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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TECHNICAL LETTER: SPECIAL STUDIES I-55

BOREHOLE GRAVITY METER OBSERVATIONS IN DRILL HOLE Ue19n, PAHUTE MESA, NEVADA TEST SITE

By

D. L. Healey

September 22, 1967

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Prepared by the Geological Survey for the U. S. Atomic Energy Commission.

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In reply refer to:
Special Projects Branch
Technical Letter
Special Studies I-55
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Federal Center, Denver, Colorado 80225

BOREHOLE GRAVITY METER OBSERVATIONS IN DRILL HOLE Ue19n, PAHUTE MESA, NEVADA TEST SITE

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ABSTRACT

Drill hole Ue19n was successfully logged with the U.S. Geological Survey La Coste-Romberg borehole gravity meter in spite of the fact that the hole was dry, penetrated very low density rocks and was badly out of gage. These conditions affected the gamma-gamma density log forcing it completely off scale in the interval between 500 and 970 feet.

The calculated *in situ* density of the Rainier Mesa Member ranges from 2.03 to 2.22 gm/cc and averages 2.13 gm/cc. The rocks comprising the Paintbrush Tuff, tuff of Blacktop Butte range in density from 1.49 to 1.70 gm/cc and the weighted average is 1.58 gm/cc. The two interval densities within the tuffs of Area 20 average 1.81 gm/cc.

INTRODUCTION

Drill hole Ue19n (Scroll) was successfully logged with the U.S. Geological Survey La Coste-Romberg borehole gravity meter on July 9 and 10, 1967. The gravity meter together with the necessary supporting equipment was operated by J. E. Schoellhamer, L. A. Beyer, and E. A. Barker of the U.S. Geological Survey, Menlo Park, Calif. Mr. Schoellhamer and Mr. Beyer also collaborated on the data reduction.

Drill hole Ue19n is located on Pahute Mesa at Nevada State coordinates (central zone) N. 942,000.97 and E. 584,600.00. The ground surface elevation at the drill hole is 6,754.4 feet. The hole is cased to a depth of 26 feet with 10-3/4-inch diameter casing. From 26 to 34 feet the casing is 20 inches in diameter. From 34 to 1,417 feet (T.D.) the hole is uncased: although this part of the hole was drilled with a 9-7/8-inch bit, it is badly caved and in places is as much as 20 inches in diameter.

Gravity observations were made at 15 places down the hole and 14 interval densities were calculated. These gravity observations were made at places selected to correspond with the lithologic breaks shown on a drilling prognosis log by E. C. Jenkins (1967, written comm.) and with the abrupt changes that appear on the Birdwell caliper and density logs. Depths to the gravity stations were obtained by measuring the cable with a steel tape and marking the reading points beforehand. This procedure resulted in depth measurements that are accurate to within ±0.1 foot. The gravity observations were made at four intervals, each about 130 feet thick, from the surface to 519-foot depth; at five intervals, each about 90 feet thick, from the 519-foot depth to the 968-foot depth; at two intervals, each about 100 feet thick, from the 968-foot depth to the 1,168-foot depth; at one 90-foot thick interval, from the 1,168-foot depth to 1,258-foot depth; and at two intervals, each about 70 feet thick, from the 1,258-foot to the 1,398-foot depth (table 1 and figure 1).

Table 1.--Calculated in situ interval densities in drill hole Ue19n, Pahute Mesa, Nevada Test Site

Depth (feet	Relative OBS gravity (mgal)	Δ Tc (mgal)	Δ g (mgal)	Δ Z (feet)	Δ g/Δ Z (mgal/foot)	X39.20 (gm/cc)	σ (gm/cc)
2.40	0.000	0.00					
130.66	5.810	-0.49	5.320	127.66	.0417	1.635	2.076
259.82	5.188	-0.24	4.948	129.76	.0381	1.494	2.217
389.68	5.276	-0.24	5.036	129.86	.0388	1.521	2.190
519.31	5.790	-0.24	5.550	129.63	.0428	1.678	2.033
609.18	5.095	-0.16	4.935	89.87	.0549	2.152	1.559
698.87	5.248	-0.16	5.088	89.69	.0567	2.223	1.488
788.86	5.105	-0.17	4.935	89.99	.0548	2.148	1.563
878.77	5.140	-0.17	4.970	89.91	.0553	2.168	1.543
968.43	5.171	-0.16	5.011	89.66	.0559	2.191	1.520
1068.27	5.387	-0.18	5.207	99.84	.0522	2.046	1.665
1168.05	5.292	-0.18	5.112	99.78	.0512	2.007	1.704
1257.91	4.537	-0.16	4.377	89.86	.0487	1.909	1.802
1327.84	3.522	-0.13	3.392	69.93	.0485	1.901	1.810
1397.74	3.295	-0.13	3.165	69.90	.0453	1.776	1.935

The design and operation of the U.S. Geological Survey La Coste-Romberg borehole gravity meter has been described in detail (McCulloh, La Coste and others, 1967, and McCulloh, Schoellhamer and others, 1967) and will not be repeated here.

DATA REDUCTION

Borehole gravity meter observations, like standard surface observations must be corrected for instrument drift, earth tides, free-air (using measured free-air gradient) Bouguer, and terrain. However, unlike standard surveys, there is no latitude correction if the drill hole is vertical.

Frequent checks with the base station at ground level and repeated observations were made to facilitate the elimination of the effects of instrument drift. The terrain correction was calculated through Zone L (Hammer, 1939), a radial distance of about 9 miles, using the extended tables calculated by C. H. Sandberg (1958) of the U.S. Geological Survey. Applying the terrain corrections and recalculating the *in situ* interval densities changed those based on the uncorrected observed gravity data by as much as +.073 gm/cc. These preliminary calculations are not reported. The resulting interval densities are given in table 1.

The *in situ* rock densities were calculated using a measured free-air gravity gradient of 0.09467 mgal/ft. This value was measured over a vertical interval of 54.1 feet on the head frame at drill hole U19g, which is about 10,000 feet south-southeast of Ue19n. This value may not be completely applicable at Ue19n; however, at this writing it is the best available.

The interval _in situ_ rock densities were calculated from the general expression

$$\Delta g = (F - 4\pi\gamma\sigma)\Delta Z + \Delta T \qquad (1)$$

where Δg (mgals) is the measured gravity, Δz is the interval thickness in feet, ΔT (in mgals) is the variation in the terrain correction over interval Δz, F is the measured free-air gradient and $4\pi\gamma\sigma$ is twice the Bouguer effect. This factor has to be doubled to account for the upward and downward attraction of the material above and below the observation point. Equation (1) may be solved directly for density (σ) giving

$$\sigma = F/4\pi\gamma - (\Delta g - \Delta T)/4\pi\gamma\Delta Z \qquad (2)$$

substituting the normal value for the gravitational constant (γ) corrected to feet and the measured value for F in mgal/foot in equation (2) permits its reduction into the more useful form

$$\sigma = 3.687 - 39.20\ (\Delta g - \Delta T)/\Delta Z \qquad (3)$$

where σ is in gm/cc, ΔZ is in feet, and Δg and ΔT are in milligals.

In equation (3) the value 3.687 is true if the free-air gradient is normal (.09406 mgal/ft). Since the measured free-air gradient (.09467) is not normal, equation (3) must be modified as follows

$$\sigma = 3.687\ \frac{.09467}{.09406} - 39.20\ \frac{\Delta g - \Delta T}{\Delta Z}$$

or

$$\sigma = 3.711 - 39.20\ \frac{\Delta g - \Delta T}{\Delta Z} \qquad (4)$$

For a complete explanation on the calculation of in situ rock densities from borehole or subsurface gravity data, the reader is referred to reports by the following authors (not a comprehensive listing): Algermissen, 1961; Domzalski, 1954; Hammer, 1950; McCulloh, 1965; and Smith, 1950.

RESULTS

The in situ rock densities determined from the borehole gravity meter observations in drill hole Ue19n are shown on figure 1. Also shown on figure 1 are the geologic section and lithologies (after E. C. Jenkins, in prep.), the laboratory-determined physical properties data, and the densities determined from a Birdwell continuous gamma-gamma density log.

The in situ density of the Rainier Mesa Member is 2.08 gm/cc from ground surface down to 131 feet. From 131 to 390 feet the average density is 2.20 gm/cc. From 390 feet to the base of the member at 519 feet the density is 2.03 gm/cc. The gamma-gamma density log data differs as much as ± 0.14 gm/cc from the densities obtained from the borehole gravity meter between 130 and 390 feet. However, the hole was dry and erratically out of gage, which adversely affected the density log.

The nonwelded ash-flow tuff of the Paintbrush Tuff, tuff of Blacktop Buttes, is marked by a prominent gravity low. The density of these rocks as determined from the gravity meter data, ranges from 1.49 to 1.70 gm/cc. This portion of the hole is badly caved;

diameter is as great as 20 inches. The combined effect of the low density rocks and large diameter irregular hole forces the density tool completely off scale over much of this interval. However, the borehole gravity meter was not adversely affected other than in evincing some leveling difficulty attributable to the large hole size. From 968 to 1,168 feet the density-log data parallels but reads 0.04 gm/cc less than the borehole meter values.

As for the rocks below 1,168 feet the nonwelded tuffs of Area 20 in Ue19n are more dense than those of the overlying Paintbrush Tuff and they average more than 1.80 gm/cc. The true density of the rhyolite of Quartet Dome is not defined by the borehole gravity meter data because the lowest interval density (1.935 gm/cc) includes rocks of the overlying tuff of Area 20. This interval density then is an average of the two types of rocks sampled.

The density log values are both lower and higher than the borehole gravity meter values obtained from the tuffs of Area 20. The density log data show a marked increase in density associated with the rhyolite of Quartet Dome.

When compared with the calculated *in situ* interval densities the laboratory-determined physical properties data exhibit considerable scatter. However, one must keep in mind that the laboratory values shown are determined on individual core samples. If the lithologic unit sampled is inhomogeneous, which is usually the case, one must expect various densities. The borehole gravity meter determines an average value for a cylinder of rocks whose radius is approximately equal to 5 times the interval footage between the points of observation (McCulloh, 1966, p. 4 and 5). This, of course, has a smoothing affect and provides the curve as shown on figure 1.

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Figure I-Density determinations in drill hole Ue 19n, Pahute Mesa, NTS