990-1,000 feet

Table 3.--Lithologic log of the Clay Evans No. 1 test hole (UW-51-28-902)--Continued

Interval (feet)	Description
l,000-1,040	Sand, very fine to coarse, poorly sorted; of rounded sanidine, subangular to rounded, brown, black, and red volcanics, and angular cemented tuff(?), with some grains of white chert and calcite and rounded heavy minerals; some grains of tan calcareous clay from 1,020-1,040 feet
l,040-1,060	Sand, very fine to very coarse; of rounded sanidine, subangular to rounded, black, brown, and red volcanics and rounded heavy minerals; some coarse grains of angular to subangular cemented tuff(?), especially from 1,050-1,060 feet, and black and pink volcanics; some grains of white chert and calcite present
,060-1,080	Sand, fine to very coarse, with some fine gravel; fine grains mostly clay and/or drilling mud with some sanidine; coarse grains and gravel are angular to subrounded black, brown, orange-brown, and pinkish-red volcanics, some in fresh chips, with some cemented tuff(?).
,080-1,110	Sand, mostly coarse to very coarse; of angular red, brown, black, and gray volcanics with some white grains; minor fine grains, more at 1,090-1,100 feet, mostly rounded sanidine and brown, black, and red volcanics; some calcareous material present
1,110-1,150	Sand, fine to very coarse, with some fine gravel; coarse grains and gravel are angular, some subangular to subrounded, red, reddish-orange, brown, black, tan, and green volcanics with some white chert and calcite, some cemented tuff(?) from 1,140-1,150 feet; fine grains are rounded sanidine and angular-subrounded volcanics of various colors, more fine clay and/or drilling mud from 1,120-1,140 feet; some calcareous material present
,150-1,160	Sand, very fine to very coarse, and fine gravel; coarse grains and gravel are angular to subrounded, gray, green, red, black, and brown volcanics with some angular cemented tuff(?) and white chert; fine grains are rounded sanidine and subrounded black, brown, and red volcanics with rounded heavy minerals and clay and/or drilling mud
1,160-1,220	Tuff or tuffaceous sandstone with calcareous cement; composed of very fine to fine grains of subrounded to rounded sanidine, subangular to subrounded, black, brown, and red volcanics, and some rounded heavy minerals; grains of cemented tuff(?) present from 1,180-1,220 feet and angular grains of tan calcareous clay from 1,200 to 1,220 feet
1,220-1,230	Tuff or tuffaceous sandstone; composed of clay, silt, and some very fine to fine sand, mostly rounded sanidine and heavy minerals; some coarse sand and fine gravel of cemented tuff(?), black and green volcanics, and tan clay
,230-1,280	Sand, very fine to medium, with coarse-sand and fine-gravel sized grains of cemented tuff(?), tan clay, and black volcanics; fine grains are tan and white clay, rounded sanidine, subangular to subrounded black and brown volcanics, and some rounded heavy minerals; more coarse grains of volcanics from 1,260-1,270 feet and more grains of tan calcareous clay from 1,270-1,280 feet

Table 3.--Lithologic log of the Clay Evans No. 1 test hole (UW-51-28-902)--Continued

Interval (feet)	Description
1,280-1,300	Sand, very fine to very coarse, with some fine gravel; fine grains are mostly clay and/or drilling mud, angular tuffaceous sandstone, rounded sanidine, subangular to subrounded brown, black, and red volcanics, and rounded heavy minerals; coarse grains are angular tuffaceous sandstone, subangular to subrounded black and brown volcanics, and tan clay grains; considerable calcareous materal
1,300-1,310	Sand, very fine to very coarse, with fine gravel, poorly sorted; coarse grains and gravel are angular to subrounded, black, brown, red, gray, and green volcanics; fine grains are tan and white clay, with some rounded sanidine, volcanics, and heavy minerals
1,310-1,370	Sand, mostly coarse to very coarse, with fine gravel; of angular to subrounded, brown, black, red, green, and gray volcanics, much in fresh chips from 1,340-1,370, with some white chert and calcareous material; minor fine-grained material is tan and yellow clay, rounded sanidine, black, brown, and red volcanics, and rounded heavy minerals; chips of hard, tan clay from 1,360-1,370 feet
1,370-1,380	Tuffaceous sandstone with calcareous cement, and hard, tan clay; in very-fine sand to fine-gravel sized grains, angular, with some brown and black volcanics; minor fine-grained material is rounded sanidine with subangular to subrounded black and brown volcanics and rounded heavy minerals
1,380-1,390	Sand, very fine to very coarse, and fine gravel, poorly sorted; coarse grains and gravel are angular to subangular with some rounded, brown, black, red, and pink volcanics with white chert, and some tan clay and tuffaceous sandstone grains; fine grains are rounded sanidine, subrounded black and brown volcanics, tan clay, and rounded heavy minerals
1,390-1,440	Sand, mostly coarse, and fine gravel; angular to subangular chips of brown, red, black, pink, and yellow volcanics with white chert and calcite, and a few grains of tuffaceous sandstone and tan clay; more fine grains from 1,400-1,440 feet, of rounded sanidine, subangular to subrounded red and brown volcanics, rounded heavy minerals, and tan clay
1,440-1,450	Sand, very fine to very coarse, with some fine gravel; mostly fine grains of tan and white clay, rounded sanidine, subrounded brown, black, and orange volcanics, and rounded heavy minerals; coarse grains and gravel are angular to subrounded, brown, black, gray, and pink volcanics with white calcite and chert
1,450-1,480	Sand, very fine to very coarse, and fine gravel; mostly coarse grains of angular to subrounded brown, red, gray, and yellow volcanics; fine grains are tan clay, rounded sanidine, subrounded volcanics, and heavy minerals; from 1,460-1,480 feet, increasing amounts of tuff or noncalcareous tuffaceous sandstone

Table 3.--Lithologic log of the Clay Evans No. 1 test hole (UW-51-28-902)--Continued

Interval (feet)	Description
1,480-1,570	Tuff, composed of fine grains of tan and white clay, rounded sanidine, and small amounts of fine, subrounded black and brown volcanics and rounded heavy minerals; minor amounts of angular to subangular sand-sized grains of multicolored volcanics; some hard, tan clay and calcareous material present
1,570-1,600	Tuffaceous sandstone, noncalcareous; composed of clay and from 1,590-1,600 feet, also of fine, angular to subrounded, brown, black, red, gray, and green volcanics, and rounded sanidine; considerable fine calcareous material present
1,600-1,700	Tuff, sticky; composed of white, tan, and orange clay and some fine grains of brown, black, and red volcanics and rounded sanidine; minor coarse grains of black volcanics and hard tuffaceous sandstone
1,700-1,710	Volcanic rock, in hard, tan-brown chips, with an altered(?) matrix and phenocrysts of sanidine or quartz and some black crystals
1,710-1,750	Tuff, composed of white, tan, and orange clay, and some heavy minerals; chips of hard, tan-brown volcanic rock; some coarse grains of black and brown volcanics and some calcareous material present
1,750-1,800	Tuff, composed of bluish-gray clay with some silt-sized heavy minerals and rounded sanidine; some coarse grains of black, brown, and red volcanics
1,800-1,840	Tuff, grayish brown; composed of tan, brown, and white clay, with silt-sized heavy minerals, fine grains of rounded sanidine, and subrounded to rounded, black, brown, and yellow volcanics
1,840-2,000	Tuff, white, sticky; composed of white and tan clay with some fine-grained heavy minerals, reddish-brown glassy volcanics, and rounded sanidine; some coarse grains of brittle, harder, white tuff also present, especially from 1,860-1,880 feet, flecked with fine-grained heavy minerals, brown volcanics, reddish-brown glassy volcanics, and rounded sanidine

Table 4.--Chemical analyses of water from the Evans No. 1 test hole

SAMPLE DESCRIPTION	DATE	DIS-SOLVED SILICA (SiO_2) (MG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAGNE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED POTAS-SIUM (K) (MG/L)	BICAR-BONATE (HCO_3) (MG/L)	CAR-BONATE (CO_3) (MG/L)	DIS-SOLVED SUL-FATE (SO_4) (MG/L)
Evans No. 1 at 1,135-1,165 feet. (Sample contaminated with drilling mud.)	4/23/74	64	60	--	24	4.1	130	8.5	168	0	120
Evans No. 1 at 971-1,001 feet. (Sample contaminated with drilling mud.)	4/25/74	70	80	--	25	2.4	120	10	174	0	100
Evans No. 1 at 850-880 feet. (Sample contaminated with drilling mud.)	4/26/74	66	30	--	20	3.2	120	6.5	162	0	120
Evans No. 1 at 345-375 feet. (Sample slightly contaminated with drilling mud.)	5/1/74	75	90	--	20	2.8	100	4.8	156	0	92

SAMPLE DESCRIPTION	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED NITRITE PLUS NITRATE (N) (MG/L)	DIS-SOLVED ORTHO PHOS-PHORUS (P) (MG/L)	DIS-SOLVED BORON (B) (UG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	HARD-NESS (CA,MG) (MG/L)	PER-CENT SODIUM	RE-SIDUAL SODIUM CAR-BONATE (RSC)	SODIUM AD-SORP-TION RATIO (SAR)	SPECIFIC CONDUCT-ANCE (MICRO-MHOS)	PH (UNITS)	TEM-PERA-TURE (°C)
Evans No. 1 at 1,135-1,165 feet. (Sample contaminated with drilling mud.)	41	2.2	1/2.6	0.23	160	490	77	76	1.21	6.2	680	8.0	--
Evans No. 1 at 971-1,001 feet. (Sample contaminated with drilling mud.)	36	2.5	1/2.8	.25	170	465	72	75	1.40	6.0	628	8.1	28
Evans No. 1 at 850-880 feet. (Sample contaminated with drilling mud.)	37	2.3	1/5.6	.07	160	478	63	78	1.40	6.6	660	8.2	--
Evans No. 1 at 345-375 feet. (Sample slightly contaminated with drilling mud.)	38	2.4	1/2.9	.19	210	430	62	77	1.35	5.7	583	8.0	--

1/ Dissolved nitrate (N).

CULBERSON COUNTY AIRPORT NO. 1 TEST HOLE

The Culberson County Airport No. 1 test hole (State well No. HL-47-58-603) was drilled in June and July 1974 on Wildhorse Flat, 4 miles (6.4 km) northeast of Van Horn (fig. 1). A test hole was drilled at this location because (1) few ground-water data were available from depths below 800 feet (244 m), (2) preliminary interpretation of earth-resistivity and gravity data indicated the occurrence of as much as 1,700 feet (518 m) of bolson fill (although some of this material may be sandstones and shales of Cretaceous age), and (3) because the ground water being pumped in the area is fresh to slightly saline and may be developed more intensively in the future.

The test site is located on colluvium and alluvial-fan deposits of Quaternary age (University of Texas Bureau of Economic Geology, 1968) about 7 miles (11 km) west-northwest of isolated outcrops of the Cox Sandstone of early Cretaceous age that protrude from the alluvial fill, about 3 miles (4.8 km) north of outcrops of the Hueco Limestone of Early Permian age in the Wylie Mountains, and 3 to 4 miles (4.8 to 6.4 km) southeast of outcrops of the Hueco Limestone and older rocks in the Beach Mountains. A later interpretation of earth-resistivity data in the area indicates the occurrence of about 1,000 feet (305 m) of alluvium containing fresh water (W. D. Stanley, written commun., Aug. 1, 1974).

Drilling and Sampling

The test hole was drilled to a total depth of 1,306 feet (398 m), mostly through sand, gravel, and clay. The drilling-time log (fig. 4) indicates slower drilling below 1,035 feet (315 m), where the alluvial fill is probably more cemented. The sample log (table 5) shows that between 1,075 and 1,195 feet (328 to 364 m), much of the material consisted of chips of limestone, and the drilling-time log shows very slow drilling between 1,145 and 1,200 feet (349 and 366 m). A core taken in the interval from 1,168-1,185 feet (356-361 m) was composed of limestone conglomerate (table 5). The rocks in the interval from about 1,145 feet to 1,200 feet (349 to 366 m) may be a cemented basal conglomerate of the alluvial fill.

From about 1,200 to 1,270 feet (366 to 387 m) drilling was rapid and the samples indicated that the material was a poorly consolidated quartz sandstone composed of very fine, well-rounded grains of various colors. This material is probably the Cox Sandstone, as it is similar to the Cox as described at the outcrop in the Wylie Mountains south of the test-hole site (Hay-Roe, 1957). From 1,270 to 1,306 feet (387 to 398 m), drilling was slower and more chert appeared in the samples, which indicates a hard, cherty zone in the Cox Sandstone. At about 1,306 feet (398 m), circulation of the drilling fluid was lost suddenly, probably because the drill bit penetrated fractured or cavernous rocks.

The static water level in the test hole was about 380 feet (116 m).

Borehole Logging

The geophysical logs run in this test hole were electrical (dual-induction laterolog and spontaneous potential), gamma ray, gamma gamma, neutron, and caliper. The electrical log indicated that from the water table at 380 feet to about 550 feet (116 to 168 m), sand and gravel, which probably contains fresh water, compose about 80 percent of the interval. From 550 to 765 feet (168 to 233 m), the proportion of clay zones of low resistivity increases, and the average resistivity decreases. From 765 to 995 feet (233 to 303 m), the resistivity ranges from 10 to 20 ohmmetres with little fluctuation, and probably represents an interval of poorly sorted, partly cemented, clayey sand and gravel. Higher resistivities from 995 to 1,147 feet (303 to 350 m) suggest that the alluvial fill is partly cemented, and high resistivities from 1,147 to 1,205 feet (350 to 367 m) probably indicate a cemented conglomerate that was sampled by coring. The interval of high resistivity from 1,205 to 1,285 feet (367 to 392 m) is the Cox Sandstone.

The caliper log shows a smoother borehole between about 700 to 900 feet (213 to 274 m) than that above. The clayey gravel in much of that interval is more competent and resists washing out. From 1,205 to 1,280 feet (367 to 390 m), the borehole is washed out to as much as 11 inches (28 cm) in diameter, as compared to the 8-inch (20-cm) diameter in the smoothest part of the borehole. This log indicates that the Cox Sandstone in this interval is poorly consolidated.

The gamma-ray log is relatively featureless over most of its depth. However, radioactivity is highest in the 740-855 foot (226-261 m) interval, probably indicating clayey gravel; is low between 1,135-1,205 feet (346-367 m), in the conglomerate; and is lowest from 1,205 to 1,265 feet (367-386 m), in the Cox Sandstone.

The gamma-gamma log shows an abrupt increase in density at about 740 feet (226 m) and a gradual increase from 740 to 1,045 feet (226 to 319 m), probably corresponding to an increase in interstitial clay and cemented alluvium. The log shows a slight decrease in density from 1,045 to 1,145 feet (319 to 349 m). The density is highest from 1,145 to 1,200 feet (349 to 366 m) in the conglomerate, and is much lower in the Cox Sandstone.

The neutron log is similar to the density (gamma-gamma) log. It does, however, show a sharp increase in porosity (corresponding to higher hydrogen content) at the water table at 377 feet (115 m). Porosities between the water table and 740 feet (226 m) range mostly from 30 to 55 percent, with the highest porosities opposite the clays. Porosities from 740 to 995 feet (226 to 303 m) range mostly from 25-38 percent, which possibly reflects partial cementation and more interstitial clay. From 995 to 1,145 feet (303 to 349 m), porosities range mostly from 20 to 32 percent, indicating greater cementation. Porosities are lowest from 1,145 to 1,200 feet (349 to 366 m) in the conglomerate, ranging from 16 to 27 percent. In the Cox Sandstone, porosities range from 20-35 percent between 1,200 and 1,240 feet (366 to 378 m) and from 19 to 28 percent below 1,240 feet.

Water Sampling and Water-Level Recovery Tests

Water samples, all of which were fresh, were jetted from the Cox Sandstone at 1,205-1,237 feet (367-377 m), from the partly cemented alluvial fill at 1,083 to 1,115 feet (330 to 340 m), and from sand and gravel at 552 to 584 feet (168 to 178 m). The water from the Cox had a dissolved-solids concentration of 761 mg/l; water from the partly cemented fill had 819 mg/l; and water from the sand and gravel had 497 mg/l. The samples were contaminated with drilling mud, so the water in the formations should be of slightly better quality than is indicated.

The water from the partly cemented fill had the poorest quality, but this sample was probably more contaminated with mud than the other samples because of the lower permeability of the material.

Analysis of the water-level recovery data obtained after jetting the well indicated that the hydraulic conductivity of the Cox Sandstone was several times greater than that of the two overlying zones of alluvial fill. However, the perforations in the tubing were partly plugged in these zones, and the rate of water-level recovery may have been more a function of the hydraulic conductivity of the perforations than of the formation.

Summary

The data from the Culberson County Airport test well indicate that between the water table at 380 feet (116 m) and a depth of 740 feet (226 m), the material is fairly well-sorted, permeable sand and gravel, saturated with fresh water and clay. Coarse material predominates to 550 feet (168 m), and the clay content increases from 550 to 740 feet (168 to 226 m). This material probably was deposited at the foot of an alluvial fan or by streams traversing the basin. From 740 to about 995 feet (226 to 303 m), the test hole penetrated poorly sorted clay, sand, and gravel of moderate to low permeability. This material was probably deposited near the head of an alluvial fan.

From about 995 to 1,145 feet (303 to 349 m), the test hole penetrated ahluvial-fan deposits that are more cemented and less permeable than the overlying material, but which contain fresh water. From 1,145 to 1,205 feet (349 to 367 m) the test hole penetrated fairly well-cemented conglomerate of low permeability that is probably at the base of the alluvial fill. From 1,205 to 1,306 feet (367 to 398 m), the test hole penetrated the Cox Sandstone, which is poorly consolidated and moderately permeable, and which contains fresh water from 1,205 to 1,265 feet (367 to 386 m). From 1,265 to 1,306 feet (386 to 398 m), the Cox Sandstone is more consolidated or cherty and less permeable.

Table 5.--Lithologic log of the Culberson County Airport No. 1 test hole (HL-47-58-603)

Interval (feet)	Description
0-25	Sand, fine to very coarse, and fine gravel
25-35	Silt and sand
35-45	Sand and fine gravel, mostly angular
45-65	Silty sand
65-85	Sand and silt
85-115	Sand, fine to coarse, well sorted
115-125	Gravel (very fine to coarse pebbles)
125-135	Gravel, coarse sand, and clay, poorly sorted
135-145	Clay, sand, and coarse gravel
145-155	Clay and fine gravel
155-165	Clay and gravel
165-175	Clay, coarse sand, and some gravel
175-185	Clay with some sand
185-195	Sand and coarse gravel
195-215	Gravel (very fine to medium pebbles), well sorted
215-235	Gravel (very fine to medium pebbles) and sandy clay
235-245	Clay or silt with some gravel
245-265	Clay, reddish brown, silt, and minor gravel from 255-265 feet
265-275	Gravel (very fine to medium pebbles), angular to subrounded, some chips
275-305	Clay, brown, sticky, and gravel; more gravel from 285-305 feet
305-315	Clay, reddish brown, sticky
315-325	Clay, silty, with minor gravel
325-345	Clay, brown, sticky
345-355	Clay and fine silty sand
355-365	Sand, fine to medium, with minor gravel
365-375	Sand, medium to coarse, well sorted
375-415	Clay, silty, with rare gravel
415-425	Gravel, angular, and silt
425-445	Gravel, angular to subrounded, sand, and silt
445-465	Silt, medium to coarse sand, and gravel (very fine pebbles)
465-475	Sand, fine to medium, and silt
475-485	Sand, medium to coarse, and gravel (very fine to fine pebbles)
485-495	Silt, sand, and angular gravel, poorly sorted
495-505	Sand, fine to medium, and silt, well sorted

Table 5.--Lithologic log of the Culberson County Airport No. 1 test hole (HL-47-58-603)--Continued

Interval (feet)	Description
505-515	Sand and gravel, mostly rounded
515-525	Sand and gravel (very fine to medium pebbles)
525-535	Silt and sand, with minor gravel (very fine to fine pebbles)
535-555	Silt and fine to coarse sand
555-565	Sand, silty
565-585	Silt, sand, and minor gravel from 565-575 feet (very fine to fine pebbles)
585-595	Clay, silt, and fine sand
595-605	Sand, medium to coarse, and gravel (very fine pebbles)
605-615	Sand, coarse, and gravel (very fine pebbles)
615-635	Sand, coarse, and gravel (very fine to fine pebbles), with some silt and clay from 625-635 feet
635-665	Clay or silt, and gravel (cavings?)
665-685	Silt, sand, and angular to subrounded gravel (very fine pebbles)
685-695	Clay and gravel-sized chips
695-705	Gravel (very fine to fine pebbles), angular, with some silt and very fine to coarse sand
705-735	Silt or clay, with minor gravel
735-775	Sand, coarse, and angular to subrounded gravel (very fine to fine pebbles), with some silt and fine sand
775-815	Gravel and fine to coarse sand, poorly sorted, less gravel from 805-815 feet
815-835	Sand, coarse, and gravel (very fine to fine pebbles)
835-845	Gravel (very fine to medium pebbles), angular to subrounded, some chips, and medium to coarse sand
845-875	Sand and gravel (very fine to coarse pebbles), poorly sorted
875-895	Gravel, angular to subangular, brown, red, black, and orange grains; with some brown sand, chips of red rock, and limestone or dolomite from 885-895 feet
895-905	Clay, gravel, and sand
905-915	Sand and gravel, angular, some in fresh chips
915-925	Clay or silt, with some pieces of dark rock
925-955	Silt, sand, and gravel (very fine pebbles), poorly sorted, with some chips of limestone
955-975	Sand, fine to coarse, angular, multicolored, silty, with some subrounded to angular gravel from 965-975 feet
975-985	Sand, coarse to very coarse, and fine gravel; angular to subrounded, red, brown, orange, black, gray, white, and clear grains, some grains of limestone

Table 5.--Lithologic log of the Culberson County Airport No. 1 test hole (HL-47-58-603)--Continued

Interval (feet)	Description
985-1,025	Sand, coarse to very coarse with some fine gravel; mostly angular to subangular with some subrounded to rounded, red, black, brown, white, clear, yellow and orange grains; with brown limestone grains and some chips of brown calcite present
1,025-1,045	Sand, coarse to very coarse, and fine gravel; angular to subrounded, multicolored, with abundant chips of translucent brownish calcite and some angular grains of brown limestone from 1,035-1,045 feet
1,045-1,075	Sand, coarse to very coarse, and fine gravel, mostly very coarse sand; mostly angular to subangular, red, brown, yellow, orange, clear, and white, with some green, abundant angular to subangular grains of brown limestone
1,075-1,085	Sand, very coarse, and fine gravel; mostly angular to subangular grains of brown and tan limestone, with some angular to subrounded multicolored sand
1,085-1,115	Sand, coarse to very coarse; composed of subangular to subrounded grains, about half multicolored - red, orange, black, and green, and half angular, brown and tan limestone with some yellow limestone from 1,105-1,115 feet; much fine calcareous material present
1,115-1,135	Sand, coarse to very coarse; composed of subangular to subrounded multicolored grains and angular brown limestone grains with abundant brittle, white calcareous material from 1,115-1,125 feet, and abundant yellowish-brown translucent chips of calcite(?) from 1,125 to 1,135 feet
1,135-1,145	Sand, coarse to very coarse; mostly angular grains of brown and tan limestone, with some multicolored grains and some soft, white clay
1,145-1,151	Sand, composed mostly of grains of angular grayish-brown limestone with abundant soft sandy clay
1,151-1,168	Core sample of this interval yielded about 3 feet of conglomerate, composed of cobbles of gray limestone, many with rounded surfaces, cemented with brown material which is composed of sand and pebbles in a calcareous matrix
1,168-1,185	Limestone chips, a few with rounded surfaces and calcareous coatings, whitish-gray, brown, tan, and black; some brown, calcareous siltstone, some silt and sand, and a few grains of brown volcanics
1,185-1,195	Sand, very coarse, and gravel; composed of chips and angular grains of gray and brown limestone, red volcanics, and green, mottled-red and brown grains; some poorly-cemented clear quartz sandstone
1,195-1,255	Sand and gravel; composed of angular gray and brown limestone, multicolored angular grains, and increasing amounts of sandstone, composed of rounded, brown quartz, poorly cemented; some white marl and shale from 1,215-1,235 feet

Table 5.--Lithologic log of the Culberson County Airport No. 1 test hole (HL-47-58-603)--Continued

Interval (feet)	Description
1,255-1,295	Sandstone, composed of silt-sized to very fine sand-sized rounded quartz, white, red, pink, and purple, with brownish tan predominant from 1,285-1,295 feet, cemented with silica or clay; and much very coarse sand-sized and fine gravel-sized material, brown, red, black, with some clear, white, and tan quartz grains; abundant red, orange, brown, and yellow chert from 1,265-1,285 feet

Table 6.--Chemical analyses of water from the Culberson County Airport No. 1 test hole

SAMPLE DESCRIPTION	DATE	DISSOLVED SILICA (SIO_2) (MG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED MANGANESE (MN) (UG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO_3) (MG/L)	CARBONATE (CO_3) (MG/L)	DISSOLVED SULFATE (SO_4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED NITRITE PLUS NITRATE (N) (MG/L)	DISSOLVED ORTHO PHOSPHORUS (P) (MG/L)	DISSOLVED BORON (B) (UG/L)	DISSOLVED SOLIDS (SUM OF CONSTITUENTS (MG/L)	HARDNESS (CA,MG) (MG/L)	PERCENT SODIUM	RESIDUAL SODIUM CARBONATE (RSC)	SODIUM ADSORPTION RATIO (SAR)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	TEMPERATURE (°C)
Culberson County Airport No. 1 at 1,205-1,237 feet. (Cox Sandstone?)(Sample slightly contaminated with drilling mud.)	7/12/74	21	--	--	32	16	210	11	288	0	200	120	1.9	1.6	--	--	761	150	74	--	7.6	1,220	7.8	26
Culberson County Airport No. 1 test hole at 1,083-1,115 feet. (Sample contaminated with drilling mud.)	7/13/74	17	--	--	24	8.5	250	12	334	0	230	110	1.8	.34	--	--	819	95	83	--	11	1,270	7.8	25
Culberson County Airport No. 1 test hole at 552-584 feet. (Sample slightly contaminated with drilling mud.)	7/16/74	17	--	--	31	27	100	5.8	228	0	140	53	1.1	2.3	--	--	497	190	53	--	3.2	867	7.8	--

J. C. DAVIS NO. 1 TEST HOLE

The J. C. Davis No. 1 test hole (State well No. PD-51-01-504) was drilled in September and October 1974 at the southeastern end of Eagle Flat in Hudspeth County, about 10 miles (16 km) southwest of Van Horn (fig. 1). A test hole was drilled at this location because few ground-water data were available, ground water in the area appeared to be fresh, and preliminary interpretation of a vertical electrical sounding indicated that the site was underlain by about 1,700 feet (518 m) of alluvial fill.

Eagle Flat overlies a basin that probably has been topographically closed and undrained for much of its geologic history, but which has recently been partly drained by ephemeral streams that have eroded headward from the Salt Basin southeast of Van Horn and from the Rio Grande basin in Red Light Draw. The clays penetrated by the test hole, however, do not appear to be the playa-lake deposits that are typical of the deposits in the center of an undrained basin. In addition, the freshness of the ground water sampled does not suggest the depositional environment of a playa lake. The basin underlying Eagle Flat may have been a closed but drained basin, which as defined by Snyder (1962, p. 58-59), has deep water levels, deposits of buff or earthy-colored nonsaline clays, and fresh ground water. Such closed basins can be drained by water discharging to adjacent basins through subsurface outlets. Gates and Smith (1975, p. 130) observed that the configuration of the water table in Eagle Flat suggests that ground water could be draining out of the basin through consolidated rocks that underlie the alluvial fill.

The test-hole site is about 3 miles (4.8 km) northeast of outcrops of Cox Sandstone and about 3 miles (4.8 km) east-northeast of outcrops of the Hueco Limestone, both in the Eagle Mountains (Underwood, 1963). The site is also about 3 miles (4.8 km) west and 4 miles (6.4 km) north-northwest of outcrops of the Hueco Limestone in the Carrizo Mountains and Van Horn Mountains, respectively (Twiss, 1959). A later interpretation of the earth-resistivity data indicated that the water table was at a depth of about 400 feet (122 m), that the alluvial fill extended to a depth of about 1,450 feet (442 m), and that the fill either contains slightly saline water or is mostly clay and silt (W. D. Stanley, written commun., Aug. 1, 1974).

Drilling and Sampling

The test hole was drilled to a depth of 2,012 feet (613 m), and the sample log indicated that it penetrated alluvial fill to its total depth. The fill is mostly clay, but contains some thin beds of sand and gravel (table 7). The drilling-time log (fig. 5) shows that much of the drilling was slow, especially in the bottom part of the hole in sticky clays. Drilling rates in the thin beds of sand and gravel were faster, and some of these beds below 1,600 feet (488 m) can be distinguished by the faster drilling rates on the log.

The static water level in the test hole was estimated to be between 410 and 450 feet (125 and 137 m) on the basis of several poor measurements made after jetting water samples.

Borehole Logging

The geophysical logs run in this test hole were electrical (dual-inducation laterolog and spontaneous potential), gamma ray, gamma gamma, neutron, and caliper. The electrical logs indicated that the composition of the alluvial fill is as follows: From the surface to a depth of 750 feet (229 m), predominantly clay with a few beds of sand and gravel; from 750 to 1,700 feet (229 to 518 m), alternating beds of clay and sand and gravel; and from 1,700 to 2,012 feet (518 to 613 m), clay with a few beds of sand and gravel. In the interval from 750 to 1,700 feet (229 to 518 m), there are about 30 to 60 beds of sand and gravel ranging from 1 foot to 10 feet (0.3 to 3 m) in thickness. These beds compose about 20 percent of the interval. The electrical log indicates that the water in the sand and gravel beds is uniformly fresh from the water table to the deepest sand penetrated at 1,900 feet (579 m).

The gamma-ray log is generally featureless, but the radioactivity fluctuates slightly between 750 and 1,700 feet (229 and 518 m), indicating the occurrence of sand beds in the sequence. The gamma-gamma log shows a slight shift to higher density at 380 feet (116 m), which may indicate increased saturation of the fill. Below 380 feet (116 m), the sand and gravel beds tend to have a higher density than the clays. The neutron log shows a slight shift to lower porosity at about 380 feet (116 m), which in contrast to the density log, may indicate less saturation, but could indicate greater compaction of the deposits. Below 380 feet (116 m), the neutron log shows less porosity for the beds of sand and gravel than for the clays.

Water Sampling

Water samples, all of which were fresh, were jetted from sand and gravel beds in the intervals 1,653-1,685 feet (504-514 m), 1,308-1,340 feet (399-408 m), 1,024-1,056 feet (312-322 m), and 845-877 feet (258-267 m). The total thickness of sand and gravel in each of the 32-foot (10-m) sampled intervals ranged from 7 to 15 feet (2.1 to 4.6 m); therefore, more than half of each interval was clay. All samples were contaminated by drilling mud. The dissolved-solids concentration, which was roughly proportional to the content of drilling mud in each sample, ranged from 841 mg/l at 1,653-1,685 feet (504-514 m) to 360 mg/l at 1,024-1,056 feet (312-322 m) as shown in table 8. The difficulty in obtaining uncontaminated samples was probably related to the aggregate hydraulic conductivity of each interval; the interval 1,653-1,685 feet (504-514 m) contained only 7 feet (2.1 m) of sand, while the interval 1,024-1,056 feet (312-322 m) contained 15 feet (4.6 m) of sand.

The quality of the water from the sand and gravel beds throughout the total depth of the test hole is probably similar because the electrical log shows that the resistivities of all of these beds are about the same. The quality of the water in the sand and gravel beds may be similar to the quality of the water (283 mg/l dissolved solids) from a stock well, which is reported to be 640 feet (195 m) deep, 0.5 mile (0.8 km) north of the test hole.

Water-level recovery data were poor and could not be used to estimate the hydraulic conductivities of the sampled intervals.

Summary

The J. C. Davis No. 1 test hole penetrated alluvial fill, consisting of clay with thin beds of sand and gravel, to a depth of 2,012 feet (613 m). The ground water throughout the depth penetrated is fresh, but because the sand and gravel beds do not have a large aggregate thickness, wells drilled in this part of Eagle Flat probably would not have large yields.

Table 7.--Lithologic log of the J. C. Davis No. 1 test hole (PD-51-01-504)

Interval	Description
0-5	Sand and gravel
5-15	Sand, limy
15-31	Sand and clay
31-59	Clay, sandy
59-65	Gravel and clay
65-75	Clay, sticky
75-115	Clay, hard dry grains
115-135	Clay, sticky
135-145	Clay, sticky, with chips of drier clay
145-185	Clay, sticky
185-195	Clay, sticky, with grains of hard dry clay
195-205	Clay, hard and dry; sample scraped from bit after bit change at 205 feet was clay, brown and gummy
205-235	Clay, runny and soft, with some harder chips of clay from 225-235 feet
235-265	Clay, runny
265-345	Clay, runny, with some chips and grains of harder clay
345-375	Clay, brown, sticky
375-395	Sand, black, and clay
395-405	Clay, sticky
405-425	Clay with some sand
425-435	Clay
435-455	Clay, soft, with some grains of sand or hard clay
455-505	Clay
505-512	Clay, soft, with some grains of hard clay
512-542	Gravel and chips of limestone
542-572	Clay, gummy
572-666	Clay, silty and gummy, with some gravel
666-737	Clay, silty and gummy, with some sand
737-760	Gravel, multicolored, and clay
760-770	Clay
770-775	Gravel
775-823	Clay with some thin beds of gravel
823-850	Clay, gummy, with some thin beds of sand
850-860	Gravel, multicolored

Table 7.--Lithologic log of the J. C. Davis No. 1 test hole (PD-51-01-504)--Continued

Interval	Description
860-884	Clay, with some gravel
884-890	Clay, gummy
890-893	Gravel
893-915	Clay with thin beds of sand
915-1,074	Clay with some beds of sand and gravel
1,074-1,110	Clay, gummy
1,110-1,115	Gravel, in thin beds
1,115-1,145	Clay
1,145-1,255	Clay with thin beds of sand and gravel
1,255-1,310	Clay or shale, hard, red
1,310-1,320	Gravel, multicolored
1,320-1,347	Clay or shale, with thin beds of gravel
1,347-1,377	Clay or shale, rare gravel
1,377-1,405	Clay or shale, silty
1,405-1,415	Sand and gravel, pink, brown, yellow, black, and white grains; sample scraped from bit after change at 1,413 feet was clay, brown, sticky, with some pieces of gravel, limestone and quartz
1,415-1,455	Clay, reddish brown, in hard and dry chips; with some chips of grayish iron-stained limestone and red and black volcanics, some with rounded surfaces and with cement coatings
1,455-1,529	Clay, in hard and dry chips and some in softer balls; with multicolored gravel, including grains of volcanics, chert, sandstone and rounded quartz, some cement coatings; sample scraped from bit during bit modification at 1,510 feet was clay, brown and sticky, with a few pieces of gravel
1,529-1,535	Sand and gravel, some rounded, multicolored
1,535-1,565	Clay, in hard and dry chips and in softer balls; with minor sand and gravel, mostly angular with some subangular to subrounded, red, black, white, green, with some cement coatings and chips of sandstone with some rounded surfaces
1,565-1,610	Clay with rare sand and gravel
1,610-1,619	Sand, mostly angular, multicolored
1,619-1,625	Clay, in hard chips and soft balls; with some sand, coarse to very coarse, and fine gravel, mostly angular, some subangular to subrounded, brown and reddish brown with black and white
1,625-1,645	Clay and sand
1,645-1,675	Clay with sand and gravel, multicolored

Table 7.--Lithologic log of the J. C. Davis No. 1 test hole (PD-51-01-504)--Continued

Interval	Description
1,675-1,685	Sand and gravel, mostly angular with some rounded surfaces, multicolored, mostly volcanics with some white limestone and some sandstone, some cement coatings
1,685-1,775	Clay or soft siltstone, in hard and dry chips, with rare sand and gravel
1,775-1,785	Clay
1,785-1,835	Siltstone or clay, soft and crumbly; with some multicolored sand and rare gravel
1,835-1,845	Siltstone or clay; with sand, very coarse, and fine gravel; some with rounded surfaces, brown, red, white, orange, green, clear, and yellow, mostly volcanics with some sandstone and calcareous material
1,845-1,895	Siltstone or clay with rare sand
1,895-1,905	Sand, multicolored, of various rock types
1,905-1,951	Siltstone, soft, brown, and clay, in soft balls
1,951-1,958	Siltstone, soft, brown, and clay; with minor gravel, some with rounded surfaces
1,958-2,012	Clay or marl, light brown, hard and calcareous, siltstone, dark brown, soft and crumbly; with about 10 percent gravel, angular with some rounded, of various rock types

Table 8.--Chemical analyses of water from the Davis No. 1 test hole

SAMPLE DESCRIPTION	DATE	DIS-SOLVED SILICA (SIO_2) (MG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAGNE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED POTAS-SIUM (K) (MG/L)	BICAR-BONATE (HCO_3) (MG/L)	CAR-BONATE (CO_3) (MG/L)	DIS-SOLVED SUL-FATE (SO_4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED NITRITE PLUS NITRATE (N) (MG/L)	DIS-SOLVED ORTHO PHOS-PHORUS (P) (MG/L)	DIS-SOLVED BORON (B) (UG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS (MG/L)	HARD-NESS (CA,MG) (MG/L)	PER-CENT SODIUM	RE-SIDUAL SODIUM CAR-BONATE (RSC)	SODIUM AD-SORP-TION RATIO (SAR)	SPECIFIC CONDUCT-ANCE (MICRO-MHOS)	PH (UNITS)	TEM-PERA-TURE (°C)
Davis No. 1 at 1,653-1,625 feet. (Poor sample, very contaminated with drilling mud.)	10/7/74	12	--	--	24	5.2	290	8.8	440	0	170	110	4.1	0.03	--	--	841	81	87	5.6	14	1,350	8.1	--
Davis No. 1 at 1,308-1,340 feet. (Sample contaminated with drilling mud.)	10/8/74	5.4	--	--	28	4.2	180	.2	332	0	140	46	4.1	.02	--	--	572	87	82	.00	8.6	982	8.3	--
Davis No. 1 at 1,024-1,056 feet. (Sample contaminated with drilling mud.)	10/10/74	8.9	--	--	14	2.1	120	3.7	252	0	70	14	3.0	.02	--	--	360	44	84	3.2	7.9	597	8.2	26
Davis No. 1 at 845-877 feet. (Sample contaminated with drilling mud.)	10/11/74	8.0	--	--	20	2.7	120	.4	236	0	110	13	2.1	.01	--	--	393	61	81	.00	6.7	661	8.2	--

BOREHOLE TEMPERATURE DATA

Temperature data were obtained from all four test holes by means of a temperature log of the Guerra test hole and bottom-hole (or maximum recorded) temperatures in the other test holes. The normal temperature at depths of 30 to 60 feet (9.1 to 18 m) in westernmost Texas is about 65°F (18°C), and the normal thermal gradient is about 1°F per 64 feet (1°C per 35 m) (Collins, 1925, pl. VIII and p. 98). The temperature at 1,170 feet (357 m) in the Guerra test hole in Red Light Draw was 94°F (34°C), which indicates an abnormally high thermal gradient of about 1°F per 39 feet (1°C per 21 m). In the Evans test hole on Ryan Flat, the maximum temperature recorded was 94°F (34°C), which indicates a thermal gradient in the normal range of about 1°F per 68 feet (1°C per 37 m). In the Culberson County Airport test hole on Wildhorse Flat, the maximum temperature was 100°F (38°C), which indicates an abnormal thermal gradient of 1°F per 36 feet (1°C per 20 m). In the Davis test hole on Eagle Flat, the maximum temperature was 100°F (38°C), which indicates a thermal gradient in the normal range of about 1°F per 57 feet (1°C per 31 m).

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