Remote sensing and hydrogeophysics for hydrogeological conceptual models of hard rocks

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Remote sensing and hydrogeophysical methods supported by field observation, were applied in the Sardon (Spain) experimental hard rock catchment (80km²) to define its conceptual model, further used to develop integrated hydrological model of that area. In line with a general conceptual model of hard rock aquifers, we identified two main hydrostratigraphic layers - a saprolite layer and a fissured layer. Both layers were intersected and drained by fault zones that control the hydrogeology of the catchment. The spatial discontinuities of the saprolite layer were well defined by RS techniques while subsurface geometry and aquifer parameters by hydrogeophysics. The processing of high-resolution satellite images and digital terrain model allowed mapping efficiently the main fault zones and the horizontal distribution of the hydrostratigraphic layers. The GPR method was able to detect shallow water table although the quantitative assessment of the water table depth could not be made routinely because it required local calibration based on measurements made in piezometers and soils and was restricted to the locations with water table depth <3 m b.g.s. The ERT method allowed to confirm local subsurface hydrostratigraphy and provided input for the MRS inversion. The multi-frequency FDEM method combined with the laterally constrained inversion technique showed to be very efficient, providing long cross-sections depicting large hydrogeological structures coherent with direct field observation, geological mapping and drilling. The MRS provided valuable results in the saprolite layer, but only in the locations with sufficient signal to noise ratio. The proposed multi-technique method of hydrogeological characterization of complex hard rock catchments, involving non-invasive, so cost effective techniques such as remote sensing and hydrogeophysics, turned to be highly suitable for development of hydrogeological conceptual models in hard rock environments.
REMOTE SENSING AND HYDROGEOPHYSICS FOR HYDROGEOLOGICAL CONCEPTUAL MODELS OF HARD ROCKS

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Presentation plan

• Need for reliable conceptual models (CM);
• Description of the Sardon hard rock study area
• Remote sensing for CM of hard rocks;
• Hydrogeophysics for CM of hard rocks;
• Conclusions
Conceptual models of hard rocks

- Role of hard rocks in water supply;
- Importance of conceptual models;
- Old vs new concept;

From a new hydrogeological conceptual model for hard rock aquifers to enhanced practical applications (survey, management of the water resource, modeling, protection, etc.)

P. Lachassagne¹, Ahmed Sh.², B. Dewandel¹, N. Courtois¹, F. Lacquement³, Maréchal J.C.¹, Perrin J.⁴, Wyns R.³
What is needed and can be provided by non-invasive methods (RS and hydrogeophysics)?

- Geometry of a system (identification of major faults and fracture systems, water table, aquifer boundaries etc.)
- System parameterization (flow and storage properties of a system)
- Spatiotemporal fluxes
HARD ROCK STUDY CASE - SARDÓN CATCHMENT

- Semi-arid climate
- Weathered and fractured granite
- Shallow water table (~2 m)
- Limited human influence on water resources
- 22 years continuously operating monitoring network
Sardon catchment - dry & wet seasons
REMOTE SENSING CONTRIBUTION TO CONCEPTUAL MODELS
Remote sensing for soil and outcrop mapping
Remote sensing for fracture mapping

Remote sensing identification of tree canopies for tree transpiration and interception mapping


Other remote sensing applications

- Rainfall;
- Evapotranspiration
- Soil moisture
- Subsurface (GW) water storage
HYDROGEOPHYSICS
CONTRIBUTION TO CONCEPTUAL MODELS
Groundwater table depth with GPR

Ground penetrating radar (GPR) in its standard implementation

Top soil thickness with electromagnetic methods

Hydrostratigraphic layering with MaxMin

Multi-frequency (444 Hz to 56 kHz) EM in horizontal coplanar loops system (Slingram) on a rigid frame

Magnetic Resonance Sounding for aquifer parameterization

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For saprolite validation
For fractured granite validation

Geological settings: highly weathered granite in fault zone

Remarks: Air flow development 15mn from 32m to 35m (column inserted at 28m up to 32m)
Conceptual models developed


CONCLUSIONS

- Remote sending is suitable for surface, spatial and some spatio-temporal contributions to conceptual models in hard rocks;
- Different non-invasive hydrogeophysical methods contribute differently to conceptual models in hard rocks:
  - GPR could detect water table but only in <3m depth and only when referenced to piezometers;
  - ERT was supportive in subsurface layering but not time efficient
  - Among EM methods the most successful was FDEM, providing similar quality info as ERT but in more time efficient way
  - MRS is the only method that can parameterize system, but its application was limited to sites with sufficiently strong signal (due to sufficient amount of water) that were not common
- The stratiform concept of Lachassgne et al. was implemented successfully although it was not possible to calibrate model with larger K of fissured rocks than saprolite
THANK YOU FOR COMING 😊