SIMILITUDE MODEL EXPERIMENTS TO DETECT MINE CAVITIES[1]

F. Ziaie, S. S. Peng, and P. M. Lin[2]

Abstract. A resistivity technique for cavity location has been developed. This technique is a combination of the Bristow arrangement and line electrode method. In this technique three line electrodes are used so that the sinkhole electrode is placed far from the other two electrodes. When one of the two electrodes and the sinkhole electrode are activated, several resistivity profiles parallel and perpendicular to the line electrode are measured for different electrode activated. Subsurface cavities cause resistivity anomalies if they are crossed by the resistivity profiles. The anomalies are interpreted and used to locate the sources of the anomalies (cavities). A tank model and a similitude model are developed to verify the effectiveness of this method for cavity detection in the saline medium and in the actual materials. The results of the experiment indicate that the location and the dimensions of the cavities can be estimated successfully.

Additional Key Words: electrical resistivity, monopole, mine cavity, tank model, similitude model.

Introduction

Abandoned mine cavities, especially those that › shallow, are an important source of surface tability. Therefore, such cavities should be :ected and stabilized to protect the surface ablishments. The earth resistivity technique is atively inexpensive and has shown a high degree success in locating subsurface cavities. One of › methods used for locating cavities is the -potential method of earth resistivity prospecting reloped by Carpenter and Habberjam (1955). er, Habberjam (1969) conducted an extensive idy by analyzing theoretical consideration of this :hod for locating the cavities by using a brine k modeling experiment. The monopole resistivity hnique originally discussed by Logn (1954), and plied to cavity location by Bristow (1966), was ntually modified by Bates (1973). This hnique was employed by the U.S. Bureau of es to locate abandoned mines and delineate the ındaries of old workings (Burdick et al. 1986). › line electrode resistivity technique which was dified using the Bristow resistivity arrangement ; introduced by Ziaie et al. (1989). This technique was used in a brine tank model experiment in order to test its effectiveness in cavity location.

Discussion of the new technique.

The proposed line electrode resistivity technique is analogous to the Bristow monopole configuration. In this method line electrodes are used instead of point electrodes. The point potential electrodes are used within or outside of the two active line electrodes to measure the potential gradient variation generated by the line electrodes. This potential variation is related to the subsurface structure. The major difference between this technique and the Bristow array is that the distribution of the potential in the subsurface delineates revolution of the half cylindrical surfaces rather than sperical surfaces. The axis of these surfaces are correlated with the closest line electrode when the two active electrodes are sufficiently far from each other (Fig. 1). If the subsurface structure does not vary laterally, then the intersections between the cylindrical surfaces and the earth surfaces are parallel equipotential lines. This equipotential gradient is montiored and is used to calculate the resistivity of the subsurface material. In the case of locally lateral variation of the subsurface material (such as the existence of mine cavities) the equipotential line will be distorted and the anomaly due to lateral variation of the subsurface can be interpreted to locate the source of the anomaly. The major advantage of this technique is that (1) the resultant anomaly for different profiles parallel and perpendicular to the line

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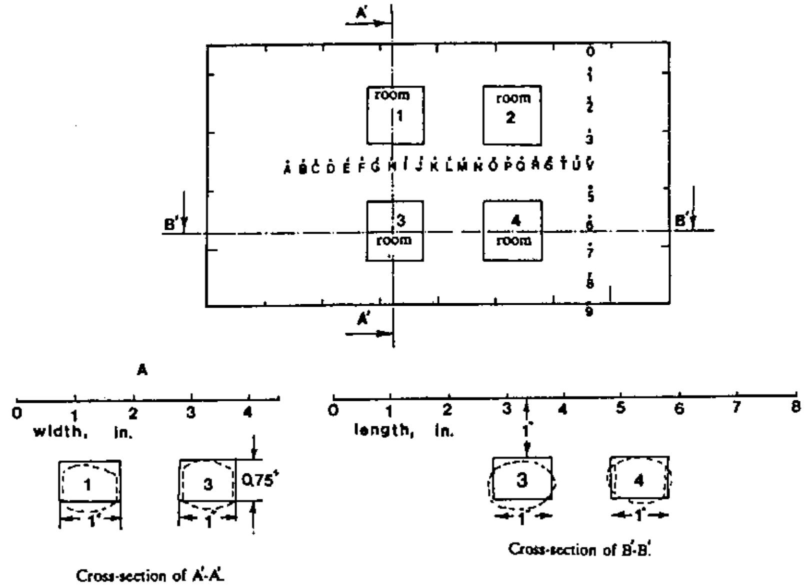

Fig. 3 Location of simulated rooms in the tank model.

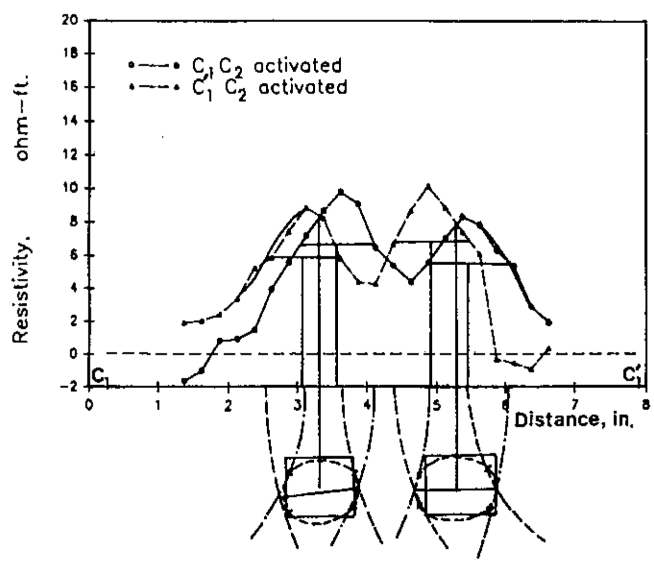

Fig. 4 Interpretation of the resistivity profile for cross-section 3-3.

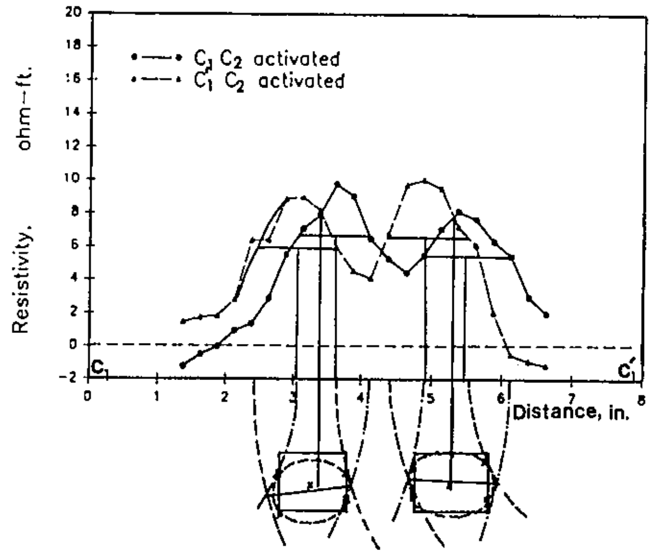

Fig. 5 Interpretation of the resistivity profile for cross-section 7-7

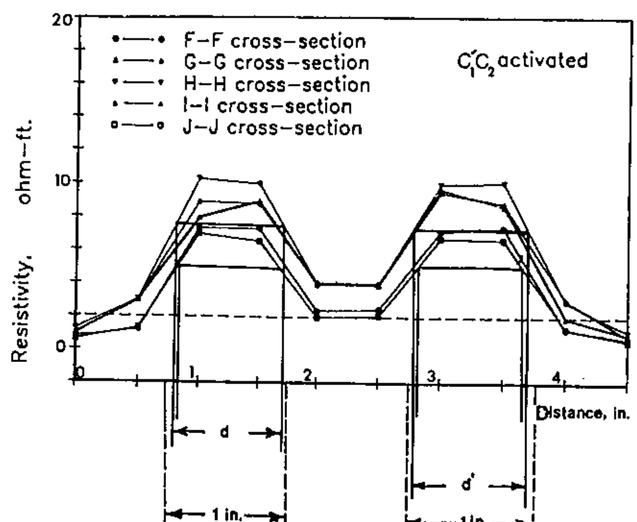

Fig. 6 Interpretation of the resistivity profiles for cross-sections parallel to the line electrodes.

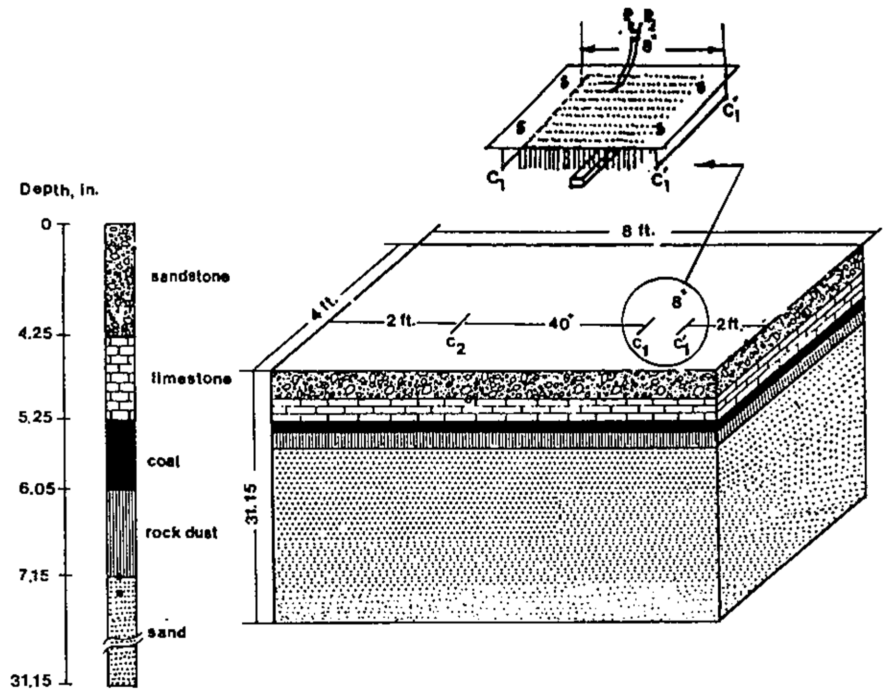

Fig. 9 The similitude model.

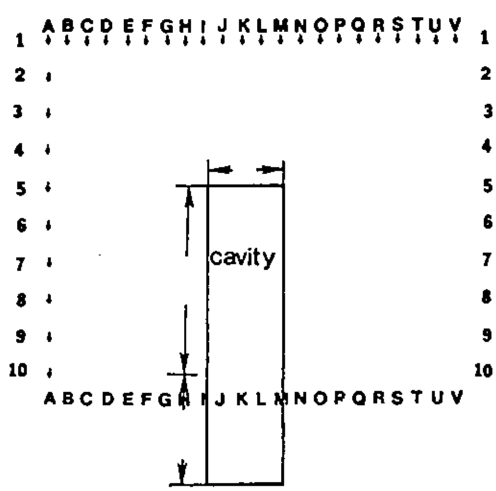

Fig. 10 Location of the created cavity within the survey area in the similitude model. The size, location, and depth of the cavity vary for any experiment.

the five layer structure without cavity creation in the similitude model. Figure 10 shows the view of the survey site. Figure 11 shows the resistivity of cross-section 8-8 stations located between midpoint of the potential electrodes versus their distance from C_1C_2 activated line electrodes. This resistivity curve is consistent with the characteristic curve of multiple layers. As shown, the apparent resistivity in this profile begins with the sandstone layer, increases in the limestone layer and then decreases in the coal layer as depth of the penetration of the injected current in the medium increases. For the rock dust layer, the apparent resistivity may be somewhere between the coal and sandstone layer because there is no apparent changed for this layer. Finally, the curve terminates with an increasingly apparent resistivity for the bottom sand layer. This type of curve is generated because the relative resistivity of the sandstone layer is less than the apparent resistivity of the limestone layer, but is higher than the apparent resistivity of the coal layer. The relative resistivity of the coal layer is also less than that of sand or rock dust layer. Therfore, the resistivity profile can provide an idea regarding the structure of the subsurface layers.

The next experiment was conducted to detect a circular cavity with a diameter of 0.70 inches that was located at a depth of 1.25 inches (Fig. 12 shows the cavity creation in the model). In the similitude model the resistivity profiles for the cross-section 8-8 was prepared (Fig. 13). The depth of the cavity was 1.30 inches in the sandstone layer. The two anomaly curves for different activation of line electrodes C_1C_2 and C'_1C_2 were plotted versus the distance of the midpoint of the potential electrode. For this type of the experiments started from one 3/4th of the maximum amplitude was used for drawing the horizontal line for interpretation purpose rather than 2/3 ratio used in the tank model experiments. The anomaly was interpreted and the predicted cavity is shown in broken line and the actual cavity in solid line. The location of the actual cavity and the detected one is close. The height of the cavity was estimated very closely to the actual one, but the width of the detected cavity was slightly overestimated. The calibration of the response anomaly related to the cavity dimension was practiced initially in order to be applied for anomaly interpretation of different resistivity profiles. Figure 14 shows the result of an anomaly response and the corresponding interpretation and locating of another cavity with a diameter of 0.20 inches which was located at a depth of 1.40 inches. In this case the detected cavity was found to be slightly deeper than its actual location. Also, the width of the cavity was overestimated slightly. The detectability ratio in this case was 7.0.

Finally, a cavity was created at a depth of 2.25 inches with a diameter of 0.20 inches. The profile of the cross section 8-8 is shown in Figure 15. The detected cavity is shown in broken line and the actual cavity in solid line. It is clear that the size and location of the cavity is in good agreement with the size and location of the actual cavity. The ratio of detectability was 11.5 in this experiment.

Conclusion

The new technique of cavity location appears to be applicable for cavity detection in experimental study either in the brine tank model or similitude model. The dimension and the depth of the cavity can be estimated by this technique within certain limits. This technique also provides some ideas related to subsurface structure as well.

Acknowledgment

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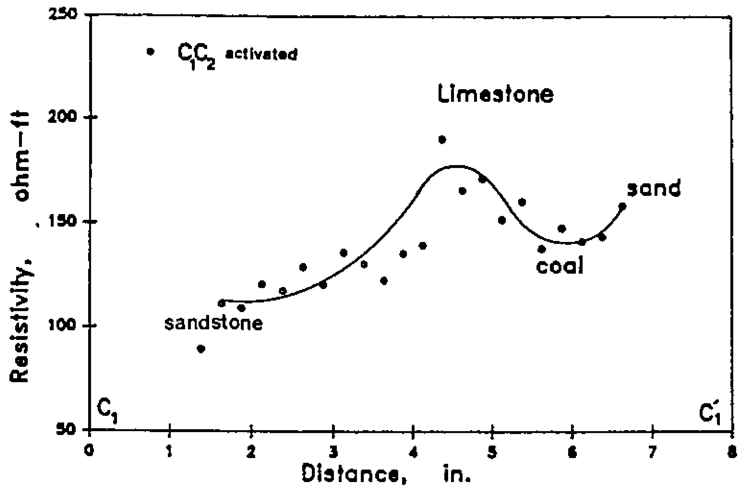

Fig. 11 Resistivity curve of the similitude model.

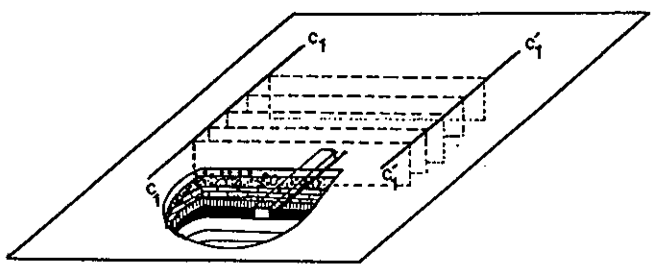

Fig. 12 Cavity creation in the similitude model.

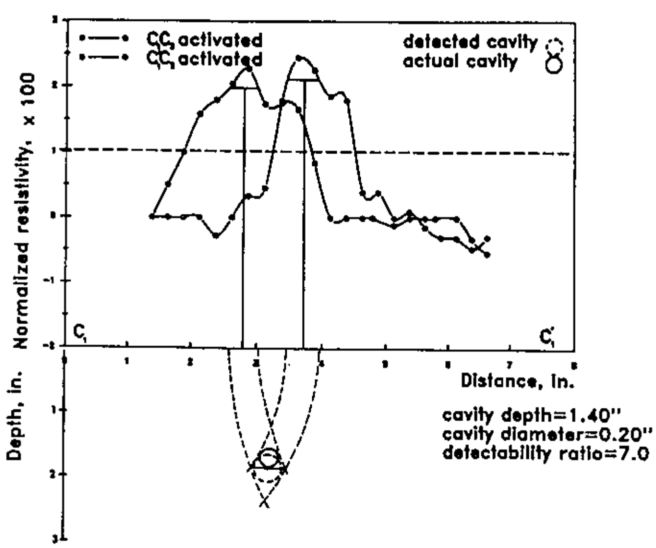

Fig. 13 Resistivity profiles for cross-section 8-8 when the cavity is located at 1.40" depth.

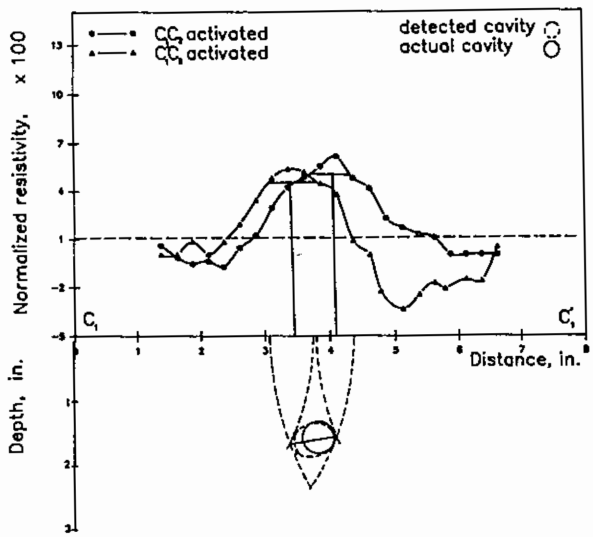

Fig. 14 Resistivity profiles for cross-section 9-9 when the cavity is located at 1.25" depth.

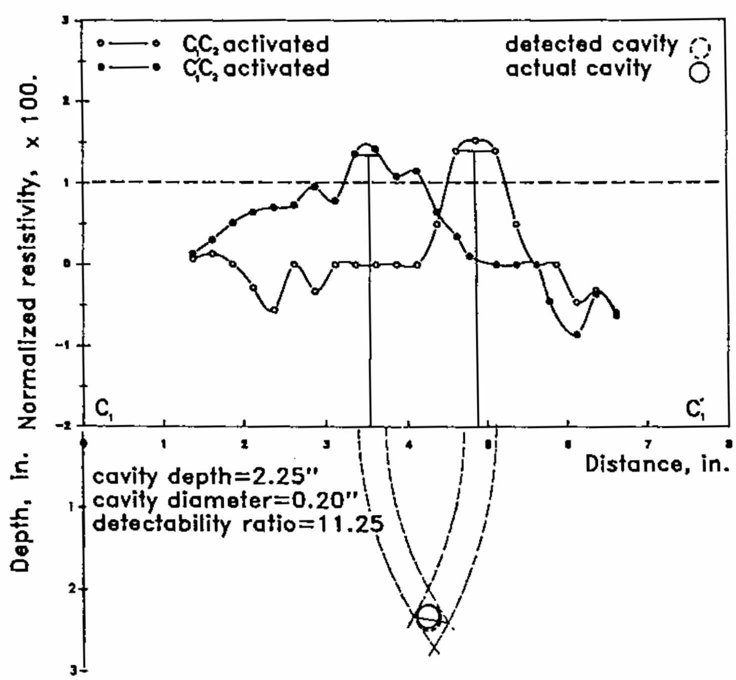

Fig. 15 Resistivity profiles for cross-section 8-8 when the cavity is located at 2.25" depth.