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Geoelectrical Possibilities of Detecting Stream Channels in Carbonate Rocks

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ABSTRACT

Several geoelectrical resistivity methods that may be used to determine the position and flow characteristics of underground water associated with carbonate bedrock and karst development are considered. The most promising method studied employs depth soundings patterned after Schlumberger. The plotting of half electrode separation against apparent resistivity yields a curve which may be used to discriminate between lateral and vertical inhomogeneities in bedrock. A network of depth soundings of this type ultimately may lead to a map that will show geoelectrical anisotropies that may be used to analyze subsurface water courses in carbonate rock.

Karst water is characterized by two properties, one good and the other bad. The good one is abundance. The bad one is that the carbonate host rock has almost no filtering potential. Once the water is polluted, the chances of its being cleaned by natural processes are very limited. For this reason as well as to understand karst hydrogeology in general, it is a challenge to find methods which would make it possible to detect underground stream channels and to determine the velocity of stream flow and the origin of springs.

The use of dye and radioactive tracers can be helpful for detecting the source of spring water which has disappeared into the ground somewhere upstream. Yet no one has found a satisfactory method by which to determine where the water flows below the surface, the characteristics of the channels in terms of average diameter and number, and whether the water is confined to narrow fissures or flows through moderate-size channels.

A geoelectrical resistivity method commonly is used to find resistivity contrasts which are based on water infiltration of rocks. An electrical current is fed into the soil. The resulting electrical field, measured between two potential electrodes, is a function of the resistivity of the rock material and its distribution. Two electrode arrangements commonly are used. One patterned after the method of Wenner generally is used in the U.S.A.; the other is after Schlumberger. One of the main problems of either method is the interpretation of the resistivity measurements. In many cases it is most difficult to determine whether an anomaly is caused by a vertical or a horizontal boundary between materials of different resistivity. The organization of the measurements can overcome this problem only partly. In the horizontal profiling method, all four electrodes are kept at a constant separation while the center of the arrangement is moved along a profile. This method responds to lateral resistivity changes, which occur at a certain depth according to the constant electrode separation. In another method, known as "depth sounding," the electrode separation is expanded successively over the same center. This arrangement forces the current deeper into the ground and makes the method responsive to vertical changes of resistivity. However, expansion of the electrode spacing may very well cause the current to cross deeply buried lateral inhomogeneities. It therefore becomes increasingly difficult to distinguish between lateral and vertical discontinuities of resistivity. Theoretical considerations as well as practical results have shown that depth sounding after Schlumberger is affected least by lateral resistivity changes, which are most disturbing in the upper layers of the overburden.

Several Schlumberger depth soundings were made at a location where the hydrogeology and the geoelecrical results are fairly unambiguous. About 20 mi south of Rolla, Missouri, is Lane Spring, in the valley of the Little Piney River. Lane Spring flows south and turns, after about 800 ft, toward the north to join the Little Piney, which flows north (Fig. 1). There is reason to assume that a large part of the water feeding Lane Spring flows underground from the eastern side of the valley, in a direction which is in alignment with the first 800 ft of exposed flow.

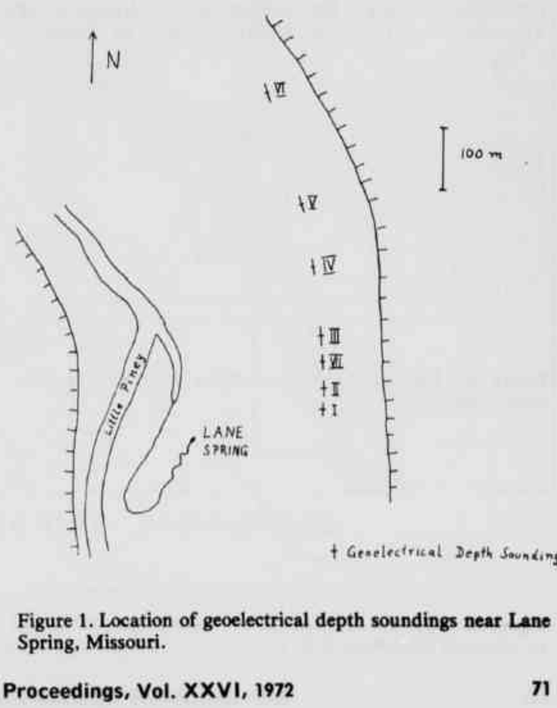

Figure 1. Location of geoelectrical depth soundings near Lane Spring, Missouri.

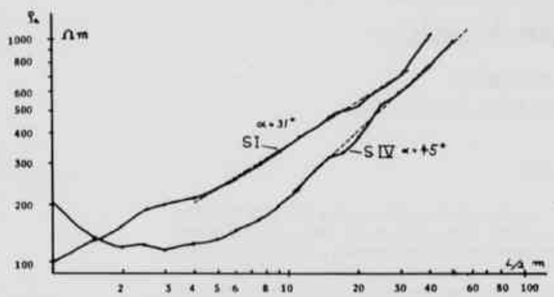

Figure 2. Geoelectrical depth soundings over Limestone; two-layer example near Lane Spring, Missouri.

Two types of depth-sounding curves are shown in Figure 2. The results are presented on bilogarithmic paper on which the half electrode separation is on the abscissa and the apparent resistivity is on the ordinate. Both curves represent a typical two-layer example which has an overburden (clay, gravel) of low resistivity and a carbonate bedrock of high resistivity. The slope of the right side of the depth sounding is characteristic for the resistivity of the bedrock. If the relation of bedrock resistivity, ρ_2, to over burden resistivity, ρ_1, approaches infinity, this slope must have an angle of 45 degrees. This condition indicates a nonconducting bedrock. Such bedrock was found in depth soundings at the three northern locations shown in Figure 1 (SIV, V, VI). Location SIV is represented in Figure 2. The other depth soundings were in an area where the water most likely flows through stream channels which feed Lane Spring. The right side of the depth soundings in Figure 2 shows a lower slope of ascent, which indicates a finite resitivity of the bedrock. The results of a total of seven depth soundings are represented in Figure 3. The resistivity of the bedrock (Fig. 3A) was interpreted from the depth soundings by means of

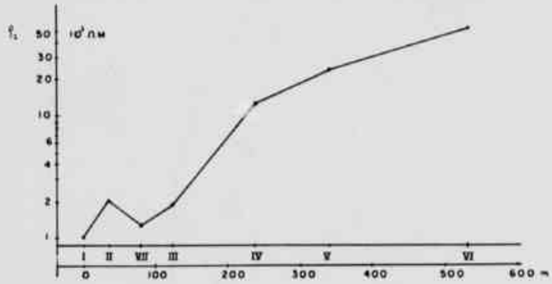

Figure 3A. Bedrock resistivity along a traverse near Lane Spring, Missouri.

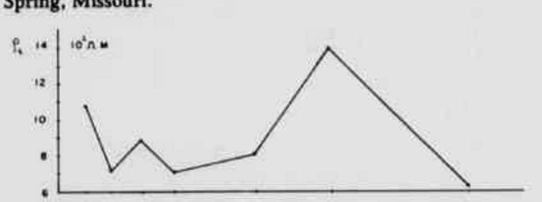

Figure 3B. Apparent resistivity of a Schlumberger profile with an electrode separation of 80 m.

two-layer interpretation master curves. Figure 3B shows the apparent resistivity one would obtain by using horizontal profiling with a constant separation of 80 m between current electrodes.

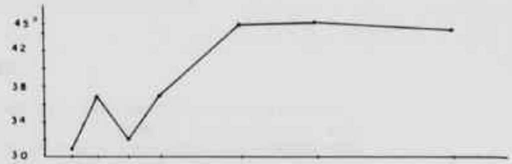

Figure 3C. Slope angle of ascending branch of depth soundings.

Horizontal profiling is a conventional way of finding lateral changes of resistivity. Figure 3B shows that, with the exception of location SV, there is no indication of an increase of bedrock resistivity on the north. The exception of SV must be considered a random value. Horizontal profiling in this case does not allow for a discrimination between lateral and vertical inhomogeneities. Finally, in Figure 3C, the slope angle of the ascending branch is plotted over each depth sounding. The slope angle is sufficiently sensitive to discriminate resistivity variations of bedrock material.

The investigations at Lane Spring will be continued with the goal of establishing a close network of depth soundings which will make it possible to draw a map of low bedrock resistivity. This map might lead to an estimate of water flow. The measurements are planned in a modified way to determine the slope angle of the right side of the sounding curve. Finally, in rotating the basis of the electrical current flow, an attempt will be made to measure the geoelectrical anisotropy, which should make it possible to draw conclusions on the direction of water flow in the stream channels.

ACKNOWLEDGEMENT

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