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DEPARTMENT OF THE INTERIOR
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Mail Stop 964, Federal Center, Box 25046
Denver, Colorado 80225

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Prepared by the U.S. Geological Survey

for

Nevada Operations Office
U.S. Department of Energy
(Memorandum of Understanding EW-78-A-08-1543)

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# Borehole Geophysical Measurements for Hole UE25a-3, Nevada Test Site, Nuclear Waste Isolation Program,

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## Abstract

Borehole geophysical measurements made in drill hole UE25a-3 with a U.S. Geological Survey research well-logging truck are presented in this paper. The purpose of these logging measurements is to provide in-situ physical properties information that is not commercially available on drill hole UE25a-3. Well logs are presented in this paper for dual-detector density, normal resistivity, gamma-ray, neutron-neutron, induced polarization, and magnetic susceptibility measurements. These data are analyzed for correlations with the core lithology.

Hole-to-surface measurements made from drill hole UE25a-3 indicate the presence of two resistive bodies at depth. The deeper resistive anomaly may be related to a granitic intrusion.

## Introduction

Borehole geophysical measurements in drill hole UE25a-3 were made to assist in evaluating different geologic regimes at the Nevada Test Site for their potential as radioactive waste-repository sites. These measurements were made using a research well-logging truck that has been developed and maintained by the U.S. Geological Survey. The purpose of this logging was: (1) to provide in-situ physical properties information for use in interpreting surface geophysical data, and (2) to provide induced polarization, magnetic susceptibility, and compensated density data not commercially available.

This report presents the well logs obtained with dual-detector density, normal resistivity, gamma-ray, neutron-neutron, induced polarization, and magnetic susceptibility probes. The digital data, sampled at 0.3048 m depth intervals, are available from the authors upon request. An explanation of the equipment and data reduction procedures is given in the Appendix.

## Measurement Procedure

Well-log data were recorded simultaneously on an analog chart recorder and digital cassette. The digital data were sampled for each well-log response at depth intervals of 0.3048 m, recorded on magnetic tape, and transferred to the U.S. Geological Survey's Honeywell Multics computer,[1] where it was corrected for probe depth and scaled to the response on the analog records. The nuclear data (density, neutron-neutron, and gamma-ray) were corrected for probe dead-time. All of the figures presented in this report were plotted using the digital data.

Hole number UE25a-3 was logged on October 8, 1978. All well logs for hole UE25a-3 are referenced with zero depth 0.3048 m above ground level. Information concerning the probes is summarized in Table 1 and explained in more detail in the Appendix.

1 The use of brand names in this report does not necessarily imply endorsement by the U.S. Geological Survey.

Table 1--Measurement characteristics of the probes used to measure the well-log response values presented in report on borehole UE25a-3.

| Probe type | Source-detector positions | Measurement plot position | Probe-Module manufacturer |
|---|---|---|---|
| Normal resistivity | "N" potential electrode at the surface<br>"B" current electrode is cable armor 12.19 m above the "A" current electrode<br>"A" current electrode at the base of the probe<br>"M" potential electrode:<br>(a) 8"-Normal; 0.2 m above the "A" current electrode<br>(b) 16"-Normal; 0.4 m above the "A" current electrode<br>(c) 32"-Normal; 0.81 m above the "A" current electrode<br>(d) 64"-Normal; 1.62 m above the "A" current electrode | between the A and M electrodes | Westinghouse, Boulder, Colorado |
| Induced Polarization | "N" potential electrode at the surface<br>"B" current electrode on cable armor 12.19 m above "A" current electrode consisting of 2 electrodes split on the probe body<br>"M" potential electrode between "A" split current electrode on the probe body | between the A and M electrodes | Mount Sopris Instruments, Delta, Colorado |
| Magnetic susceptibility | 0.3048 m high-mu coil (single coil) | center of coil | Simplec Mfg., Dallas, Texas |
| Gamma-ray | Gamma-ray detector is a photomultiplier tube on the probe body | center of detector | Comprobe, Inc., Dallas, Texas |
| Neutron-neutron | Ameresium-beryllium source is located 38 cm below the detector | between source and detector | Comprobe, Inc., Dallas, Texas |
| Density | Near detector is located 16.5 cm above the source (Geiger-Mueller tube). Far detector is located 43.2 cm above the source (photomultiplier tube) | between source and detector | Comprobe, Inc., Dallas, Texas |

## Geology Related to the Well Logs

A generalized lithologic log (Maldonado and others, 1979) for UE25a-3 is shown in figure 1. The hole was drilled in units I and J (Mississippian) of the Eleana Formation. Maldonado and others define the following three major lithologic types penetrated by the drill hole: (1) an upper unaltered argillite (30.5-416 m), (2) an altered argillite section (416-676.9 m), and (3) a marbleized, calcareous, altered argillite (676.9-720.6 m). The upper altered and unaltered argillite zones are in unit J, while the lower marbleized zone is in unit I of the Eleana Formation. Other major lithologies that have been interpreted by Maldonado and others include quartzite, metamorphosed sandstone, limestone, and conglomerate.

The upper argillite is intensely fractured. These fractures are filled with the following minerals: kaolinite, dickite, nacrite, pyrite, calcite, chlorite, quartz, montmorillonite, illite, and hematite. A quantitative analysis has not been made on the individual minerals contained within the fractures. The minerals in the altered argillite fractures, from 416.1 m to 452.6 m, include calcite, chlorite, red clay, and iron oxide. The minerals in the altered argillite fractures from 452.6 m to 676.9 m include quartz, hematite, chlorite, calcite, magnetite, and garnet. Fracture-filling minerals in the marbleized zone (676.9-681.2 m) have not been analyzed. Below the marbleized region, the fracture-filling minerals include calcite, chlorite, and quartz from 681.2 to 720.6 m. Fracture-filling minerals from 720.6 m to 771.2 m include ferruginous clay and magnetite.

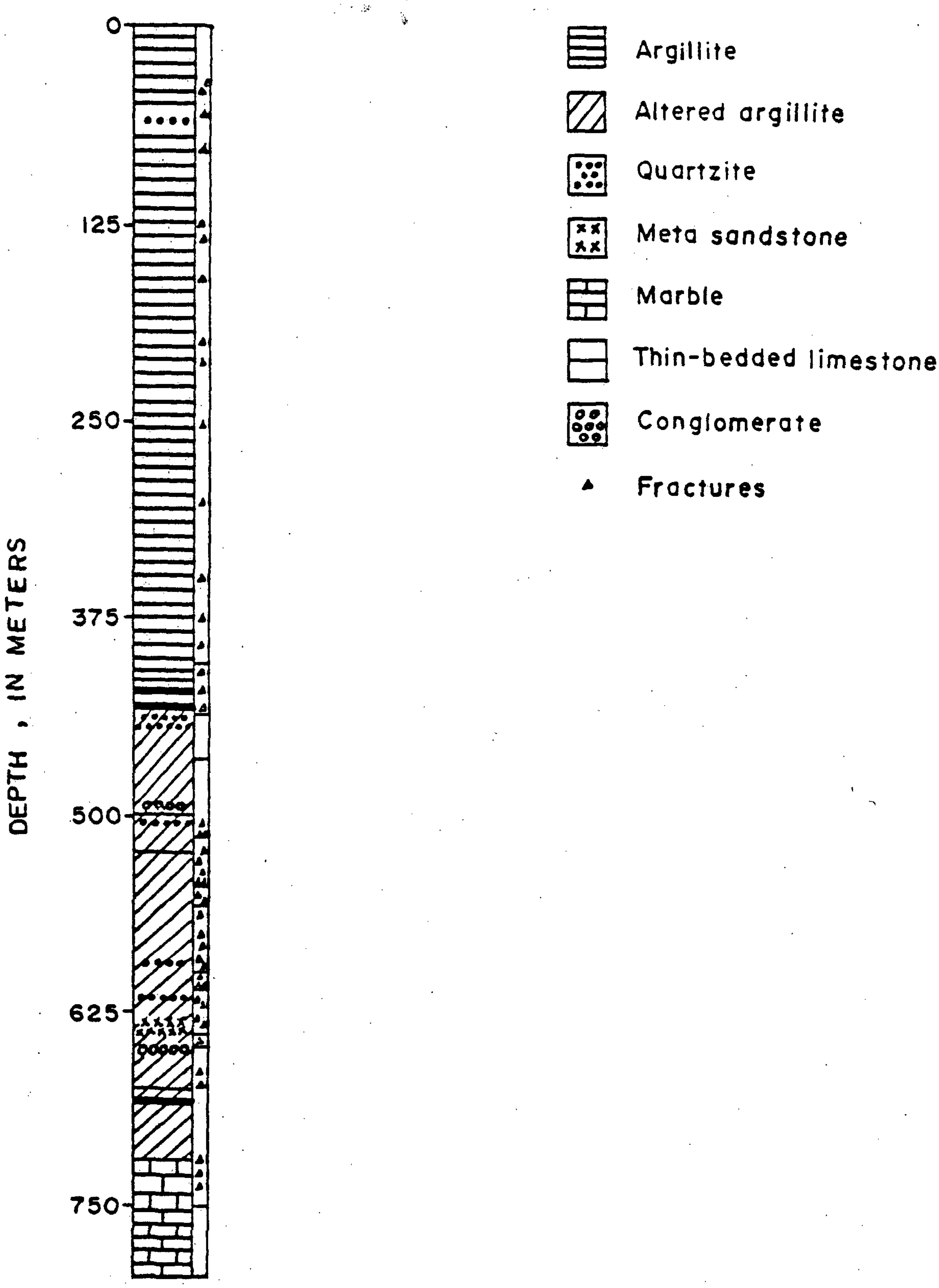


Figure 1.--Generalized lithologic core analysis for drill hole UE25a-3 (after Maldanado and others, 1979).

## Interpretation of Well-Log Response Values

Table 2 is a summary of the relative well-log response values for the lithologies that have been interpreted from the core (Maldonado and others, 1979). The depth locations of these lithologic zones are indicated by the numbers "1" through "14" on the individual well logs shown in figures 2 through 6.

A measurement response on the gamma-ray well log is caused by rocks that contain natural gamma-ray-emitting minerals such as uranium, thorium, or potassium-40. In the argillite sequence in drill hole UE25a-3, the principle gamma-ray-emitting rocks are carbonaceous material containing uranium, and shales and clay rich in potassium-40. Pure calcareous rocks do not contain gamma-ray-emitting minerals (Table 2; intervals 2, 3, 4, 7, 10, 11, 13, and 14). The noncalcareous quartzite (interval 5) and the altered argillite at the bottom of the hole (interval 12) have the highest gamma-ray response values. The high response values in the altered argillite are probably caused by radioactive minerals contained in clay in fractures.

The neutron log response is inversely proportional to the amount of moisture in the rocks. The water level in the neutron-neutron log shown in figure 3 is indicated as "WL", and corresponds to a shift in the well-log response that is unrelated to rock type. The lowest neutron count rate (taking into consideration the WL shift) occurs in intervals 3, 4, 7, and 13. Intervals 3 and 4 are calcareous quartzite, interval 7

Table 2--Relative response values for well logs (gamma-ray, neutron-neutron, density, resistivity, magnetic susceptibility, and induced polarization) for lithologic zones 1 through 14, as indicated on the well logs for borehole UE25a-3

| Rock type interval | Gamma-ray | Neutron-neutron | Density | Resistivity | Magnetic susceptibility | Induced polarization |
|---|---|---|---|---|---|---|
| (1) Fine-grained, calcareous quartzite | inter-mediate | inter-mediate | no data | no data | very low | no data |
| (2) Fine-grained, calcareous quartzite | low | inter-mediate | very low | no data | very low | no data |
| (3) Fine-grained, calcareous quartzite | very low | very low | high | no data | low | no data |
| (4) Fine-grained, calcareous quartzite | very low | very low | high | no data | low | no data |
| (5) Non-calcareous quartzite | high | inter-mediate | inter-mediate | no data | high | no data |
| (6) Conglomerate | very low | inter-mediate | low | no data | very low | no data |
| (7) Altered, carbonaceous shale | very low | very low | inter-mediate to high | no data | very low | no data |
| (8) Altered, carbonaceous shale | high | very low | inter-mediate | no data | very high | no data |
| (9) Meta-sandstone | inter-mediate | low to inter-mediate | no data | low to inter-mediate | low to inter-mediate | no data |
| (10) Marbleized, calcareous argillite | very low | low to | no data | high | | inter-mediate |
| (11) Calcareous, altered argillite | low | high | no data | very low | very low | low |
| (12) Altered argillite | inter-mediate to very high | high to very high | no data | inter-mediate | very low | high |
| (13) Silicified marble | low | low to inter-mediate | no data | low | very low | inter-mediate |
| (14) Marble | very low | inter-mediate to high | no data | very high | very low | low |

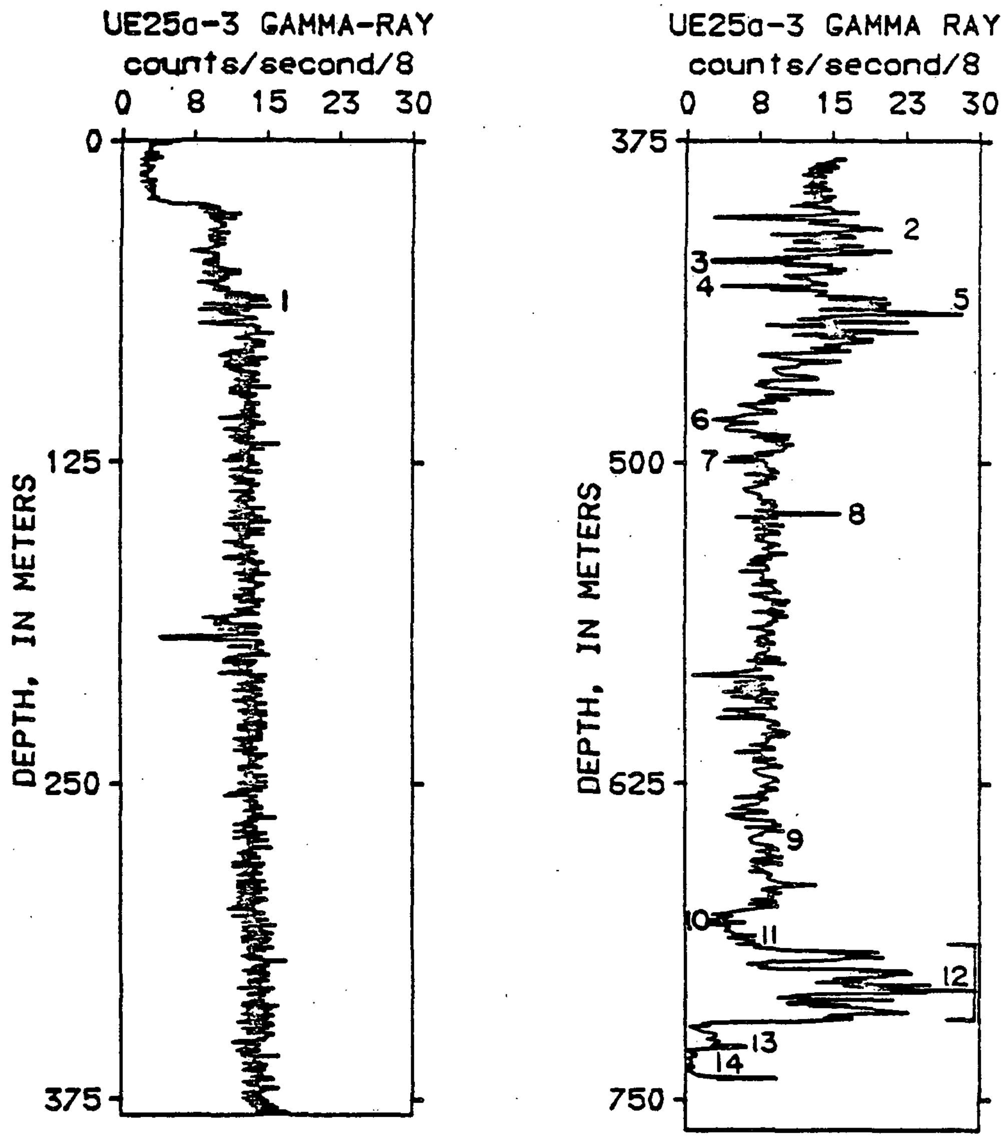


Figure 2.--Gamma-ray well log (after application of a five-point running average filter) for drill hole UE25a-3. Numbers 1 through 14 show the locations keyed to lithologic intervals in Table 2.

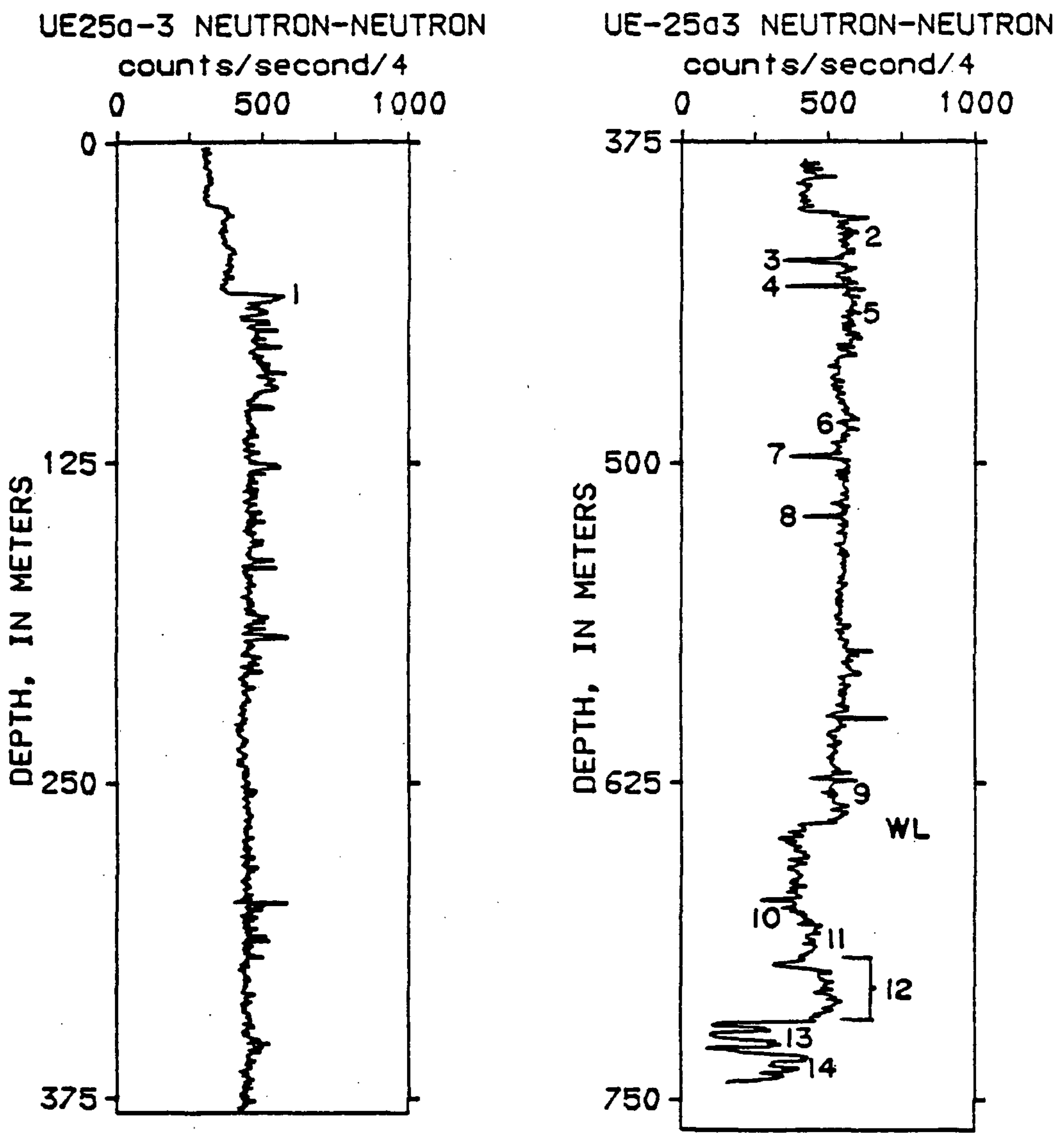


Figure 3.--Neutron-neutron well log for drill hole UE25a-3. Numbers 1 through 14 show the locations of lithologic intervals in Table 2.

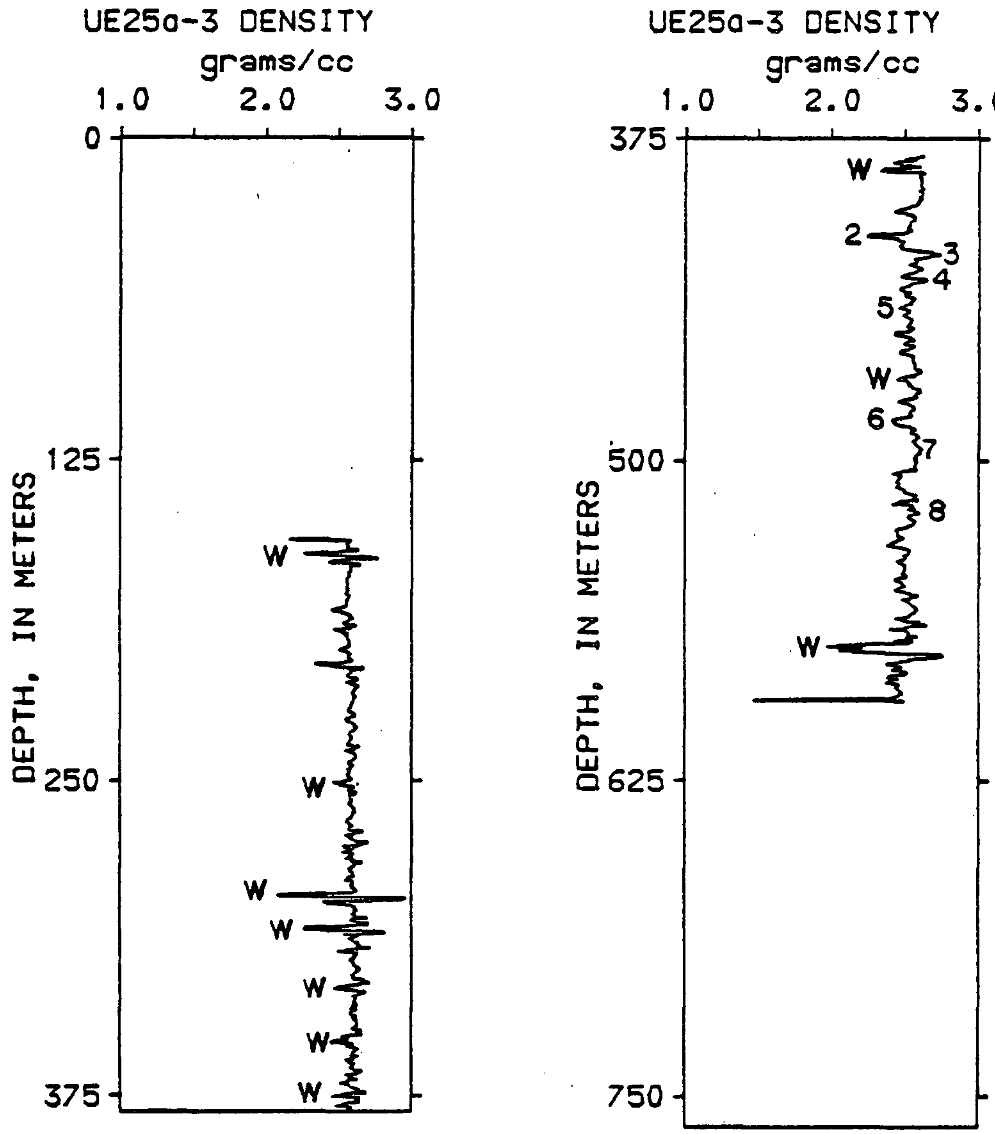


Figure 4.--Compensated density well log for drill hole UE25a-3. Numbers 1 through 14 show the locations of lithologic intervals in Table 2. Drill hole washouts are indicated by the letter "W". Density values are in grams/cubic centimeter. The original data have been smoothed by a five-point running average filter.

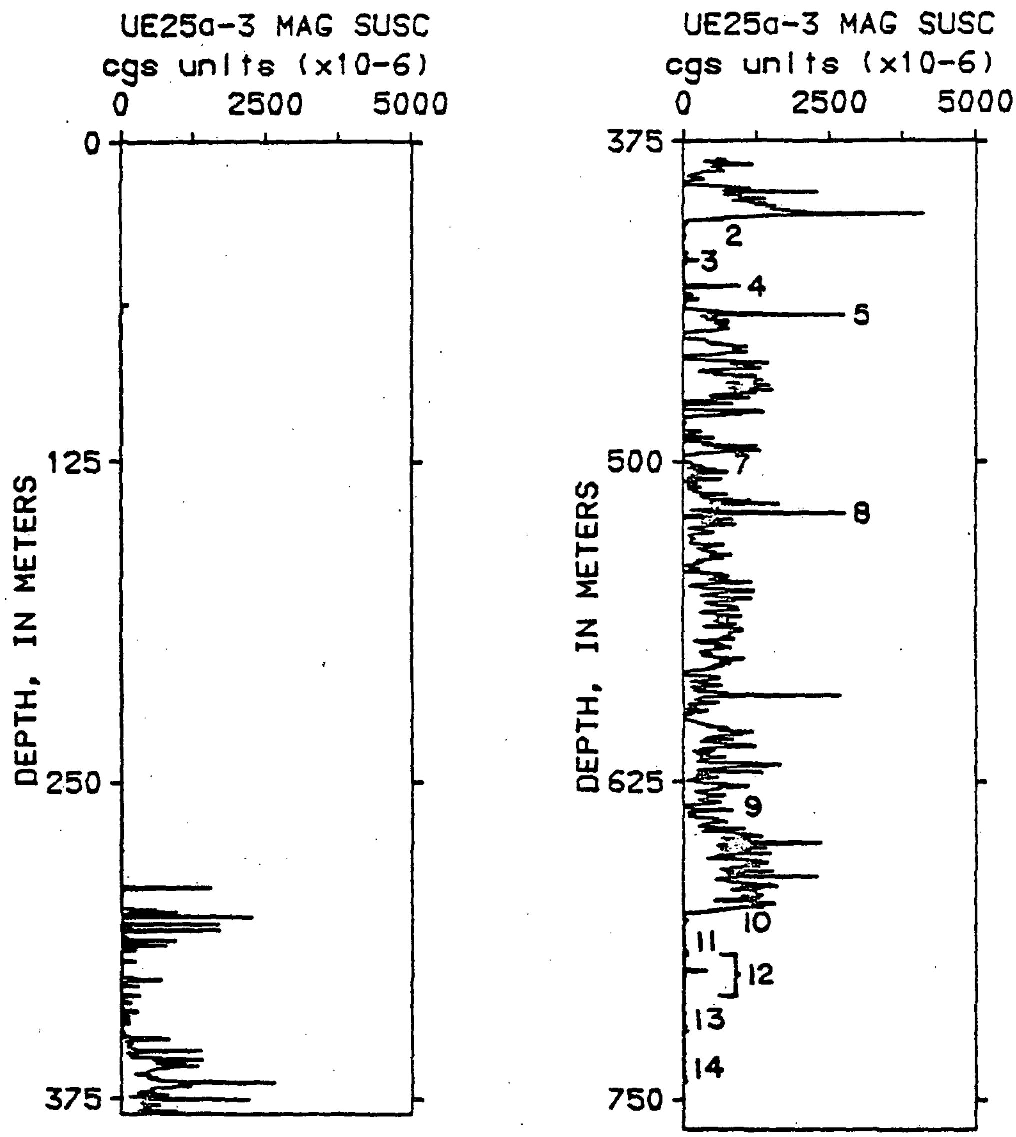


Figure 5.--Magnetic suscetibility well log for drill hole UE25a-3. Numbers 1 through 14 show the locations of lithologic intervals in Table 2.

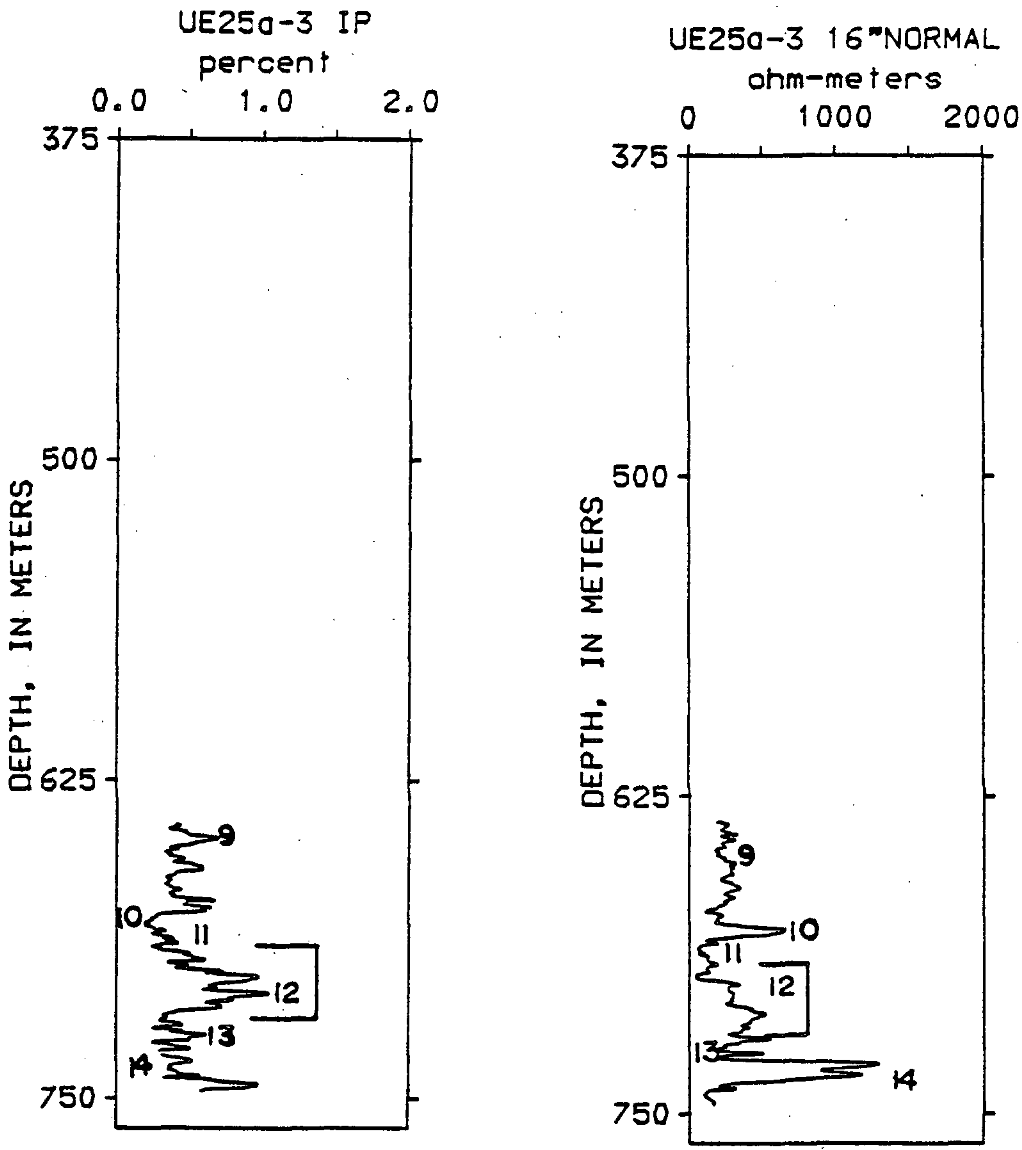


Figure 6.--Induced polarization (IP) and 16-in. normal resistivity well logs below the water level for drill hole UE25a-3. Numbers 10 through 14 on the IP well log, and numbers 9 through 14 on the 16-in. normal well log are keyed to locations of lithologic intervals in Table 2.

is an altered carbonate, and interval 13 is a silicified marble. The increase in moisture in these intervals is probably related to an increase in fracture porosity. The lowest moisture content is in the altered argillite in interval 12. Although the gamma-ray log indicates the possibility of fractures in interval 12, the neutron log shows that these fractures are probably sealed by post-fracture mineralization.

The density-log response (fig. 4) was measured in the intermediate section of the hole. The density-log response shows a fairly uniform density throughout the logged interval. However, the fine-grained, calcareous quartzites in intervals 3 and 4 have densities that are higher than the background values. This high density is consistent with the low neutron response seen in figure 3 for intervals 3 and 4.

The magnetic susceptibility response (fig. 5) shows high values in the "altered" argillite and low values in the "unaltered" argillite. The high magnetic susceptibility values are caused by an increase in the amount of fine-grained magnetite that is possibly formed by hydrothermal alteration (D. Watson, April, 1979, oral commun.). Most of the magnetite occurs in fracture fills. Magnetite is virtually absent from the lower marbleized interval (intervals 10 through 14).

The induced polarization and 16-inch (0.0406 m) normal resistivity logs for hole UE25a-3 are shown in figure 6. The induced polarization log response shows the highest values for the altered argillite in interval 12. Variations in induced polarization response may be caused by differing amounts of montmorillonite or pyrite which are good polarizers. The highest resistivity is seen in the marble in interval 14.

The high resistivity, low induced polarization, and high neutron responses indicate that the marble zone is relatively homogenous compared to the lithologic intervals above interval 14.

## Hole-to-Surface DC-Resistivity Measurements from UE25a-3

Hole-to-surface dc-resistivity measurements were made from drill hole UE25a-3 by placing one current source electrode (A-electrode) at the surface (next to the drill hole) and the other current source electrode (B-electrode) in the drill hole at a depth of 610 m. The distribution of dc-electrical potentials-differences on the surface resulting from the current generated between the A and B was measured around the drill hole. Figure 7 shows the electrode configuration used in this study. By using the hole-to-surface method, the depth of investigation is enhanced.

The potential difference measurements were corrected to apparent resistivity (Daniels, 1977) and the resulting contoured data are shown in figure 8. The contours indicate that two high resistivity zones northeast of the drill occur at different depths. Anomaly $\alpha$ is possibly caused by a shallow resistive body, while anomaly $\beta$ is possibly caused by a deeper resistive body. It is possible that anomaly $\beta$ is caused by the intrusive body that is responsible for the alteration of the argillite.

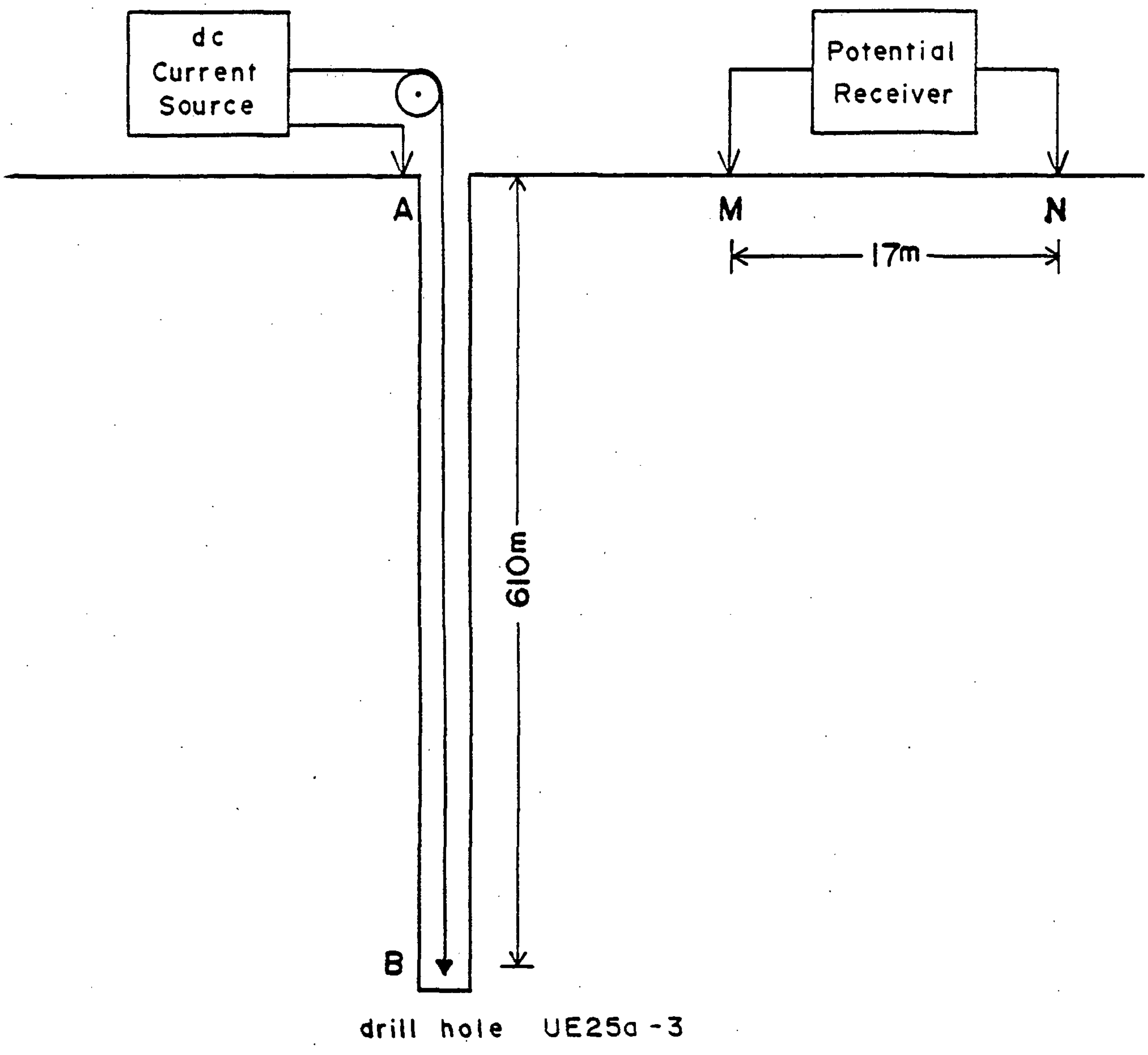


Figure 7.--Electrode configuration.

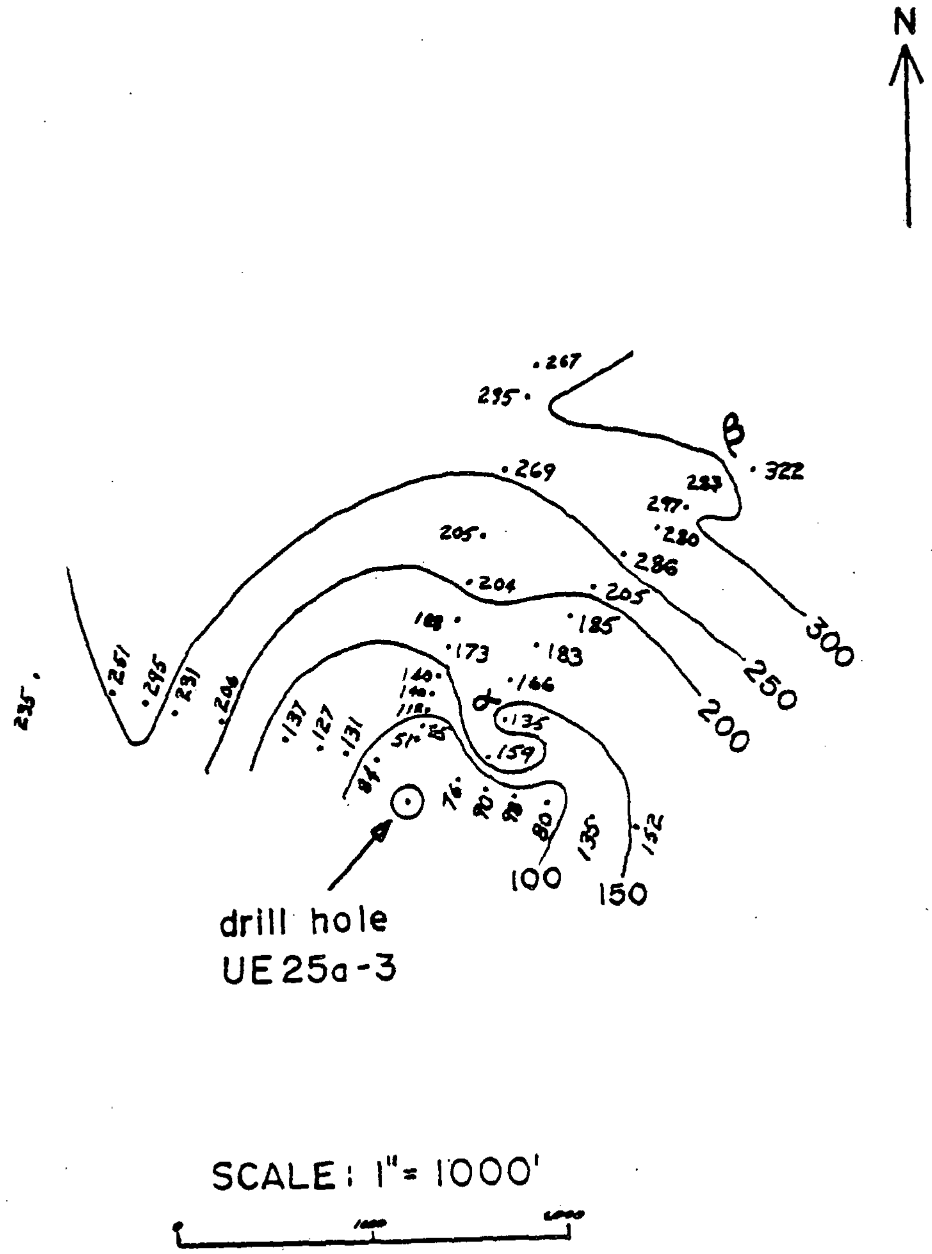


Figure 8.--Hole-to-surface dc-resistivity measurements for hole UE25a-3. The values are plotted at the center of the M and N potential receiver electrodes.

# APPENDIX

## WELL-LOG PROBE CHARACTERISTICS

## AND WELL-LOG MEASUREMENTS FOR HOLE UE25a-3

## Density

Density measurements were made with a dual-detector gamma-gamma density probe. The density was calculated using the compensation algorithm developed by Scott (1978). This algorithm uses the water level, hole diameter, and the two gamma-ray count rate logs to calculate an apparent density that is compensated for borehole rugosity. The caliper and computer density logs are shown in figures A1 and A2, respectively.

## Normal Resistivity

The normal resistivity probe uses a potential electrode on the surface ("N" electrode) and a potential electrode on the probe ("M" electrode). The "A" current electrode is on the probe and the "B" current electrode is on the steel armor (13 m above the "A" electrode). The "B" current electrode and the "N" potential are assumed to be theoretically at an infinite distance from the "A" current and "B" potential electrodes, and the four-terminal formula for calculating apparent resistivity is:

$$\rho_a = \frac{4\pi}{\frac{1}{AM} - \frac{1}{AN} - \frac{1}{BM} + \frac{1}{BN}} \frac{V}{I} \qquad (1)$$

Equation (1) reduces to the form $\rho_a = 4\pi \cdot AM(V/I)$ when AN, BM, and BN are very large where

a is the apparent resistivity in ohm-meters,

AM is the distance between the A and M electrodes,

AN is the distance between the A and N electrodes,

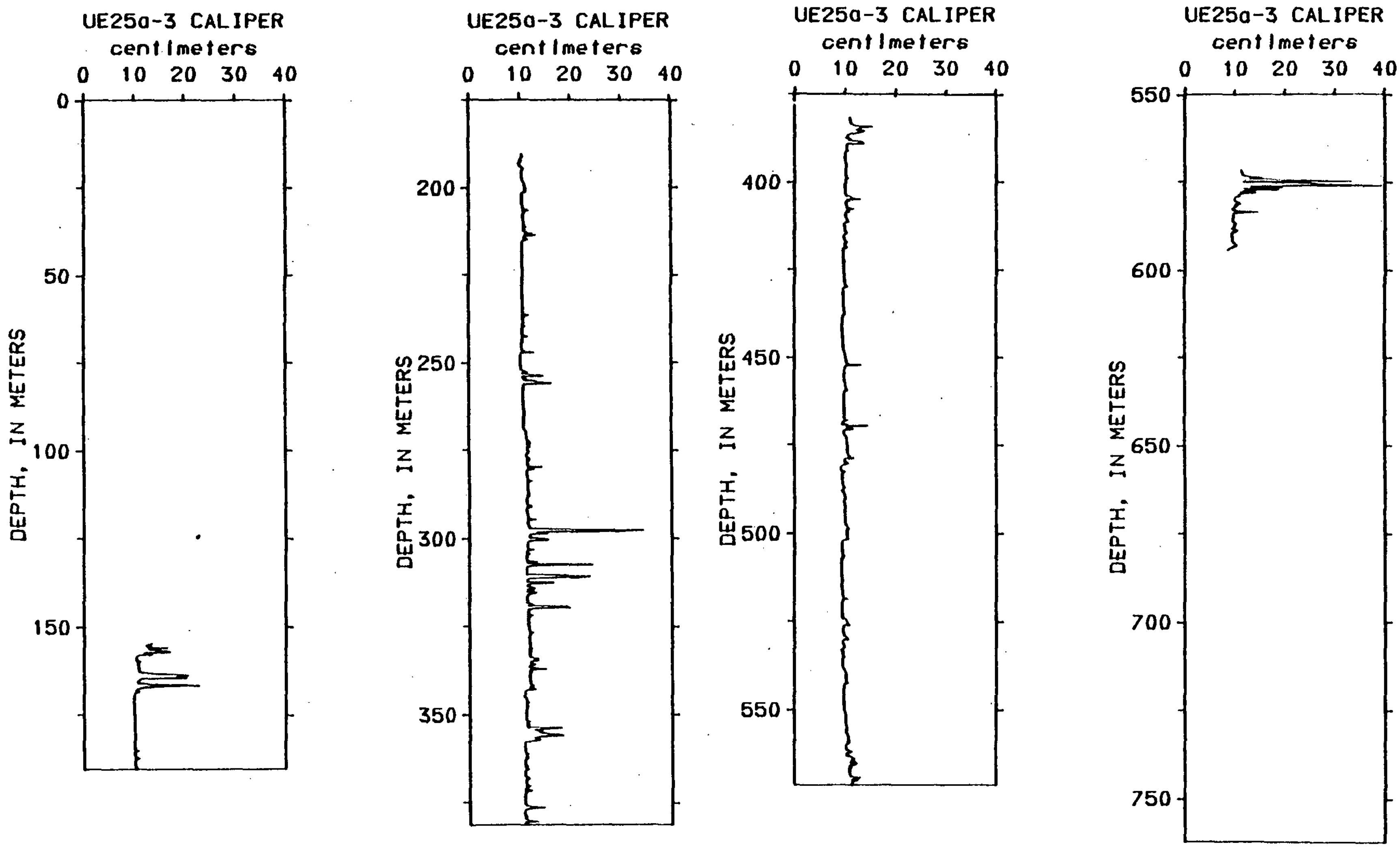


Figure A1.--Caliper well log for hole UE25a-3.

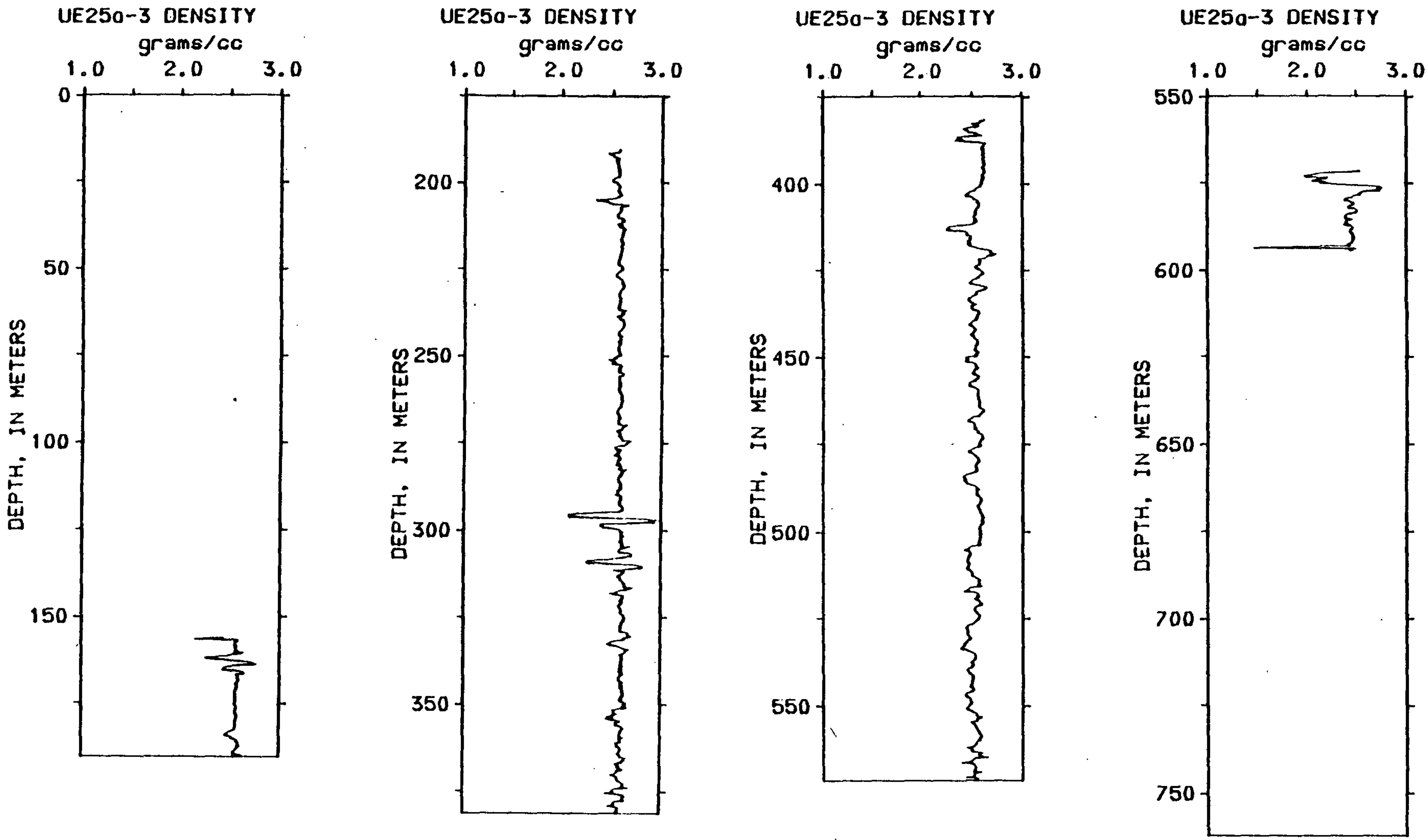


Figure A2.--Compensated density well log for hole UE25a-3. The data have been smoothed by using a five-point running average filter.

BM is the distance between the B and M electrodes,

BN is the distance between the B and N electrodes,

V is the potential difference between the M and N electrodes,

and I is the input current between the A and B electrodes.

All of the source-current and receiver-potential controls are electronic (rather than mechanical commutators) and contained in a surface module. The surface control module is described in detail by Scott and others (1977). The composite normal resistivity well logs are shown in figures A3 through A6.

Induced Polarization

The induced polarization system uses a time-domain input signal in which the current wave form has a 0.2 second positive constant current, 0.2 second zero input, 0.2 second negative constant current, and 0.2 second zero current. The decay voltage is integrated during the off-time over a second window. The integrated decay voltage is divided by the voltage over a window of equal length during the on-time. The resulting value is multiplied by 100 and the average of 8 consecutive ON-OFF values is recorded digitally as the percent IP response. The resulting well log is shown in figure A6.

Neutron-neutron, Gamma-ray

The neutron-neutron, gamma-ray probe is free-hanging in the bore-hole. The neutron-neutron measurement consists of measuring the neutron count rate emitted from an ameresium-berylium neutron source. The single detector is not compensated for borehole rugosity, therefore, the neutron-neutron well log can only be used to give a relative measurement

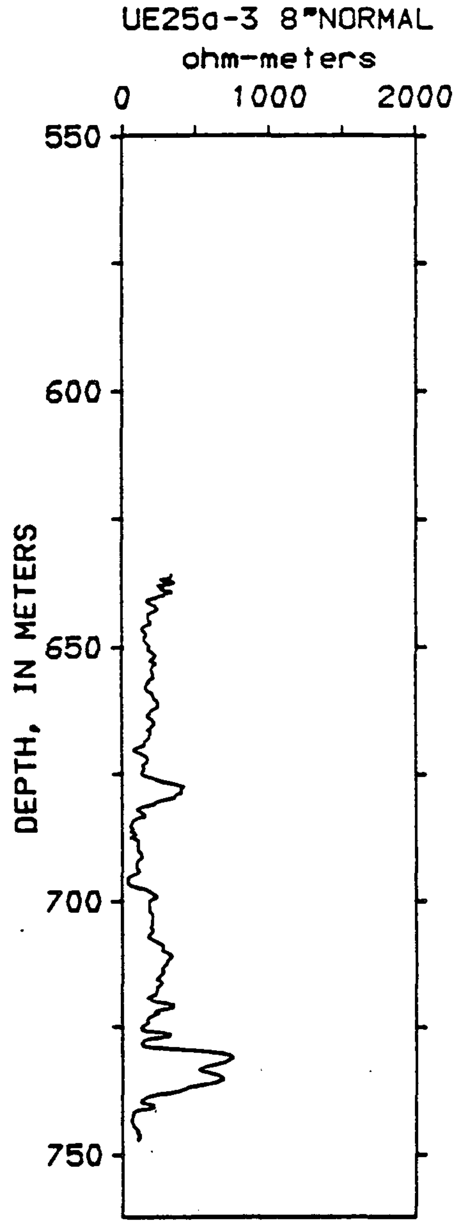


Figure A3.--8-inch (0.203 m) normal resistivity well log for drill hole UE25a-3.

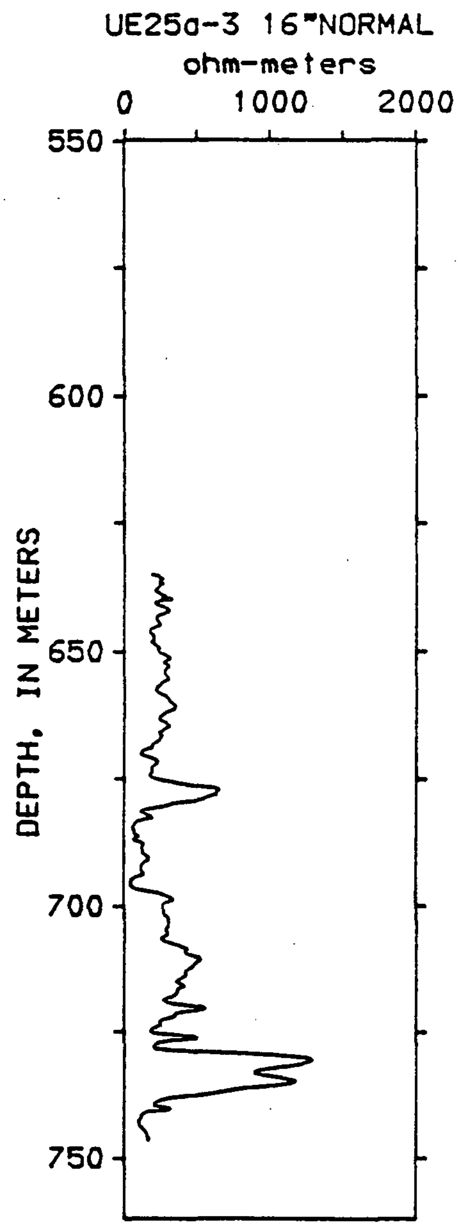


Figure A4.--16-inch (0.406 m) normal resistivity well log for drill hole UE25a-3.

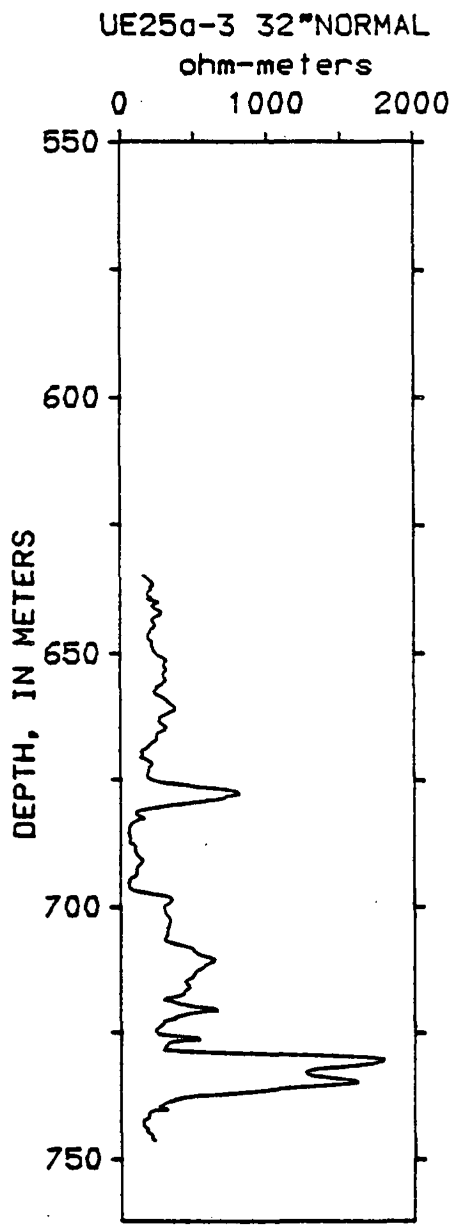


Figure A5.--32-inch (0.812 m) normal resistivity well log for drill hole UE25a-3.

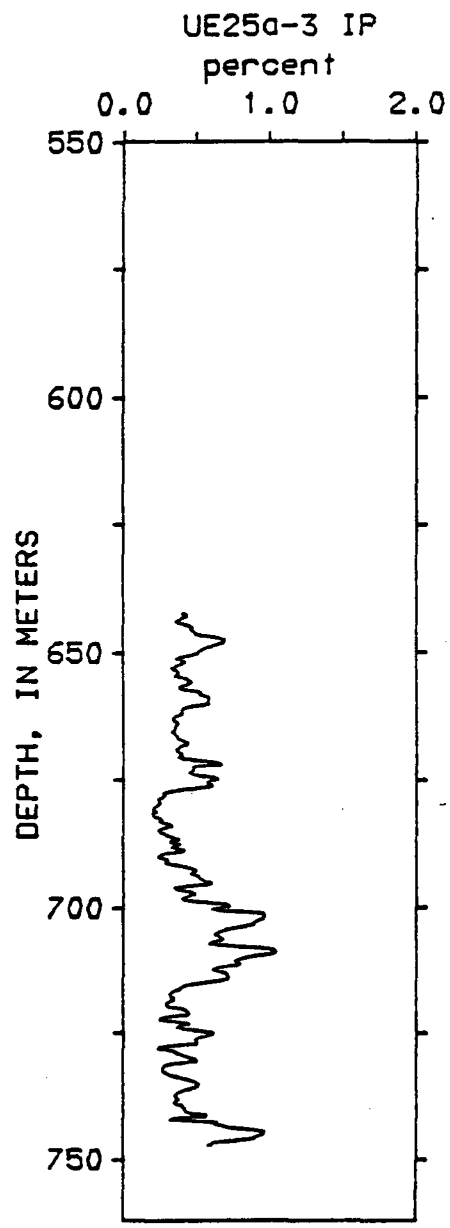


Figure A6.--Induced polarization (IP) well log for drill hole UE25a-3.

of rock moisture and porosity. The natural gamma-ray detector is a low-sensitivity scintillometer designed for use in high gamma-ray-emitting rocks, such as uranium-bearing sandstone. The low sensitivity results in a low count rate and statistically noisy data. The neutron-neutron and gamma-ray well log are shown in figures A7 and A8, respectively.

Magnetic Susceptibility

The magnetic susceptibility probe consists of a high permeability solonoid that is connected as one arm of a Maxwell inductance bridge. The quadrature component of the bridge output signal is approximately proportional to the magnetic susceptibility of the rock adjacent to the probe. This probe is explained in detail by Scott and others (1977). The logs in this report have been corrected for temperature drift and were calibrated using magnetic susceptibility values measured on drill core. These core measurements were made by Gordon Bath (written communication, 1978). The composite magnetic susceptibility log is shown in figure A9.

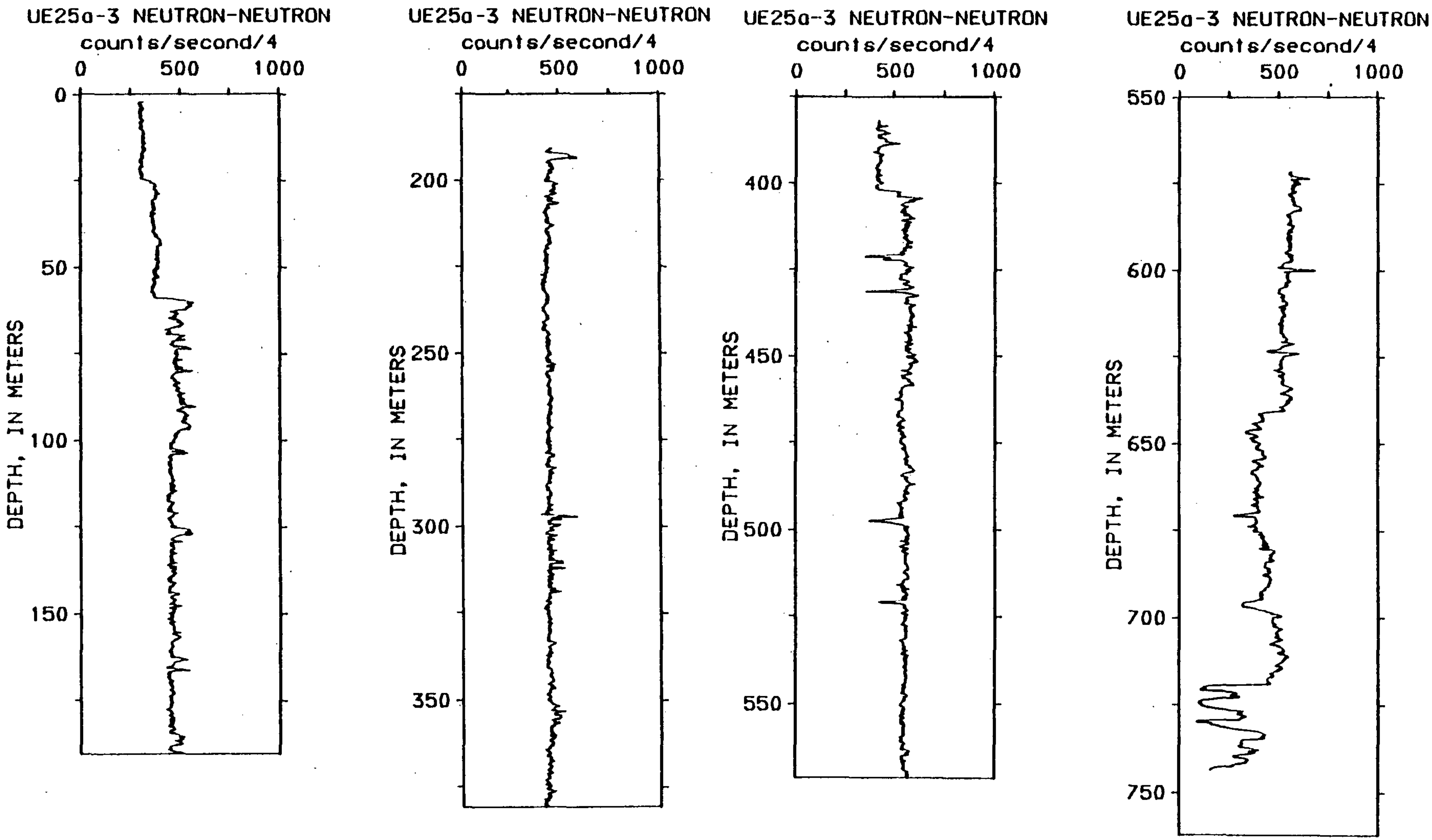


Figure A7.--Neutron-neutron well log for drill hole UE25a-3.

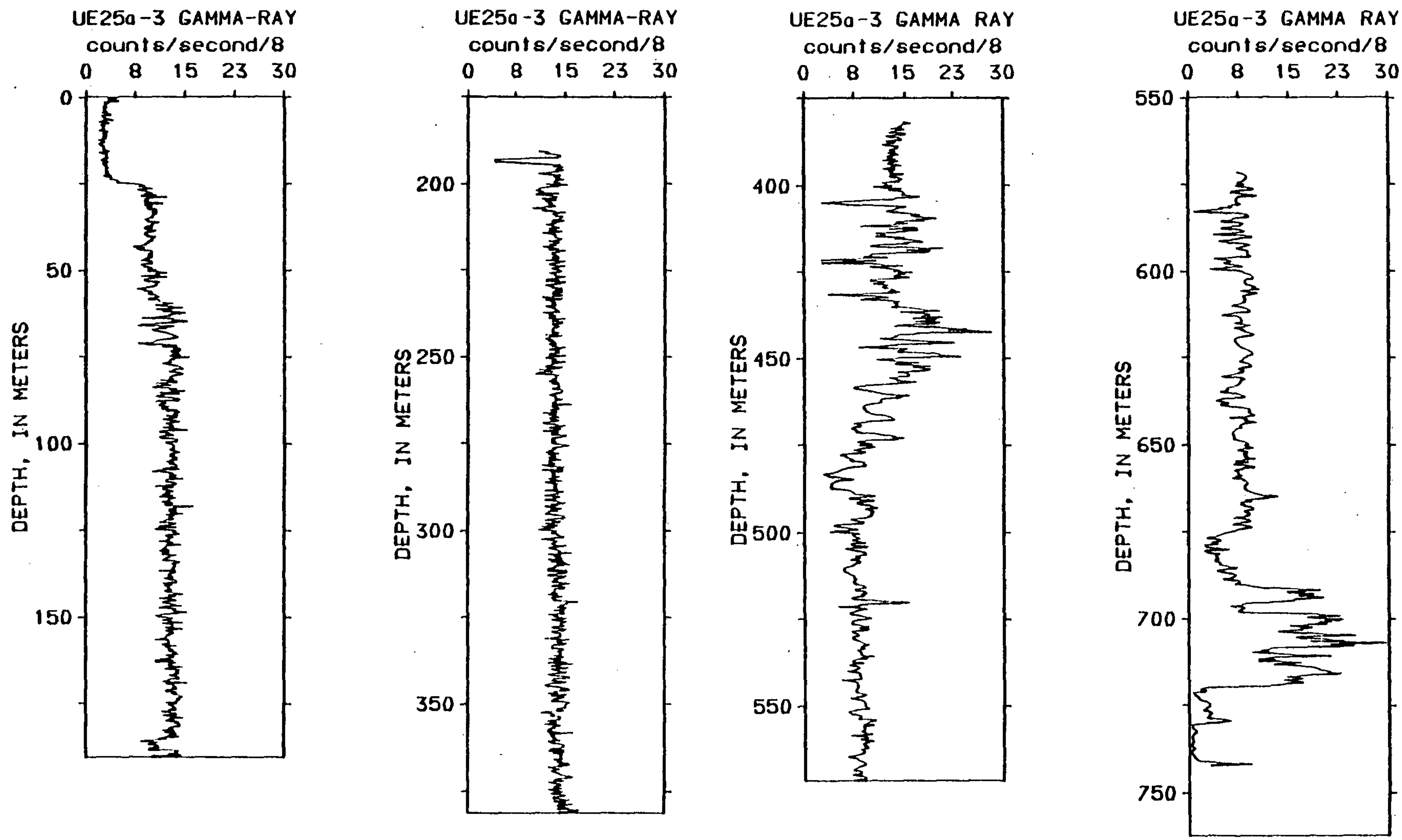


Figure A8.--Gamma-ray well log for drill hole UE25a-3. The data have been smoothed by using a five-point running average filter.

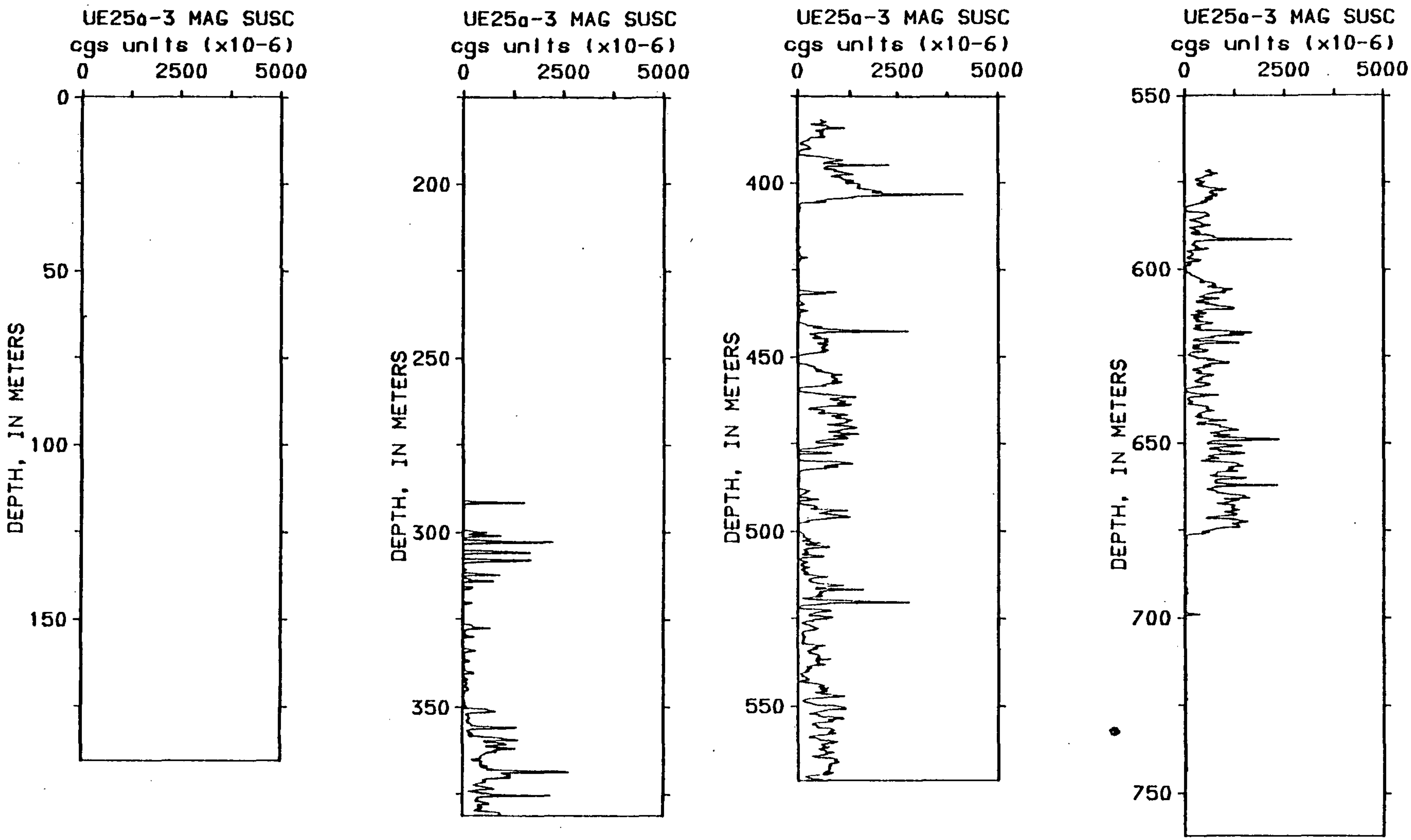


Figure A9.--Magnetic susceptibility well log for drill hole UE25a-3.

## References

Daniels, J. J., 1977, Three-dimensional resistivity and induced polarization modeling using buried electrodes: Geophysics, v. 42, no. 5, p. 1006-1019.

Maldonado, Florian, Muller, D. C., and Dodson, J. N., 1979, Preliminary geologic and geophysical data of the UE25a-3 exploratory drill hole, Nevada Test Site, Nevada: U.S. Geological Survey Report USGS-1543-6, 47 p.; available only from U.S. Dept. of Commerce National Technical Information Service, Springfield, VA 22161.

Scott, J. H., Barth, J. J., and Summers, G. C., 1977, A magnetic-susceptibility well-logging system for mineral exploration: U.S. Geological Survey Open-File Report 77- ,

Scott, J. H., 1978, A computer program for borehole compensation of dual-detector density well logs: U.S. Geological Survey Open-File Report 78-515,



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