Characterization of aquifers by Magnetic Resonance Soundings: an example in Niger

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The knowledge of the geometry and of the hydrodynamic properties of geological media is a key element for understanding the hydrologic process in aquifers and for the management of groundwater resources. However, the implementation of usual method for characterizing aquifers (e.g. geological investigation by drilling or pumping tests) is often difficult and expensive, and does not allow multiplying measurements for correctly describing heterogeneities. Geophysical investigations can be used to improve the efficiency of hydrogeological study. Among the non invasive geophysical method, the Magnetic Resonance Sounding (MRS) method has the advantage of having a signal directly sensitive to groundwater (Legchenko et al. 2004). This method gives an estimate of the vertical distribution of water content (Fig. 1), and, after calibration with pumping test, an estimate of the local productivity of investigated aquifer (transmissivity in m²/s).

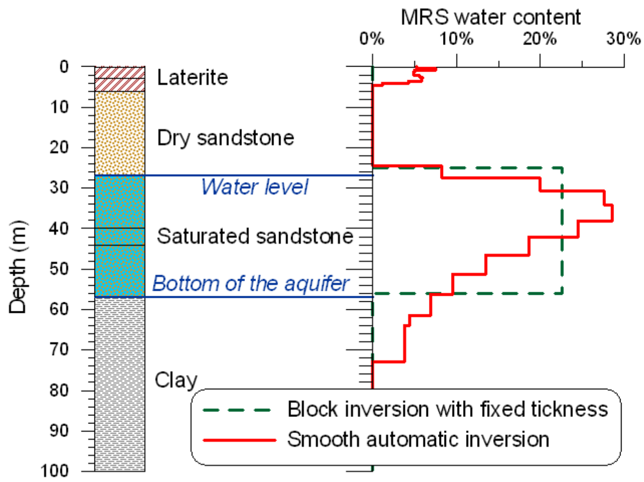

Fig. 1: Example of MRS results on Kolobosseye site.

In SW Niger, the unconfined Continental Terminal sedimentary aquifer is the main resource of drinking water for the rural population which grows rapidly (+ 3 % per year, 30 inhabitants per km²). In this context, MRS and TDEM (Time domain Electromagnetism) soundings were performed in 2005 and 2006 on twenty-two sites spread on 4000 km² and representative of the aquifer variability. The two objectives of these measurements are: (1) to calibrate the empirical relationships that allow estimating the hydrodynamic properties (transmissivity and specific yield) from MRS results on some well-known sites, (2) to improve the knowledge of the geometry and hydrodynamic properties of the aquifer for groundwater modelling.

The results have shown that the depth of the water level estimated by MRS (Fig. 2A) is in a good agreement with the previous estimate obtained by invasive measurement (borehole), but has a worse accuracy (averaged uncertainty of 15%). The bottom of the aquifer, characterized by a clay layer, is accurately detected with TDEM interpretation (Fig. 2B). The averaged MRS water content is 13 % with values ranging from 5 to 19% and comprising between the total porosity (25-36%) measured on sample and the specific yield (1-8%) estimated by pumping tests (Boucher et al. 2008). The empirical relationship allowing the estimate of transmissivity from MRS results was calibrated and checked by the comparison with results of pumping tests. The uncertainty of MRS transmissivity (about +100% / -50%) is similar of the uncertainty obtained by the interpretation of pumping tests (Vouillamoz et al. 2008). The interpretation of MRS on new sites allowed enlarging by one order in magnitude the range of transmissivity of the Continental Terminal sedimentary aquifer when comparing to the range of transmissivity obtained by pumping tests.

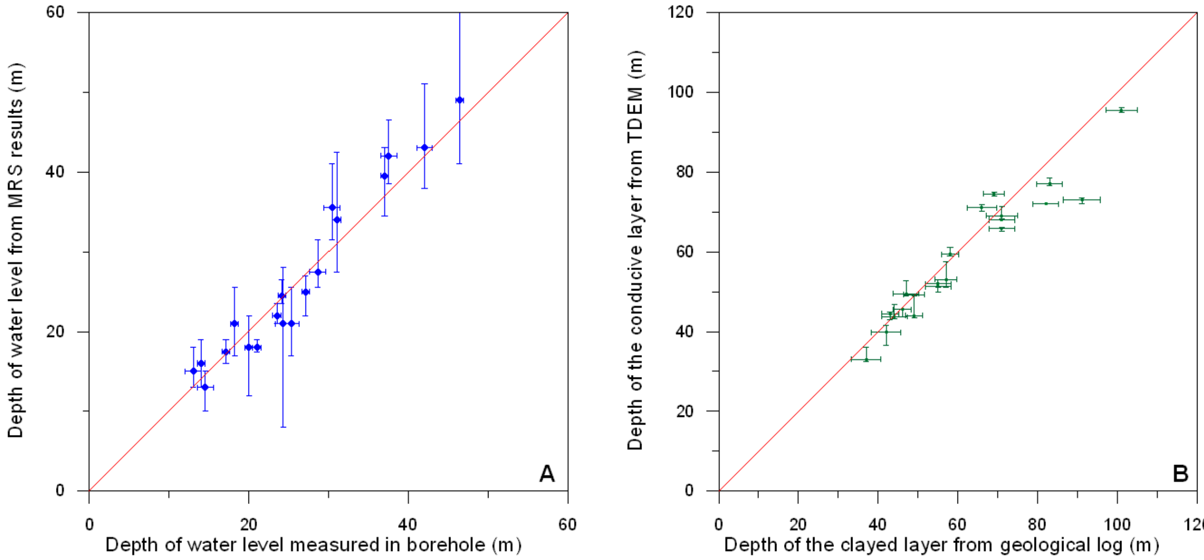

Fig. 2: Comparison of the geometry of aquifer obtained by geophysical and by invasive methods. A. Water level. B. Bottom of aquifer.

This example of application in a well-known sedimentary aquifer showed the efficiency of the MRS method combined with TDEM soundings for: (1) evaluating the groundwater resources (thanks to the porosity and the geometry); (2) estimating the transmissivity for implementation of borehole; (3) defining the ranges of hydrodynamic parameters for groundwater modelling.

References

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