Gravimetric and leveling measurements for basement aquifers in West Africa
Ferhat Gilbert1, Genthon Pierre2, Mouhouyoudine Ali Houmadi2,3, Hinderer Jacques1, Hector Basile1, Yameogo Suzanne2

Hydraulic conductivity at the base of the weathering profile?

**THE MODEL**

**AQUIFER TESTING IN GRANITE AQUIFERS**

Water level changes are computed in a simplified aquifer using the finite difference Modflow package and a variable grid (dz=0.4-2500 m). A constant pumping rate of 55 m³/h is imposed during 7 days.

The geometry of the fissured layer inside the fault and outside the fault are supposed to be known from exploration geophysics. The width of the fracture zone is 40 m.

**Gravity effects**

- Direct effect: -400 nms/m for each drawdown meter
- Indirect effect (1/m² + 100 nm²) for each drawdown meter (using free air gradient of 3000 nms/m)

**DRAWDOWN RESULTS**

**Drawdown after 7 days (m)**

Drawdown decreases with increasing permeabilities K2 and K3.

Anisotropy increases with increasing K3.

**INVERSION WITH GRAVITY DATA**

**Experimental design**

It consists of 6 gravity points and 12 leveling points distributed along the fault and parallel to it. These points can be measured in one day by an experienced team.

**The objective function**

It is defined as the RMS of the differences of actual observations with those of a reference case (K2=1×10⁻⁶ m/s, K3=4×10⁻⁶ m/s, K=3×10⁻⁶ Pa⁻¹) normalized by the standard error of each measurement (Δg=200 nms/m, Δh=1 mm, Δh=0.5 m for the central borehole, and 0.02 m otherwise).

\[
OF = \frac{1}{\sqrt{N}} \times \text{SORT} \left( \sum_{i=1}^{N} \frac{(g_i - g_{ref})^2}{\Delta g^2} + \sum_{i=1}^{N} \frac{(h_i - h_{ref})^2}{\Delta h^2} \right)
\]

Where \( i \) indices refer to the reference case, \( g \) is the gravity signal, \( h \) refer to leveling, and \( r \) to the water level in the aquifer. An objective function \( r = 1 \) only can be achieved with current experimental methods. \( n_x, n_y, n_z \) are the number of gravity, leveling and water level points and \( n \) is \( n_x + n_y + n_z \).

**Gravity monitoring of aquifers**

Large experience in West Africa on sedimentary as well on basement aquifers was obtained thanks to the GHYRAF project (2008-2011, Hinderer et al., 2011).

Presently, a gravimeter can be considered as a poor tool for measuring water levels (0.5 m for 10 % porosity), but this will change with the new generation of portable superconducting gravimeters (iGrav) (better than 0.02 m)

**INVERSION RESULTS (objective function OF)**

Gravity + leveling

K2/K3 is well defined, however K2-K3 is poorly resolved

+ 2 boreholes 55 m away (Δh=0.02 m)

The two additional boreholes provide a strong constraint on the mean value of K2 and K3, but poorly resolve the difference between K2 and K3 (probably due to the poor definition of anisotropy of drawdown with only 2 boreholes).

**CONCLUSION**

- Gravity data provide information on water level fluctuations, but only a few points can be measured in one day. For weathering profiles including highly deformable clays, we propose to use combine gravity and high precision leveling.
- With current gravimeter precision, a fair constraint can be brought on the mean value of the high permeability fractured layer with a 7 days aquifer testing experiment. However, the geometry of this layer must be known (for example by exploration geophysics).
- The difference of permeability in the fault zone and outside the fault zone (K2-K3) is poorly constrained.
- 2 additional borehole provide a stronger constraint on the mean permeability, but not on the K2-K3 difference.
- With 2 nm²/s precise gravity data, both K2 and K3 could be resolved. This order of magnitude of precision fall in the range of future portable gravimeters. These results stand for an idealized granitc aquifer including heterogeneities relying on an idealized weathering profile and should be therefore confirmed by field experiments.

**References**