# RESISTIVITY TOMOGRAPHY OF THE GRANITE MASSIF IN THE BEDŘICHOV GALLERY.
# ODPOROVÁ TOMOGRAFIE GRANITOVÉHO MASIVU V BEDŘICHOVSKÉ ŠTOLE.

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**Abstract**

This paper describes the measurements and processing and interpretation of the resistivity data measured in the Bedřichov gallery (the northern part of the Czech Republic) between years 2003 and 2010. The data were measured by G IMPULS Praha spol. s r.o. staff members and our research are going to continue in the next years. The gallery is driven in the granites which are considered as a highly appropriate host medium for the future deep repository of radioactive wastes in the Czech Republic. The multielectrode resistivity method clearly demonstrated time variations in the resistivities, probably caused by the presence and the character (mineralization) of groundwater. Groundwater saturates joint systems in the rock massif. Consequently, time variations in the resistivities probably indirectly predicate also variations in the state of stress of the rock massif (gradual confining or opening of joint systems).

**Abstrakt**

Příspěvek popisuje měření, zpracování a interpretaci odporových dat naměřených ve štole Bedřichov (severní část České republiky) mezi roky 2003 a 2010. Data byla naměřena týmem G IMPULS Praha spol. s r.o. a výzkumy dále pokračují. Štola je ražena v granitech, které jsou uvažovány jako vhodné hostitelské prostředí pro budoucí hlubinné úložiště radioaktivních odpadů v České republice. Multielektrodová odporová metoda zřetelně demonstruje časové změny měrných odporů, pravděpodobně zapříčiněných přítomností a charakterem (mineralizace) podzemní vody. Podzemní voda saturuje puklinový systém v horninovém masivu. Proto časové změny měrných odporů pravděpodobně nepřímo predikují také změny v rozložení napětí v horninovém masivu (postupné zavírání a otvírání puklin).

**Keywords**

*resistivity tomography, granite massif*

## 1 Introduction

The area of interest is situated in the Liberec Region in the municipality of Bedřichov. The subject of concern is investigations conducted in the gallery serving as water conduit. The water conduit itself is a large-diameter (600 mm) metal piping, which is placed on a special structure (supports) and is running along the entire gallery length. Initially, the gallery was driven using DEMAG system, i.e. the technique of machine driving. At metre 893 (from the gallery portal in Bedřichov), a serious failure of the driving mechanism occurred.

The failure led to a decision to dismantle the mechanism and complete the driving using explosives (i.e. the technique of hand driving using common accessories). In both parts (i.e. machine and hand-driven), the gallery is very well passable – the tunnel bottom is concreted to form a flat floor. The weakened places from the point of geomechanics are protected by a concrete mixture coat with steel fabric reinforcement. The gallery is regularly ventilated using forced air circulation.

The gallery was driven in the beginning of the 1980s. Basically, the tunnel passes through the granite, strictly speaking, medium-grained, markedly porphyric granite of Variscan age. Exceptionally, also olivine basalt veins (reaching a thickness of about 1 metre) were identified in the gallery. Water inflows to the documented gallery are largely weak. The entire area of interest is situated in the central part of the Krkonoše - Jizera massif. The overlying beds above the gallery reach a thickness of up to 141 metres.

The fact of very serious considerations regarding the construction of deep-seated radioactive waste repository is the reason for paying attention to the gallery in Bedřichov. This repository should be developed in granites (in the last resort, in the rocks showing similar properties). The repository depth should be between 0.5 and 1 km below the ground level. With regard to these purposes, investigation including, among others, in-situ study of the granite properties, has been conducted for a number of years. From 2004 on, the investigation using the geophysical methods has been implemented; especially, the measurements using the methods of resistivity tomography, seismic prospecting and observation of stray (parasitic) currents. The basic research complex was later followed up with additional investigations, such as the monitoring of temperature changes in the gallery, monitoring of the seismological situation in the gallery and its surroundings, and study of the physical properties using the collected rock samples.

The presented geoelectric investigation in the gallery focuses on the behaviour of the rock massif in depths reaching, maximally 10 m from the workspace. According to the terminology taken over from preparing of the deep repository this zone is so-called EDZ (Excavation Damaged or Disturbed Zone).

The information presented here refers only to resistivity measurements as the scope of the paper does not allow to describe in detail all activities carried out in the gallery. Nevertheless, as mentioned above, also seismic measurements and observations of stray currents are intensively conducted in the gallery. Their description and analyses will deserve in the future to be dealt with in a separate paper.

## 2 The methodology of the resistivity tomography

The method of resistivity tomography (multielectrode resistivity method) which was applied in our measurements is based on the measurement of electric resistivity of the rocks. In contrast to the classical measurements (resistivity profiling) with the four-electrode system, the fieldwork proceeds using the multielectrode system. Through the use of computer connected to the layout it is possible to change the electrode configurations (we note that the maximum penetration depth equals approximately one third of the distance between the current electrodes AB) and so to acquire very „dense“information on resistivity conditions of the rocks. Result of the measurement after the data processing is the resistivity cross section which allows further geological (geotechnical) interpretation. The conditions for resistivity measurements in solid rocks are largely extreme. Ionic conductivity is ensured only via a joint system (if it is water-bearing). Electron conductivity cannot be assumed for the majority of solid rocks. Nevertheless, despite these problems arising in the measurement it can be stated that the measurement using the method of resistivity tomography is reliable even in the conditions of solid rocks and fully reproducible in constant conditions.

The electrodes for the measurement using the multielectrode resistivity method were placed into pre-drilled holes reaching a depth of approx. 3 cm and approx. 1 cm in diameter. The spacing between the electrodes on the gallery wall was fifty centimetres. The placing of the electrodes is shown in Fig. 1.

***Fig. 1 The placing of the electrodes on the Bedřichov gallery wall***

## 3 Interpretation and examples

The data acquired by the measurements were standardly processed using the programme Res2Dinv (Loke). In Fig. 2 (below), an example of comparison of the resistivity cross sections acquired from the data which were measured in June and September 2010 is shown. It is a measurement at base remarked as A, (approx. 170 m from the gallery entrance). The measurement was conducted in a height of 1.5 m above the gallery bottom.

To gain the maximum objective insight into geoelectric cross sections, also the imaging of so-called raw (unprocessed) data acquired directly from the apparatus (i.e. the original data tables) was performed, with a depth of the individual points having been approximated roughly according to the value of AB/3 (A, B – current electrodes), i.e. the depth scale is AB/3. This processing technique was used at the primary observation base, i.e. at the transition between machine-driven and hand-driven parts of the tunnel (around metre 893 from the gallery entrance). At this location, the longest series of observations (since 2004) is available. The next processing steps were as follows:

Using the above mentioned approximation of depth, data table x, z with apparent resistivity values was produced. Data from the profile P3 (in a height of 1.5 m) from June 2010 were used as baseline data and imaged into the geoelectric resistivity cross section according to the programme Res2Dinv.

Further, other measurement values acquired since 2004 were compared with the measurements from 2010 according to the formula:

$$\frac{R_a\left(\,2.6.2010\,\right)}{R_a\left(\,day.month.year\,\right)}\ . \qquad (1)$$

From whence it follows that we get cross sections of mutual ratios of apparent resistivity values, serving as an indicator of time variations in the resistivities. An example of one of the ratios is shown in Fig. 3. In the top resistivity cross section, contour lines of apparent resistivities from the measurements performed 2.6.2010 at profile P3 (1.5 m above the floor) are shown. The resistivity cross section in the bottom part of the Figure shows the data calculated according to equation 1 conversion for the measurement performed 29.4.2010.

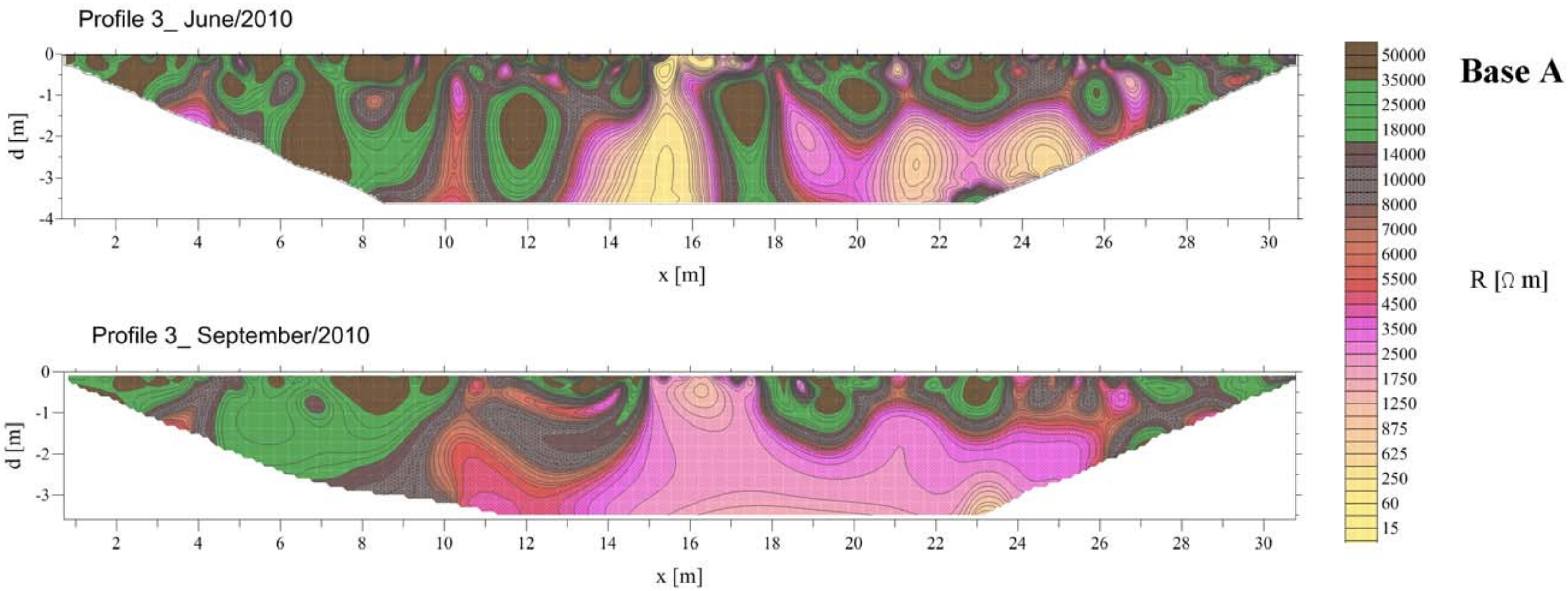


***Fig. 2 The comparison of resistivity cross sections from June and September 2010 at base A***

# 4 Conclusions

Resistivity cross sections show demonstrable variations in time and place. In the author's opinion, the variations are primarily associated with variable moisture contents in joint systems, with variable water mineralization, with different petro graphic composition and fracturing of the rock massif. Also pressure variations (opening or confining of joints) are probably indirectly shown. The next significant fact is that the ventilation regime in the studied gallery is changed from time to time, which means that in the subsurface layer around the worked-out space the drying or moistening of the rock environment may occur even without the direct relation with water supply from the ambient environment. This hypothesis may be of significance to the microclimate in the future repository of radioactive wastes. The ventilation system operation inside the repository may in certain cases be of higher significance, compared to the climatic conditions on the ground surface.

- As regards the statistical processing of raw data, it can generally be stated that
- Cross sections of apparent resistivities as well as cross sections acquired using the programme Res2Dinv demonstrate resistivity variations in time.
- Resistivity variations show a continuous and local character.

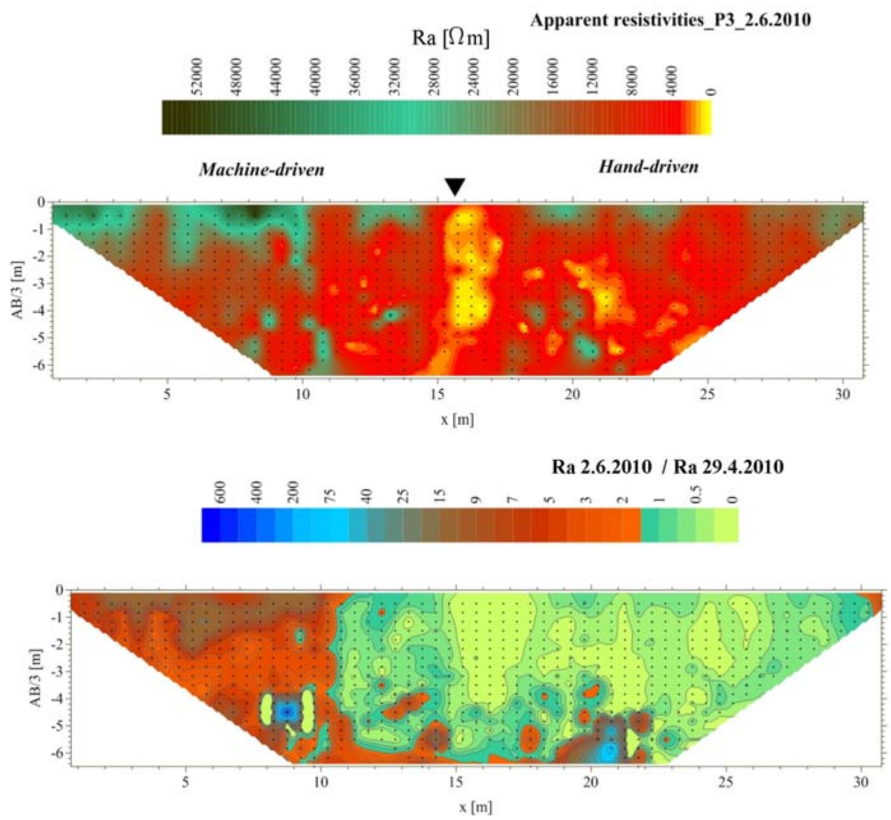


*Fig. 3 Statistical comparison of raw resistivity data*

At Profile 3 see Fig. 3, comparison of the measurement from 2.6.2010 with the measurement from 29.4.2010), the transition between the tunnel driving types is markedly shown approx. at metre 15. Similar results can also be observed for other measurement dates.

From the character of cross sections it follows that the measurements conducted in June 2010 showed higher resistivity values compared to all of the earlier measurements, especially in the left part of the profiles. The reason for that can be searched in the fact that at metre 15.5 is the transition between the hand-driven and machine-driven parts of the tunnel, or, it might also be possible to take into account the effect of a marked tectonic zone which was detected nearby.

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**References**

BÁRTA J., BUDINSKÝ V., JIRKŮ J. Tunel Bedřichov – charakterizace granitoidů in situ. *G IMPULS Praha spol.s.r.o.* Praha, 2010, 50 s.

BÁRTA J., KNĚZ J., JIRKŮ J. Srovnávací studie ke geofyzikálním měřením ve štole Bedřichov. *G IMPULS Praha spol.s.r.o.* Praha, 2010, 45 s.

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