Petrophysical 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 petrophysical characteristics of the formation of saturated gravels: total porosity and density. The estimation of matrix density values starting from these parameters led to the determination of dominating mineral contents in the solid phase. The obtained petrophysical and mineralogical information can be used to understanding to hydraulic behaviours and paleogeographical 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 petrophysical and hydraulic parameters. Applied to Kappelen test site, electric and nuclear logging methods enabled us to characterize saturated gravels from petrophysical 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.

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 indicates 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.

Using the Archie’s law (Eq. 1) with Humble’s formula (Eq. 2), we obtained values of total porosity between 22 and 29%.
\[ R = R_w \cdot F \] with \[ F = a \cdot \Phi^n \]  

(1)

\( R \): Resistivity, \( R_w \): Resistivity of the imbibition water, \( F \): Formation factor, \( \Phi \): 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).

\[ F = 0.62 \cdot \Phi^{-1.15} \]  

(2)

\[ \rho_r = (1 - \Phi) \cdot \rho_m + \Phi \cdot \rho_w \]  

(3)

\( \rho_r \): Total density, \( \rho_m \): Matrix density, \( \rho_w \): Water density and \( \Phi \): 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).

\[ \text{Table 1 - Summary of results of mineralogical analyses} \]

<table>
<thead>
<tr>
<th>Minerals</th>
<th>Size Fraction (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x&lt;63 63&lt;x&lt;250 250&lt;x&lt;500 500&lt;x&lt;2000</td>
</tr>
<tr>
<td>Calcite</td>
<td>40 25 28 41</td>
</tr>
<tr>
<td>Quartz</td>
<td>27 39 39 33</td>
</tr>
<tr>
<td>Feldspar</td>
<td>9 14 15 7</td>
</tr>
<tr>
<td>Dolomite</td>
<td>4 1 1 0</td>
</tr>
<tr>
<td>Sheet Silicates</td>
<td>6 3 3 3</td>
</tr>
<tr>
<td>Residual Minerals</td>
<td>15 17 14 16</td>
</tr>
</tbody>
</table>

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


