GL00148

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

The role of borehole electrical measurements in uranium exploration: transcript of talk presented at the Uranium-Thorium Research and Resources Conference, April 27-29, 1977

by

Jeffrey J. Daniels and James H. Scott
U.S. Geological Survey, Denver, Colorado 80225

Open-File Report 78-326

1978

The role of borehole electrical measurements in uranium exploration:
transcript of talk presented at
the Uranium-Thorium Research and Resources Conference,
April 27-29, 1977

by

Jeffrey J. Daniels and James H. Scott
U.S. Geological Survey, Denver, Colorado 80225

Drilling costs have reached a point where the use of sophisticated borehole tools makes good economic sense. The average cost of drilling a deep hole on the Colorado plateau is somewhere between $25,000 and $50,000. Coring is prohibitively expensive. Even in shallow sedimentary environments the cost of drilling a well is over 1 dollar per foot.

The days of successful random drilling are numbered. The successful explorationist of today must use every available piece of geological, geochemical, and geophysical information at his disposal. Semi-random placement of drill holes (looking for peaks on the gamma-ray logs) is, in many cases, an extravagant way to find uranium. The per-foot costs may look small, but the final costs to locate an orebody can get extremely large.

Fortunately, we have a fairly good model for the depositional environment of sedimentary deposits. The precise model varies from area to area and from explorationist-to-explorationist. But nearly everywhere it shows some type of geochemical variation across the deposit; as figure 1, taken after Rubin's 1971 article, shows.

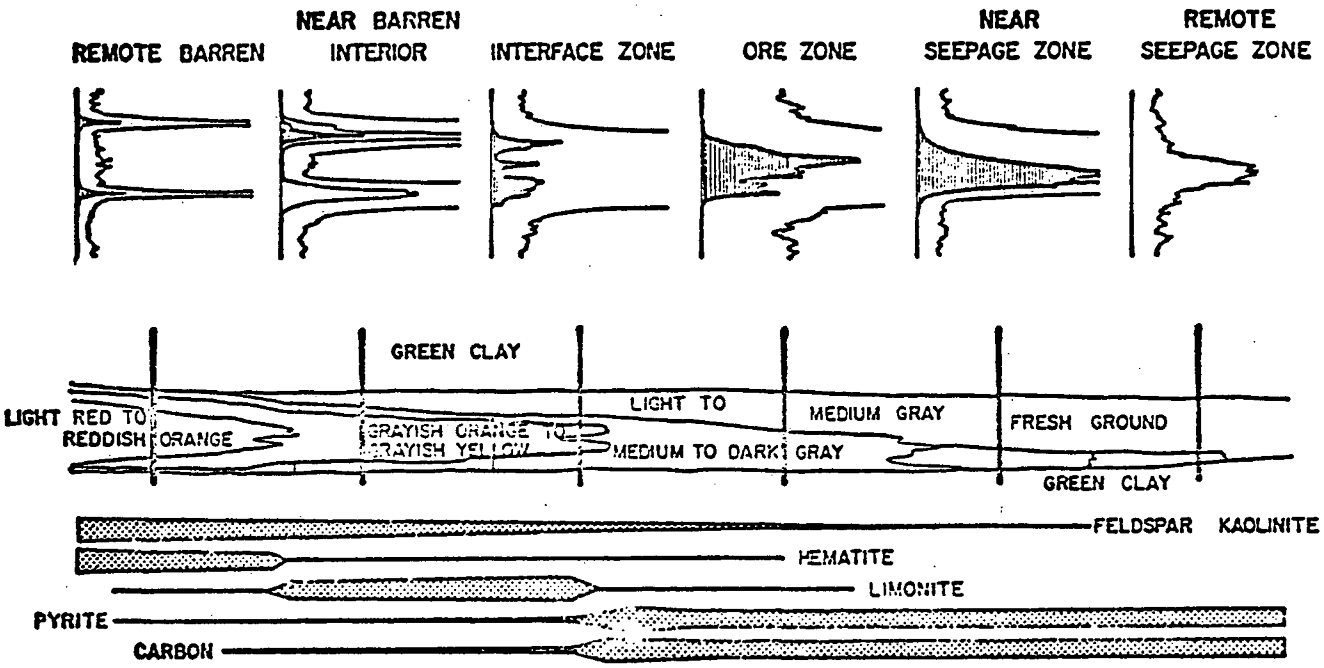


Figure 1. "Type" geochemical cell, after Rubin, 1971. Gamma-ray logs, at two different relative scales, are shown at the top of the figure.

The iron minerals vary from hematite on the oxidized side of the deposit to magnetite on the reduced side of the deposit (although there is not a universal range of mineral species between hematite and magnetite). Pyrite is present on the reduced side of the deposit and absent on the oxidized side (post ore-stage pyrite can occasionally occur on the oxidized side of the deposit). Clay minerals also change across the deposit; kaolinite is dominant on the oxidized side, while montmorillonite is present on the reduced side.

Changes in physical properties usually accompany these chemical variations. Knowledge of the areal distribution of these properties, can lead to a better pinpointing of drill hole sites. The truth of this statement is obvious to all explorationists. The best method of obtaining this information is not so obvious. Detailed core analysis gives the most complete information. Fortunately, borehole probes are available that can be used to measure rock properties without going to the expense of coring every hole.

The sand-to-clay ratio of sedimentary rocks is often directly proportional to the resistivity of the rock (in the absence of calcite cement). A rock's magnetic susceptibility is usually proportional to its magnetite content. Pyrite and certain clays, such as montmorillonite, yield an anomalous induced polarization response. Inexpensive borehole probes are available that can measure these parameters.

Most logging programs do not include probes that can quantatively measure responses representing physical properties changes. The most commonly used geophysical logging suite is the gross count gamma ray, SP, and single point resistance log. The gross count gamma ray log is an inexpensive indicator of possible U_3O_8 occurrences. The SP log is inexpensive, but rarely contains consistent quantitative information. The resistance log is inexpensive and can be used for gross stratigraphic correlation. However, as figure 2 shows, the resistance log gives no quantative information concerning lithologic variations. The ore zone of the deposit, from which the data shown in figure 2 was taken, is characterized by the absence of calcite cement near the top of the ore sand (35-47 meters) and the presence of calcite cement in the lower part of the ore zone (47-60 meters). Calcite cement increases the resistivity of the sand. However, the resistance log does not reflect the lack of calcite cement in the upper part of the ore zone as does the resistivity log. Many of the peaks seen on the resistance log are caused by variations in hole conditions rather than by resistivity changes in the rocks.

In some cases, logs can be used to estimate the amount of a particular mineral constituent, such as the clay content from resistivity logs as is shown by the plot in figure 3 of clay vs. resistivity. From this same set of drill holes, figure 4 shows a pronounced induced polarization anomaly that is correlated with the center of the ore deposit and a corresponding increase in the pyrite and montmorillonite content. Every ore deposit gives log responses that can be used to characterize the physical and chemical environment of the ore deposit. But each ore deposit has different depositional and chemical characteristics--therefore, a suite of logs that helps the geologist in one area will not necessarily be useful elsewhere.

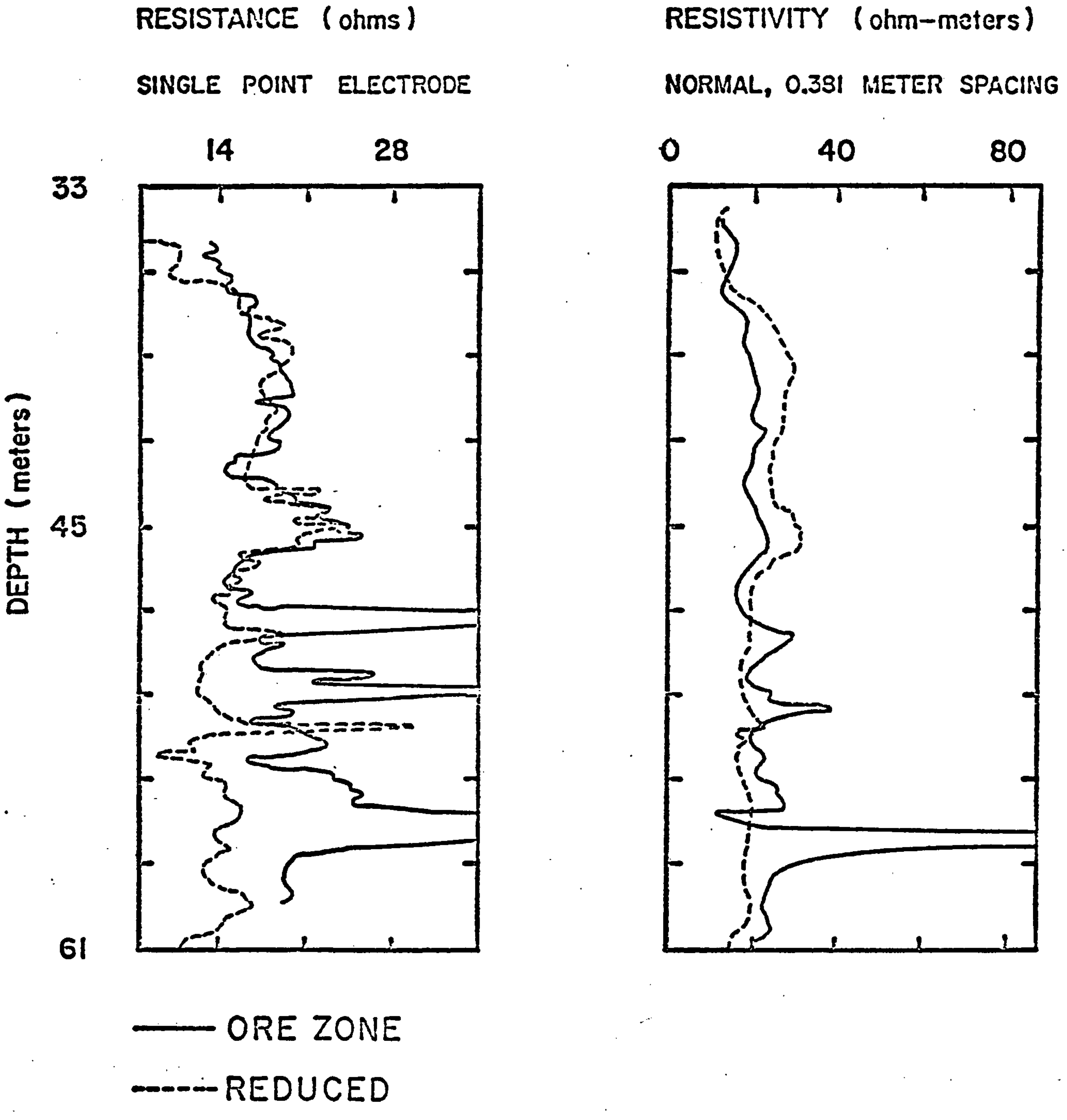


FIGURE 2: Comparison of resistance and resistivity log values off of the ore zone and on the ore zone for a Powder River Basin uranium deposit.

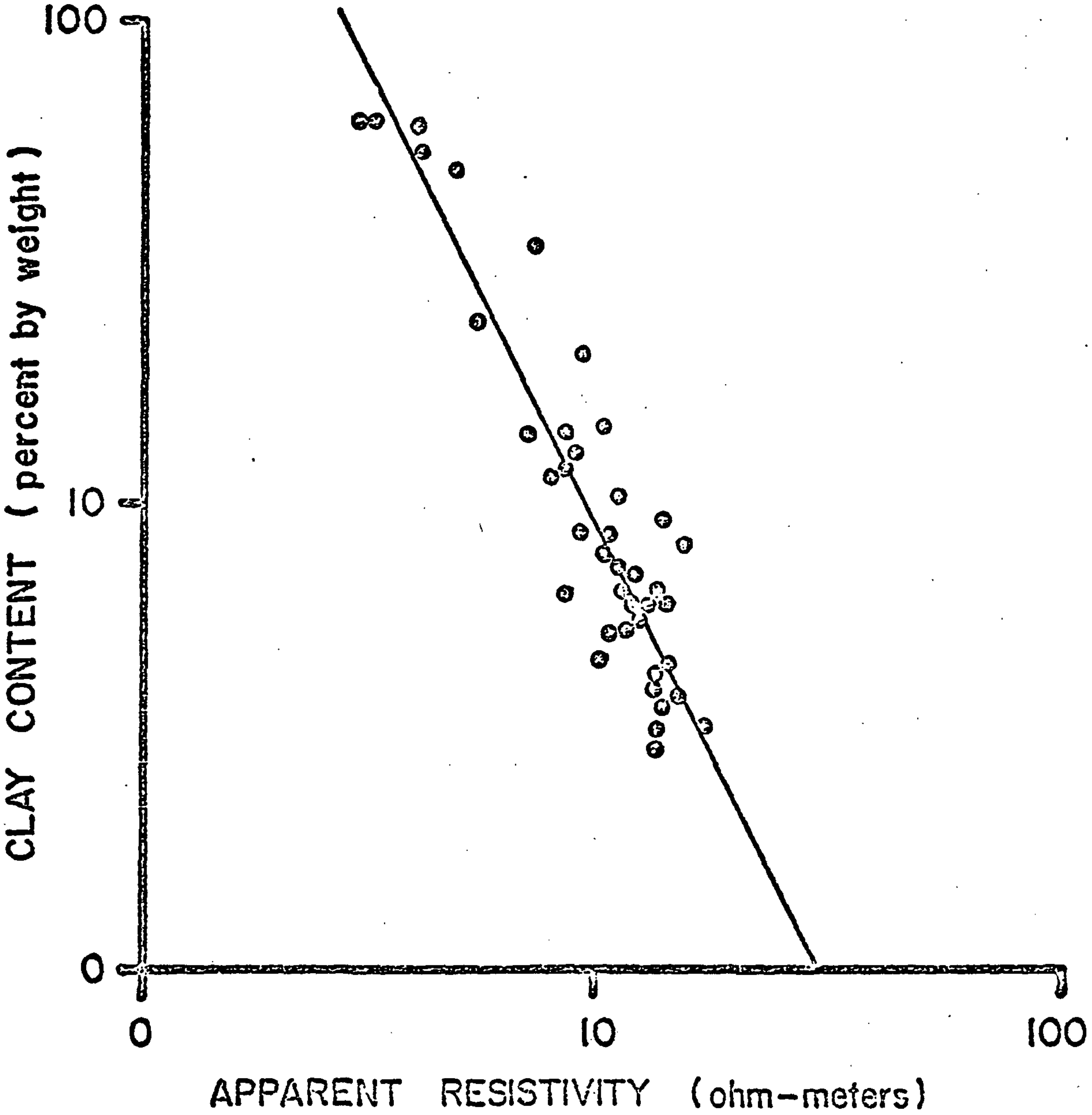


FIGURE 3: Clay content (from core analysis) versus apparent resistivity log values for a uranium deposit in South Texas.

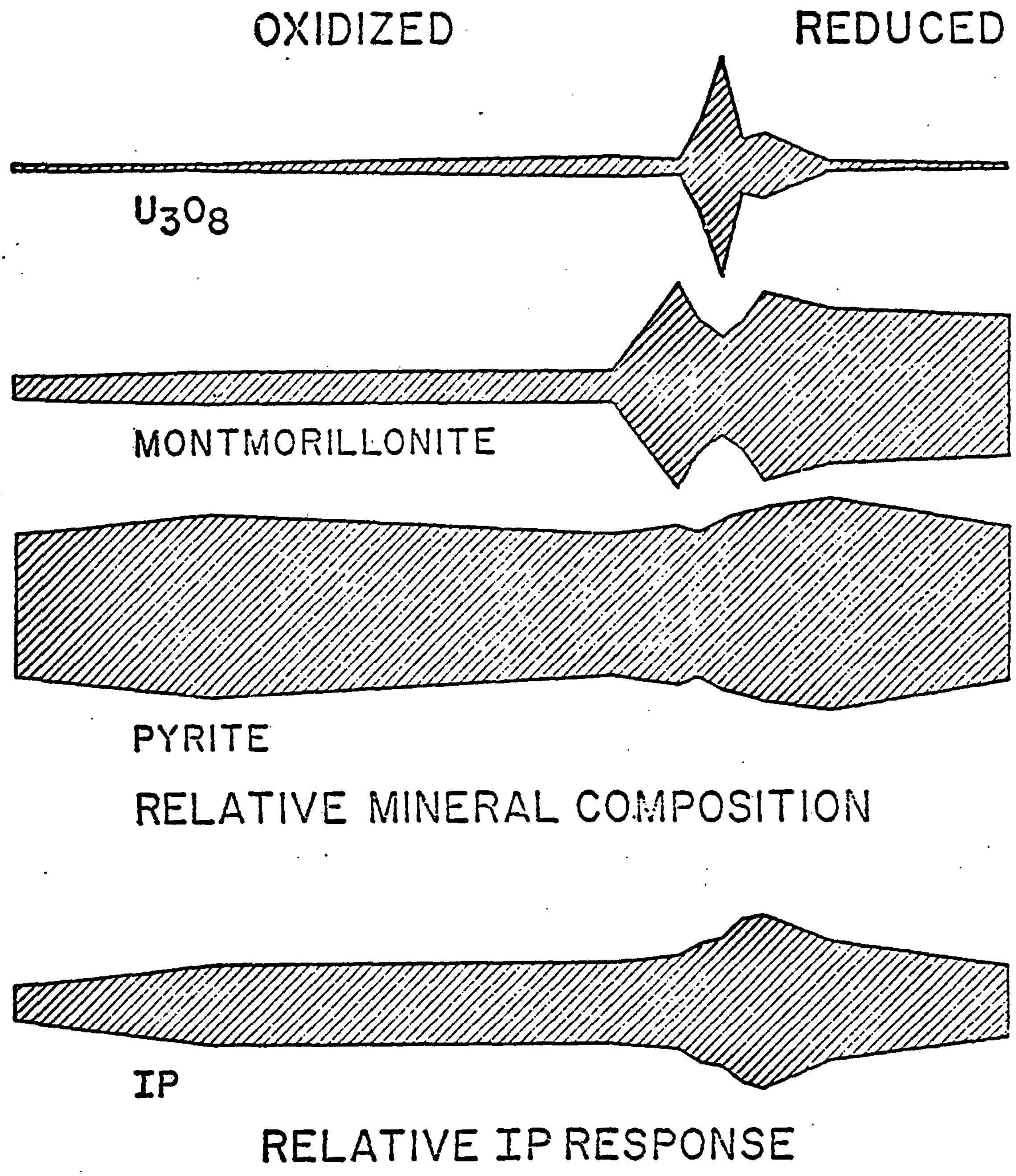


Figure 4. Comparison of IP response, montmorillonite, U_3O_8, and pyrite average values across a South Texas ore deposit. IP values are from well logs. Pyrite, U_3O_8, and montmorillonite values are taken from core analyses. Note that all values have been doubled for visual presentation.

Unlike the previous example, the example shown in figure 5, from the Powder River Basin shows the induced polarization logs as only slightly anomalous across the deposit. However, the porosity, density, and magnetic susceptibility logs show pronounced anomalies across the ore zone. In this case porosity-density variations could be mapped and give a good indication of directional trends in the depositional environment. Further work near this deposit may show that the magnitude of the magnetic susceptibility anomaly is proportional to the distance from the ore deposit. If the amount of ore deposited is proportional to the intensity of chemical alteration, the amount of magnetic minerals, as measured by the susceptibility logs might be used to predict the size of the ore deposits, even before drilling precisely locates them.

It might be said that much of this information can be derived from lithology logs based on grab samples. However, grab samples cannot provide as much detail as physical property logs. The following figures show the complete logs from which the average values were computed for figure 5; figure 6, resistivity logs and IP logs; figure 7, neutron-neutron logs; figure 8, gamma-gamma density logs; and figure 9, magnetic susceptibility logs.

In conjunction with our logging work, we have been developing techniques to locate physical property changes between drill holes by hole-to-hole electrode configuration as shown in figure 10. The technique consists of placing a current source down one hole and receiver electrodes down a hole located some distance away. Resistivity and induced polarization changes occurring between the drill holes can be detected.

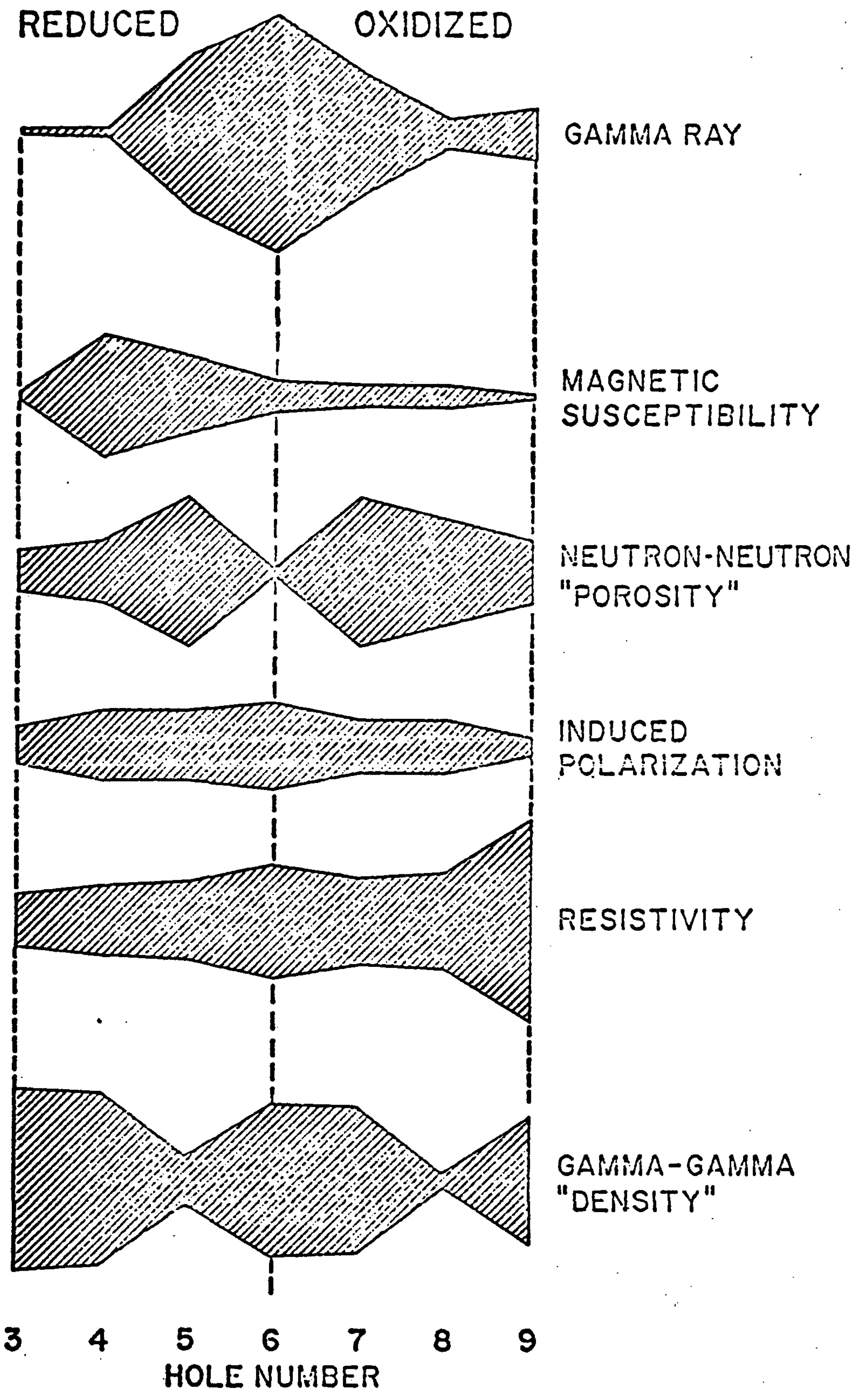


Figure 5. Average log response values for an ore zone across a deposit in the Powder River Basin, Wyoming. Note that all values have been doubled for visual presentation.

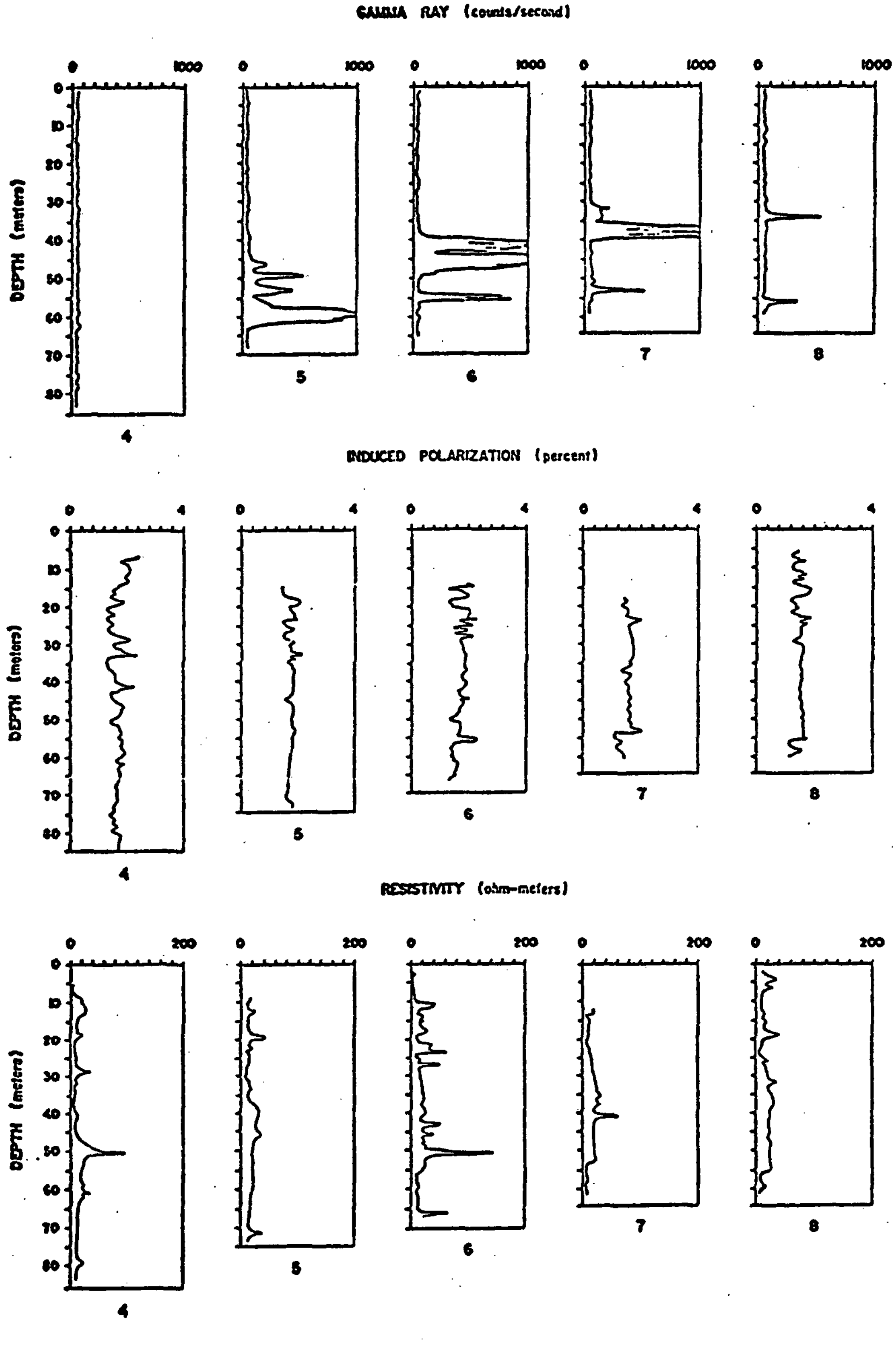


Figure 6. Gamma ray, induced polarization, and resistivity logs across a Powder River Basin uranium deposit.

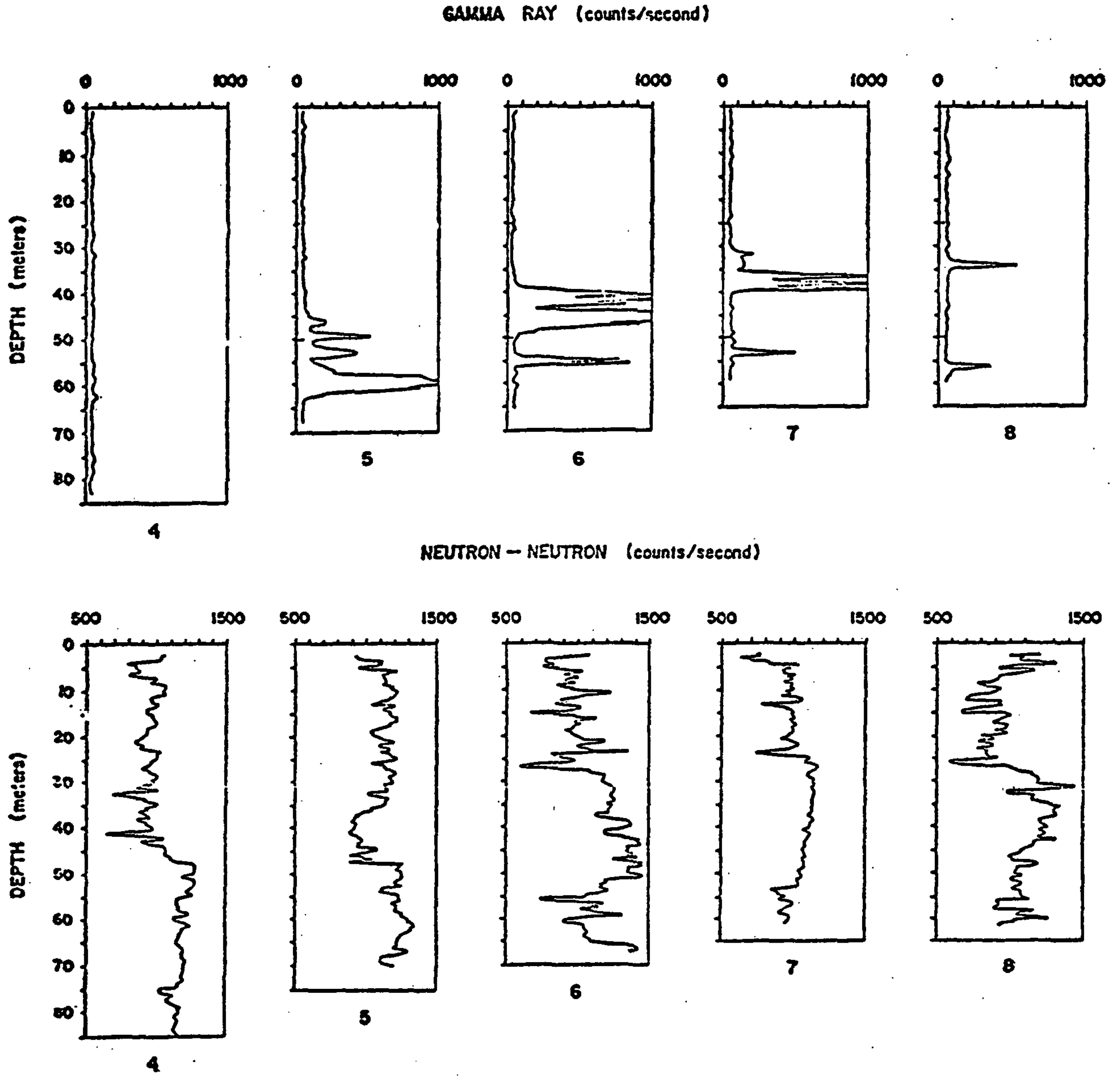


Figure 7. Gamma ray and neutron-neutron logs across a Powder River Basin uranium deposit.

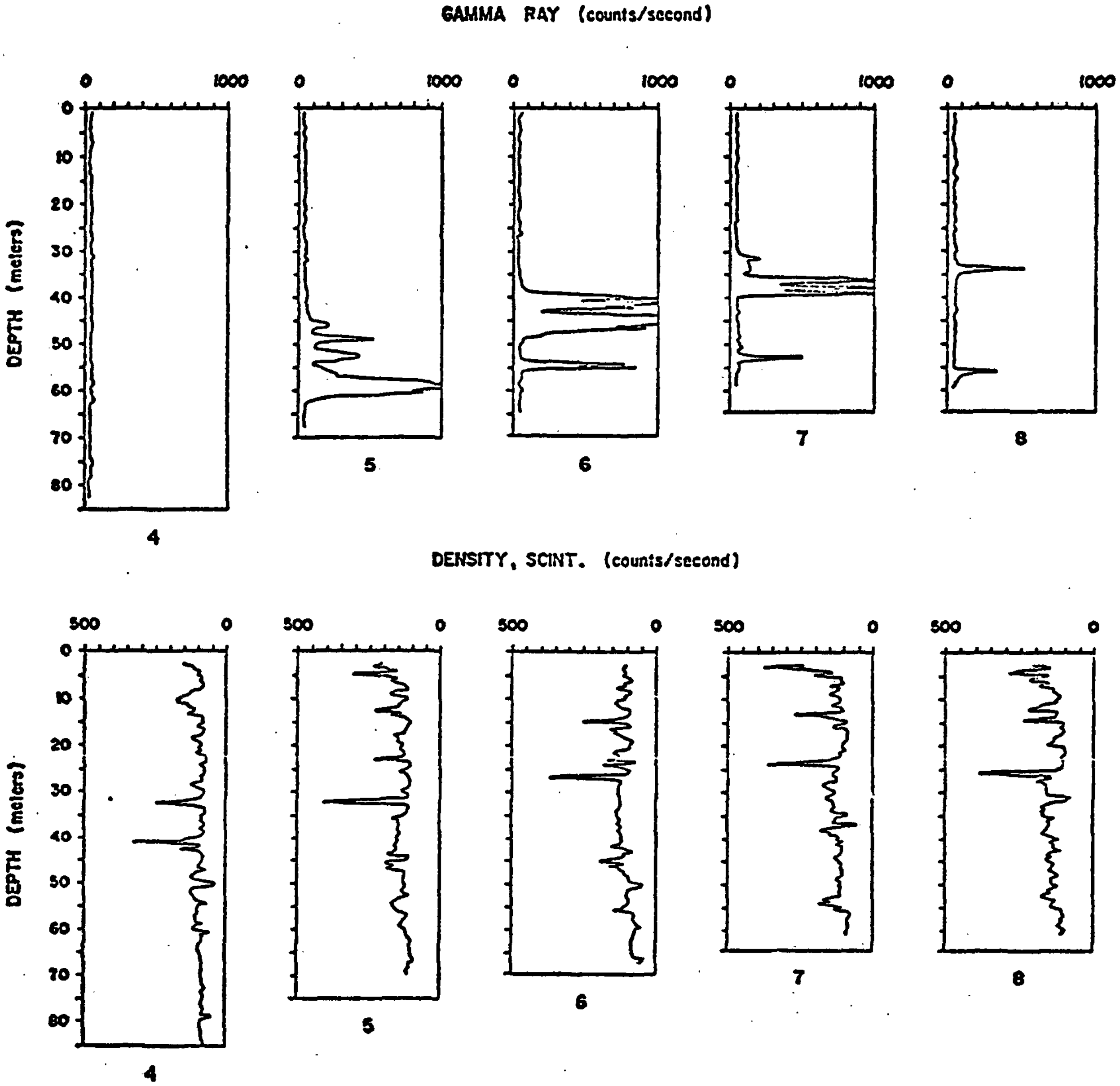


Figure 8. Gamma ray and gamma-gamma density (uncalibrated) logs across a Powder River Basin uranium deposit.

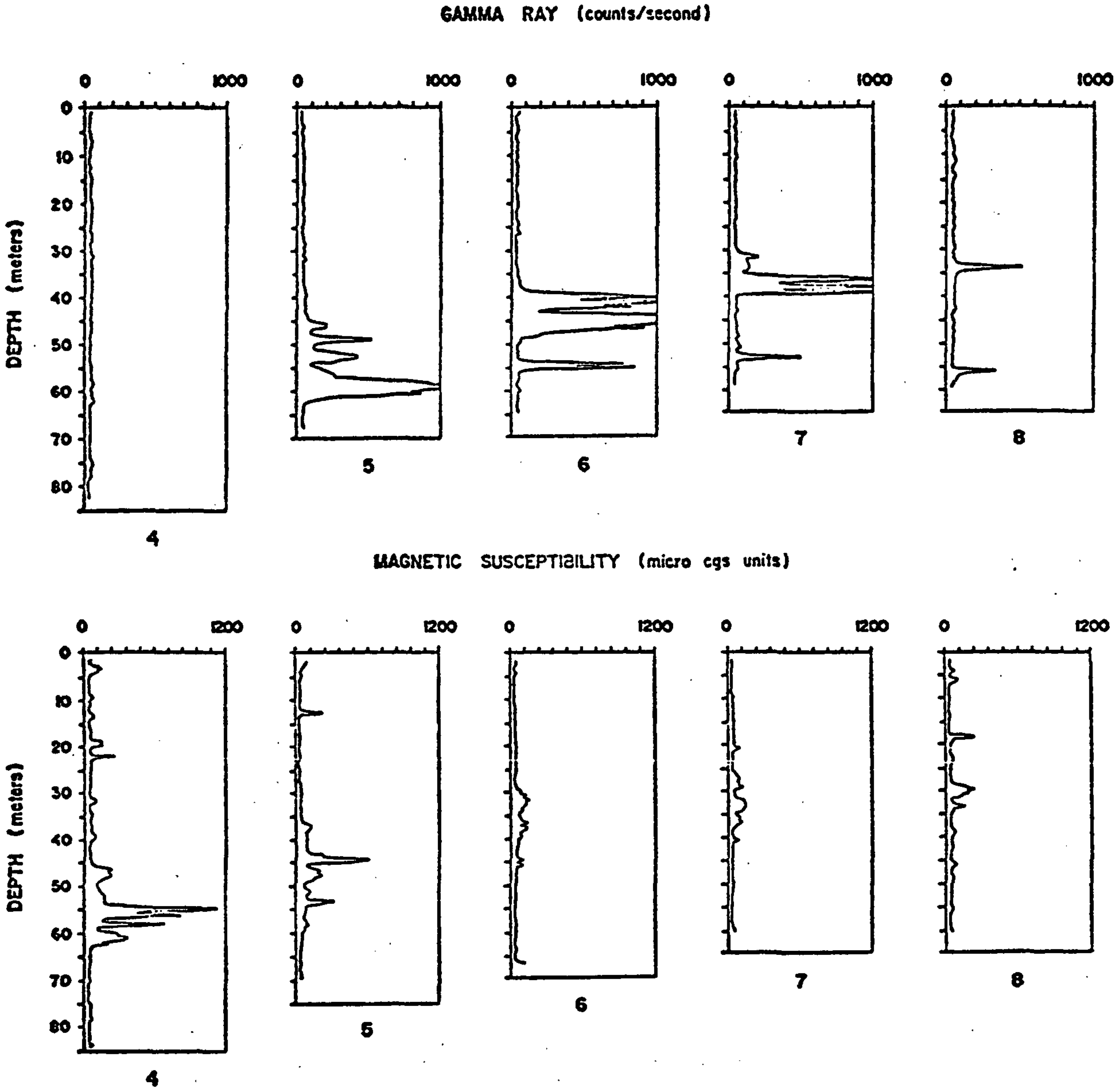
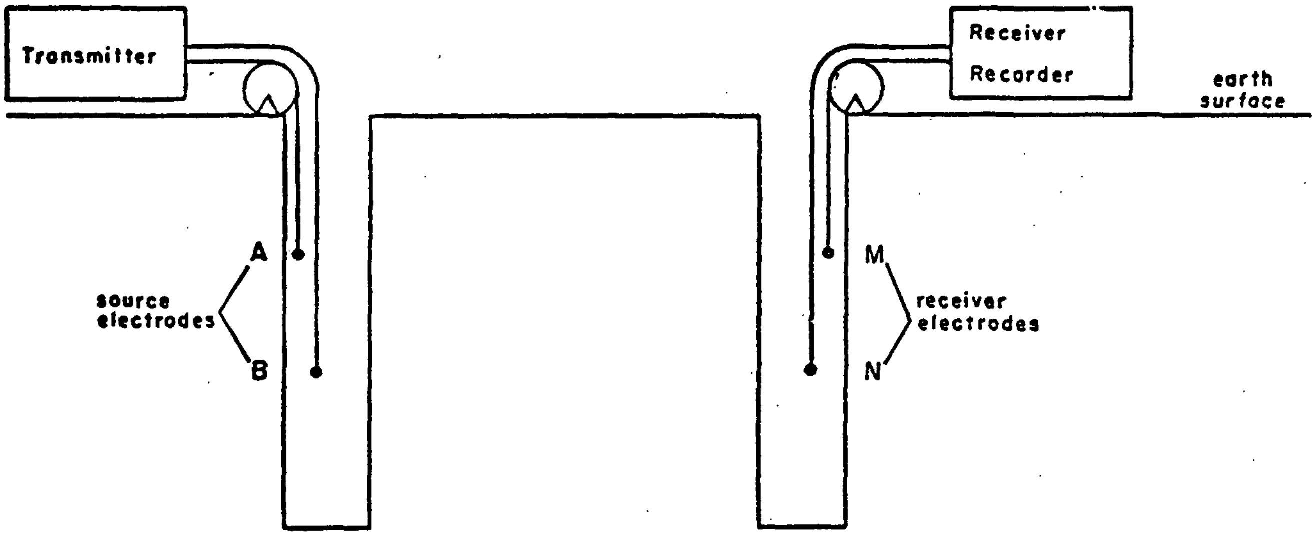
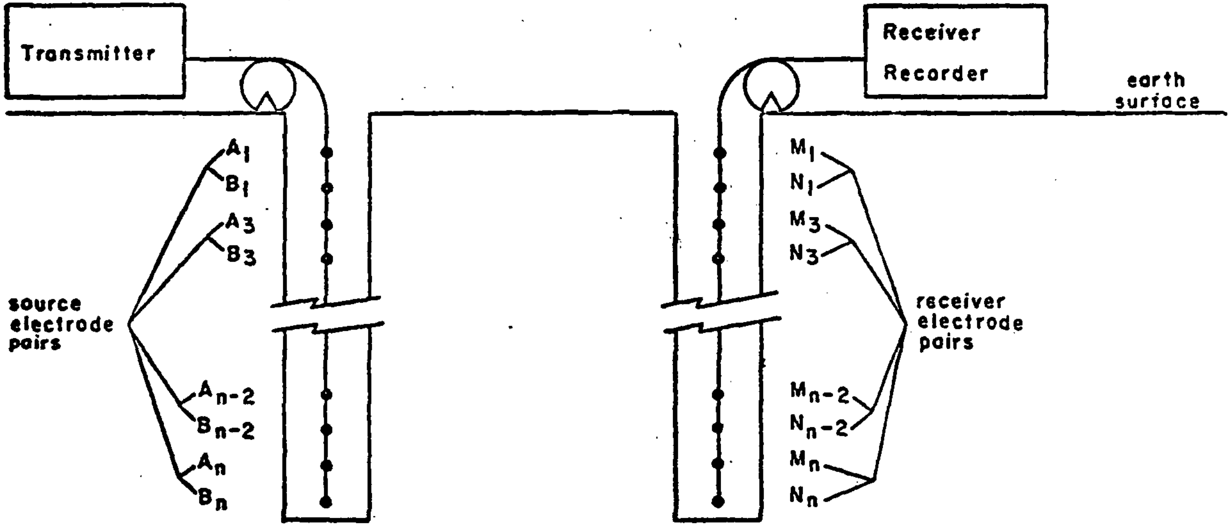


Figure 9. Gamma ray and magnetic susceptibility logs across a Powder River Basin uranium deposit.



(a) Fixed Source



(b) Moving Source

Figure 10. Hole-to-hole electrode configurations: a) stationary, or fixed, source, and b) moving source. (Source electrodes A and B the same depth as the receiver electrodes, M and N).

The following figures (11 and 12) show two different situations encountered for hole-to-hole measurements. Figure 11, from South Texas, shows an increase in the IP values across the ore zone (as is seen in the average values for figure 4). The Wyoming hole-to-hole data (figure 12) shows very little variation in the IP values across the ore zone, but there is an increase in the resistivity values across the ore zone (as is also seen in figure 6 for the well logs).

An efficient exploration program uses all of the available information to maximum advantage. This means exploiting all geological, geochemical, and geophysical information to minimize exploration costs. The well logging program should be tailored to obtain physical properties variations that help define the geologic environment on a given property. Hole-to-hole methods use existing holes to maximum advantage and can greatly extend the information base. Flexibility in trying different methods will make for a more efficient exploration program.

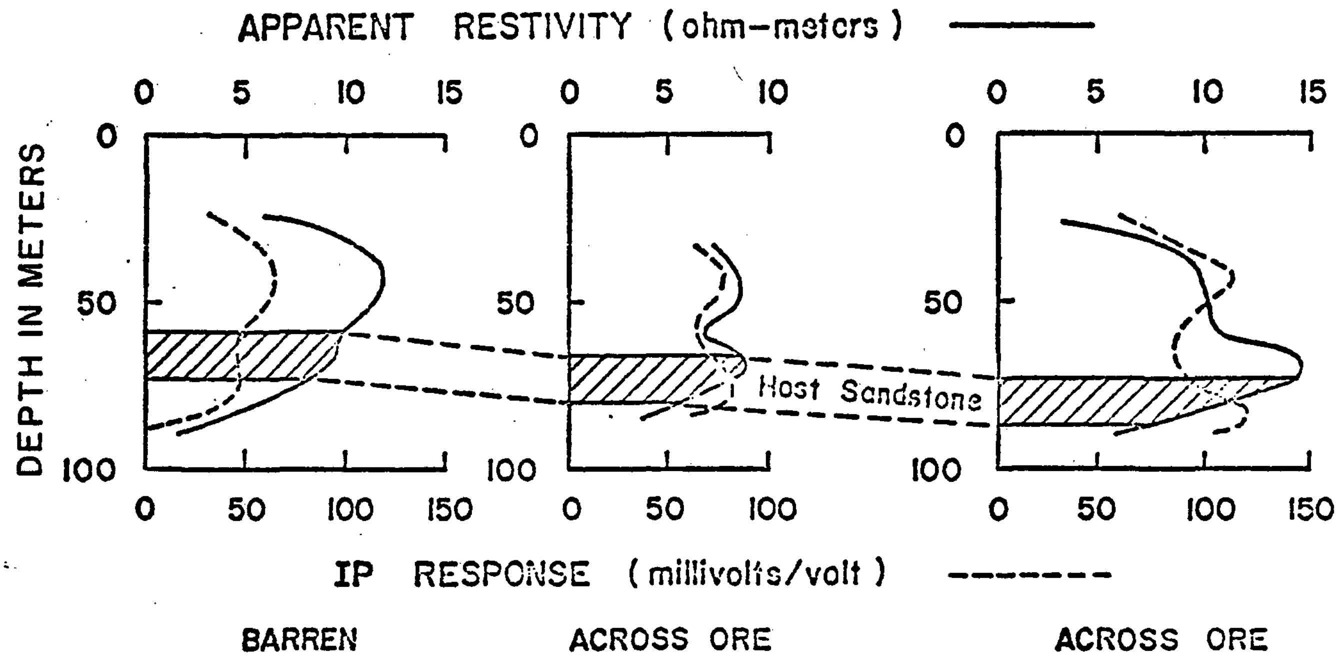


Figure 11. Hole-to-hole resistivity and induced polarization (IP) values across (and near) a South Texas uranium deposit.

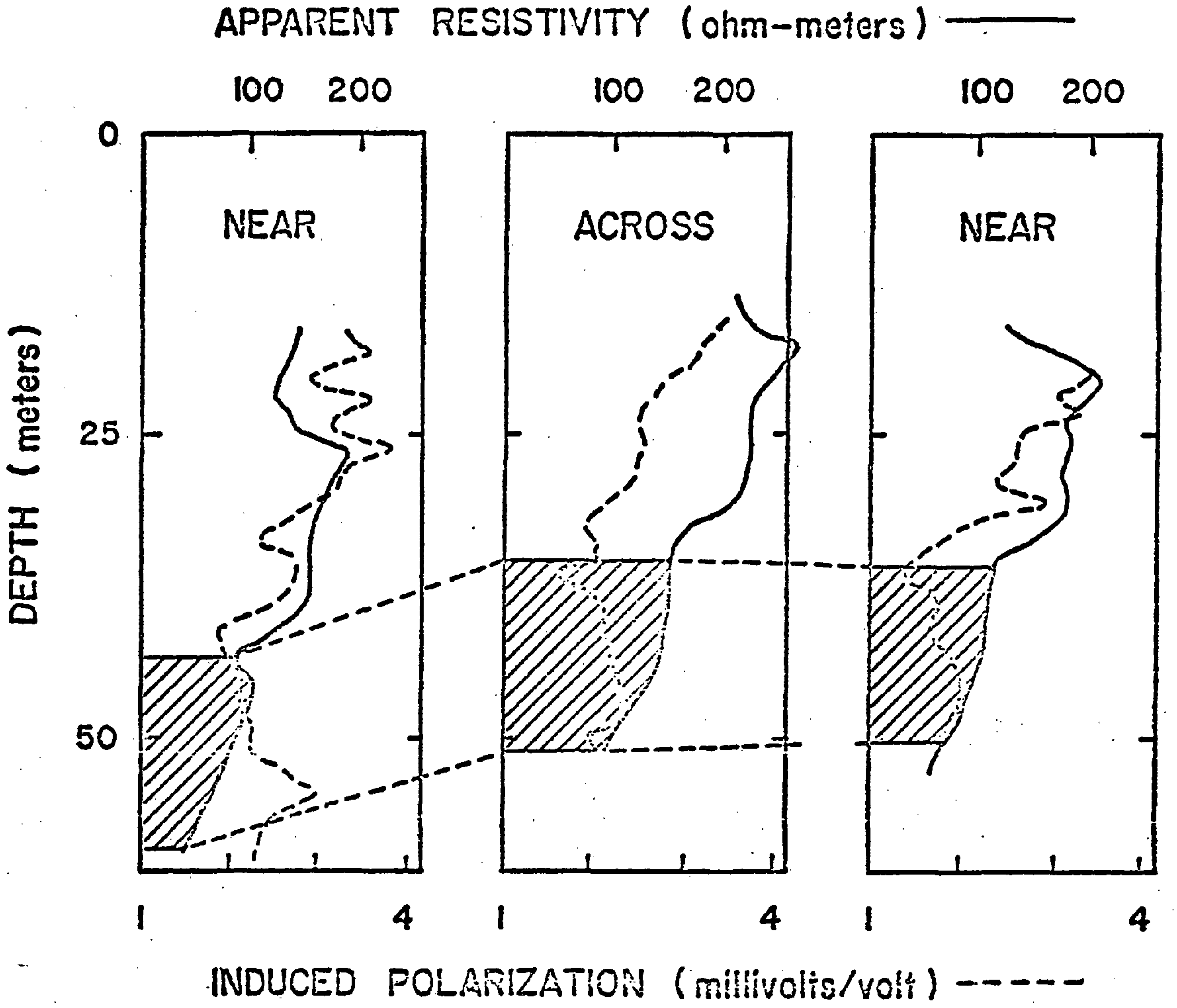


Figure 12. Hole-to-hole resistivity and induced polarization (IP) values across (and near) a Powder River Basin uranium deposit.

Reference cited

Rubin, Bruce, 1971, Uranium roll front zonation in the southern Powder River basin, Wyoming: Wyo. Geol. Assoc. Earth Sciences Bull., v. 3, no. 4, p. 5-12.