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ON THE COMPARISON OF THE DATA FROM AN EPITHERMAL NEUTRON LOG
TO WATER CONTENT MEASURED FROM IN SITU SAMPLES
IN YUCCA FLAT, NEVADA TEST SITE

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ABSTRACT

The count rate from an epithermal neutron log has been compared to the volume percent water obtained from many borehole samples taken from Yucca Flat at the Nevada Test Site. Over a limited range of bulk density and water content, it appears possible to fit a reasonable calibration curve to core samples from the southern part of Yucca Flat. For the northern part, where bulk density varies over a considerably larger range, and only sidewall samples are generally available, no acceptable calibration curve seems possible.

INTRODUCTION

Volume percent water of the medium is a very important quantity in the prediction of the effects of underground nuclear explosions. The best way to measure volume percent water by wireline logging seems to be through the diffusion of neutrons, although in some cases electrical resistivity of the medium appears to be an equally good measure. Monte Carlo calculations¹ indicate that the diffusion of epithermal neutrons depends primarily on the water content and bulk density of the medium, and a calibration facility¹ is under construction to separate the two effects.

However, for some time it has been thought that an epithermal neutron log can be calibrated simply by comparing the count rate in a hole to the water content obtained from samples in the hole. This is common practice in industry.² This report investigates the feasibility of applying this method to the alluvium and tuffs of Yucca Flat at the Nevada Test Site.

METHOD

R. D. Carroll and D. C. Muller of the U.S. Geological Survey have prepared an excellent study of the behavior of resistivity logs in southern* Yucca Flat.³ In the course of this study, Carroll and Muller also investigated neutron logs and compared the count rate of the logs to the volume percent water obtained from standard cores. First they divided each hole into sections on the basis of the resistivity log. Next they averaged bulk density, count rate, and water content from samples over each section.

* Southern and northern Yucca Flat are those areas used by LASL and LLL, respectively.

Then they used the "reduced major axis method,"⁴ which considers uncertainties in both variables, for fitting an exponential to the averages from many sections of many holes.

In the present work, several modifications were made to Carroll and Muller's method, mainly for convenience. They had made separate fits to exploratory and emplacement hole data. However, only exploratory hole data were used here, mainly in holes of nominal 317.5-mm diameter, because the epithermal neutron log exhibits large hole-size effects when not properly shielded.⁵ For this study, resistivity logs were unavailable and the holes in northern Yucca Flat were therefore divided into sections on the basis of the neutron and density logs and the sample data. Also, the water content was obtained from sidewall samples rather than from core samples, because in general there are no cores. Finally, the fitting method was a fit to the expression: $Aw + B \log I + C = 0$, where I is the count rate and w is the volume percent water. The data were weighted by the number of samples in each section. This method, which assumes equal uncertainties in both variables, was chosen over more sophisticated methods which take into account actual estimates of the uncertainties in each variable because a subroutine⁶ to do it was available; because equal uncertainties are a reasonable assumption; and because, after using it, it was clear that the fitting method would not affect the final conclusions of the investigation.

RESULTS

Figure 1 is a map of part of Yucca Flat, showing the locations of the holes used in this study. Each hole is identified by its unique NTS hole number and also by the single letter used in plots of the data obtained from that hole.

Figure 2 shows the data points from southern Yucca Flat as supplied in Carroll and Muller's report. Both the fit using the method described above and Carroll and Muller's fit³ are shown. (We apologize for the non-SI unit of kilocounts/minute on these figures: that is the output of the log.) The standard error in the water content from the fit in this report (simply the rms deviation from the fit) is 3.54 vol% water; that from Carroll and Muller's fit is 3.3 vol%.⁷ The fits are quite different, and it is left to the reader to decide which appears more plausible. The standard error in the water content is acceptable for use as a calibration curve. However, the range of the data is quite limited: 80% of the data lie between 16 and 32 vol% water, and 80% of the bulk densities³ lie between 1.5 and 1.9 Mg/m³.

Figure 3 shows the data points from northern Yucca Flat. While the standard error of 5.4 vol% is not too much worse than that in Fig. 2, the general appearance of the data seems much less satisfactory (perhaps because much of the data may span only about 4 standard deviations). While again 80% of the points lie between 16 and 32 vol% water, we find the bulk densities to vary almost equally between 1.4 and 2.3 Mg/m³. The extremes of the water content are much farther apart than those in Fig. 1, and the

Fig. 1. Locations of bore holes used in this study.

Fig. 2. Epithermal neutron count rate vs volume percent water from southern Yucca Flat (Carroll and Muller³) showing the fit from Ref. 3 and the fit developed in this report.

Fig. 3. Epithermal neutron count rate vs volume percent water from northern Yucca Flat. The fit is compared to that developed in this report for all southern data (Fig. 2).

general appearance has been likened to the results of a shotgun blast.⁸ This author has a lurking suspicion that a horizontal line might be a reasonable fit.

The fit from Fig. 2 is also shown on Fig. 3, and it may be that that line fits a somewhat isolated part of the data in Fig. 3, but this is only a qualitative idea which will be expanded below. It should be noted in passing that Carroll's fit from Fig. 2 would be even less satisfactory for these data.

DISCUSSION

It would be desirable to understand why the data from northern Yucca Flat scatter so much more than those from the southern part. One possibility is the nature of the medium from which the samples were taken. Figures 4 and 5 show the northern data separated into those from above and those from below the alluvium-tuff contact. There is no evidence that either material contributes more to the scatter. Perhaps the density range contributes, as would be expected from Ref. 1, but there seems to be no systematic effect. Attempts at fits which took into consideration density, or difference between density and mean density, were fruitless.

The most plausible explanation seems to be the type of sample. For example, Fig. 6 shows the data from a fairly typical single hole in northern Yucca Flat. Some points, shown, were obtained from supposedly "natural-state" sidewall samples.* None of the data look like anything could be fitted. However, both sidewall and core samples were available from one northern hole, and the data from that hole are shown in Fig. 7. There are only a few points obtained from core samples, and the result may be fortuitous, but four of the six points lie close to the curve fitted to the southern data in Fig. 2 (which, it should be recalled, were all from core), even though the bulk density is much higher than any in Fig. 2.

CONCLUSIONS

Data from sidewall samples appear worthless for calibrating the epithermal neutron log to any degree of accuracy, but core data may well be satisfactory. However, we lack core data at high density anywhere on the Test Site, and we lack core data at all densities for northern Yucca Flat. The best solution to the problem is the completion of the Hydrogen Content Test Facility¹ and the comparison of its results with those in Fig. 2.

* Holes in northern Yucca Flat are normally drilled with water. A "natural-state" sample is one taken after sufficient time has supposedly elapsed for the effect of this drilling water to disappear.

Fig. 5. Epithermal neutron count rate vs volume percent water from tuff in northern Yucca Flat. The fit is compared to that developed in this report for all southern data (Fig. 2).

Fig. 6. Epithermal neutron count rate vs volume percent water for standard and "natural state" sidewall samples from northern hole Ue2ax #2. The line is the fit developed in this report for all southern data (Fig. 2).

Fig. 7. Epithermal neutron count rate vs volume percent water for sidewall samples and core data in northern hole Ue2aw. The line is the fit developed in this report for all southern data (Fig. 2).

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