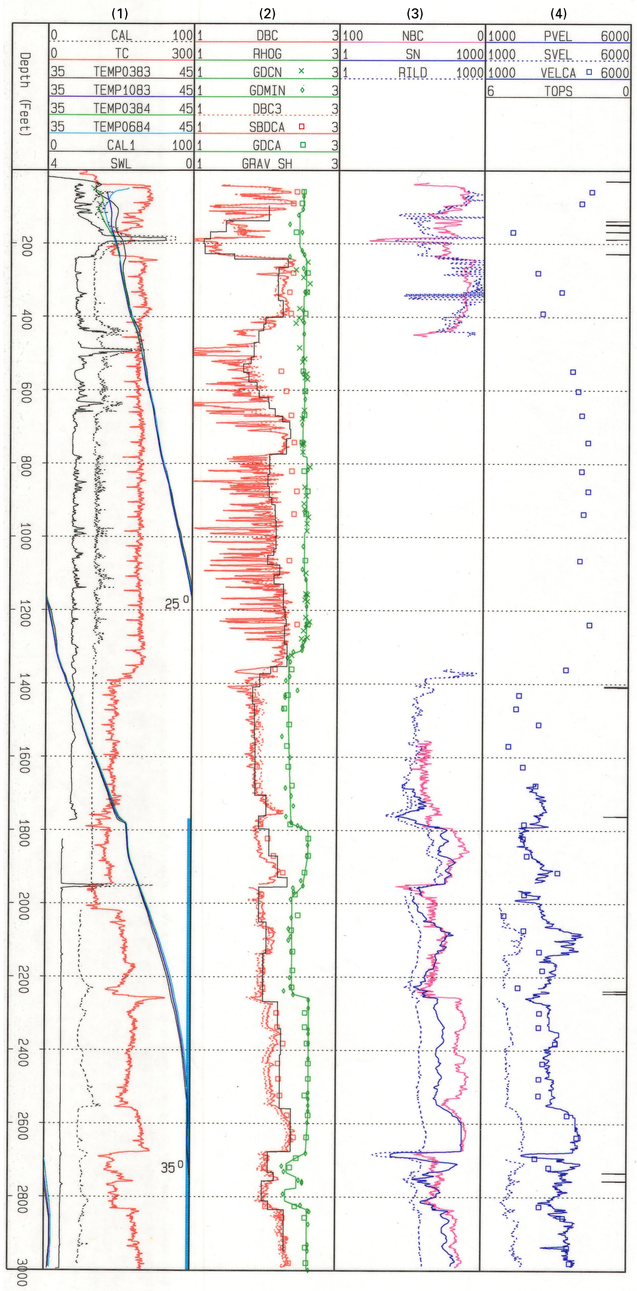
Open-File Report 2014–1023
Plate 4 of 27

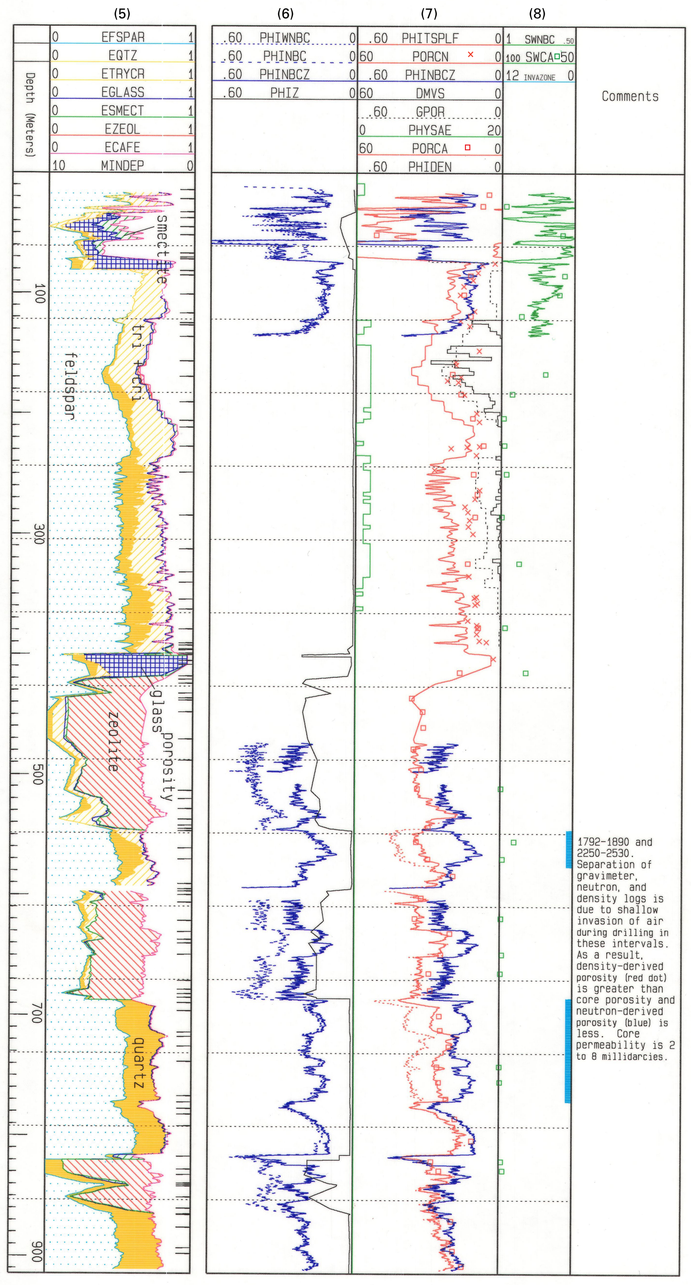
U.S. Department of the Interior
U.S. Geological Survey

USW G-4

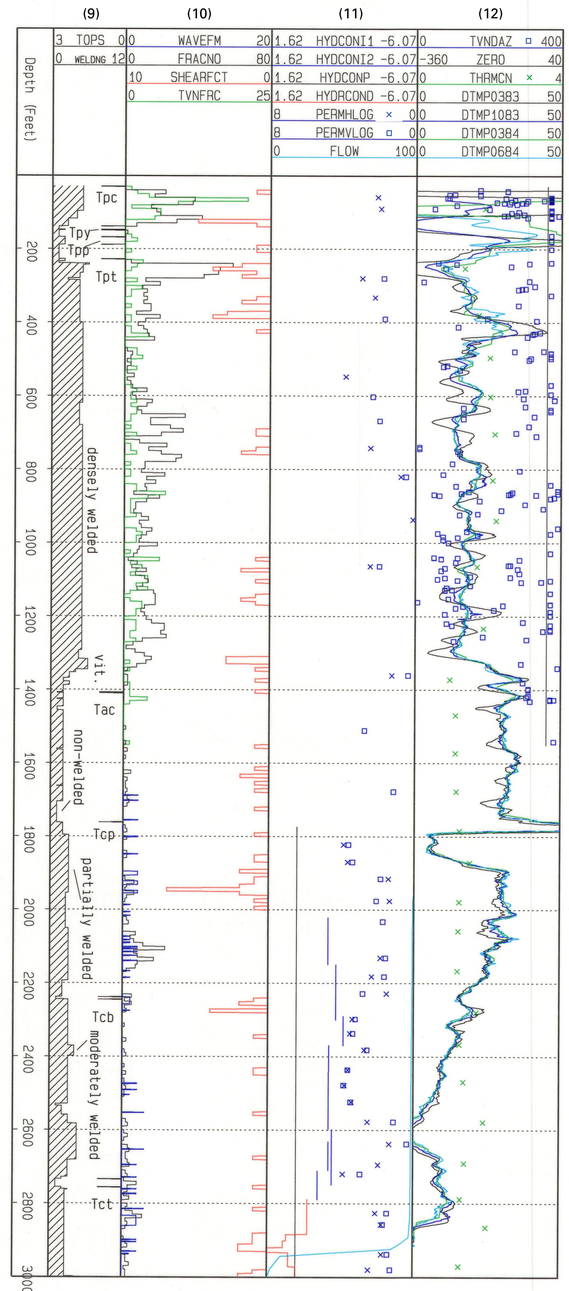
Original Logs and Core Data



Mineralogy, Porosity and Water Content



Stratigraphy, Fractures, and Flow



BOREHOLE USW G-4, YUCCA MOUNTAIN, NEVADA

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Drilling of USW G-4 commenced on August 22, 1982 and continued until nearly continuous coring was completed at a depth of 3,001 feet on November 7, 1982 (Spengler and others, 1984). Drilling fluid was air foam. Drilling problems required reaming of the hole. Logs were run in stages in response to the drilling difficulties. For example, a section of the neutron log from 1671 to 1981 feet was run after reaming. Two caliper logs give the hole size before and after reaming.

Depth on the plot is measured along hole, and has not been corrected for deviation. Deviation from vertical in G-4 is 5 degrees at 1000 feet, 6 degrees at 2000 feet and 9 degrees at 3000 feet. At a true vertical depth of 2959.6 feet, the measured depth is 2975 feet and horizontal offset is 259 feet from the surface location (from Plate 4, Nelson and others, 1991).

Most of the original logs in columns 1–4 were acquired between September and November, 1982 (Nelson and others, 1991). The gravimeter log was acquired in April, 1985. Four temperature logs obtained between March, 1983 and June, 1984 from Sass and others (1988) also appear in column 1.

Bulk density, grain density, and porosity from core measurements were presented by Nelson and others (1991). Anderson (1984) reported on measurements on large-volume core samples; Anderson (1994) later reported measurements on oriented plugs. Here the permeability data are from plugs, and all other core data by Anderson are from large-volume samples. Measurements by Anderson are designated with an 'A' in the curve name (GDCA, SBDCA, etc.). Nelson and Anderson (1992) discuss the measurements and examine the core data in terms of mineralogy.

Mineralogy in column 5 is derived from X-ray diffraction data by Bish and Chipera (1989). Their data have been converted to volume percent, combined with the porosity curve phitsplf, and extrapolated to boundaries inserted in several places where marked changes in log response occur.

Column 6 shows the estimates of water content. Phinbc and phiwnbc are based upon the thermal neutron log, nbc, after correction for hole size. Phiwnbc is computed only in the unsaturated zone where an additional correction for air content is required. Saturation, swnbc, is the ratio of phiwnbc to porosity. Structural water, phiz, was computed from mineralogical data. To create an estimate of pore space water, the curve phinbcz = phinbc – phiz in the saturated zone, whereas phinbcz = phiwnbc – phiz in the unsaturated zone.

Column 7 compares a final porosity estimate, phitsplf, with core porosity and with the water content, phinbcz. Porosity phitsplf is a filtered splice of several computational segments required by the mix of saturation conditions and available logs. In the unsaturated zone, water content is accounted for either by using the neutron log or else, where no neutron log was run, by assuming a water saturation and using the density or gravimeter log. In the saturated zone, porosity was computed directly from the density log in the uninvaded zones, and after compensation of the density log for air invasion in the two invaded zones.

Muller and Spengler (1989) estimated lithophysal pore space, dmvs, from inspection of core, and computed a second estimate, gpor, from the gravimeter log. Presence of lithophysal occurrences (physae) was also documented by Spengler and others (1984). Nelson and others (Fig. 18, 1991) identified two permeable zones on the basis of separation between the neutron, density, and gravimeter-based density logs (invazone, column 8).

Stratigraphic tops, degree of welding, and fracture densities (fracno and shearfct) given in columns 9 and 10 are taken from Spengler and others (1984). Spengler and others (1984) note that "the amount of offset can rarely be determined along recognized shear fractures. However, the lack of any significant thinning of major stratigraphic units and the absence of any abrupt terminations in welding characteristics of rock on either side of the fractures suggest that displacements are of small scale". Disruptions in the sonic waveform log (wavefm) are often due to fractures or faults. Fractures picked from a television log are shown on a dip azimuth plot (tvndaz) and in bar graph format (tvnfrc).

Hydraulic conductivity from pump tests (hydrconp) and injection tests (hydrconi) are taken from Lobmeyer (1986). Permeability data from core measurements are taken from Anderson (1994). The logarithmic scales in column 11 are arranged so that permeability and hydraulic conductivity can be compared, using a conversion of 1.196 darcy = 1 m/day. Lobmeyer (1986) interpreted the original pump test results (hydrconp) and tracer results (flow) to produce hydraulic conductivity values (hydrcond) in the lowermost 200 feet of the hole.

Temperature gradients, dtmp, were computed by differencing the temperature logs over fourteen-foot intervals. Thermal conductivities, thrmcn, are from Sass and others (1988).

EXPLANATION OF CURVES AND SYMBOLS

Column 1
CAL1 Caliper in cm, black curve.
CAL Caliper in cm, reamed hole, black dot curve.
SWL Static water level, vertical cyan bar.
TEMP Temperature in deg C, four curves (month, year).
TC Gamma ray in API units, red curve.

Column 2
DBC Density in g/cm3, red curve.
DBC3 Density bound in g/cm3, red dot curve.
SBDCA Density of saturated samples in g/cm3, red squares.
RHOG Grain density in g/cm3, green curve.
GDCA, GDCN Grain density from cores, green squares, green X.
GDMIN Grain density from mineralogy, green diamonds.
GRAV_SH Density from gravimeter in g/cc, black line.

Column 3
NBC Thermal neutron log in porosity, magenta curve.
SN Short normal resistivity in ohm-m, blue curve.
RILD Induction resistivity in ohm-m, blue dot curve.

Column 4
PVEL P-wave velocity in m/s, blue curve.
SVEL S-wave velocity in m/s, blue dot.
VELCA P-wave velocity core in m/s, blue squares.
TOPS Stratigraphic boundaries, black ticks.

Column 5 [shaded areas represent volume fractions]
EFSPAR Feldspar, blue dotted area to left-hand edge.
EQTZ Quartz, dark yellow area.
ETRYCR Tridymite + cristobalite + opal, light yellow.
EGLASS Glass, blue gridded area.
ESMECT Smectite + kaolinite, green slanted area.
EZEOL Clinoptilolite + mordenite + analcime, red slant.
ECAFE Calcite + hornblende + hematite + chlorite, magenta hatch.
Porosity Unshaded area to the right-hand edge.
MINDEP Depth of x-ray diffraction samples, ticks.

Column 6 [fractional volumes of whole rock, increasing to the left]
PHINBC Water content from corrected NBC, dashed blue curve.
PHIWNBC Water content from NBC, corrected for partial saturation, dotted blue curve.
PHIZ Structural water from mineralogy, black curve.
PHINBCZ Water content with structural water removed, blue solid.

Column 7 [fractional volumes of whole rock, increasing to the left]
PHITSPLF Porosity, computed in several segments using different methods, filtered, red curve.
PHIDEN Porosity, computed from density log assuming full saturation, red dotted curve.
PHINBCZ Water content with structural water removed, blue solid.
PORCA, PORCN Porosity from core measurements, red squares, X.
DMVS Void space from core inspection, black line.
GPOR Void space from gravimeter log, black dotted curve.
PHYSAE Lithophysal zone, value of 1 where sparse, value of 2 where abundant, green bar.

Column 8 [fractional volumes of pore space, increasing to the left]
SWNBC Water saturation from NBC, green curve.
SWCA Water saturation from core, green squares.
INVAZONE Zones where air invaded the formation during drilling, cyan bar.

Column 9
WELDNG Degree of welding from core inspection, black slant.
TOPS Lithologic tops, black ticks.

Column 10
WAVEFM Disruptions in sonic waveform log, blue ticks and bars.
FRACNO Natural fractures, number per 10-foot interval, black bars.
SHEARFCT Shear fractures, number per 10-foot interval, red bars.
TVNFRC Fractures from television, number per 10-foot interval, green bars.

Column 11
PERMHLOG Permeability from horizontal plugs in microdarcy, logarithmic scale, blue X.
PERMVLOG Permeability from vertical plugs in microdarcy, logarithmic scale, blue squares.
HYDRCONI Hydraulic conductivity in m/day, from injection tests, blue lines.
HYDRCONP Hydraulic conductivity in m/day, average of four pump tests, black line.
HYDRCOND Hydraulic conductivity in m/day, interpreted from pump tests and flow log, red line.
FLOW Flow from tracer, percent of total, cyan curve.

Column 12
TVNDAZ Dip azimuth of fractures from television, in degrees, blue squares.
DTMP Temperature gradient, deg C/km, four curves (month, year).
THRMCN Thermal conductivity, W/m/degK, green X.

Stratigraphic Names

-Paintbrush Group-	
Tpc	Tiva Canyon Tuff
Tpy	Yucca Mountain Tuff
Tpp	Pah Canyon Tuff
Tpt	Topopah Spring Tuff
Tac	Calico Hills Formation
-Crater Flat Group-	
Tcp	Prow Pass Tuff
Tcb	Bullfrog Tuff
Tct	Tram Tuff

NOTES

Last computation: August 1995 Plotted: September 1995
Scientific Notebook: SN-0092

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Petrophysical Properties, Mineralogy, Fractures, and Flow Tests in 25 Deep Boreholes at Yucca Mountain, Nevada

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