LITHOLOGIC AND GEOPHYSICAL LOGS OF DRILL HOLES FELDERHOFF FEDERAL 5-1 AND 25-1, AMARGOSA DESERT, NYE COUNTY, NEVADA

U.S. GEOLOGICAL SURVEY

Open-File Report 95-155

Prepared in cooperation with the
NEVADA OPERATIONS OFFICE,
U.S. DEPARTMENT OF ENERGY under
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Denver, Colorado
1995

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = 9/5\ (°C) + 32.$$

The following terms and abbreviations also are used in this report:

g/cm^3 = grams per cubic centimeter

ohmms = ohmmeters

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Lithologic and Geophysical Logs of Drill Holes Felderhoff Federal 5-1 and 25-1, Amargosa Desert, Nye County, Nevada

By W.J. Carr, S.M. Keller, *and* J.A. Grow

Abstract

Two wildcat oil and gas exploration holes drilled in 1991 on the northern edge of the Amargosa Desert penetrated Tertiary and Quaternary sedimentary rocks, alluvium, and basalt, possible Tertiary volcanic or volcaniclastic rocks, and Tertiary (?) and Paleozoic carbonate rocks. The easternmost of the two holes, Felderhoff-Federal 5-1, encountered about 200 feet of alluvium, underlain by 305 feet of basalt breccia and basalt, about 345 feet of probable Tertiary tuffaceous sedimentary rocks, and 616 feet of dense limestone and dolomite of uncertain age. Drill hole 25-1 penetrated 240 feet of alluvium and marl (?), and 250 feet of basalt breccia (?) and basalt, 270 feet of tuff (?) and/or tuffaceous sedimentary rocks, 360 feet of slide blocks (?) and large boulders of Paleozoic carbonate rocks, and 2,800 feet of Paleozoic limestone and dolomite.

The two drill holes are located within a northerly trending fault zone defined largely by geophysical data; this fault zone lies along the east side of a major rift containing many small basalt eruptive centers and, farther north, several caldera complexes. Drill hole 25-1 penetrated an inverted Paleozoic rock sequence; drill hole 5-1 encountered two large cavities 24-inches wide or more in dense carbonate rock of uncertain, but probable Paleozoic age. These openings may be tectonic and controlled by a regional system of northeast-striking faults.

INTRODUCTION

The structural importance of the Amargosa Desert area, which is along the regional ground-water flow path from the Nevada Test Site (fig. 1), led to an interest in the geology, paleontology, and chronology of the rocks encountered by the two wildcat wells briefly described here. This report is intended to record the lithology and general stratigraphy in the drill holes, as determined by study and logging of the cuttings and interpretation of the geophysical logs. Other studies (Harris and others, 1992), particularly of the conodonts, indicated little potential for oil and gas in the Paleozoic rocks: cuttings from drill hole 25-1 show heating of the carbonate rocks to at least 300°C. Carbonate rocks below 850 ft in drill hole 5-1 were described as "thermally immature" (Harris and others, 1992); on this basis, and the absence of conodonts, they assigned these rocks to the Tertiary (Neogene?).

The authors thank Frank M. Byers, Jr., for his microscopic examination of thin sections of basalt cuttings handpicked from the two drill holes.

The holes were drilled by Transwestern Drilling, Inc., for Felderhoff Production Co. of Gainesville, Texas. Felderhoff Federal 25-1 and 5-1 were drilled to depths of approximately 5,020 and 1,466 ft. Drill hole 25-1 is located at latitude 36°37.1'N., longitude 116°24.5'W.; drill hole 5-1 is located at approximately latitude 36°35.6'N., longitude 116°23.1'W., or about 2 mi SSW, and 3.5 mi SSE of the town of Amargosa Valley, Nye County, Nevada (fig. 1). The cuttings were poor, contaminated, or not available for many intervals; hence, determination of lithology, particularly above the Paleozoic rocks, is difficult.

DESCRIPTION OF LOG DATA

Although this is primarily a data report, several observations and interpretations are made here that help place the drill holes in the context of regional geology.

Basalt

Both drill holes encountered basalt lava, and basalt breccia or pyroclastic material (tables 1 and 2 at the back of the report). The presence of basalt in 25-1 was predicted (Carr, 1984, fig. 14) from aeromagnetic data (Glen and Ponce, 1991), which show a very pro-

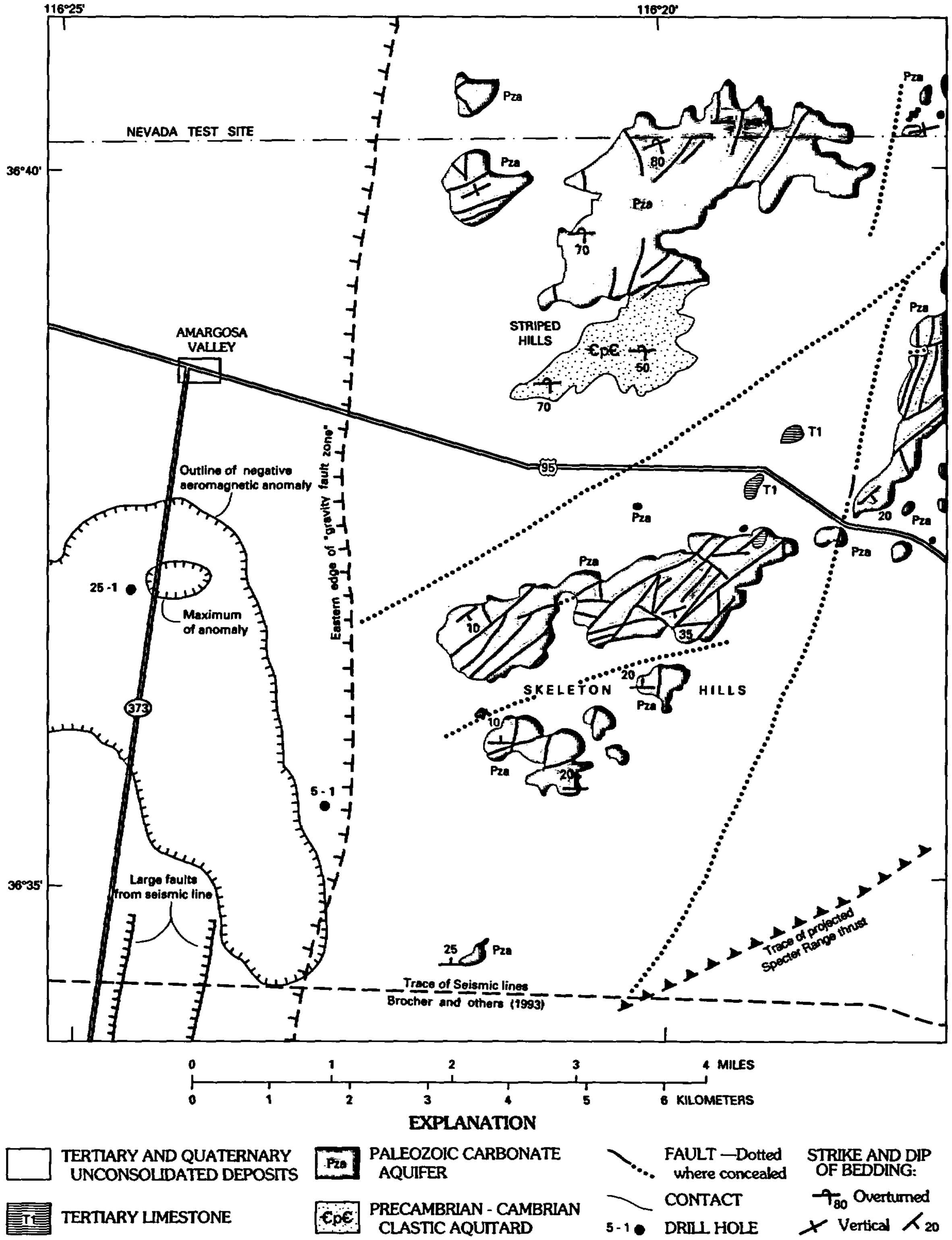

Figure 1. Map of area around drill holes Felderhoff Federal 25-1 and 5-1.

nounced negative magnetic anomaly centered about 2,000 ft east of the drill hole site (fig. 1). In drill hole 25-1, the top and bottom of basaltic material, determined mainly from gamma-ray logs (fig. 2), are at about 240 and 520 ft, respectively. Drill hole caving near the base of the basalt apparently yielded altered fragments that became obvious in the samples at about 1,850 ft and continued down to total depth. A hand-picked sample of these fragments was studied in an epoxy thin section by F.M. Byers, Jr. (U.S. Geological Survey, written commun., 1992), who described them as altered, porphyritic, pilotaxitic, microgranular basalt, similar to fragments picked from cuttings from drill hole 5-1. Iddingsite, calcite veinlets, and penninite (?) after clinopyroxene were noted. The caving presumably occurred around the bottom of the casing at about 500 ft, the latter depth suggested by geophysical logs (fig. 2) and the well completion report, as no samples were obtained between 330 and 545 ft.

Basalts in the drill holes are being dated by Brent D. Turrin (U.S. Geological Survey, oral commun., 1993), but results are not yet published. Basalts in drill holes nine miles east-southeast of drill hole 5-1 have been correlated chemically with basalts in the southern Nevada Test Site region dated at 8.5–11 Ma (Crowe and others, 1986).

The strength and roughly circular shape of the main part of the aeromagnetic anomaly near drill hole 25-1, and the shallow structural position of the buried basalt, suggest that at least part of the body is younger than the above-mentioned basalts in drill holes nine miles to the east. In other words, a basalt as old as 10 Ma or so should be draped over or downdropped by the "gravity fault" system (Winograd and Thordarson, 1975; Brocher and others, 1993) which passes through the area of drill holes 25-1 and 5-1 (fig. 1). From the drill hole data (tables 1 and 2), the basalt lava is about the same thickness in both drill holes, and the top and base are at nearly the same elevation in both drill holes (25-1: 2,234 and 2,054 ft; 5-1: 2,236 and 2,036 ft). Even though the basalt in both drill holes is similar in depth, thickness, and petrography, the area near drill hole 5-1 is outside the anomaly (fig. 1) and has much weaker magnetization than the area near drill hole 25-1. Thus, despite the apparent similarity of basalts from the two locations, the large difference in magnetic signature suggests important differences in the eruptive histories.

Silicic Volcanic Units

No definite intervals of silicic tuff were identified in the cuttings from these drill holes because of drill hole caving and the fact that the alluvium and other units above the Paleozoic rocks contain abundant volcanic clasts. Possible tuff intervals were noted from 615–760, 1,300–1,480, and 1,570–1,690 ft in drill hole 25-1; the latter interval is judged most likely to be tuff, possibly the nonwelded tuff of the Timber Mountain Group (Byers and others, 1976), an important ash-flow tuff in the region to the north. No definite tuff intervals were indicated by the cuttings from drill hole 5-1.

Paleozoic Rocks

On the basis of conodonts, Paleozoic rocks in drill hole 25-1 have been correlated with the Goodwin Limestone and possibly with the Nopah Formation (Harris and others, 1992). Color indices of conodonts from cuttings samples suggest heating of the rocks to at least 300°C (Harris and others, 1992), a common condition in southern Nye County. Proximity of the drill hole to the basalt eruptive center could account for some of the heating, but depth of burial is the most likely cause of the high thermal maturity. The interval in drill hole 25-1 from 2,200 to 3,300 ft did not yield conodonts, but those found between 3,300 and 5,000 ft are of Early Ordovician age and indicate an inverted sequence (Harris and others, 1992). Overturned rocks equivalent to those found in the drill hole sequence crop out 4 mi to the northeast in the Striped Hills (fig. 1).

In drill hole 5-1, no conodonts were found in the carbonate rocks, which were penetrated below about 850 ft. These rocks were assigned to the Neogene (?) (Harris and others, 1992), largely on the basis of thermally immature fish teeth found in the cuttings. Existing paleontologic information does not rule out the possibility that some or all of the carbonate rocks are Paleozoic. Middle Tertiary limestones of the region are generally at or near the Paleozoic surface and have been assigned to the Oligocene or lower Miocene by most workers (Sargent and others, 1970; Barnes and others, 1982; Cemen and others, 1985). The Tertiary limestones are not easily distinguished from Paleozoic, even in outcrop. In drill hole 5-1, cuttings samples are poor and contaminated, and there were several intervals of no circulation. The presence of dolomite in the lower 200 ft of the drill hole (table 2) suggests that at least this part of the section is Paleozoic, as the senior author has not observed pervasive dolomite in Tertiary rocks of this area. It is possible that both Tertiary and Paleozoic carbonate rocks are present in drill hole 5-1.

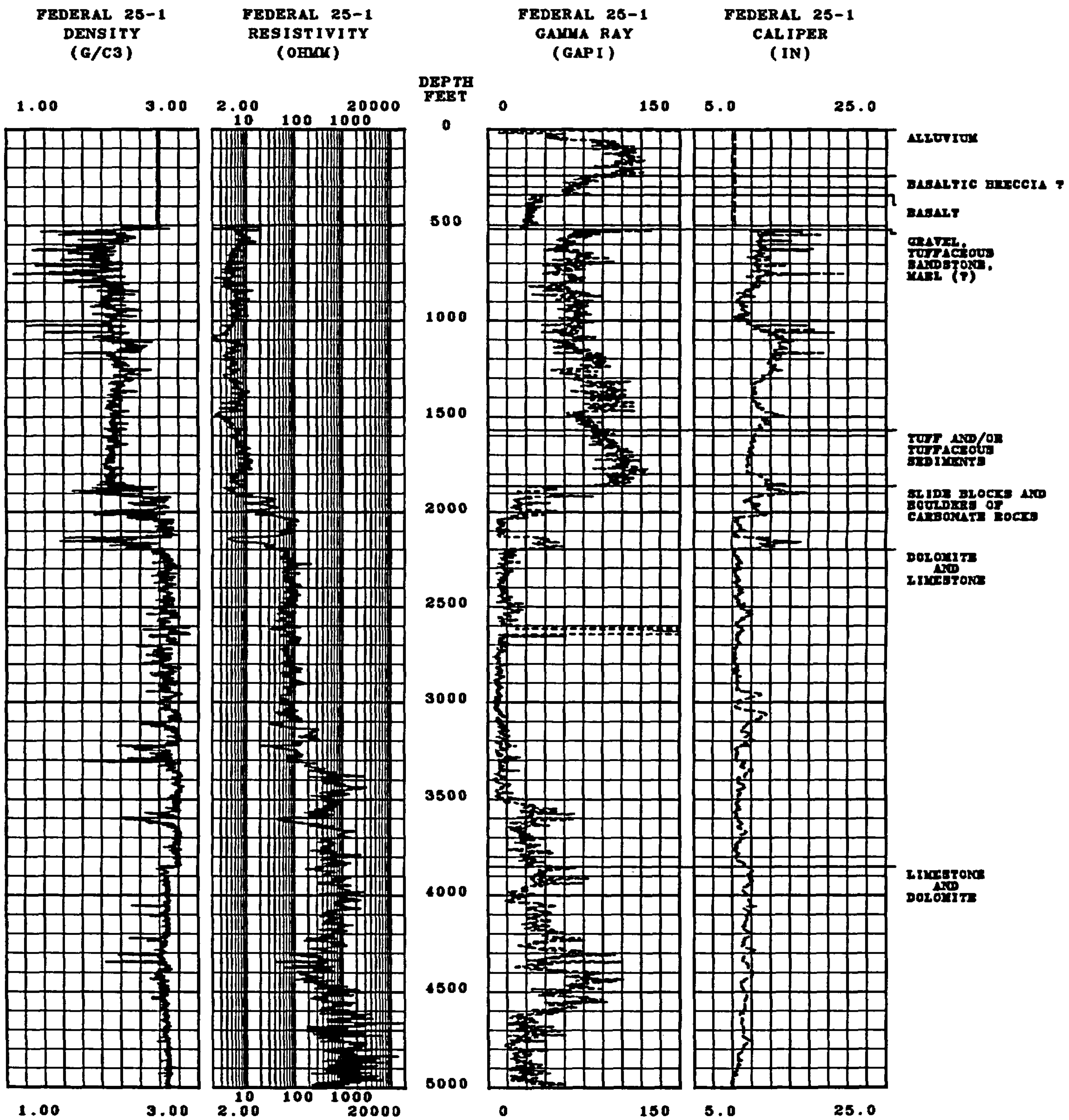

Figure 2. Geophysical logs of drill hole Felderhoff Federal 25-1.

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Lakewood, Colorado 80225-0046

M E M O R A N D U M

Date: April 25, 1991
To: Larry Hayes
From: J. B. Czarnecki
Subject: Conversion of planned oil wells in the Amargosa Desert

The Yucca Mountain Project has a unique opportunity to capitalize on planned drilling in the Amargosa Desert by an oil company this spring. My project (Characterization of the Regional Ground-Water Flow System) is scheduled at some future date to construct 1 deep observation well in the Amargosa Desert in the very same area that these drillholes are to be constructed. One million dollars ($1,000,000) has been ear marked for this effort. We are now looking at an unbelievable opportunity to convert three planned oil exploration drillholes (provided no oil or gas is found) to high-quality water wells that will yield invaluable data regarding the deep flow system--at a fraction of that cost.

These drillholes are targeted by the oil company for completion in Paleozoic carbonate rocks, the same rocks that are thought to form a regional carbonate aquifer that discharges in Death Valley National Monument. The National Park Service has raised concerns regarding potentially adverse ground-water withdrawals from Yucca Mountain, and long term contamination from the potential high-level nuclear-waste repository. Conversion of these holes to monitoring wells will address the question of whether ground-water withdrawals during the construction of the repository will have adverse effects on ground-water quantity and quality.

Ground-water samples from the deep Paleozoic carbonate rocks (or possibly Precambrian rocks) penetrated by these drillholes will provide a basis for comparison with hydrochemistries of ground waters suspected by a few individuals to be, at least partially, remnants of past water-table excursions. Ratios of selected hydrogen, carbon, oxygen, sulfur, strontium, and uranium isotopes will provide estimates of paleoclimatic conditions, the types of rock(s) that the ground water have flowed through, solute sources, and evolutionary history. Concentrations and isotopic ratios of dissolved noble gases will provide insight to: paleotemperatures at the water table; gas sources; ground-water flow paths and the extent of mixing of possible end-member waters; and sample representedness. Radioisotopes of hydrogen, carbon, and chlorine will provide the capability to estimate ground-water ages from recent to about 2 million years ago. All of the above, together with data describing the concentrations of routinely determined inorganic constituents will provide a means to rigorously test chemically based hypotheses regarding the origins of selected NTS and vicinity ground waters.

I have obtained additional design and cost information regarding the conversion of three planned oil wells to observation wells, to be drilled about 20 km south of Yucca Mountain in the Amargosa Desert. These holes are to be drilled as early as mid-May, 1991 (pending permits) so speed is of the essence if USGS and DOE is to avail themselves of this fortuitous opportunity. Per conversations with Jim Gemmell (HIP) and Scott Williamson (Baker Oil Tools, Inc.), I have determined a way to cost effectively convert these oil wells to observation wells containing multiple observation intervals.

The attached schematic shows the envisioned arrangement of equipment downhole. By utilizing a sliding sleeve access port (the same kind planned for use in the C-Holes), one can use a single pipe string to monitor water-levels and obtain hydrochemical samples at multiple packed-off locations in the borehole. The access ports can be opened or closed from land surface through the use of a wire-line tool. Prior to packer inflation, all ports would be in the closed position and the bottom of the pipe string open. Water would be used to flush mud and cuttings from within the annular space of the borehole. The bottom of the string is then plugged (using an RZB plug), hydraulic pressure applied to within the string, and the packers inflated. Any of the multiple ports can then be opened to test or monitor the desired interval. The upper pipe string would be six inches in diameter to permit pumping with a high capacity pump.

I am including two different equipment options and rig time estimates so that you can get a range on expected costs. Option 1 would be the preferable one to plan for based on uncertainties in rig time needed and hole conditions. I anticipate that the equipment can be installed in one day (option 2) under normal operating conditions.

We have little time to waste; therefore I am asking you to come to a decision on available funding by COB Tuesday, April 30. Please call me before then if you have any questions.

John B. Czarnecki

John B. Czarnecki

attachments

xc: D. Gillies
D. Appel
T. Buono

Oil-exploration drillhole conversion to observation water well
Amargosa Desert

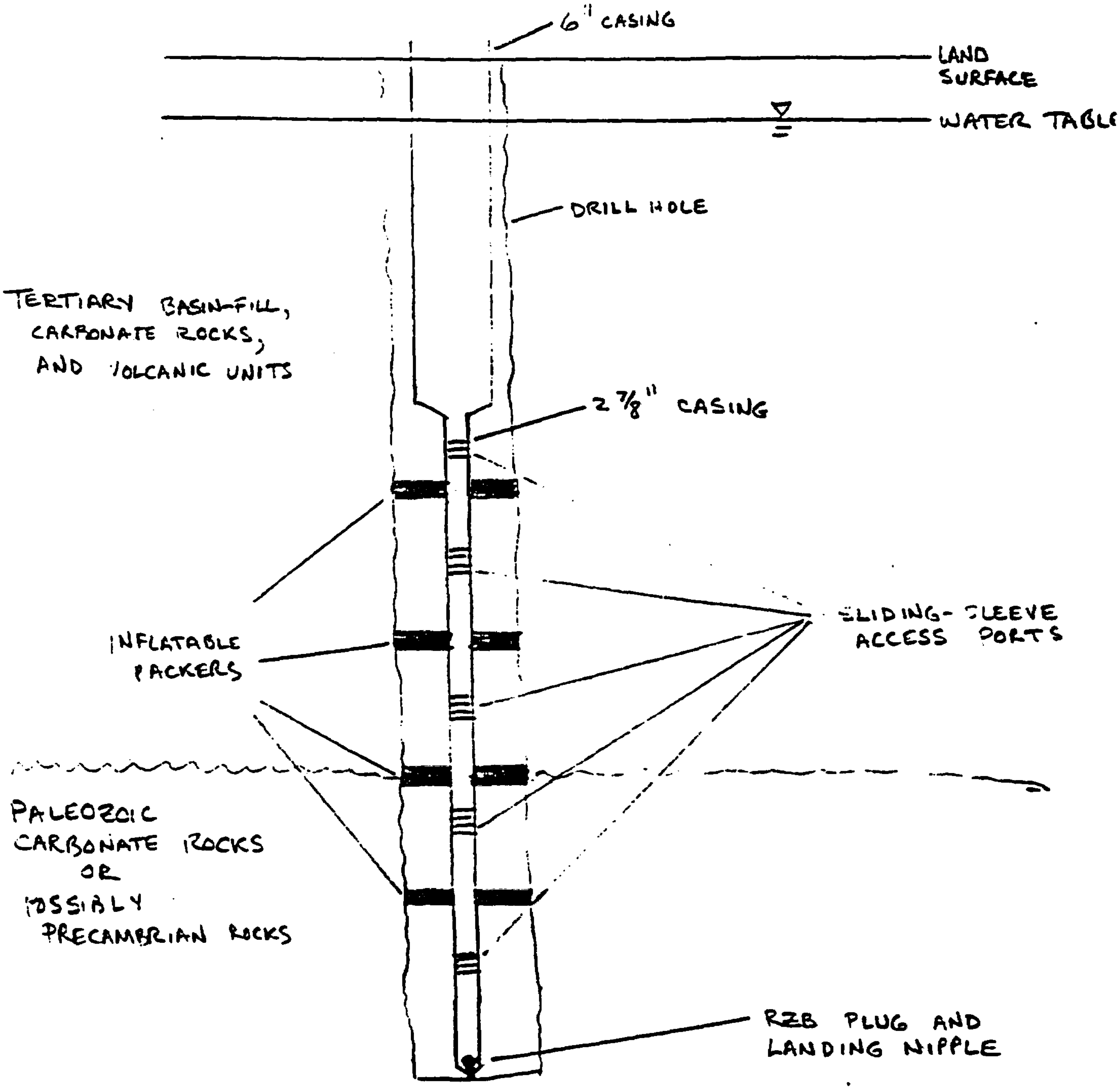
Option 1: 5,000 ft hole, 5 observation intervals, 3 days rig time

Item	Cost
4500 ft of 2 7/8" J-55 casing ($1.69/ft used)	$ 7,605
Transfer of drillhole and geophysical logs	7,500
5 sliding sleeve access ports ($2,051 ea.)	15,132
4 inflatable packers	10,255
Landing nipple	601
RZB Plug	2,419
500 ft 6" casing ($4.50/ft)	2,250
3 days rig time	14,250
Pipe shipping and miscellaneous	1,000
Total for one well	$61,012

Option 2: 5,000 ft hole, 3 observation intervals, 1 day rig time

Item	Cost
4500 ft of 2 7/8" J-55 casing ($1.69/ft used)	$ 7,605
Transfer of drillhole and geophysical logs	7,500
3 sliding sleeve access ports ($2,051 ea.)	6,153
2 inflatable packers	7,566
Landing nipple	601
RZB Plug	2,419
500 ft 6" casing ($4.50/ft)	2,250
1 days rig time	4,750
Pipe shipping and miscellaneous	1,000
Total for one well	$39,844

OPTION 1



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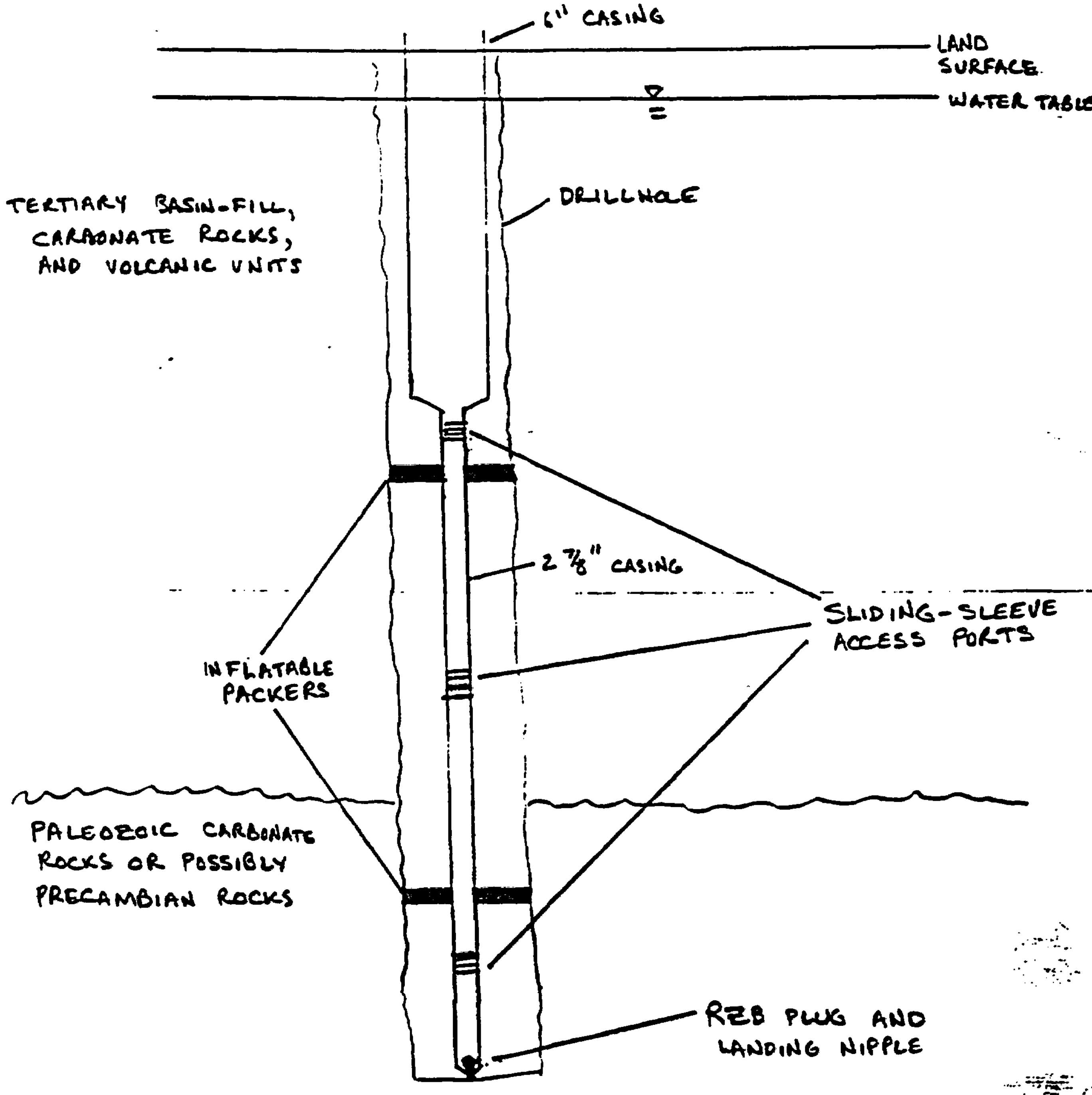
JBC

OPTION 2



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JBC
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Geophysical Logs

Density, resistivity, gamma ray, and caliper logs were run in drill holes 25-1 and 5-1 (figs. 2 and 3). Except for gamma-ray logs, which can be run through casing, the logs begin at 500 ft. The wells were cased to 519 and 504 ft, respectively. Below the casing, 8.75-in.-diameter drill bits were used. Analysis of the caliper logs shows that washouts with diameters in excess of 12 in. were common down to 2,200 ft in drill hole 25-1 and to 850 ft in drill hole 5-1, where dense carbonate rocks were encountered. The washouts in the shallow part of these wells caused contamination problems at all deeper levels down to total depth. Washout zones and lost circulation problems occurred in both drill holes, but were most severe in drill hole 5-1.

The first 50 to 80 ft in both wells have relatively low gamma-ray values (15–60 API units) and correlate with alluvium composed of heterogeneous volcanic and carbonate clasts identified in the cuttings (tables 1 and 2). From there down to about 200 ft, the gamma-ray values increase to 80–120 API units and correlate with a coarsening and increasing percentage of volcanic clasts in the alluvium. The high gamma-ray values in this interval suggest the presence of radiogenic clays. Although clays were generally absent in the cuttings, they may have been washed away.

From 200 down to 340 ft, the gamma-ray values of the two wells drop to between 40 and 80 API units. Between 340 and 520 ft depths, the gamma-ray values drop to about 30 API units. The latter zone correlates with basalt lava, which extends down to about 505 ft in the 5-1 well and to 520 ft in the 25-1 well. The gamma-ray pattern of the zone between 200 and 340 ft appears more like the basalt lava than the overlying alluvium, suggesting a lithology of basaltic breccia or cinders.

Between the base of the basalt and the top of the dense carbonates, the densities average about 2.1 g/cm^3, the resistivities are low (5–10 ohms), and the gamma-ray values are high (60–120 API units). These are Tertiary valley-fill deposits composed of a variety of tuffaceous clastic units with volcanic debris, Paleozoic debris, and possible lacustrine marls or spring deposits.

Alternating high and low density zones between 1,900 and 2,200 ft in the 25-1 well (fig. 2) are interpreted as slide blocks or megabreccias of Paleozoic (?) carbonates intercalated with the valley-fill deposits.

Below 2,200 ft in the 25-1 well, the densities are a relatively uniform 2.6–2.8 g/cm^3. Between 2,200 and 3,300 ft, the densities are 2.6–2.7 g/cm^3, the resistivity is intermediate (50–100 ohms), and the gamma-ray count is low (~10 API units), suggesting relatively pure carbonate rock. From about 3,300 to 3,850 ft, density is the same or very slightly higher, and resistivity is higher but variable, between 300 and 1,100 ohm-meters. The gamma-ray log is also very slightly higher from 3,300 to 3,500 ft, but then increases abruptly at 3,500 ft to values of 30 to about 100 API units. These geophysical log changes in the Paleozoic rocks do not appear to correlate well with observed variations in the cuttings. The higher resistivity of the section below 3,300 ft seems to conflict with the higher gamma-ray count between 3,500 and 4,500 ft. The cuttings give no obvious indication of an increase in clays in this part of the section.

STRUCTURAL AND POSSIBLE HYDROLOGIC IMPLICATIONS OF LOG DATA

Drill holes 25-1 and 5-1 are located near the eastern margin of a regional asymmetric north-south structural trough named the Kawich-Greenwater rift (Carr, 1990). This 100-mile-long gravity low contains several caldera complexes and volcanic centers. In general, the east margin of the rift is characterized by a series of relatively small northerly striking faults stepping down to the west, whereas the west margin is more abrupt, consisting of a narrow zone of large faults down to the east. The structure on the east rift margin near drill holes 25-1 and 5-1 is referred to informally as the "gravity fault". Interpretation of geophysical data in the vicinity of drill holes 25-1 and 5-1 suggests (Brocher and others, 1993) that the "gravity fault" is a zone at least 1.5-mi wide, and that the main displacement lies about 1 mile farther west than shown by Winograd and Thordarson (1975, pl. 1). The data are from east-west seismic reflection and refraction lines (Brocher and others, 1993) located about 3.1 mi south of drill hole 25-1 and 1.4 mi south of drill hole 5-1 (fig. 1), and from gravity (Healey and others, 1980) and resistivity (Greenhaus and Zablocki, 1982) data for the area. A west-dipping listric fault with more than 1,000 ft of displacement is shown (Brocher and others, 1993, fig. 3) passing through the 25-1 drill hole, which is projected 3.2 mi southward. A larger down-to-the-west fault, suggested by geophysical data, is shown (Brocher and others, 1993, fig. 3) about 0.5 mile farther west. Several smaller faults are suggested by the reflection profile in the area south of drill hole 5-1. Owing to the considerable distance between the seismic line and the drill holes, northward projection of specific faults to the drill hole area is problematical, although it is clear from the drill hole (figs. 2–5) and geophysical data (Brocher and others, 1993) that

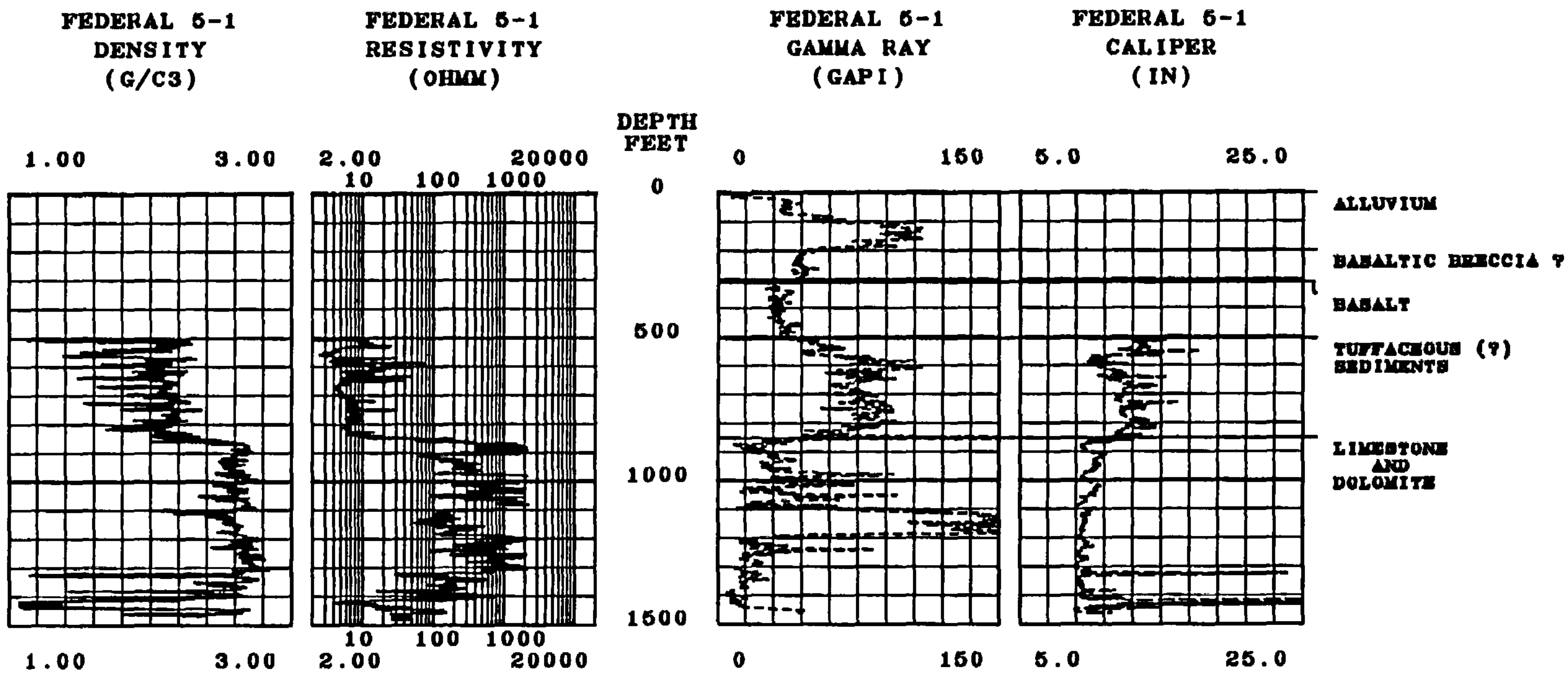

Figure 3. Geophysical logs of drill hole Felderhoff Federal 5-1.

considerable prebasalt tectonic displacement of the Paleozoic surface occurs in the area between the two drill holes.

The water table is shallow in the area of drill holes 25-1 and 5-1, lying at altitudes between about 2,300 and 2,360 ft (Winograd and Thordarson, 1975), or at depths of about 200 to 250 ft (Oatfield and Czarnecki, 1989), within the alluvium above the basalt. Paleozoic rocks (Ordovician Goodwin Limestone and possibly the Cambrian Nopah Formation) encountered by the 25-1 drill hole (Harris and others, 1992) belong to the "lower carbonate aquifer" of Winograd and Thordarson (1975), an important regional aquifer. In addition to having high fracture permeability, the carbonate rocks have tectonically enhanced permeability (Carr, 1984, 1987), especially in the region east of the Kawich-Greenwater rift. On the basis of conodont stratigraphy, the Paleozoic rocks in drill hole 25-1 are believed to be overturned (Harris and others, 1992) like those in the nearby Striped Hills (fig. 1). Thrusts or reverse faults as a cause for the inverted stratigraphy cannot be ruled out. There does not appear to be stratigraphic continuity between the Striped Hills overturned section and that in drill hole 25-1 (fig. 1); the lower clastic confining units (Carrara Formation, Zabriskie Quartzite, Wood Canyon Formation, etc.) (Winograd and Thordarson, 1975) that forms the southern part of the Striped Hills does not continue on strike to drill hole 25-1. Offset on the "gravity" fault zone may be responsible for the mismatch.

Drill hole 5-1 lies (fig. 1) along the trend of a zone of predominantly northeast-striking faults mapped (Burchfiel, 1966) in the Skeleton Hills 2 mi to the northeast. The fault pattern is part of a 20–40 mile-wide regional system of northeast-striking faults called the Spotted Range-Mine Mountain zone (Carr, 1984, p. 56). Many of the seismically active and Quaternary displacement faults of the region lie within this zone (Carr, 1984, fig. 7). In areas such as Ash Meadows and Devils Hole, 10 to 15 mi to the south and southeast of the Felderhoff drill holes, exposed tectonic openings (Carr, 1987; A.C. Riggs, U.S. Geological Survey, written commun., 1993) of northeast strike are commonly lined or filled with banded travertine veins (Carr, 1988; Pexton, 1984; Winograd and Pearson, 1976). Large openings encountered by drill hole 5-1 in carbonate rock could not be plugged with lost circulation material and caused the drill hole to be abandoned considerably above its planned depth. The upper zone, as indicated by the caliper log (fig. 3), lies between about 1,310 and 1,330 ft and is about 24 in. wide; the lower zone is at the bottom of the drill hole from about 1,400 ft to 1,466 ft and exceeds 25 in. in width. Samples were not recovered from either zone. Drill hole 5-1 provides clear evidence of sizeable openings in carbonate rock at a location that may be within a system of hydrologically transmissive structures. If the openings encountered in drill hole 5-1 are within the Paleozoic lower carbonate aquifer, and strike northeast as postulated, an effective transmissive path exists for southwestward movement of groundwater and possibly leakage into the late Tertiary and Quaternary deposits along the east side of the Kawich-Greenwater rift.

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TABLE 1. LITHOLOGIC LOG AND OTHER DATA FOR DRILL HOLE FELDERHOFF FEDERAL 25-1

LOCATION: 1,845 ft from south line, 1,980 ft from east line, NW 1/4, SE 1/4, Sec. 25, T. 15S., R. 49E, Nye County, Nevada

ALTITUDE: 2,574 ft

HOLE DIAMETER: 36 in. 0–50 ft; 12 1/4 in. 50–569 ft; 8 3/4 in. to 5,020 ft

TOTAL DEPTH: 5,020 ft

COMPLETION: October 8, 1991

CASING: 20 in. conductor to 50 ft; 9 5/8 in. conductor 50–519 ft; uncased 519 to 5,020 ft (T.D.)

DRILLED BY: Transwestern Drilling, Inc., for Felderhoff Production Co., Gainesville, Texas

LITHOLOGY LOGGED BY: W.J. Carr, January 13–16, 1992, from microscopic examination of cuttings samples. Some contacts and lithology derived in part from geophysical logs.

Depth interval below land surface (feet)	Lithology
0–38	No samples.
38–131	Alluvium, consisting almost entirely of volcanic rock clasts, many coated with calcium carbonate. Clay coatings increase downward.
131–240	Alluvium, coarse, probably bouldery. Nearly all volcanic clasts. Very little carbonate coating or clay remain in cuttings, but high gamma-ray log values (fig. 2) suggest presence of clay or marl beds.
240–340	Cuttings similar to 131–240 ft, except a few basaltic fragments appear at about 290 ft. No samples from 310–340 ft. Gamma-ray geophysical log (fig. 2) suggests this interval is at least partly basaltic breccia.
340–490	Basalt, dark gray to dark reddish brown, with olivine phenocrysts, largely altered to iddingsite. Cuttings are at least 75% basalt.
490–520	Lost circulation material. Fibrous wood and plastic fragments. Geophysical logs suggest base of basalt at about 520 ft. Casing set to 520 ft.
520–540	Alluvium, light purplish gray to tan, tuffaceous. Fragments variable in lithology, but all are volcanic, and mostly tuff. A few basalt fragments.
540–600	Alluvium or tuffaceous sediment, light purplish gray to tan. Fragments variable in lithology as in 520–540 ft, but quartz and biotite grains are more abundant. Grains thinly coated with clay and carbonate.
600–615	No samples.

Depth interval below land surface (feet)	Lithology
615–760	Tuffaceous sandstone or tuff (?), light gray to tan, mostly 1–3 mm tuff and mineral grains, including prominent quartz, some euhedral. Calcium-carbonate coatings. Lost circulation material present. Carbonate increases downward. Biotite common. Soft, very light gray, highly calcareous material (cement?) as dried lumps in cuttings; lumps commonly contain small fibers and occasional pieces of orange and blue plastic.
760–820	Lost circulation material. Largely lost circulation material (wood fibers and plastic) and soft, very light gray calcareous siltstone (?) or ground-up cement.
820–850	Marl or fine-grained lacustrine(?) limestone. About 30% calcium carbonate, tan to light pinkish gray; 40% mineral and rock grains mostly <2 mm; and siltstone (?) similar to 760–820 ft. A fragment of Paleozoic quartzite noted in 835–850 ft (254.5–259.1 m) sample.
850–1,030	Volcanic rock and mineral grains. Largely volcanic and mineral rock grains, nearly all <1 mm. Quartz and feldspar prominent, together with white to light pink carbonate grains, which decrease downward; nearly all grains are rounded and frosted, especially in lower part of interval.
1,030–1,250	Volcanic sandstone (?). Mineral and volcanic rock grains mostly <0.5 mm. Quartz, feldspar, minor biotite, mostly frosted and rounded, 60%; remainder is rounded volcanic rock fragments. None to very little carbonate cement. Magnetite and hornblende present. Probably a volcanic sandstone, well sorted, very poorly indurated, fine grained. Magnetite grains increase downward.
1,250–1,300	Sandstone (?), light gray to tan, fine- to coarse-grained, calcareous. Most clasts are volcanic rock, 1–5 mm; minor (<20%) mineral grains, mostly quartz and feldspar. Rock fragments are angular to subrounded.
1,300–1,480	Sandstone or tuff (?). Similar to 1,250–1,300 ft, except for abundant fragments of white to pink nonwelded ash-flow tuff. Phenocrysts of biotite, quartz, and feldspar. Possibly Rainier Mesa Tuff, Timber Mountain Group (Tmr). Fragments mostly subangular to angular.
1,480–1,510	Sandstone (?). Samples are fine-grained sandstone clasts, mostly well rounded, and frosted volcanic rock and mineral grains averaging 0.5 mm diameter. A few (about 5%) grains of calcium carbonate.
1,510–1,570	Gravel. Clasts same as above, but mostly 1–5 mm.
1,570–1,690	Tuff (?), light gray to light pinkish brown, nonwelded, contaminated with a variety of volcanic rock fragments. Montmorillonite clay present. Phenocrysts are mostly quartz, feldspar, and biotite. (The main reason to suspect this might be tuff and not alluvium or sediment is that there is a subtle increase in consistency and size of fragments.) Quartz is distinctly bipyramidal. This interval is another candidate for Timber Mountain Group.
1,690–1,780	Sandstone (?) and gravel (?). Heterogeneous cuttings, similar to 1,480–1,570 ft.
1,780–1,840	Gravel. Mostly volcanic rock fragments averaging about 2 mm, but a few gray Paleozoic carbonate rock fragments.

Depth interval below land surface (feet)	Lithology
1,840–1,990	Gravel, Paleozoic blocks, and basalt. Same as 1,780–1,840 ft, except about 5% of fragments are Paleozoic, and increase downward. At 1,930 ft, fragments are about 50% Paleozoic, mostly gray dolomite and limestone, but occasional quartzite fragments are present. Density and resistivity logs show great variation in the interval 1,840–2,150 ft, suggesting large boulders or blocks of Paleozoic rocks intercalated with volcanic debris. Gray Paleozoic carbonate is about 75% of sample at 2,030 ft.
	At about 1,850 ft (563.9 m) is the first appearance of a trachytic mafic volcanic rock that is found as caving fragments throughout the remainder of the drill hole. The fragments appear to be from an altered basalt with plagioclase, clinopyroxene, and olivine phenocrysts; plagioclase is largely altered to calcite and clay, clinopyroxene to chlorite, and olivine to iddingsite. Breccia and/or pyroclastic material in some fragments. Very similar to basalt in cuttings in Felderhoff Federal 5-1 at about 300–500 ft (91.4–152.4 m).
1,990–2,000	No samples.
2,000–2,150	Gravel and Paleozoic blocks. Continuation of unit 1,840–1,990 ft. Cuttings and geophysical logs suggest a large mass of carbonate rocks, possibly Bonanza King Formation, from about 2,020–2,120 ft (615.7–646.2 m).
2,150–2,200	Gravel (?) or Paleozoic rock debris (?). Contains about 50% volcanic and 50% Paleozoic carbonate rock fragments. Geophysical logs suggest the upper contact of this unit is closer to 2,120 ft than 2,150 ft.
2,200–2,360	Limestone and dolomitic limestone. Top of Paleozoic. Light to dark gray. Zones of white to pink calcite veins (?). Fragments average about 1 mm. Trachytic basalt fragments notable here and in many succeeding samples are presumably cavings from higher in hole.
2,360–2,490	Limestone and calcite, pink to gray, cuttings very fine (<1 mm). Much of light-colored material is siliceous.
2,490–2,630	Dolomite and limestone, light gray to white, tan and pink, somewhat siliceous. Many fragments below 2,540 ft are reddish color. Resistivity log shows some lower resistivity (clayey) zones in the interval 2,500–2,620 ft. Intervals of irregular gamma-ray log spikes between 2,600–2,650 ft.
2,630–2,700	Dolomite and limestone, gray to red-brown, with much orange-pink siliceous material, which is translucent on thin edges and has tiny white opaque spots that could be altered feldspar. Might be a quartz siltstone or silicification in a fault zone.
2,700–2,820	Dolomite and minor limestone, gray to very light gray, with about 10% fragments of the orange-pink siliceous material mentioned in interval 2,630–2,700 ft.
2,820–2,870	Limestone and subordinate dolomite, light gray to very light gray; dolomite increases downward.
2,870–2,900	Dolomite and subordinate limestone, gray to light gray.
2,900–2,960	Limestone and subordinate dolomite, light gray to gray.
2,960–3,050	Dolomite and limestone, gray to pink; slight alteration (?) or silty carbonate layers (?).
3,050–3,140	Dolomite and minor limestone, gray to dark gray.
3,140–3,170	Dolomite, gray to light gray, with minor iron staining and silicification.

Depth interval below land surface (feet)	Lithology
3,170–3,340	Limestone and dolomite, gray to light gray; slight iron staining 3,620–3,340 ft. Cuttings contaminated.
3,340–3,350	Contaminated cuttings. More than half are Tertiary rock fragments.
3,350–3,380	No samples. Caving; fishing operation.
3,380–3,420	Contaminated cuttings. More than half are Tertiary rock fragments.
3,420–3,625	Dolomite and minor limestone, gray to dark gray. White calcite veins sporadically present. Rock is more coarsely crystalline than overlying section. Cuttings are better and larger.
3,625–3,650	Limestone and dolomite, gray to dark gray, very fine grained. Probably interbedded with dolomite like 3,420–3,625 ft.
3,650–3,860	Dolomite, dark gray, coarse grained, with calcite veins.
3,860–3,950	Dolomite, gray to light gray, very fine to medium grained. Occasional pyrite. Corresponds to break to slightly lower density on neutron log. Slickensides noted on a fragment in 3,900-3,925-ft sample, and at other places down hole.
3,950–4,320	Limestone and minor dolomite, gray to light gray, fine grained. Occasional pyrite. Cuttings throughout the limestone unit tend to be flatter chips, suggesting thinner bedding.
4,320–4,610	Limestone. Similar to 3,950–4,320 ft, except with some medium-grained zones.
4,610–5,000	Limestone and subordinate dolomite, gray to light gray, fine to medium grained, becoming finer grained downward, but coarser again below about 4,950 ft, finer near bottom.
5,000–5,020	No samples.

TABLE 2. LITHOLOGIC LOG AND OTHER DATA FOR DRILL HOLE FELDERHOFF FEDERAL 5-1

LOCATION: 1,980 ft from north line, 660 ft from west line, SW 1/4, NW 1/4, Sec. 5, T. 16S., R. 50E, Nye County, Nevada

ALTITUDE: 2,536 ft

HOLE DIAMETER: 36 in. 0–60 ft; 12 1/4 in. 60–504 ft; 8 3/4 in. to 504–1,466 ft (T.D.)

TOTAL DEPTH: 1,466 ft

COMPLETION: October 25, 1991

CASING: 20 in. conductor to 60 ft; 9 5/8 in. conductor to 504 ft; uncased 504–1,466 ft

DRILLED BY: Transwestern Drilling, Inc., for Felderhoff Production Co., Gainesville, Texas

LITHOLOGY LOGGED BY: W.J. Carr, January 21–22, 1992, from microscopic examination of cuttings samples. Some contacts and lithology derived in part from geophysical logs.

Depth interval below land surface (feet)	Lithology
0–60	No samples.
60–200	Alluvium, consisting of heterogeneous volcanic rocks, and a few Paleozoic carbonate rock fragments. Cuttings coarsen downward.
200–270	Alluvium, marl (?), and basalt breccia. Cuttings are nearly all volcanic clasts and quartz, feldspar, and biotite; mostly pebble-sized clasts 240–270 ft. Gamma-ray log (fig. 4) suggests this interval is at least partly basaltic breccia.
270–300	Volcanic breccia, basaltic, light brown to gray-brown, partly cemented by calcite; plagioclase and olivine are largely altered to calcite and iron oxide.
300–330	Basalt, gray to dark gray, mostly fine equigranular; relatively fresh, including olivine.
330–505	No samples, but well completion report and geophysical logs indicate this interval is basalt.
505–545	No samples.
545–640	Siltstone and calcareous claystone, very light yellow to light gray. Siltstone silicified. Cavings include basalt, tuff, cement, and lost circulation material; latter two components increase downward.
640–850	Lost circulation material, cement, and clay or gel. A few fragments of silicified and slightly calcareous light-colored tuff. Texture of the latter is shard-like. Cement and lost circulation material increase downward, until nearly 100% in lower half of interval. Samples unrepresentative of formation.
850–1,000	Limestone. Top of Tertiary (?) or Paleozoic (?) limestone. Sample is similar to 640–850 ft, except gray to light gray fragments of Paleozoic carbonate rock begin to be evident; these are mostly finely crystalline limestone. Geophysical logs show increase in density and resistivity and decrease in hole size at about 850 ft (259.1 m). Most fragments are very light gray, fine grained, uniform, and could be Tertiary carbonate. Pyrite noted.

Depth interval below land surface (feet)	Lithology
1,000–1,220	Limestone, gray to light gray, most fragments are medium crystalline, and many have calcite veinlets or spots. Occasional fragments with slickensides (?). Lithology uniform, but color darkens downward to dark gray and rock becomes more dolomitic.
1,220–1,260	Limestone, dolomitic, gray, medium grained.
1,260–1,310	Dolomite and minor limestone, gray, medium crystalline.
1,310–1,330	Lost circulation material. Wood fibers and a few gray dolomite fragments. Caliper log indicates large void 1,320–1,330 ft (402.3–405.4 m), more than 20 in. across. Probable fault.
1,330–1,340	Dolomite, gray, medium crystalline.
1,340–1,370	Dolomite, very light gray to gray, medium crystalline, with minor brownish-gray calcareous siltstone (?). Fragments of calcite and iron-stained siliceous material. Fault zone (?).
1,370–1,466	No samples. Lost circulation zone. Caliper log indicates large openings 1,410–1,445 ft (429.8–440.4 m) and at 1,462 ft (445.6 m). Openings exceed 24 in. Probable major fault zone.

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