Rock body classification based on geophysical measurements

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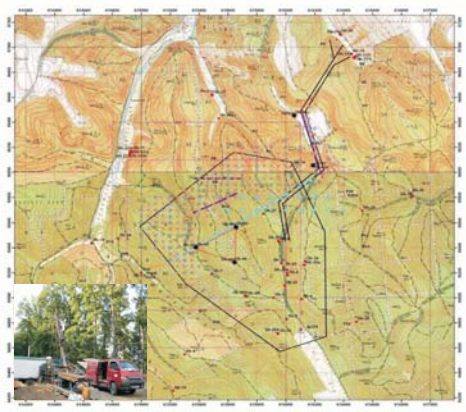
Introduction

A big volume complex geological research started in 1996 in Hungary, Bátaapáti to locate the nuclear power plant's small- and medium activity nuclear waste deposit. During the 10 years period of the surface research Geo-Log Ltd. did the well logging in 62 drills, which was about 10000 meter in total. The research has been succesfull, as the underground storage rooms handing over took place in September 2011.
This poster shows the Geo-Log Ltd.'s activity in supporting the researches, the tunnel driving and the development of the storage rooms.

Summary

The geophysical well-logging provides substantial information on surface geophysics, geology, tectonics and hydrogeology during surface geophysical exploration [1,2,4,6]. Some of the geophysical measurements (e.g. gamma ray) reveal petrological properties of the rocks, while resistivity and full acoustic waveform show the geotechnical conditions. A few deepened drills which had rock body classicfication both from the core materials and geophysical measurements, a regressive correlation can be determined, that can provide a very effective and quick rock body classification for further drillings.
A very effective and prompt rock body classification can be done based on the resistivity and acoustic measurements, which complement and considerably help to evaluate the information from the core investigation and pressure tests. These methods were made suitable for the considerably changed conditions of underground measurements.
Furthermore, we developed the method of predicting the physical properties of rocks based on geophysical well-logging.
We show some practical examples in this poster, that resistivity and acoustic methods are suitable in hard rocks (e.g., granite) to the drilled cross regions preliminary geotechnical layout quantitative characterization.



Bátaapáti surface exploration map

Bátaapáti, the Eastern and Western inclined shaft from the air

Mária shaft entrance

1. The undertaken measurements

The conditions during underground measurements differ considerably from those of surface exploration, therefore, the applied instruments were adjusted to the needs of the underground environment.

Due to the unstable electric network of the mines separator transformers and stable power supplies had to be used.
The equipment has to be protected against the intensive precipitation of humidity,
The placement of the carrier vehicle and the installment of the communication cables were successfully resolved in narrow places and under unfavorable conditions,
Due to the small diameter of boreholes 36-40 mm diameter probes were utilized,
n sub-horizontal boreholes the probes centering is a serious challenge, especially for the acoustic televiewer measurements, because this method is extremely sensitive for eccentricity,
Because the uncertain state of the boreholes and the limited time it was not possible to repeat the measurements.

Logging unit in the tunnel

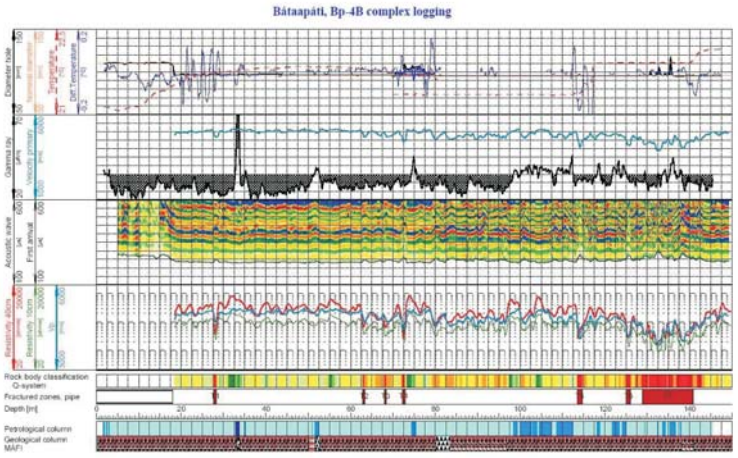
2. Applied methods and information obtained from water-saturated core drillings:

Resistivity (10 and 40 cm potentials) prediction of the physical properties of rocks (RMR = Rock Mass Rating = classification of rock bodies, Q = Quality).
Gamma ray - petrology.
Caliper (i.e., Caverns).
Temperature, differential temperature places of water influx.
Full Acoustic waveform longitudinal (V_p) and transversal (V_s) velocity, Poisson coefficient, Young- modulus, shear modulus, Strength-index, uniaxial compressional strength
Acoustic televiewer:
-caliper log (in 72 or 144 directions), ovality.
-Dip of the drilling and its direction.
-frequency of fractures (pcs/fm).
-reflecting amplitude average.
-orientation of fractures (dip, line of dip).
-classification of fractures (open, closed, semi-open etc.)
-statistical processing of the above mentioned data (rose-diagram, histogram, pole-density plots).
Optical televiewer:
-frequency of fractures (pcs/fm).
-identification of fractures (original, drifting).
-quality of material (cement-boundary etc.).

3. Bp-4B complex logging interpretation:

The entire series of measurements are presented in potential borehole Bp-4B [8]. The petrological, hydrogeological and geotechnical evaluation were done based on the measurements.
The petrological interpretation was done using the results of the gamma ray analysis considering the geological column provided by the Geological Institute of Hungary (GIS).
The low- and high value parts of the gamma ray section could be correlated well with the alteration zones identified in the cores.
The caliper log section from BHTV image indicates the individual open fractures and the strongly fractured zones, where materials falling-out from the fractures..
The temperature varies in a narrow range 20-22 °C, each and every temperature anomaly, which is indicated spectacularly by the differential temperature-curves, is associated with a particular water inflow.
The fracture zones (T1, T2 etc.) were marked based on the resistivity and full acoustic waveform sections and acoustic televiewer images.

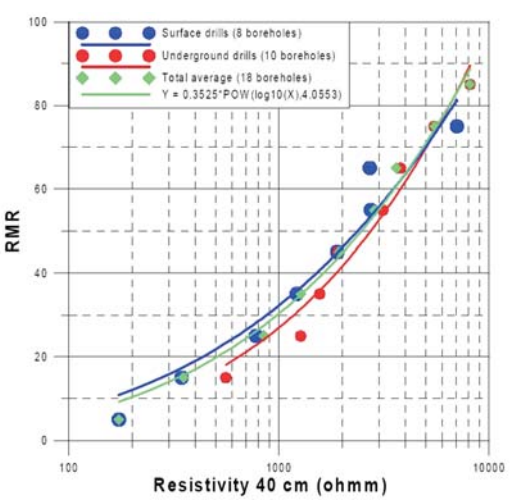
Bátaapáti, Bp-4B complex logging



4. Rock body classification

During the analysis and interpretation of the more than 10 000 m surface drillings that in granitoid rocks (most probably even every stiff, fractured rock) the resistivity and full acoustic waveform measurements represent extremely well the geotechnical state of the rock. Following the realization of this relationship, we determined the regressive connection between some electric and acoustic methods and the state of the rock [3,6] by the comparison of geophysical well-logging and rock body classification in RMR-method in 8 surface drillings [3,6]. Initially only with experimental intention, but later, at request we started doing the prediction of rock class in subsurface drillings based on geophysical well-logging [9].
When the number of underground measurements reached 10 we created the regression of the boreholes against the geotechnical RMR-values. The character of the curves obtained from the surface and underground measurements agree considerably well.
The slight difference between the curve's characters and relationships can originate from several factors which include: the underground geophysical well-loggings are implemented under different conditions than on the surface (i.e., diameter of the borehole, caverntiy, resistivity of the drilling mud, effects of sub-horizontal drillings); the descriptions of the cores were done by different firms and different experts; the conditions of drilling were changed (percentage of the core recovery, slip of the core, asymmetrical caverntiy). For the farther analysis the regressional relationship determined from underground measurements were utilized.
In the end we used the relationship between the resistvity and RMR in the evaluations, because here was the best connection, and so the rock body classification can be calculated directly from the measured resistivity log.
We show an example to the RMR and Q determination in the right figure.

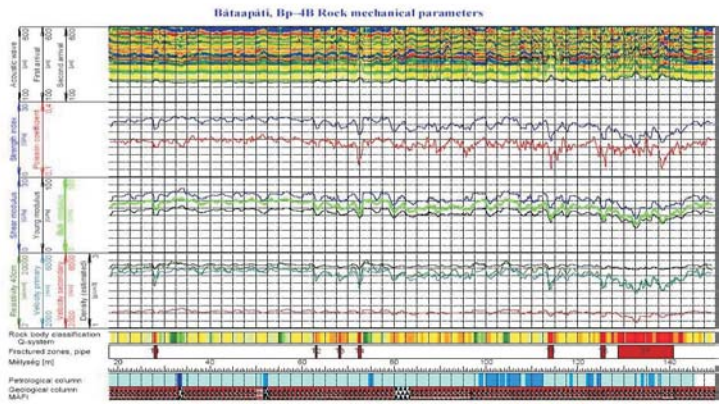
RMR regression from the surface and underground drills in Bátaapáti



5. Bátaapáti, Bp-4B rock mechanical parameters determination:

The arrival times were determined based on the full acoustic waveform logs and then the longitudinal (V_p) and transversal (V_s) velocities were calculated. We have not made density measurement in the underground drills, duo to safety reasons. The density were determined by a relationship between resistivity and density from the surface drills. From the two kinds of velocity logs and the density log, we determined the rock mechanical parameters (Young-modulus, shear modulus, strength index, Bulk modulus, Poisson coefficient).

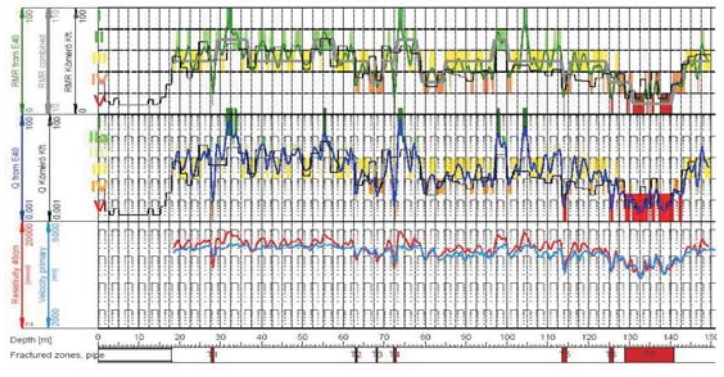
Bátaapáti, Bp-4B Rock mechanical parameters



6. Bátaapáti, Bp-4B rock body classification:

In the lower field the resistivity log and the V_p rock velocity log were plot on such a scale, that the two curves would best fit each other. The reliability of the fit would also serve to check the measurements. If the level and character of the two curves, which are based on different physical methods, are close to each other then the measurements are suitable for quantitative calculations. In the middle and upper fields the Q- and RMR-type rock body classifications are plot respectively. In both of these fields the rock body classifications calculated based on core geotechnical descriptions (Kőmérő Ltd.) and resistivity logs are displayed.
Well logging based rock body classifications benefits:
-does not require core drilling
-does not require laboratory tests
-objective
-can be prepared in situ
-cheap

Bátaapáti, Bp-4B Rock body classification

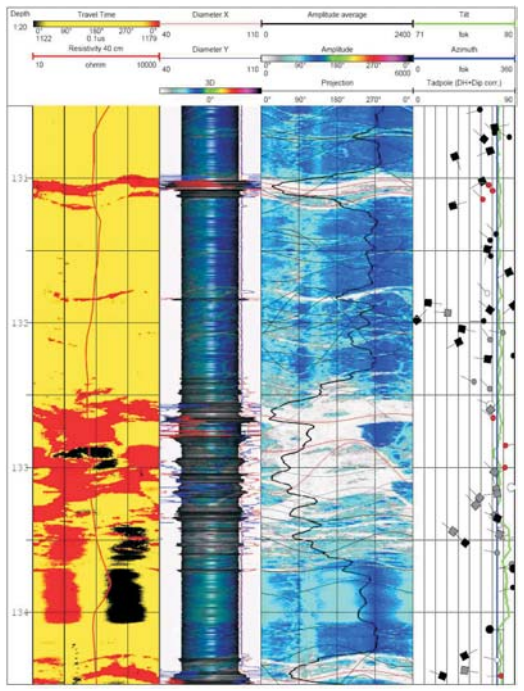


7-8. The acoustic and optical televiewers data interpretation

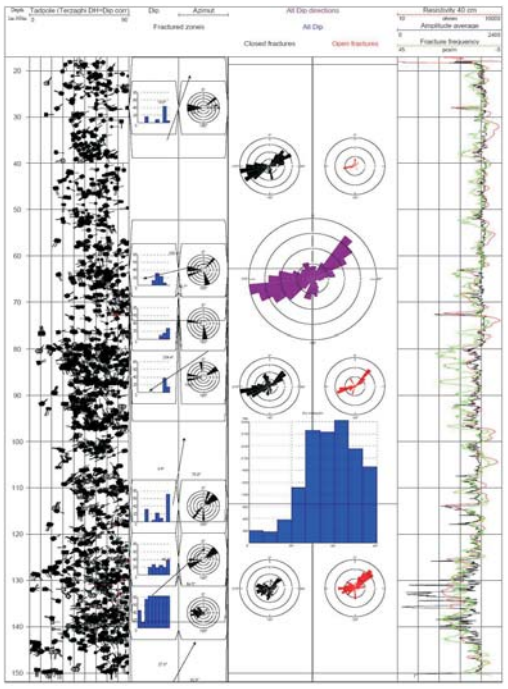
The processing of the acoustic and optical televiewer images was done according to the protocol developed during the surface explorations [2,7]. The line and angle of the dip were constrained with 10 cm resolution and then we marked the position and quality of fractures. The fractures classification was very useful to the hydrogeological interpretation, the effective water inflows are usually relate to open fractures.

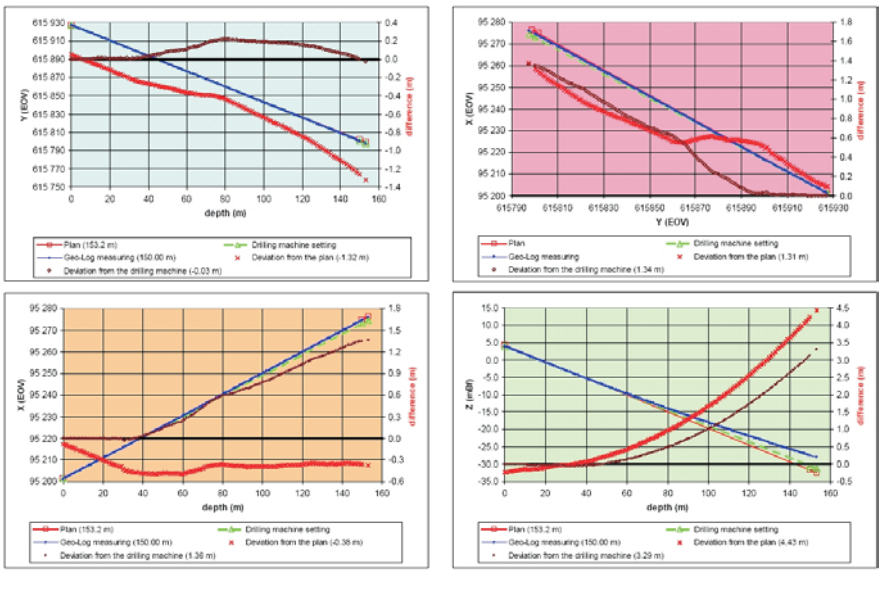
We compiled the fracture-frequency and amplitude-average log and did the fracture statistics[7]. The prepared fracture statistics from different aspects were used to the tectonic interpretation, which provided very important information on the fractured zones positions and helping to indicate the storage rooms' exact location.

Fractured zones and fracture indications



Fracture statistics



9. Bp-4B deviation plots

The real direction and dip of the borehole as well as the spatial position (X,Y,Z) of individual points were constrained by the acoustic televiewer record. The variation of the X,Y, Z coordinates are plot as a function of borehole-length as well as the deviation from the measured and set direction. In this 150 m deep borehole the deviation was especially significant (4.4 m) because the drilling differs increasingly from the depth of 40 m from the original direction. The planned and the actual direction of the drillings were usually matched well, the presented example had a big difference because during the drilling the drilling machine shift slightly from its position caused by the wrong supporting.