MRS AND RESISTIVITY CHARACTERISATION OF THE RINGELBACH CATCHMENT AQUIFER, VOSGES MASSIF, FRANCE

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INTRODUCTION

In the crystalline Vosges massif, where the bedrock is mainly composed of intensely weathered and deformed granitic and metamorphic hard rocks, water supply is mainly derived from small aquifers in the heterogeneous surficial formations and in the weathered and fissured bedrock. The geometry and hydrodynamic properties of these aquifers are still poorly known. The small Ringelbach research catchment (36 ha; 750-1000 m a.s.l.; 75% pasture and 25% forest), which has been studied since 1975, is highly representative of this type of environment (Ambroise, 1995; Ambroise et al., 1995). Several geophysical techniques have been applied to investigate the 3-D structure of the subsurface, which is composed of two types of granite partly covered by Triassic sandstone. The main goal of this study is a better understanding and numerical modelling of the hydrologic behaviour. A preliminary resistivity map of the surficial formations obtained using many short AB/2 vertical electrical soundings (VES) has made it possible to identify several contrasted formations (Schott et al., 1996). Since 1999, 25 magnetic resonance soundings (MRS) along transects and 7 long resistivity imaging profiles across the main geological formations have been performed.

SIGNAL-TO-NOISE RATIO CONDITIONS

The MRS, recorded using a 37.5-m-side figure-of-eight-shaped antenna, show a low signal amplitude (<30 nV) and a high environmental noise level (between 200 and 9000 nV, figure 1a). The signal-to-noise ratio (S/N) was improved by applying to each sounding a 100- to 300-stack program using the weighting technique described in Legchenko and Valla (2002), and a notch filter centered on 50-Hz-harmonics (Legchenko and Valla, 2003). As a result (figure 1b), the maximum amplitude of the measured signals is close to the instrumental noise value (stacked environmental noise to instrumental noise ratio EN/IN < 3), but the signal-to-noise (filtered) ratio (S/N) is generally low, i.e. less than three. Careful analysis of the data shows that 13 MRS can be modeled (figure 1b). A maximum possible value of water volume and water content per unit surface (V_W) will nevertheless be estimated for the remaining 12 MRS.

MRS ANALYSIS IN RELATION TO THE GEOLOGICAL SETTING

A preliminary analysis of the MRS data in relation to the geological setting of the site (figure 2) shows that sandstone clearly provides better MRS characteristics (amplitude and relaxation constant) than granite. Examination of the resistivity map obtained from interpretation of the electrical soundings (figure 3) shows that sandstone and fresh granite, both characterized by high resistivities, cannot be differentiated electrically, but only by MRS data. Conversely, low and high resistivity areas in the granite are not distinguished by contrasted MRS characteristics. The low resistivity area, corresponding to MRS characteristics that are as poor as the high resistivity fresh granite, is attributed to unsaturated weathered granite.

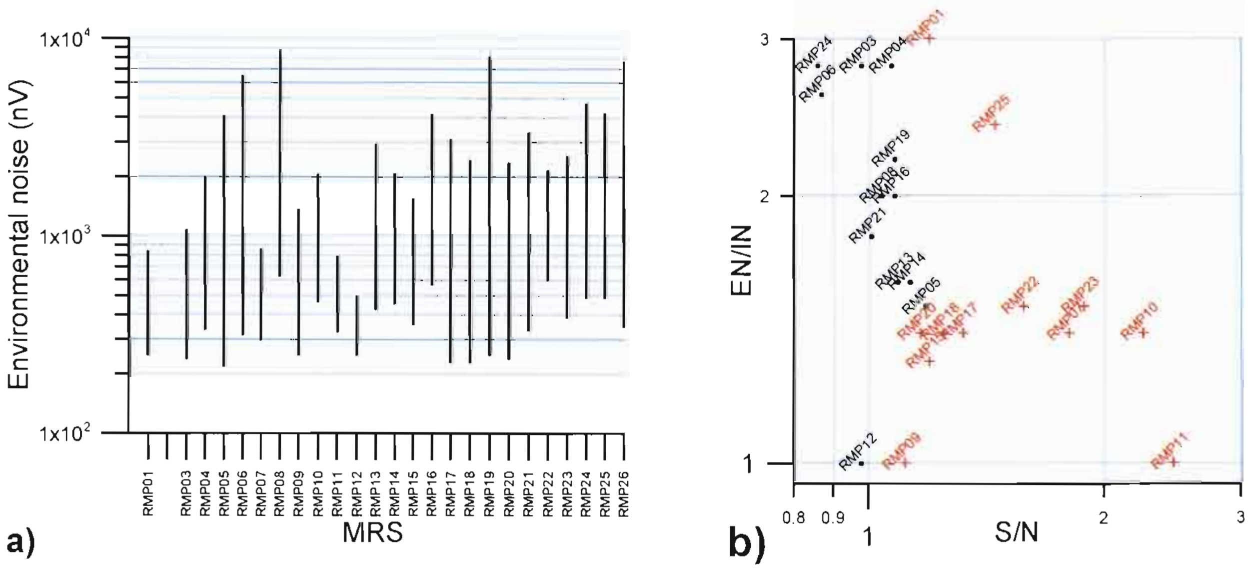

Figure 1: a) Range of environmental noise level. b) Quality evaluation based on the signal-to-noise ratio (S/N) against the stacked environmental noise to instrumental noise ratio (EN/IN). The MRS that can be modeled are represented by crosses.

WATER STORAGE MAPPING

As for any geophysical investigation method operating from the surface, the inversion of MRS in terms of the water content (W) and thickness (e) of a given layer may lead to differing modeling results because of equivalence problems. For example, two layers with respective MRS characteristics (W_1, e_1) and (W_2, e_2), situated at the same depth, that satisfy the relationship $W_1 . e_1 = W_2 . e_2$, fit equally well a given MRS experimental data set. These two layers are said to be equivalent. The water volume per unit surface (V_W), defined as $V_W = \Sigma W_i . e_i$, is thus better determined by MRS than W_i or e_i, which cannot be determined separately without external information. V_W is expressed in m^3/m^2 and has the dimension of a height.

Within the granite area, where no thickness or water content data are available, the best result that MRS can provide is V_W. For the soundings that cannot be modelled, a maximum possible value of V_W is estimated from a linear relationship established between V_W and the maximum signal amplitude of the modeled soundings of the granite. The map of V_W (figure 3), which shows a good agreement with the sandstone/granite geological boundary, is proposed as a basis for evaluating the water storage within the catchment.

A FAULTED STRUCTURE REVEALED BY MRS AND RESISTIVITY

Assuming that sandstone can be considered as a homogeneous reservoir, we attempted to model RMP7, RMP10 and RMP11 with a one-layer model of constant water content, with layer thickness being defined by resistivity imaging profiles. A very constant water content, ranging from 2.7 to 2.9%, is obtained and is thus considered as being characteristic of this formation. The NNW part of the cross section presented on figure 4, combining MRS and electrical measurements, suggests a block structure cut by a fault that downthrows the southeastern block with respect to the northwestern block.

CONCLUSION

It was possible to define the general structure of the catchment by electrical methods in conjunction with MRS, which also enabled mapping of the water volume per unit surface within the different geological formations and blocks. The corresponding map is proposed as a basis for evaluating water storage within the catchment. These results were obtained despite difficult signal-to-noise conditions (S/N < 2.5) and only half of the soundings being suitable for modeling.

The mean water contents of less than 1.5% for the granite are particularly low in comparison to similar granitic environments elsewhere, for example, in French Brittany (Wyns et al., 2003). Although a water content of 1% is not surprising for fissured granites, values of 3 to 5% are more common for weathered granite. The areas where low resistivity indicates weathered granite are thus interpreted as being unsaturated.

It is foreseen, in the framework of this project, to drill boreholes intersecting the different geological formations and sited by geophysics in order to check and calibrate the geophysical results. It is expected that these data will improve the accuracy of hydrogeological modeling.

ACKNOWLEDGEMENTS

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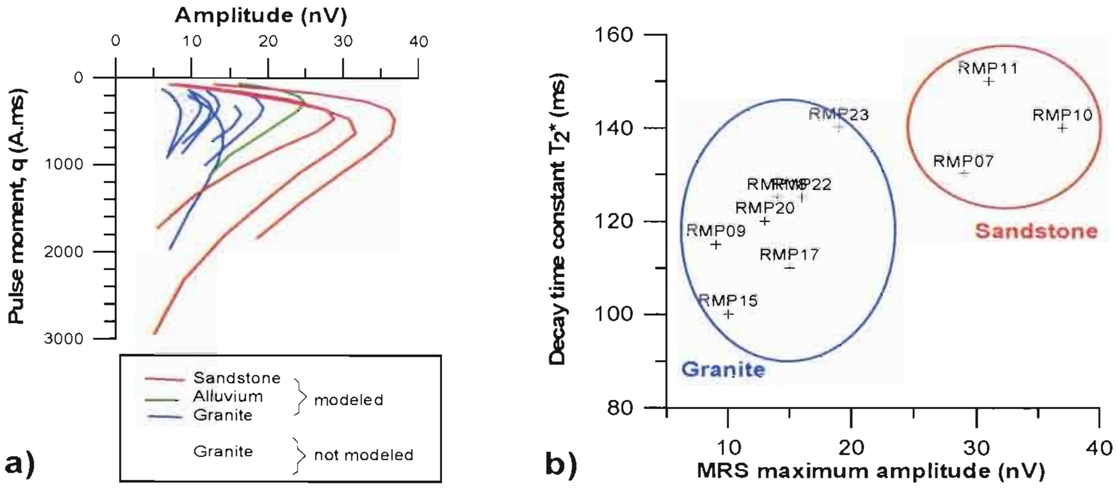


Figure 2: a) Comparison of MRS amplitudes from various presumed geological environments. b) MRS characteristics compared to the presumed geological environment of sounding.

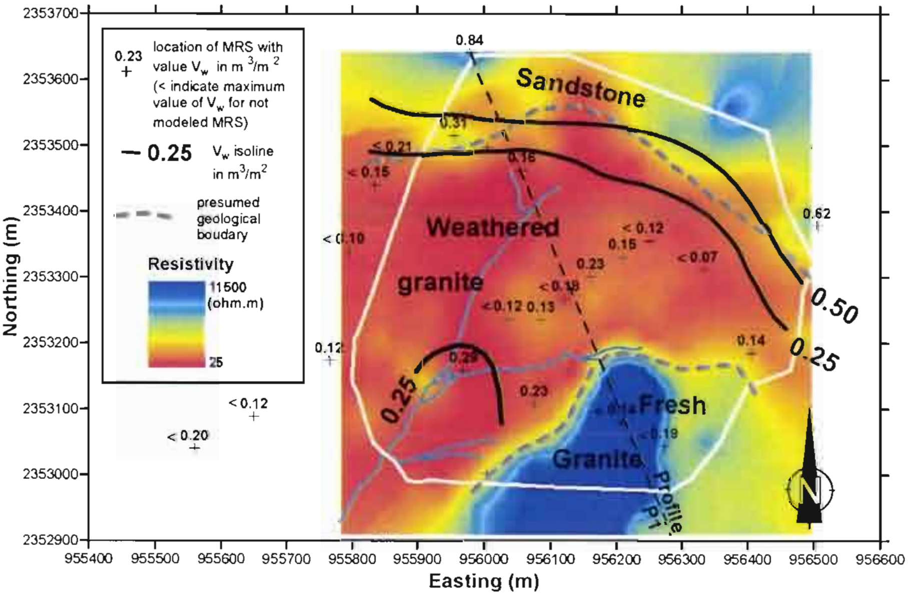


Figure 3: Map of water volume per unit surface (V_W) overlying the resistivity map at 13 m depth, results of VES interpretation and indication of geology.

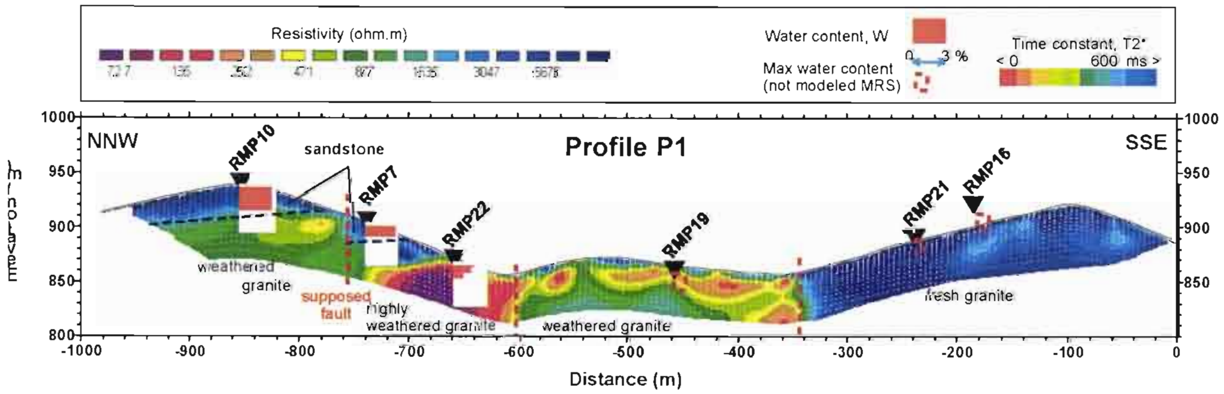
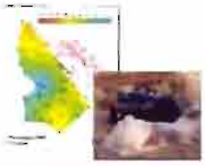


Figure 4: MRS and resistivity cross section through the catchment.



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