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An experiment to test hole-to-hole resistivity measurements for locating mine openings in coal seams

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An experiment to test hole-to-hole resistivity measurements for locating mine openings in coal seams

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Abstract

Hole-to-hole resistivity measurements can be useful for interpreting resistivity anomalies that are located too far away from the borehole to be detected with conventional well logging probes. Hole-to-hole direct current resistivity measurements are shown in this study to be useful for detecting mine openings in a coal seam.

Introduction

Hole-to-hole direct current resistivity measurements are made by placing a current source in a borehole and measuring the resulting potential difference between two electrodes in an adjacent borehole. This electrode configuration is illustrated in figure 1. The source current passes through the earth between the A and B electrodes. Electrode A is at the surface and electrode B is located at depth. The potential difference is measured in another borehole between potential electrodes labeled "M" and "N". An apparent resistivity is calculated using the distance between the current and potential electrodes, the source current, and the measured potential difference. An explanation of theory of these calculations has been given previously by the author (Daniels, 1977).

The five holes in this study were drilled into the No. 9 coal in the Carbondale formation of Pennsylvanian age. The site is located in Ohio

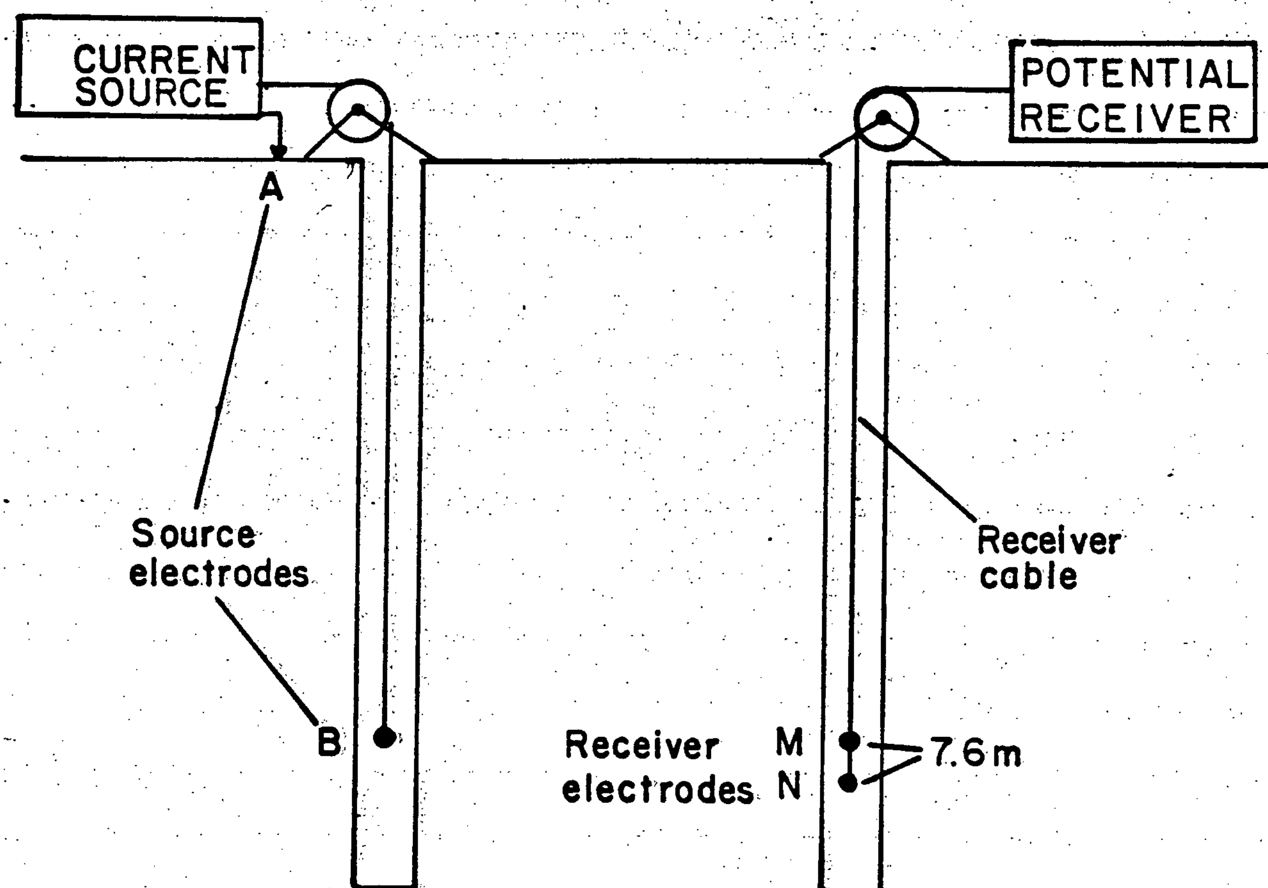

Figure 1.--Hole-to-hole direct current resistivity array. The spacing between the "M" and "N" electrodes in this study is 7.6 m. Measurements were made at 1.9 m intervals in the receiver borehole.

County, Kentucky. The areal positions of the five drill holes and old mine workings are shown in figure 2. The depth of the No. 9 coal seam that contains the mine openings is shown on the density well logs in figure 3.

Interpretation Approach

A study presented in a previous paper (Daniels, 1978) shows that resistivity well logs can be used to calculate a theoretical model. Differences between hole-to-hole field data and hole-to-hole theoretical model results can be attributed to lateral changes in the resistivity of the rocks between or near the source and receiver holes. A high resistivity layer (such as coal) will cause anomalously high resistivities to be measured just below the high resistivity layer. In order to utilize an interpretation procedure such as that described previously (Daniels, 1978), it is necessary that the sedimentary section adjacent to the layer of interest contains no large lateral variations that could contribute to the anomalies on the hole-to-hole measurements records. Unfortunately, in the example given in this paper, the resistivity well logs (fig. 4) show that lateral variations in the resistivities of the rocks are present above the coal.

In addition to resistivity variations above the coal seam, there are other factors associated with the coal seam in mine openings (such as the presence of steel rails, changes in the thickness of the coal seam, and variations in the ash content of the coal), that can have an effect on the results of hole-to-hole resistivity measurements. It is assumed in this paper that these factors have a minimal effect on the hole-to-hole measurements. Since the resistivity of the open area in the coal seam is infinity, it is reasonable to assume that the increases in the resistivity anomaly associated

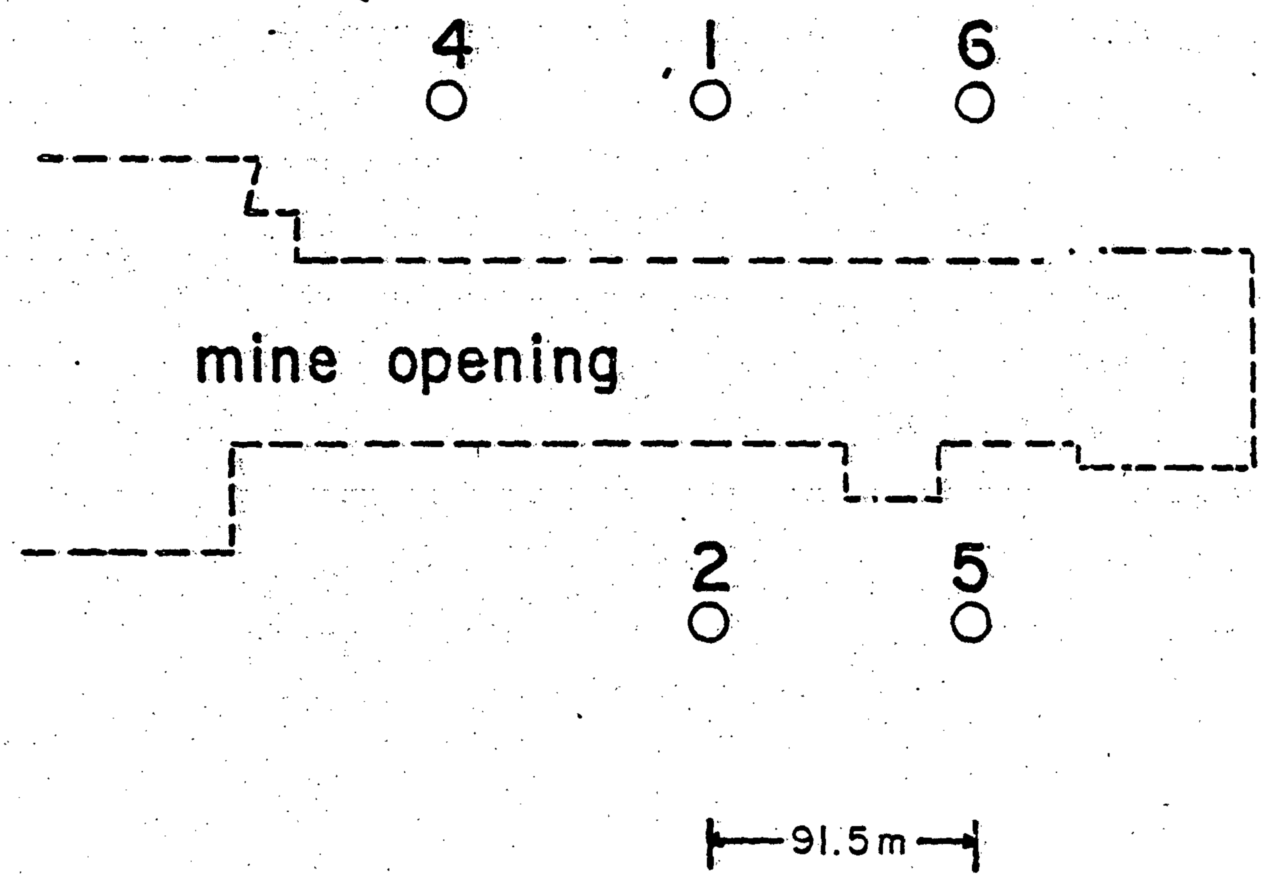

Figure 2.—Location of the five drill holes considered in this study. The mine opening is outlined by the dashed line.

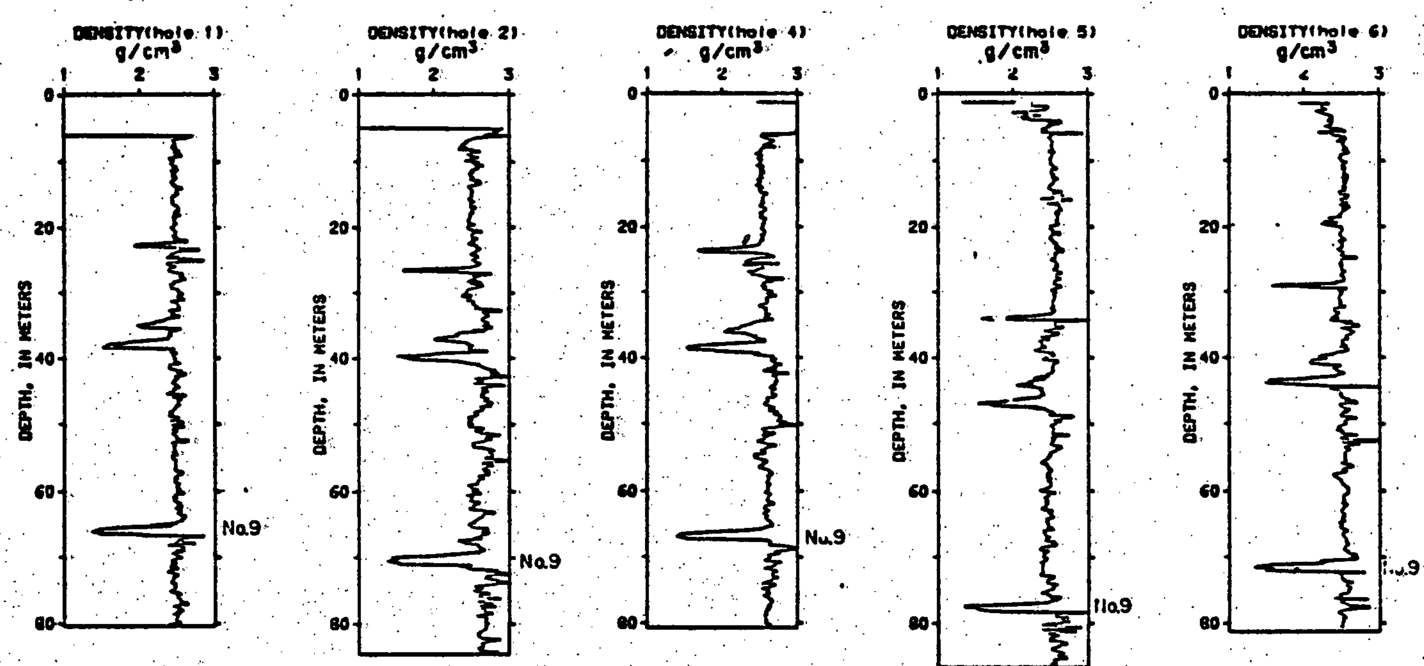

Figure 3.—Density well logs for each of the five drill holes considered in this study. The depth of the coal seam containing the mine opening (No. 9) is indicated on each of the well logs.

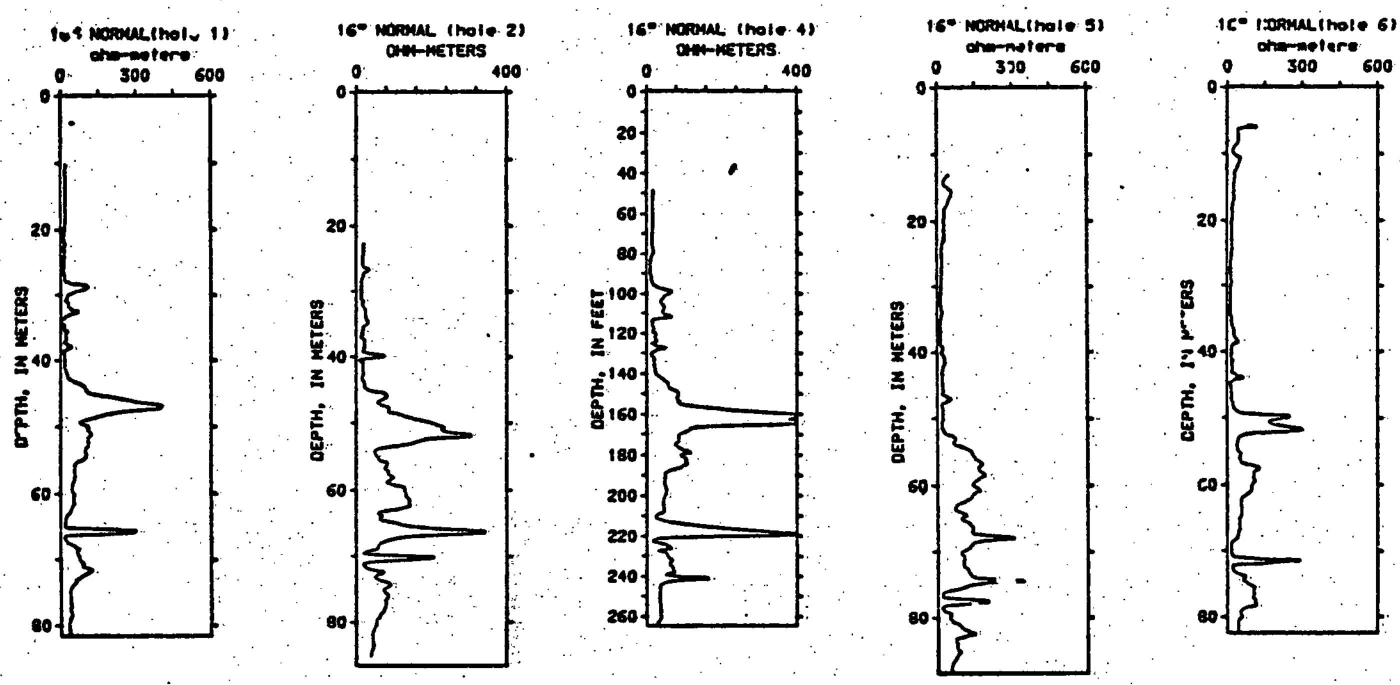

Figure 4.--Resistivity well logs for each of the five drill holes considered in this study.

with the coal seam are primarily caused by the presence of the mine opening. The amplitude of this anomaly varies with the distance of the source and receiver holes from the mine opening.

Field Measurements

The electric current source in this study consisted of a time-domain direct-current resistivity transmitter that was switched on and off for a period of 1 second. The source current was maintained at 1 ampere. One source current electrode (A) was placed on the surface adjacent to the source-current hole, while the other current electrode (B) was placed at the depth of the No. 9 coal. The receiver cable consisted of 10 separate conductors connected to lead electrodes that were wrapped around the outside of the cable at spacings of 7.6 meters. The potential difference between pairs of these electrodes (electrodes M and N) was measured with an analog chart recorder at approximately 2 m intervals in the receiver drill hole.

Figure 5 shows hole-to-hole measurements made in pairs of holes located across the mine openings. A flat, high-amplitude anomaly is located at the bottom of each of the vertical profiles in figure 5. These anomalies are caused by the coal seam and the mine workings. The anomalies in Figure 5(a) and Figure 5(b) are approximately the same amplitude.

Hole-to-hole measurements for hole pairs that parallel the mine workings are shown in figure 6. These data illustrate that the amplitude of hole-to-hole measurements parallel to the mine workings depends upon the spacing of the source and receiver holes and the distance of the holes from the mine workings. The lowest amplitude anomaly at the depth of the coal seam is seen in figure 6(b) when the source is in hole 6 and the receiver is in hole 1. A

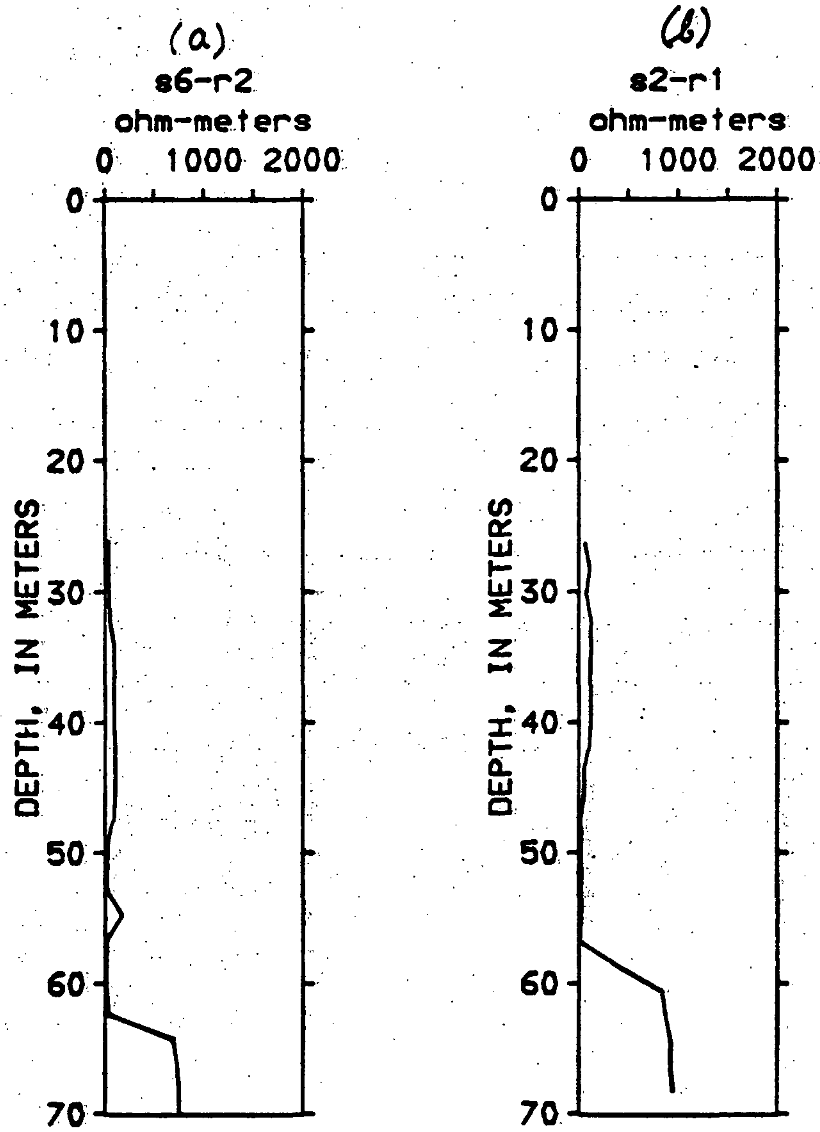

Figure 5.--Hole-to-hole measurements made across the mine openings for (a) the source in hole 6, the receiver in hole 2, and (b) the source in hole 2, the receiver in hole 1.

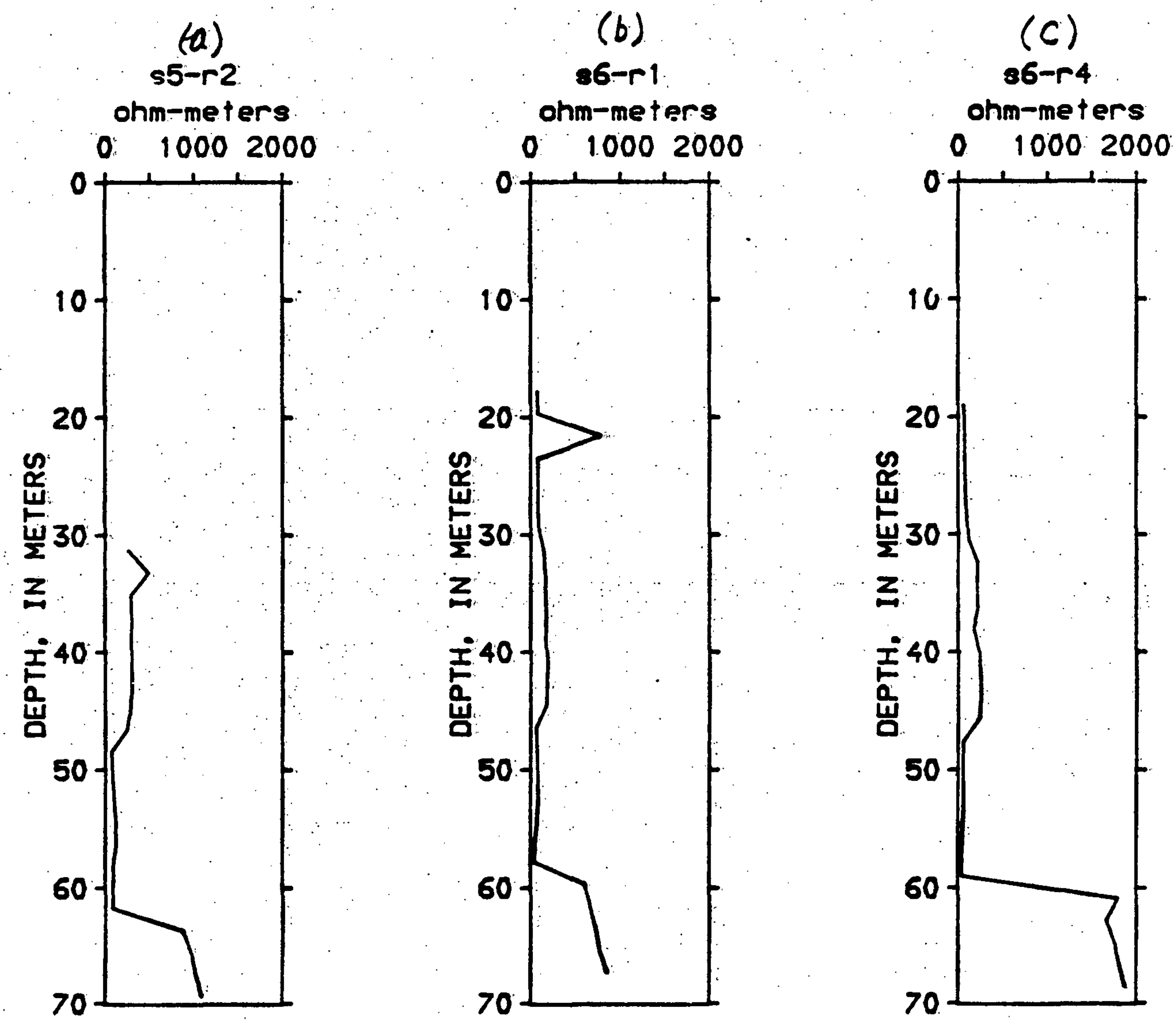

Figure 6.--Hole-to-hole measurements made parallel to the mine openings for (a) the source in hole 5, the receiver in hole 2, (b) the source in hole 6, and the receiver in hole 1, and (c) the source in hole 6, the receiver in hole 4.

slightly higher amplitude anomaly corresponds to the source-receiver holes 5 and 2. Holes 2 and 5 have the same horizontal spacing as holes 1 and 6, but holes 2 and 5 are located closer to the mine workings than holes 1 and 6. The highest amplitude anomaly is seen in figure 6(c), when the source is in hole 6 and the receiver is in hole 4. This widely spaced source-receiver hole pair encompasses a larger volume than the source-receiver pair represented in figure 5(a) or figure 5(b) and, therefore, yields a higher amplitude response caused by the resistive mine workings.

Conclusions

Hole-to-hole resistivity measurements can be used to detect voids in buried coal seams caused by previous mining activity. The amplitude of the resistivity anomaly is a function of the separation between the source and receiver boreholes, the distance of the source and receiver boreholes from the mine openings, and the volume of the void space in the coal seams. Several sets of measurements from different pairs of source-receiver holes are necessary to qualitatively define the location of the mine workings.

References

Daniels, J. J., 1977, Extending the range of investigation of borehole electrical measurements: SPWLA Eighteenth Annual Logging Symposium, June 5-8, 1977.

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