REMAPRO - Cartographie 3D de la perméabilité des aquifères par REsonance MAgnétique PROtonique et mesures géophysiques couplées pour une meilleure estimation des risques sur les sites pollués.

REMAPRO project - 3D mapping of hydraulic permeability using PROtonic MAgnetic REsonance and joint inversion of geophysical methods at a site scale for a better estimation of pollution risks.

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Objectives & main tasks of REMAPRO project

• From MR sounding (pre-existing technology) towards 2D/3D tomography (task 1)
• Quantitative interpretation (task 2)
  – Calibration of the response in various geological contexts
  – Probabilistic & Multi-parameter modelling
• New generation of MR equipment (task 3) to make measurements
  – More accurate
  – More robust: main drawback for application is the electromagnetic noise of industrial electric current (50 Hz harmonics).
• On-site validation of the new methodology (task 4)
  – on polluted areas currently under investigation with detailed and validated documentation used as test-sites (where the aquifer has a complexity).
Impact of the developed methodology & tools for environmental studies

• Increase reliability of aquifer characterization
  – Better flow model
  – Better risk assessment or remediation
• Proton Magnetic Resonance is non-invasive
  – measured from the surface, without borehole
• Combined with other informations (logs, geophysics) it leads to spatialize objectively and quantitatively the aquifer properties
Characterization of heterogeneous near-surface materials by joint stochastic approach

Girard Jean-François, Lalande Jean-Marie, Grandjean Gilles, Roulle Agathe, Bitri Adnand, J-M. Baltassat, Legtchenko A.
Ground electrical resistivity measurement

- 4 electrodes array

$$\rho = \frac{\Delta V}{I} K$$

Vertical electrical sounding (VES in 1D) or electrical imaging in 2D/3D
Ground electrical resistivity measurement

- Mesure de la variation du champ d’induction secondaire
- Distribution de la valeur des résistivités en fonction de la profondeur
- Adapté au milieu stratifié
- Profondeur d’investigation : fonction de la boucle. En général, jusqu’à 200 mètres
- Détection de couches conductrice

Time Domain Electro-Magnetism (TEM)
Magnetic resonance Sounding (MRS or PMR)

- Principle of Nuclear Magnetic resonance used in MRI
- Based on the resonance of the H+ of the water molecule \(\Leftrightarrow\) method specific to direct detection of groundwater
Magnetic resonance Sounding (MRS or PMR)

**PMR parameters:**
- Water content (porosity)
- Relaxation time (pore size)

Estimate of hydraulic permeability
A priori information: lithofacies
A priori information : lithofacies
Application to a synthetic case

> Inversion of a synthetic VES / RMP dataset
  • with 5% gaussian noise
Application to a synthetic case
Inversion VES / **RMP**

- **Water Content**
- **MRS water content (%)**
- **Layer Number**
- **Water content**
- **Likelihood**
Correlation matrix ≈ resolution matrix

Correlation matrix: rho parameter

Correlation matrix: water content parameter

Layers strongly dependent = 1 single layer

Strong anti-correlation = equivalence phenomenon = limit of resolution without additional extern constraint
Smooth model inversion

Mesh is composed of 30 layers 2 meters thick + half-space
Inversion VES / RMP
Inversion VES / RMP
Characterization of heterogeneous near-surface materials by joint stochastic approach

> **Joint inversion of geophysical data**

- Reduce equivalence problem by multiphysics / independent methods
- « facies » inversion (lithologic inversion etc.)

> **Stochastic approach (Metropolis algorithm)**

- Statistical results of interpretation
- Sensitivity and accuracy estimation of the model
- Scenarii Analysis (filtering the satisfying models through additional criteria)

> **Outlooks**

- Seismic (SASW) integration with MRS and electrical methods
- Use physical laws (Archie etc.) between parameters as an additional constraint
- Apply it in 2D / 3D (MRS is ruled by linear with water content equations: fast !)
- Use spatial variability as an input information (correlation length etc.)
Characterization of heterogeneous near-surface materials by joint stochastic approach

> Joint inversion of geophysical data

• Reduce equivalence problem by multiphysics / independent methods
• “facies” inversion (lithologic inversion etc..)

> Stochastic approach (Metropolis algorithm)

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2D – 3D MR tomography

Girard Jean-François, Legtchenko A.
From interpolation of 1D results...
...towards a true 2D/3D tomography.

Test-site Montreuil-sur-Epte: 2D vertical section (above) & water content map (right)
Conclusion

> A new methodology with a large potential of application

> After the project (end in december 2009)
  • Industrializing the prototype in a commercial equipment
  • Diffusion of the methodology and the results of the on-site validation

> Thanks for your attention!
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