INTEGRATED STUDY (MRS, GPR AND 2D ELECTRICAL IMAGING) OF GROUNDWATER IN A 2D GEOLOGICAL CONTEXT

Henri Robain[1], Christian Camerlynck[2], Fayçal Rejiba[2], Anatoly Legchenko[1,3], Jean-Michel Vouillamoz[1], Charlotte Martin[4]

[1]Institut de Recherche pour le Développement (IRD), UR R027 GEOVAST ; 32 avenue Henri Varagnat 93143 Bondy Cedex France
[2]Université Paris 6 UMR 7619 Sisyphe ; 4 place Jussieu 75252 Paris Cedex 05 France
[3]BRGM, Development Planning and Natural Risks, 3, avenue Claude Guillemin, BP 6009, Orléans Cedex, France
[4]INRA UMR Sol-Agronomie-Spatialisation de Rennes-Quimper ; 65 Route de Saint Brieuc 35042 Rennes Cedex, France

INTRODUCTION

This paper presents an integrated geophysical study undertaken in French Brittany on a small catchment 15km south of Quimper (Figure1). In such catchment, high levels of manure corresponding to intensive agricultural land use, lead to an environmental hazard with worrying nitrate concentrations in surface and ground waters. In this region, there is hence a major interest to shallow groundwater characterization. The crystalline basement may be considered as impervious relatively to the weathered materials. As a matter of fact, the hydrological and geochemical processes involved in streamwater fluxes at outlet of the catchment are mainly related both to fast run off phenomenon during rainy events and to backward fluctuations in shallow groundwater quantity and quality.

GEOPHYSICAL METHODS INVOLVED

Near surface geophysics applied to hydrogeology more and more associates MRS and electric imaging. GPR because of its strong sensitivity to conductivity, acts like a complement to characterize structural organization down to a few meters depth. .In Kerbernez area, many boreholes were drilled in addition to MRS survey and 2D electric imaging profiles to follow the hydrogeological processes.

The hereafter described survey associates MRS, GPR and 2D electrical imaging along a 500 m profile (Figure 1). 6 MRS were done using NUMIS^{plus} equipment (Iris Instruments) and a so called "height square loop" with 37.5m side length. The 2D electrical imaging was made along the same profile using SYSCAL R2 MULTINODE system, with 64 electrodes and using a "roll along procedure. The chosen inter-electrode spacing was 2m and measurements were made using 4 different electrode configurations (Wenner alpha, Wenner beta, forward and reverse pole dipole). The GPR survey was made on the first half of this profile using a Pulse Echo 100 equipment (Sensor and Software) with 50, 100 and 200 MHz antennas.

RESULTS – INTERPRETATION

MRS survey shows that the noise level is rather important in the area (800-8000 nV). On the contrary, the MRS signal is generally weak (<90 nV). Nevertheless, using a "height square loop" that allows to reduce noise influence; it was possible to characterize ground waters between 0 and 40 m. The top of the aquifer varies between 2 and 6 m, in good agreement with piezometric observations, and its thickness lies between 10 and 40 m. The most important water bearing structure is located close to the outlet of the catchment. The estimation of hydrological parameters shows a large spatial variability for such an aquifer. Particularly hydraulic transmissivity varies between $2{,}6.10^{-5}$ à $2{,}6.10^{-3}$ m²/s.

Electrical imaging allows to precise the lateral extension of water bearing structures revealed by MRS. It also allows to identify vertical structures that may be interpreted as faults in the granitic basement and that may explain the important variations of weathered materials thickness along the surveyed profile (Figure 2).

GPR profiles were done along 210 meters, down the northern slope of the watershed, between borehole 1 to 6 throug 4. The radargrams are shifted using the topography. Three frequencies were used 50MHz, 100MHz, 200MHz that respectively allow depth investigation of approximatively one, three and 10 meters depending of the attenuation distribution. Nevertheless, in the radargrams time scale is still used because of the difficulties to give a proper velocity distribution. Furtermore, the higher the antenna frequency, the better the accuracy for underground details description.

Attenuation is generally due to clay and water content, while granite even in their altered form lead to good penetration. Along the profile we distinguish two propagation conditions:

- fractured and weathered granite does not imply strong attenuation, but many diffraction pictures due to fracturation ;
- high electrical conductivities lead to strong attenuation of the GPR signal.

Those zones are underlined in respectively in blue line and red arrows (Figure 3). When compared to the 2D electric imaging, GPR sections show good qualitative correlation (takein into account that the discrepancy between investigation depths for electric and GPR survey. Conductive and resistant anomalies in electric imaging correspond to the zone were GPR signal is strong and weak; and this is true for all frequencies.

Between 150 and 210 meters along the profile the presence of water near the surface (top of the groundwater) induced increasing apparent frequency in the signal, which is in accordance with MRS survey interprtation. On the other hand, the lack of accuracy of the MRS survey (comparing to GPR) does not allow a good correlation between the level of fracturation in the granite well evaluated in GPR, and the hydraulic conductivity determined from too few surveys in MRS.

CONCLUSIONS

In conclusion, it appears that 1D MRS application in contexts that present strong spatial variations is feasible. Nevertheless complementary measurements using 2D electrical imaging and/or GPR seem necessary in order to estimate more accurately the geological settings or the lateral extension of water bearing structures revealed by MRS.

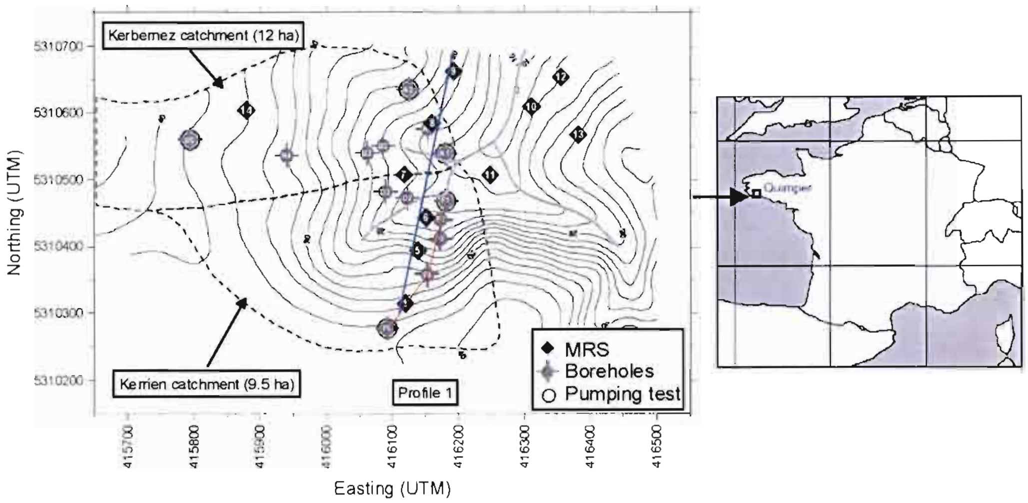

Figure 1 : Kerbernez watersheds (French Brittany): situation map of survey - MRS, boreholes, pumping test + roll-along electric acquisition (bleue lines) + GPR profiles (red lines).

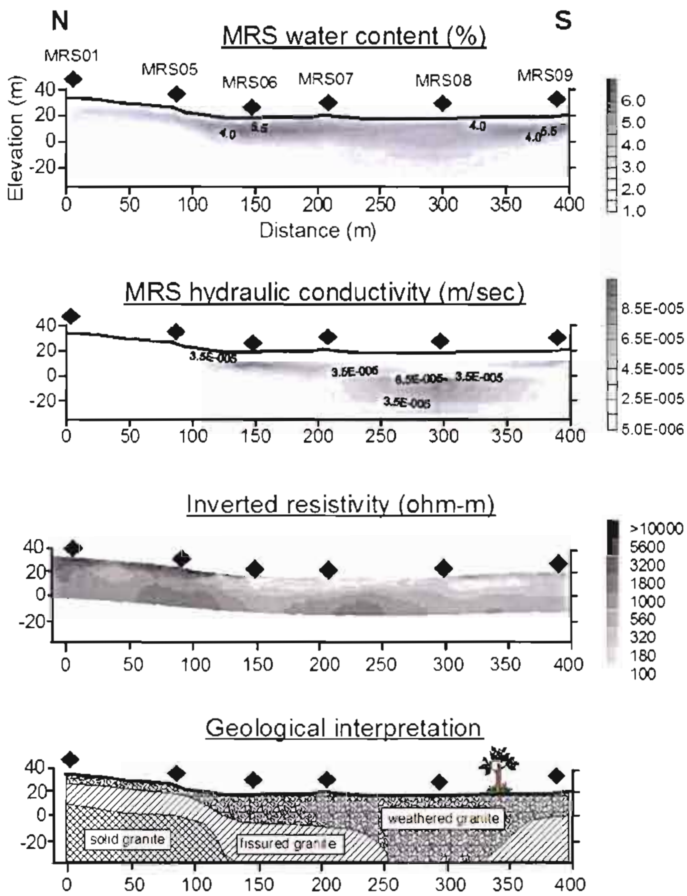

Figure 2 : MRS interpretation in hydraulic conductivity and water content versus electric resistivity imaging. Geological interpretation is shown below.

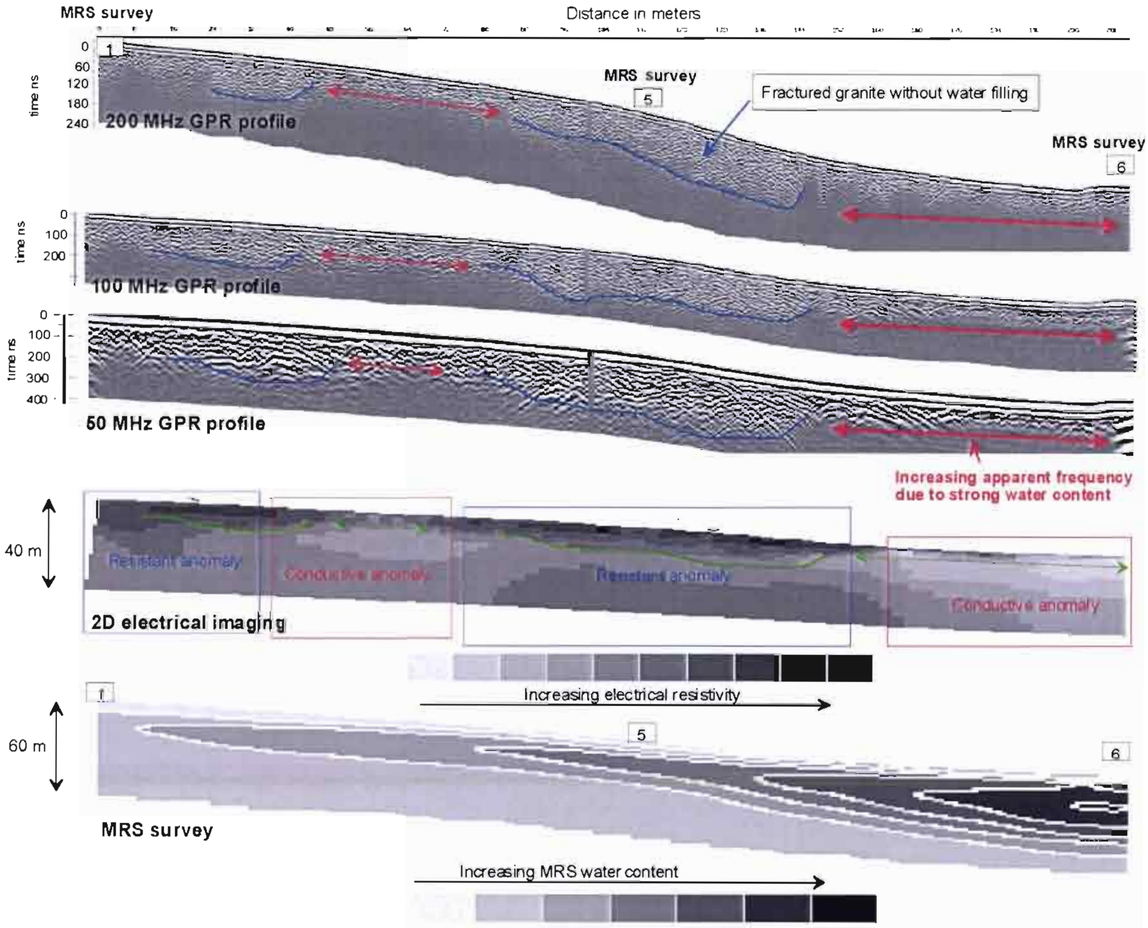

Figure 3 : GPR 50, 100 200 MHz profiles, 2D electrical imaging, and MRS water content distribution.

MRS

2[ND] INTERNATIONAL WORKSHOP

on the Magnetic Resonance Sounding method applied to non-invasive groundwater investigations

19 - 21 November 2003 - Orléans - France

PROCEEDINGS

<u>Organizer</u>

brgm — Geoscience for a sustainable Earth

<u>Co-organizer</u>

TU berlin

<u>Support</u>

IRIS Instruments

EAGE — European Association of Geoscientists & Engineers