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Perspective

# Geophysical prospecting for water resources in arid zones

Alain Tabbagh

*UMR CNRS SISYPHE 7619, université Pierre-et-Marie-Curie (Paris-6), 4, place Jussieu, 75252 Paris cedex 05, France*

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Investigations of underground water-bearing formations in arid zones are rapidly becoming a worldwide priority with the need for additional water resources to satisfy economic development and demographic growth. The presence of freshwater in sedimentary rocks such as sandstone or limestone is characterized by an average or even high electric resistivity, whereas brackish water corresponds to conductors with a low resistivity. It is extremely difficult to distinguish freshwater from brackish water with any other physical property that can be measured from the surface. It is therefore logical to use vertical electrical soundings, or the audio-magneto-telluric method, or else the TDEM (Time Domain ElectroMagnetic) sounding to prospect for aquifers; these methods are all the more attractive because they are cheaper than seismic prospecting due to the short duration of the measurements and to the light weight of the equipment. This is why the authors of the three articles [1,3,4] have selected the electric prospecting method for their work. By comparison, petroleum engineers mostly use seismic methods as they are more interested in structural information (structural oil traps) and less by the presence of freshwater or brine. They try however to relate the physical properties with which they are most concerned (permeability and porosity) to the properties of the seismic signal.

The article [3], by M.T. Hussein and H.S. Awad, deals with vertical electrical soundings (VES) in the Khartoum area of Sudan to locate freshwater aquifers within the first 200 m below the ground. The geology goes from the Precambrian to the Quaternary, with sandstone, mudstone, occasional basaltic sills and recent unconsolidated gravel, sand, silt and clay, in the triangular area between the White Nile and the Blue Nile. The calibration of the VES was made with existing well logs. The outcome of the survey is presented as electric sections with resistivity maps at four different depths (50 to 200 m). The major difficulty was to distinguish mudstones from brackish water aquifers, as they can have the same resistivity. This was made possible by the good calibration of the VES with the well logs. The authors eventually outlined the locations of freshwater aquifers in the area.

The article [1], by M. Gouasmia et al., uses VES and audio-magneto-telluric soundings (MTS) to locate a water-bearing reef limestone within the first kilometres below the ground. The calibration of both the VES and MTS is made from existing well logs, but the interpretation was made independently for each method, as the locations of the soundings were different. The MTS method is better able to determine the thickness of the layers at great depth (down to 1 km), which the VES even with 2- or 3-km-long lines on the surface cannot do. The results are given as cross-sections in the basin and as isobath and isopach maps of the reef limestone formation likely to contain hot water. Note that the temperature here is too low (around 45 °C) for any detectable effect on the electric resistivity to occur. The emphasis of the study is on the presence and role of faults detected by the survey that greatly affect the system. Two favourable zones for reconnaissance boreholes in the reef limestone are indicated.

*E-mail address:* sisyphe@ccr.jussieu.fr (A. Tabbagh).

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The article [4], by A. Mhamdi et al., deals with the detection of freshwater versus brackish water aquifers within a deep (500 m) basin. The VES method is used, and the soundings are calibrated with existing well logs. The results are presented as cross-sections and isobath and isopach maps. Thick brackish water aquifers are identified, and the origin of the salinity is discussed. But deep freshwater aquifers are also identified, which need to be confirmed by new reconnaissance boreholes. The presence and role of faults are also detected.

The various techniques used by these authors are well known and widely used, the test cases are however original, and display a wide range of conditions, all in arid zones. The authors have always used a 1-D interpretation, i.e. a tabular model, whereas 2-D or even 3-D inversion is now possible. But their choice in each case is reasonable, given the geological context, and, as is the case, when the locations of the measurement points have been carefully selected.

Although not presented in these three papers, there are nowadays new developments of electrical methods that help identify fresh groundwater resources at depth, see, e.g., a recent and comprehensive review by R. Guérin [2]. Among them, the following are worth mentioning:

– for shallow aquifers (0 to 50 m), both the electrical resistivity tomography and the rapidly moving frequency domain Slingram multi-depth systems, which allows a full 3D description of the underground structure;
– TDEM soundings, which can be used in place of VES for the medium range of depth (from 2 to 700 m). First designed for mining prospecting, this method can be used with either surface measurements, or airborne or helicopter-borne measurements.

One must also cite the 'PMR' method (Proton Magnetic Resonance, also called Magnetic Resonance Sounding, MRS) with which one can estimate the depth variations of the total liquid free water content when rocks have sufficiently weak magnetic properties.

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