Long-term monitoring of rock mass properties in the underground excavation

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Monitoring of the behavior of the rock massif joint systems by means of geophysical methods.

Technology Agency of the Czech Republic
... from ideas to applications

Project no. TA03020408

- G IMPULS Ltd., Prague
- Charles University in Prague, Dept. of Hydrogeology, Engineering Geology and Applied Geophysics
- Technical University of Liberec, Institute of Systems Control and Reliability Management

The measurement / monitoring

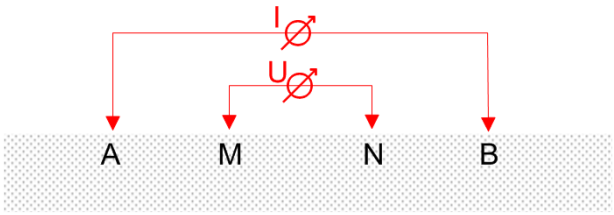
- Test site: underground gallery made by TBM (Tunnel Boring Machine)
- Coarse grained granite, measurement across macroscopically visible void
- Electrical resistivity tomography
- Seismic time of flight measurement

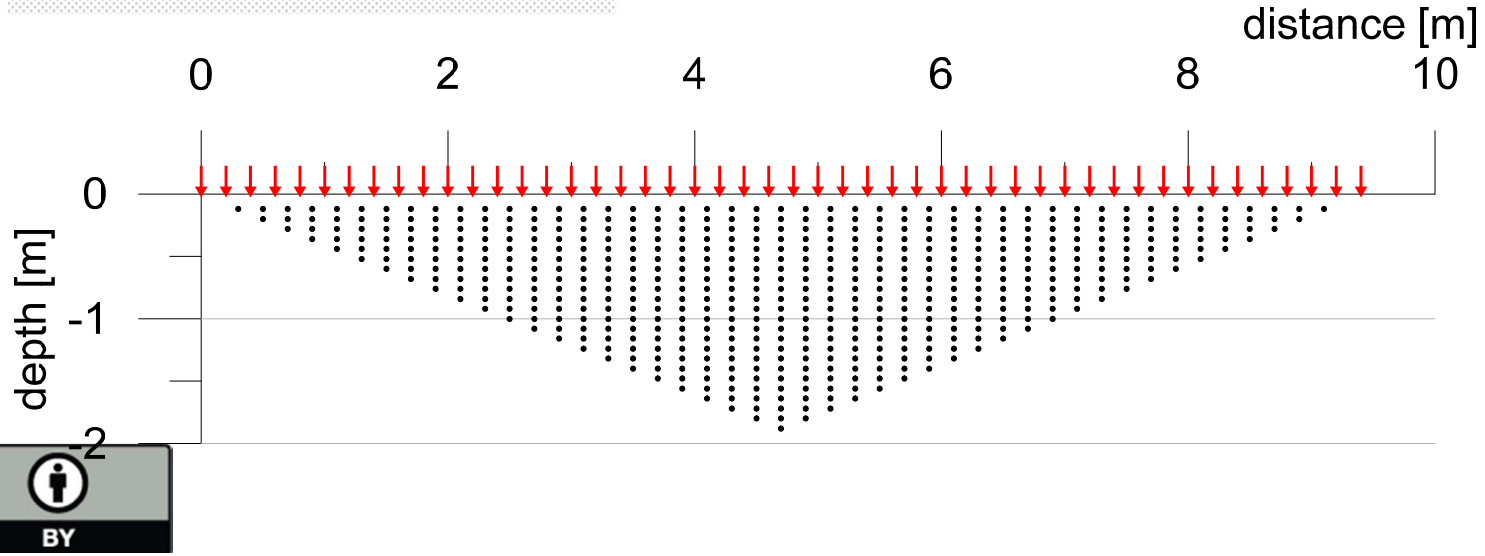
Electrical resistivity tomography

- ARES II - 10-channel automatic resistivity system, GF Instruments
- Remote control – automatic data collection over internet
- Long term monitoring – measurement every 6 hours

Electrical resistivity tomography

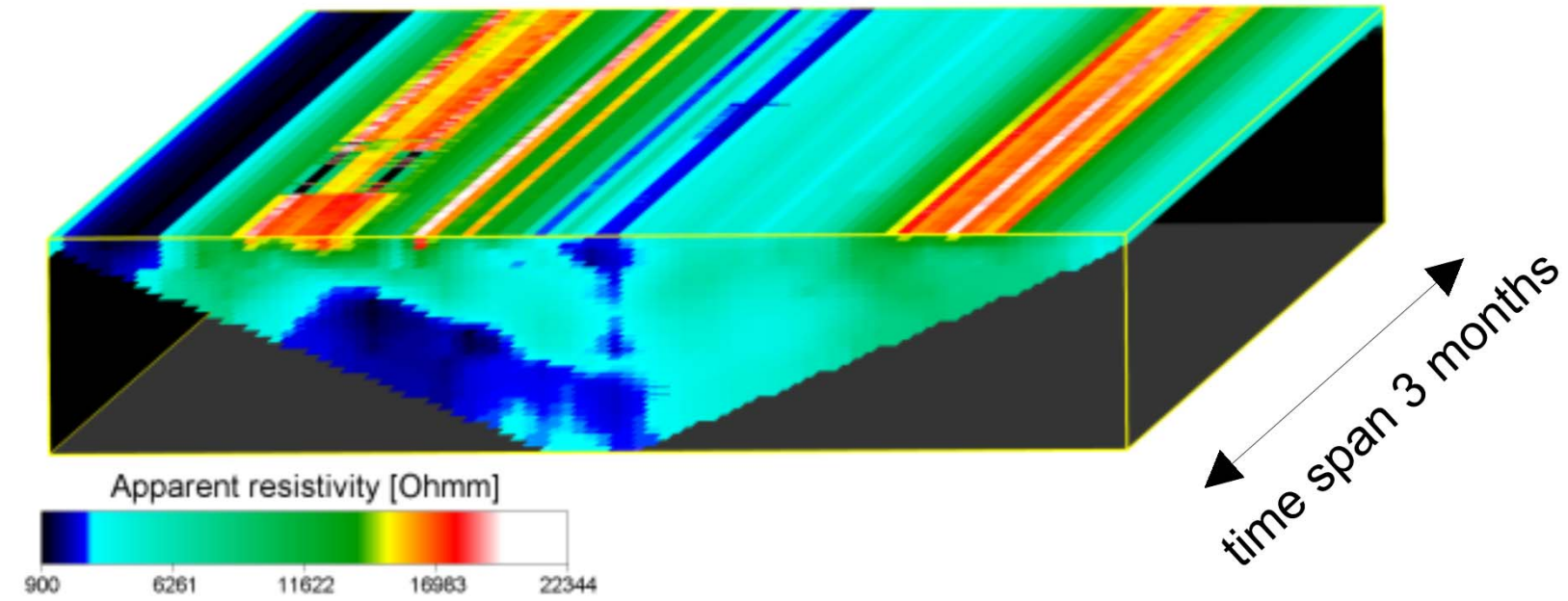
- 48 electrodes, distance 0.2 m, totally 23 different four electrode arrays (Wenner to Schlumberger)
- depth = AB/5



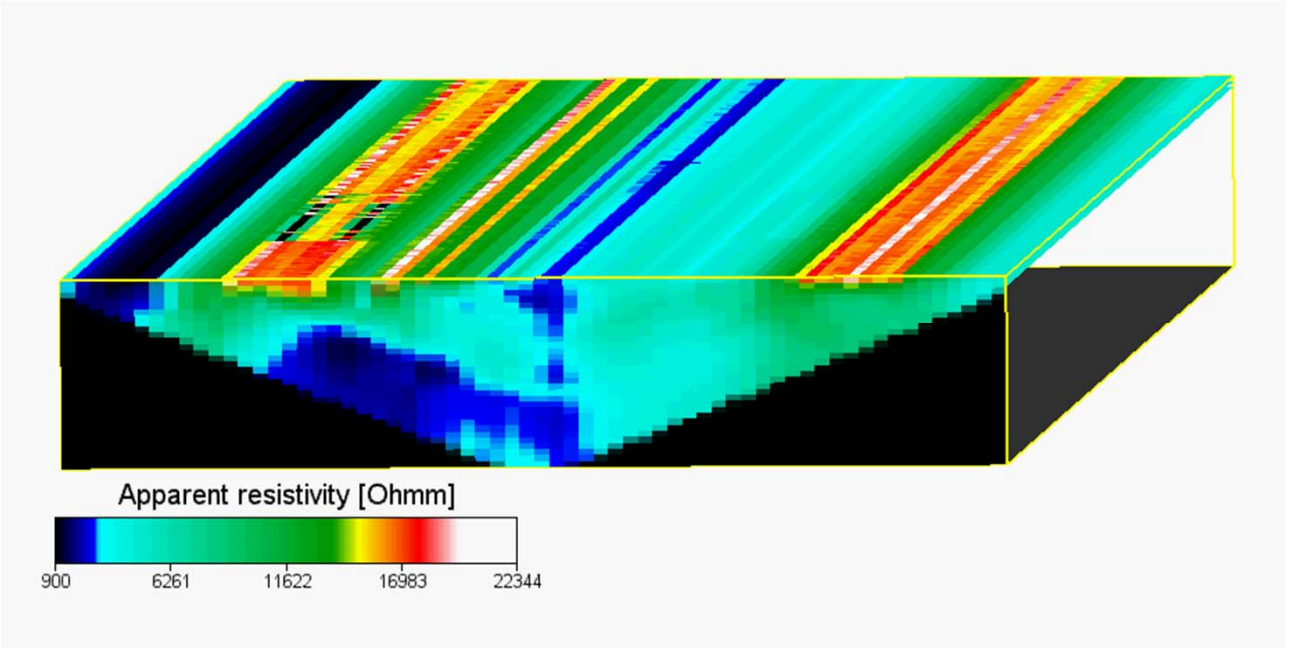


Electrical resistivity tomography

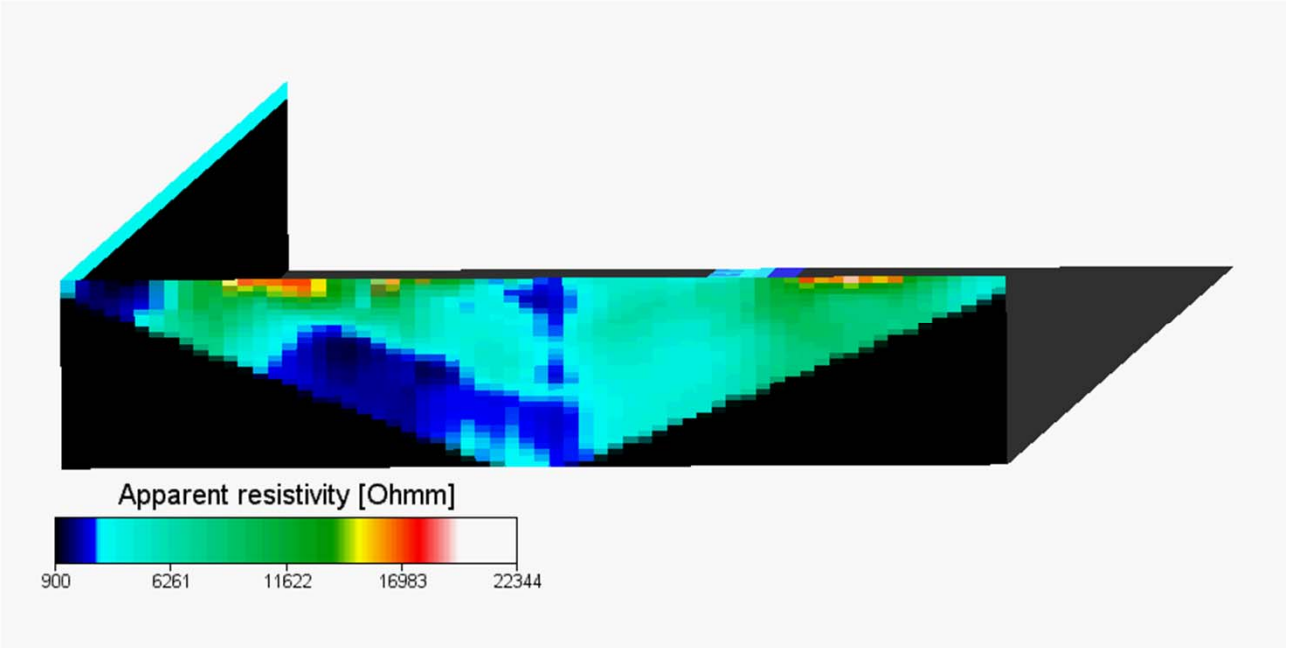
- Monitoring in time interval 3 months
- One resistivity section per 6 hours



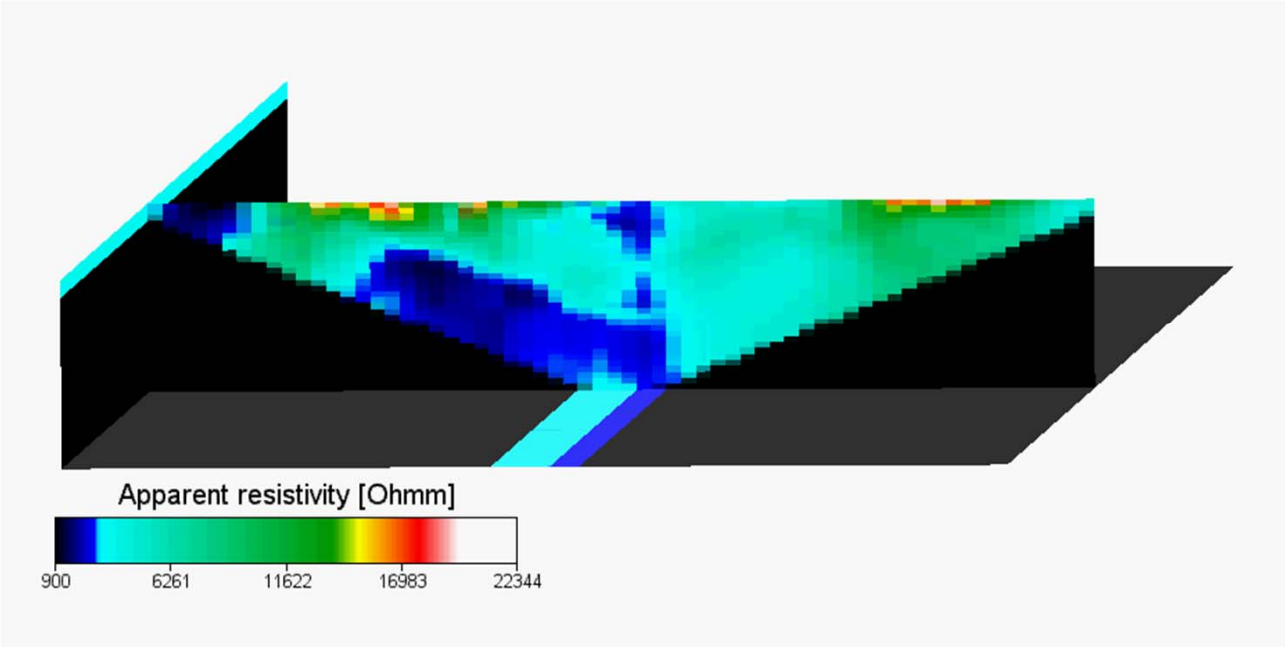
Electrical resistivity tomography



Electrical resistivity tomography

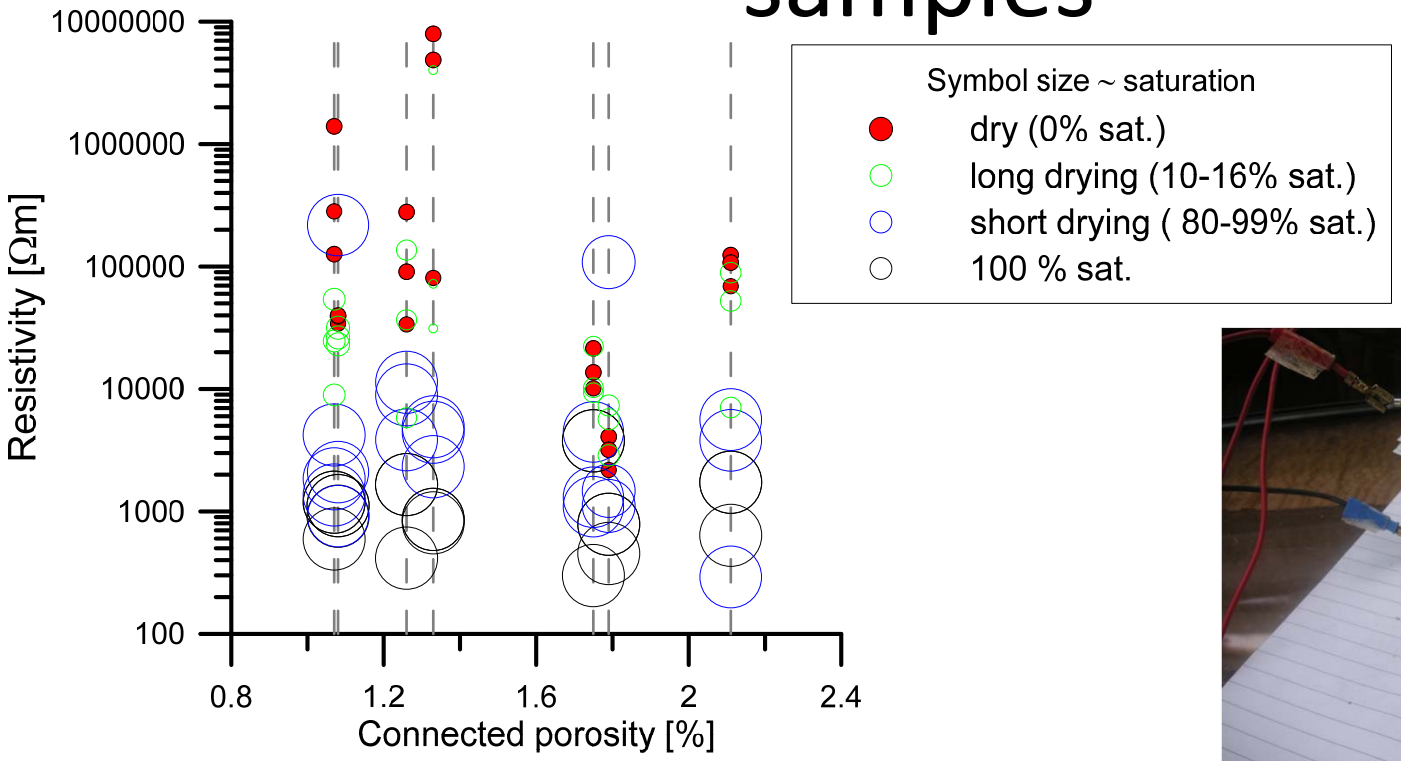


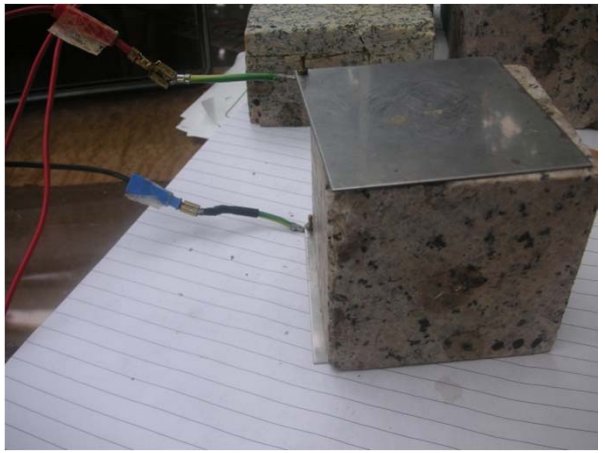
Electrical resistivity tomography



- The duration of local increase of apparent resistivity was 14 days (about 55 resistivity sections)
- We propose it is result of changes in saturation of existing fracture (macroscopically visible fracture in the underground gallery)

Resistivity of dry and saturated granite samples



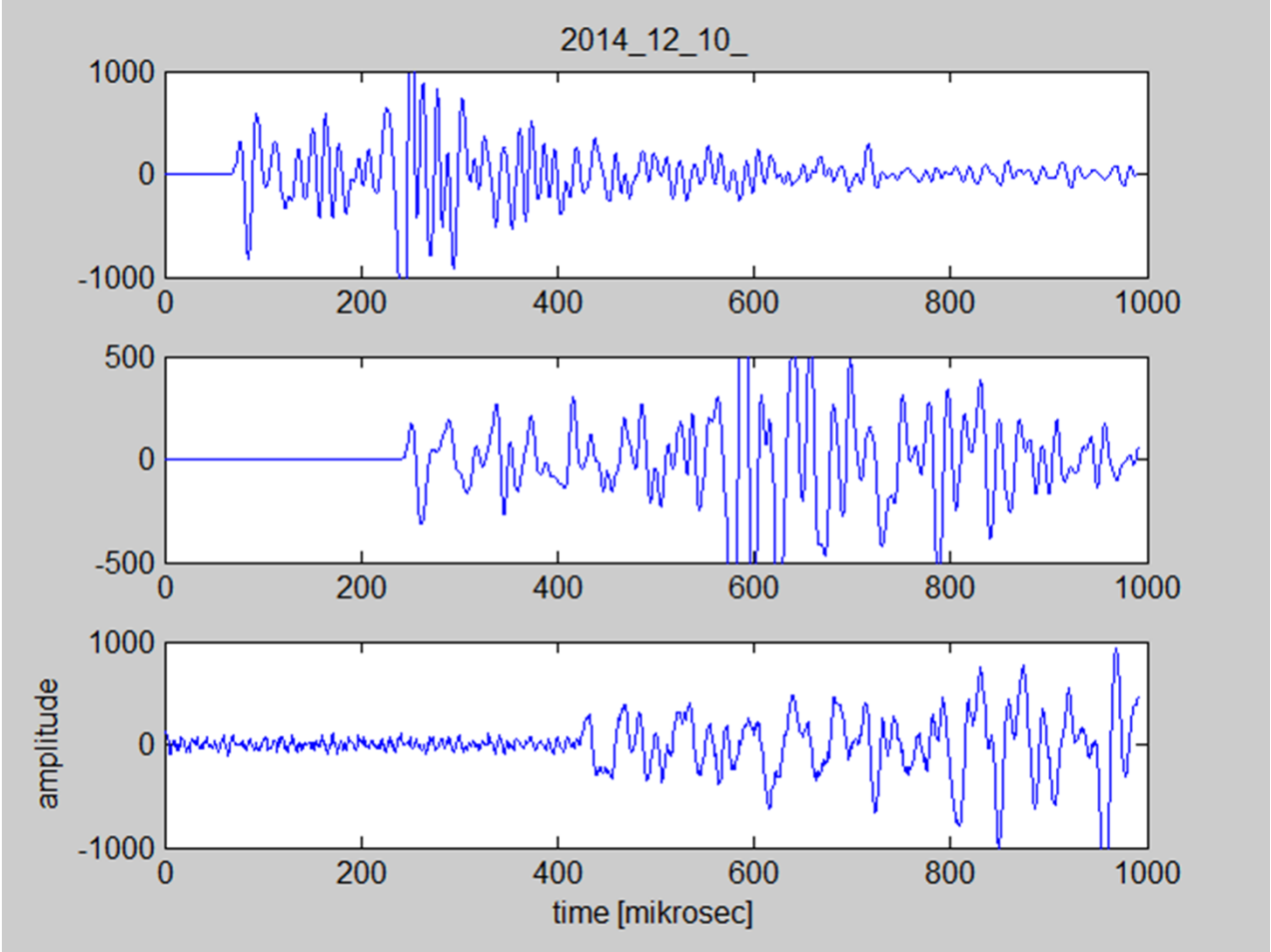


- 7 granite samples, 3 resistivity values in 3 directions - anisotropy
- Resistivity significantly depends on saturation

Seismic time of flight monitoring

- Piezoceramic accelerometers – 1 source, 3 receivers
- Directly at rock surface
- Measurement base 1 to 3 m
- Frequency of seismic waves ~ 40 kHz
- Recording of waveforms
- Long term monitoring – one measurement every 5 minutes (about 280 measurements per day)

Seismic monitoring



Seismic monitoring – accuracy of velocity determination

- Cross correlation analysis – comparison of the first record with following records (averaged per day, last sensor – distance 3 m)
- With the used sampling – no time shift observed during three months

P – wave velocity	Sampling	Distance	Time of flight for P-wave	Velocity uncertainty per 1 sample
5300 m/s	1 μs	3 m	566 μs	9 m/s (0.17%)

Seismic monitoring

- Analysis of seismic signal amplitude
- Amplitude is usually more sensitive, than time of propagation
- Mounting of sensors using anchors and cement

Conclusions

- ERT can be used for long-term monitoring in the underground for granitic rocks
- Accuracy of repeated P-wave velocity measurements can be better then 0.2% for measuring base of 3 m
- Electrical resistivity changes in granitic rocks are in connection with the saturation of fractures – the mechanical properties show no change of P-wave velocity (high frequency seismic P-wave)

Further development

- Resistivity model of saturated/unsaturated fracture in high resistivity medium will be calculated
- Analysis of seismic wave amplitudes will be tested after stable fixing of piezoceramic transducers