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Spectral Induced Polarisation (SIP) applied on volcanic rocks of the Styrian basin (Austria)

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Introduction

The Styrian basin in the southeastern part of Austria is characterised by volcanic activity during the Miocene (23 Mio. years ago) and the Pliocene (5,5 Mio years ago).

Whereas the volcanic rocks of the Miocene are of latitic composition (high SiO_2-contents and potassium accentuated) the Plio/-Pleistocene delivered mainly basic rocks (low SiO_2-contents and sodium accentuated).

These differences in mineralogy should allow a discrimination of the physical properties. Moreover variations in grain size distribution, pore volume and density are expected to be accompanied by different petrophysical responses and thus enable a differentiation of stratigraphic arrangements, e.g tuff layers.

Seven sites were sampled including the following rock types:

basalt, basaltic scoria, tuff, lapilli-tuff and latite.

First standard parameters as porosity, density, magnetic remanence, magnetic susceptibility, elastic properties and thermal conductivity were determined at the Montanuniversität Leoben before a measurement of the complex resistivity spectra of the samples followed at the Institut für Geophysik, TU Clausthal.

Spectral Induced Polarisation

Compared to conventional resistivity measurement at a distinct frequency the complex resistivity spectra or spectral induced polarisation (SIP) delivers the resistivity and phase angle over a frequency range from 0.001 Hz up to 1000 Hz.

Resistivity is generally dominated by the properties of the pore fluid. It depends on the connectivity of pores. The phase shift between injected current and measured potential yields additional information on the pore structure of the rock sample.

Many observed phase spectra can be described by the well-known Cole-Cole model which is characterised by a single phase maximum at a distinct frequency.

However there are also spectra known who show a constant phase angle allowing a deviation of hydraulic parameters (Börner et al., 1996).

In order to understand the different frequency responses research was carried out on sandstone samples (e. g. Scott and Barker, 2003; Scott et al., 2003; Klitzsch, 2004) considering the influence of the pore geometry (e.g. pore throat size distribution).

Results

Within the laboratory measurement series, the volcanic rock samples showed a wide variation of frequency spectra. The basalt and basaltic scoria characterised by low porosities show constant phase angles. Tuff, lapilli-tuff and latite on the other hand showed a Cole-Cole model behaviour as it is know from investigations on sandstones. These are quite unique results as the SIP measurement has not been applied so-far on volcanic rocks.

The most interesting group are three tuff samples coming from one location (Burg Kapfenstein) but out of different sequences of strata. These three samples are characterised by a single phase peak in the spectra and their resistivities vary between 70 and 130 Ωm. This slight variation of the measured resistivities allows no differentiation between the strata. However using the phase spectra a clear discrimination is possible.

As the frequency of the phase peaks and their amplitudes vary the question arose what causes the specific frequency behaviour of these tuff samples. Thin section images show that the grain size distribution of the samples varies significantly.

Conclusions and outlook

It seems that SIP is an appropriate method to discriminate between tuffs and tuff layers characterising sequences of strata and thus different volcanic events.

As these are the first SIP laboratory measurements on volcanic rocks further investigations concerning the mineralogy and the properties specific internal surface, grain density and pore throat size distribution are planned in order to understand their electrical spectra. Similar research has been carried out to understand the SIP response of sandstones with the aim to deviate the hydraulic permeability from SIP measurements, This investigation should therefore contribute to a better understand of the relation between pore geometry and phase spectra.

Moreover, the availability of the mentioned petrophysical parameters provides the opportunity for a comparison and correlation with the SIP results.

References

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