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Abstract

The following geophysical well-log measurements were made in drill hole UPH-3, Stephenson County, Illinois: (1) resistivity, (2) induced polarization, (3) self potential, (4) magnetic susceptibility, (5) total count gamma ray, (6) neutron-neutron, (7) density, (8) caliper, (9) acoustic velocity, and (10) temperature. Drill hole UPH-3 penetrated nearly 1000 m of granite in the logged interval (656 m - 1600 m). A description of the function of each type of well log is given and the data are presented at two scales in both english and metric units.

Introduction

Core hole UPH-3, located near Winslow, in Stephenson County, Illinois, was cored to a depth of approximately 1600 m and penetrated granite in the 656 m - to - 1600 m depth interval. This hole was drilled in the spring of 1980 by Commonwealth Edison of Illinois for engineering purposes. Upon completion, the Continental Scientific Drilling Committee of the Geophysics Research Board, National Academy of Science agreed to organize scientific investigations in UPH-3 through a steering group. The history of this drill hole has been described by Haimson and others (1980).

The U. S. Geological Survey made the following geophysical well-log measurements in drill hole UPH-3: (1) resistivity, (2) induced polarization

(IP), (3) self potential, (4) magnetic susceptibility, (5) total count gamma ray, (6) neutron-neutron, (7) density, (8) caliper, (9) sonic velocity, (10) acoustic waveforms, (11) non-linear complex resistivity, and (12) temperature. The non-linear complex resistivity and acoustic waveforms are not presented in this paper. The magnetic susceptibility, gamma ray, neutron, density, caliper, and sonic velocity measurements were recorded digitally at 15.24 cm intervals. The digital measurements are plotted in plates 1-4. Each of the four plates show the same well logs at different depth scales and units. The resistivity and induced polarization measurements shown in plate 1-4 were recorded digitally and plotted at approximately 70 cm intervals. These data represent the most comprehensive suite of geophysical well logs to have been recorded in a granitic section.

Description of geophysical well-log measurements

Each geophysical well-log measurement is affected by the physical properties of the rock, the interstitial fluid of the formation, the conditions in the borehole (fluid and rugosity), the volume of rock investigated by the probe, the vertical resolution of the probe, and the design characteristics of each probe, and so should be considered an apparent rather than a true physical property value. Some characteristics of individual well-logging probes follow:

(1) Resistivity

Resistivity is a measure of the facility with which electric current passes through a material. Borehole resistivity measurements depend upon the porosity, fluid resistivity, and grain resistivity of the rock investigated.

Apparent resistivities in drill hole UPH-3 average approximately 6000 ohm-meters in the non-fractured zones. The resistivity measurements presented in this paper were made with the Wenner Array at an a-spacing of 20 cm (labeled 16" resistivity on the log headings).

(2) Density

The density probe consists of a gamma-ray source and one or more gamma-ray detectors. Gamma rays emitted by the source are scattered by the rock, and the gamma radiation measured at the detector is inversely proportional to the electron density of the rock. By using two detectors, the effects of fluid density and rugosity on the calibrated density measurement can be compensated, yielding a computed density that is approximately equal to the bulk density of the rock.

(3) Neutron

A neutron source and detector, separated by approximately 50 cm, compose the neutron well-logging probe. The number of neutrons counted by the detector is an inverse function of the hydrogen content of the rock surrounding the borehole, and is primarily a measure of the amount of water contained in the rock. The neutron count is lowest in the fractured region of the drill hole.

(4) Gamma Ray

The gamma-ray probe measures the natural gamma radiation emitted by the rocks surrounding the borehole. The principal natural gamma-ray-emitting minerals in granite are uranium-series isotopes and potassium-40.

(5) Induced Polarization (IP)

The IP log measurements were calculated from nonlinear complex resistivity equipment from the Petrophysics laboratory as described by Olhoeft

(1979). Briefly, a 1 Hz sinewave is driven by a power amplifier into current electrodes of a 20 cm Wenner array with all platinum electrodes. The phase angle of the received signal is measured as the frequency domain IP. A phase angle of -20 mR corresponds to a percent frequency effect of approximately 2.9.

(6) Magnetic Susceptibility

Magnetic susceptibility is a measure of the intensity of magnetization of a magnetizable substance in the presence of a known magnetic field. The magnetic susceptibility of a rock depends largely on the amount of ferrimagnetic minerals that it contains. The magnetic susceptibility measurement is made by measuring the out-of-phase self-inductance of a high-μ permalloy-cored coil that is driven at a frequency of 100 Hz.

(7) Acoustic

Acoustic velocity is measured with two piezoelectric ceramic detectors spaced .91 and 1.52 m from a magnetostrictive source. The acoustic velocity is the reciprocal of the interval transit time (Δt) of the P-wave between the two dectectors.

Laboratory sample measurements

Laboratory physical-property measurements serve as a general check on the reliability of physical properties measured by borehole geophysical probes. However, there is always some doubt as to the exact depths of the core samples. Laboratory measurements of specific gravity, density, porosity, and magnetic susceptibility are given in the table. In addition to the measurements shown in the table, preliminary laboratory determinations of P-wave sonic velocity measurements indicate a velocity of approximately 6 km/sec.

Preliminary physical properties measurements on selected core samples from core holes UPH-3 ("-" indicates no sampling made).

Depth (ft)	SGG	SGH	SGA	DBD3 (g/cm^3)	WBD ($gm/cm3$)	WAP (in pct)	HAP (in pct)	TP (in pct)	MS (cgs)
2209B	2.7248	2.655	2.654	2.641	2.654	0.024	0.527	3.08	4.856e-6
2271A	-	2.656	2.648	2.501	2.647	0.055	5.84	-	6.095e-6
2290B	-	2.642	2.644	2.587	2.641	0.115	2.08	-	7.887e-6
2351A	-	2.628	2.648	2.634	2.647	0.045*	0.00	-	1.199e-5
2397A	-	2.642	2.645	2.513	2.643	0.068	4.88	-	1.122e-5
2622A	-	2.625	2.649	2.625	2.648	0.127	0.643	-	5.774e-5
2791B	-	2.641	2.638	2.632	2.635	0.114	0.682	-	4.405e-5
2422A	2.7165	2.637	2.649	2.636	2.646	0.090*	0.038	2.96	4.801e-6
2969A	-	2.644	2.648	2.634	2.644	0.149	0.378	-	6.703e-5
3151A	-	2.639	2.638	2.627	2.634	0.169	0.455	-	2.079e-5
3333A	-	2.650	2.643	2.632	2.638	0.174	1.109	-	6.665e-5
3514A	-	2.635	2.640	2.632	2.637	0.128*	0.114	-	7.056e-5
3699A	-	2.651	2.654	2.643	2.650	0.160	0.302	-	1.522e-4
3880A	-	2.686	2.661	2.555	2.658	0.108	4.877	-	2.706e-4
4059A	-	2.633	2.664	2.576	2.660	0.170	2.165	-	2.731e-4
4242A	-	2.631	2.642	2.521	2.640	0.072	4.181	-	1.337e-4
4421A	-	2.651	2.656	2.643	2.652	0.157	0.302	-	2.123e-4
4608	-	2.628	2.620	2.604	2.614	0.209	0.913	-	5.051e-5
4689A	-	2.674	2.653	2.631	2.649	0.127	1.608	-	6.400e-5
4878A	-	2.699	2.690	2.665	2.686	0.170	1.260	-	2.663e-4
4969A	-	2.667	2.663	2.638	2.659	0.146	1.087	-	1.526e-4
5056A	-	2.675	2.658	2.634	2.654	0.138	1.533	-	1.763e-4

SGG = grain specific gravity of crushed sample
SGH = helium pycnometer specific gravity of 25.4mmx25.4mm core
SHA = Archimede's specific gravity of 25.4mmx25.4mm core
DBD = dry bulk density of whole core
WBD = Archimede's wet bulk density of 25.4mmx25.4mm core
HAP = helium accessible porosity
WAP = water accessible porosity
TP = total porosity
MS = magnetic susceptibility

*Statistical error in the measurements which occurs when the water accessible porosity exceeds the helium accesible porosity.

References

Haimson, B. H., Bredehoeft, John, and Coates, Mary Sue, 1980, Illinois borehole offers rare chance for research: EOS, v. 61, no. 17, p. 182-183.

Olhoeft, G. R., 1979, Electrical properties in Initial report of the Petrophysics Laboratory: U.S. Geological Survey Circular 789, p. 1-25.