Petrophysic and mineralogical characterization of a perialpine gravel aquifer using geophysical logging methods. Kappelen test Site, Switzerland.

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SUMMARY

Applied to the Kappelen test site, electric and nuclear logging methods permit to determine petrophysic characteristics of the formation of saturated gravels: total porosity and density. The estimation of matrix densityvalues starting from these parameters led to the determination of dominating mineral contents in the solid phase. The obtained petrophysic and mineralogical information can be used to understainding to hydraulic behaviours and paleogegraphical history.

1. INTRODUCTION

Geophysical logging methods measure the variation of physical parameters of the formations in boreholes. The variation of these parameters makes it possible to specify mineralogical nature and determine petrophysic and hydraulic parameters. Applied to Kappelen test site, electric and nuclear logging methods enabled us to characterize saturated gravels from petrophysic and mineralogical point of view.

2. KAPPELEN TEST SITE

The site is located in Canton of Bern, close to the Swiss village of Kappelen, (Fig.1). This site forms part the Seeland aquifer. 16 wells (7 couples short well - long well and 2 long wells) were drilled by the Center of Hydrogeology of the University of Neuchâtel.

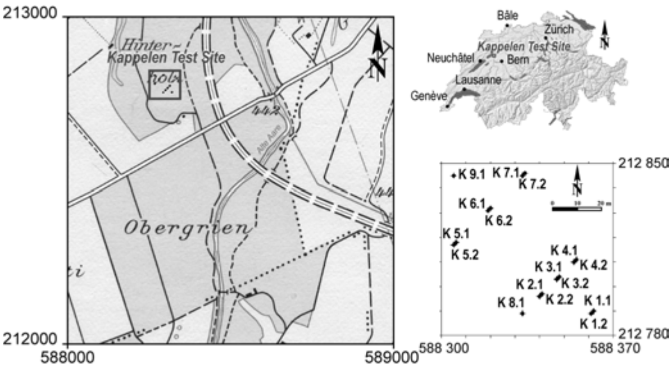

Figure 1 - **Kappelen test site location.**

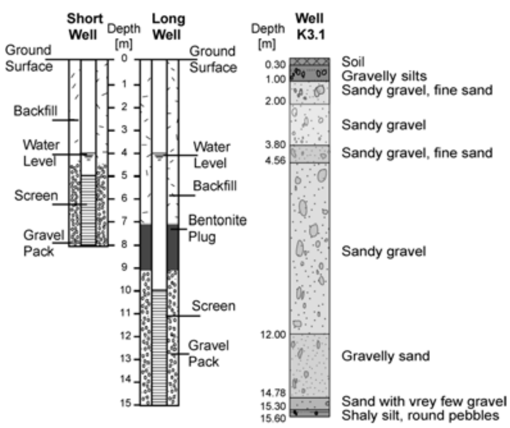

Figure 2 - **Boreholes equipments and lithology**

Visual analysis of borehole cuttings (Fig. 2) revealed that the site is underlain by approximately 15 m of unconsolidated polymineralic gravel containing 20 % of sand and silt (Flynn, 2003). This granulometric heterogeneity is due to the deltaic nature of the site (Hoffmeyer, 1995).

3. GEOPHYSICAL INVESTIGATIONS

In this work, we used electric and nuclear logging tools. The Polyprobe (2PEA-1000/F Mount Sopris) makes it possible to measure the following logs at the same time: Normal electric resistivity 8", 16 "; water electric resistivity and Gamma Ray. Laterolog 3 (Mount Sopris ILP-2491) is a focused measurement tool of electric resistivity, with a better vertical resolution.

Nuclear tools Gamma Ray (contained in polyprobe 2PEA-1000/F Mount Sopris) measures natural radioactivity of a formation which indicate its clay contents. Other nuclear tools make it possible to measure radioactivity when a formation is subjected to gamma radiation for Gamma-Gamma (Mount Sopris KLP-2780) and to a bombardment of fast neutrons for Neutron-Neutron (Mount Sopris LLP-2676). Attenuation is a function of the density of the formation for Gamma-Gamma log, and its porosity for Neutron-Neutron log.

With a sampling rate of 0.02 m, measurements were performed in all 16 boreholes of the site in the saturated zone and only in screened parts for electric tools.

4. RESULTS

Electric logs give resistivity values varying from 250 to 400 Ohm.m for saturated gravels (Fig. 3) and average of water resistivity of 28 Ohm.m.

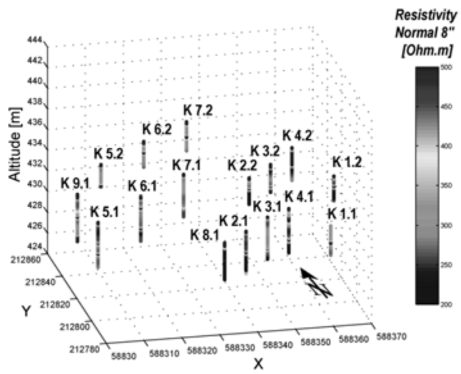

Figure 3: **Electric resistivity variations**.

Using the Archie's law (Eq. 1) with Humble's formula (Eq. 2), we obtained values of total porosity between 22 and 29 %.

$$\mathbf{R} = \mathbf{R}_w \cdot \mathbf{F} \text{ with } \mathbf{F} = \mathbf{a} \cdot \Phi^{-m} \quad (1)$$

R: Resistivity, $\mathbf{R_w}$**:** Resitivity of the imbibition water, **F**: Formation factor, Φ: Porosity ; **a**: Factor which depends of lithology and that varies between 0.6 and 2 (a < 1 for rocks with intergranular porosity and a > 1 for rocks with fractured porosity) and **m**: Cementation factor (It depends of pores shape, compaction and varies between 1,3 for unconsolidated sands to 2,2 for cimented limestone.

For unconsolidated formations (Humble's formula).

$$\mathbf{F} = 0.62 \cdot \Phi^{-2.15} \quad (2)$$

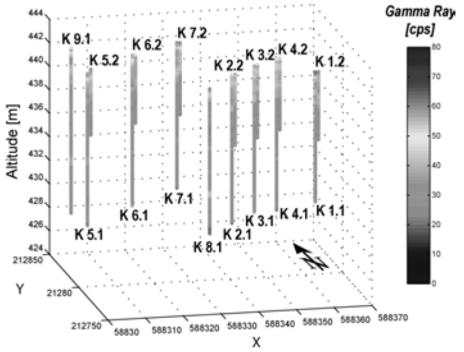

Figure 4: **Gamma Ray variations**

Low Gamma Ray values (30 to 50 cps) are representative of gravels in this area. There is no pure clay and relatively high values correspond to higher clay content (Fig.4).

$$\rho_r = (1 - \Phi) \cdot \rho_{ma} + \Phi \cdot \rho_w \quad (3)$$

ρ_r: Total density, ρ_{ma}: Matrix density, ρ_w: Water density and Φ: Total porosity.

Calibrated nuclear tools Gamma-gamma and Neutron-neutron (Baron, 2000) provided, for saturated gravels total porosity values between 20 and 30 % and total density values between 2.20 and 2.40 g/cc (Fig. 5). From these two parameters, we obtained matrix density values between 2.6 and 2.75 g/cc (Eq. 3).

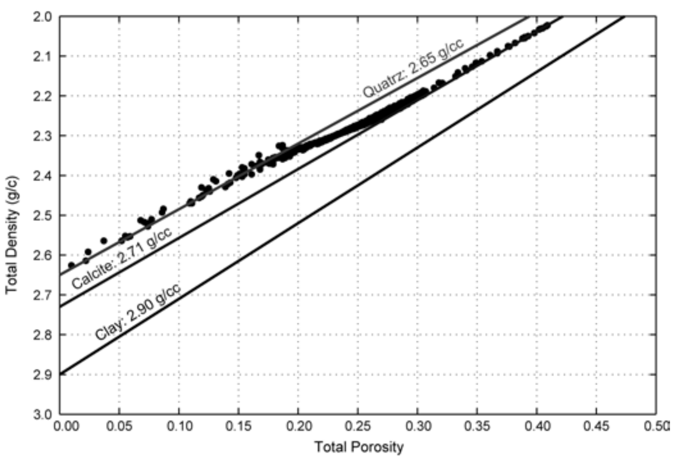

Figure 5: **Volumic analysis**

These results indicate that the matrix of these formations presents two dominating mineral phases: quartz with 2.65 g/cc and limestone with 2.71 g/cc (Serra, 1985).

These results are in agreement with mineralogical analyses results (by x-rays diffraction) of 33 samples coming from borehole cuttings (Flynn, 2003). This reveals that these two minerals constitute approximately 65 to 75 % of the mineral matrix (Tab. 1).

Table 1- **Summary of results of mineralogical analyses**

Minerals (% Vol.)	Size Fraction (µm)			
	x<63	63<x<250	250<x<500	500<x<2000
Calcite	40	25	28	41
Quartz	27	39	39	33
Feldspar	9	14	15	7
Dolomite	4	1	1	0
Sheet Silicates	6	3	3	3
Residual Minerals	15	17	14	16

5. CONCLUSIONS

Porosity values obtained by nuclear logs (from 20 to 30 %) are equivalent with that are obtained by electric logs (from 22 to 29 %). This equivalence confirms the absence of clays because Archie's law is applicable only under such conditions.

Moreover, Electric resistivity variations do not significantly correspond with those of Gamma Ray. This implies that there is no mineralogical clay. This is confirmed by the matrix density values obtained from other nuclear logging tools.

Matrix density values make it possible to highlight two minerals dominating the solid phase of gravels: quartz and calcite. These results can make it possible to define geographical origin of these deposits and to bring information concerning the paleogeography of the site.

Obtained petrophysic parameters and mineralogical indications, closely related to hydrodynamic characteristics, will permit understanding of hydraulic behaviour on this site.

Geophysical logging measurements are performed with a sampling rate chosen by the operator (0.02 m in this work), this high resolution allows realization of studies at various scales. Lastly, a good spatial distribution of boreholes permits realization of lithostratigraphic correlations for the spatial continuity of given petrophysic and hydraulics parameters variations.

6. REFERENCES

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