SEVEN YEARS OF EXPERIENCE IN EXPERIMENTAL TESTING OF GRANITE ROCKS IN THE GALLERY SERVING AS WATER CONDUIT FROM THE JOSEFŮV DŮL HYDRAULIC STRUCTURE TO WATER TREATMENT PLANT IN BEDŘICHOV (NORTHERN BOHEMIA).

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Abstract

An underground laboratory whose aim is to acquire findings on the behaviour of granite rocks in worked-out space is being developed in Bedřichov. These experiences are necessary to prepare the planned construction of a deep-seated radioactive waste repository in the Czech Republic. The gallery serves, among others, for the long-term monitoring of the seismic and electric properties of the granite massif. Attention was primarily paid to the points of transition between hand-driven and machine-driven parts of the tunnel, where a systematic monitoring using the seismic method and the method of resistivity tomography has been conducted. The measurements in the conditions of worked-out space in solid rocks bring certain specificities which are not encountered when performing standard ground surface investigations. The methodology of works has been gradually developing and extending. In 2010, experimental measurement using TDR (Time Domain Reflectometry) method to study changes in moisture content in the rocks was started. The basic monitoring base at the transition between machine-driven and hand-driven parts of the tunnel was extended for two new comparative bases in other parts of the gallery.

In the area of interest, already in 2003 the presence of interfering electromagnetic field (stray currents) was detected. This interfering field as well is a subject of study for the geophysical team.

Sedm let zkušeností s experimentálním testováním granitových hornin ve štole sloužící jako přivaděč vody z vodní nádrže Josefův Důl k úpravně vody v Bedřichově (Severní Čechy)

Podzemní laboratoř, jejímž cílem je získávat zjištění týkajících se chování granitových hornin ve vyrubaném prostoru, je vybudována v Bedřichově. Tyto zkušenosti jsou potřebné pro přípravu plánované výstavby skladiště radioaktivních odpadů ve velké hloubce v České Republice. Štola slouží, kromě jiného, dlouhodobému monitorování seizmických a elektrických vlastností granitového masivu. Pozornost byla především zaměřena na místa přechodu mezi ručně a strojově raženými částmi tunelu, kde se provádělo systematické monitorování s využitím seizmické metody a metody odporové tomografie. Měření v podmínkách vyrubaného prostoru v pevných horninách vyžadovala určitá specifika, s kterými se nesetkáte při standardních pozorováních na zemském povrchu. Metodologie prací se postupně vyvíjí a rozšiřuje. V roce 2010 bylo započato s experimentálním měřením, které používá ke studiu změn obsahu vlhkosti v horninách metodu TDR (časová reflektometrie – sledování dielektrické konstanty). Základní monitorovací báze nalézající se na přechodu mezi strojově raženou a ručně raženou částí tunelu se rozšířila na dvě nové srovnávací báze v jiných částech štoly.

V zájmové oblasti už v roce 2003 byla detekována přítomnost interferenčního elektromagnetického pole (bludné proudy). Zmíněné interferenční pole je také předmětem studia geofyzikální skupiny.

Key words

granite rock, parasitic electric fields (stray currents), resistivity tomography, seismic measurements, TDR (Time Domain Reflectometry)

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. The gallery connects the Josefův Důl hydraulic structure with

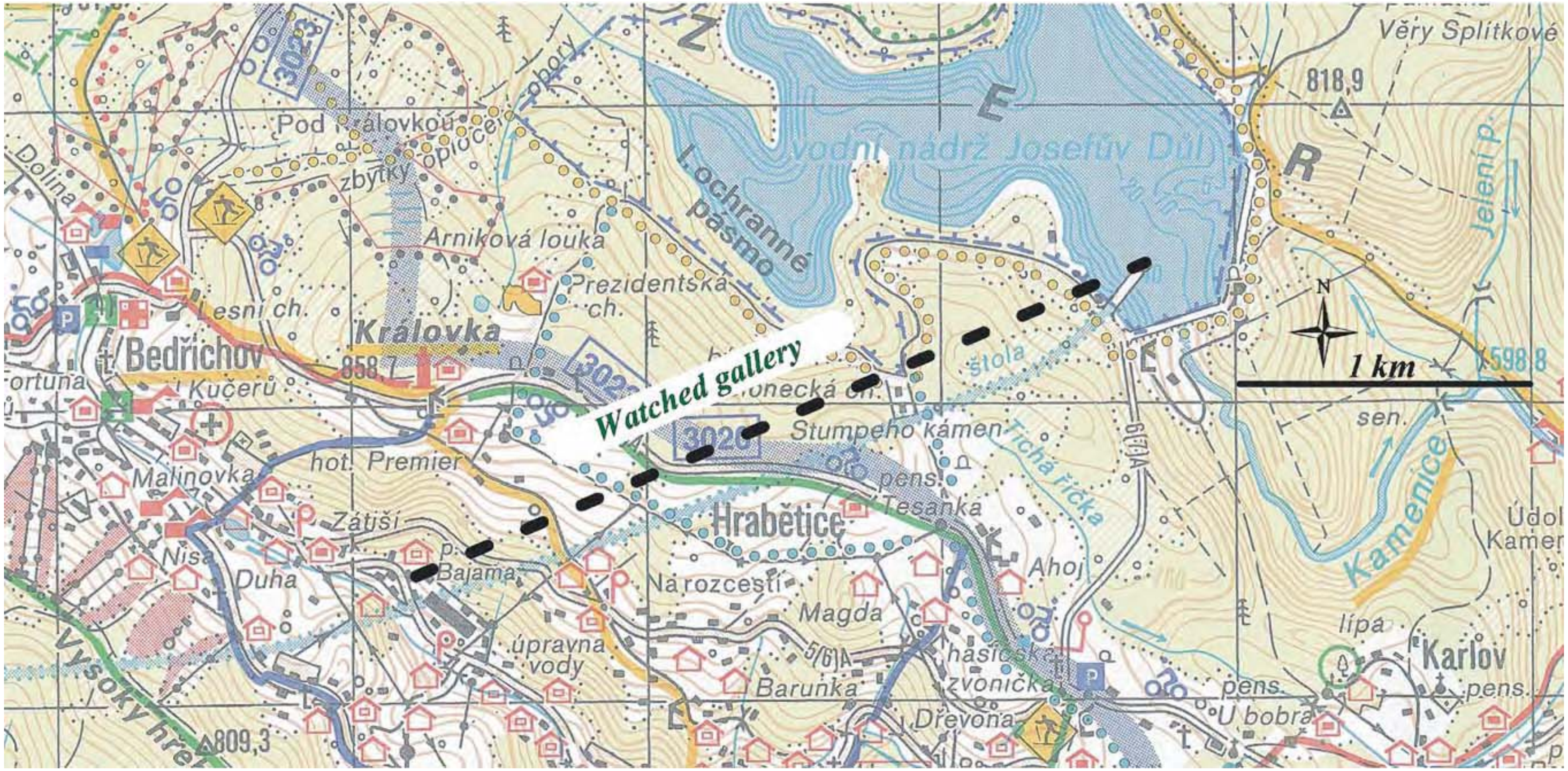

Fig. 1: Skeleton sketch of the watched gallery.

water treatment plant, i.e. the conduit conveys water from the reservoir to the treatment plant where it is treated to reach the quality for end users. The difference in altitude between the reservoir and water treatment plant is exploited by two electric power generating units (basically at the beginning and at the termination of the gallery), which using turbines generate electric power. 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 the machine-driven and hand-driven parts, 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 at the beginning of the 1980s. Basically, the working 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 gallery layout is shown in Fig. 1 (map of the area of interest). The landscape above the gallery is sparsely populated, partly forested, partly covered with forest meadows. The gallery axis intersects the overhead high voltage transmission line. The character of the medium inside the gallery is illustrated in Fig. 2.

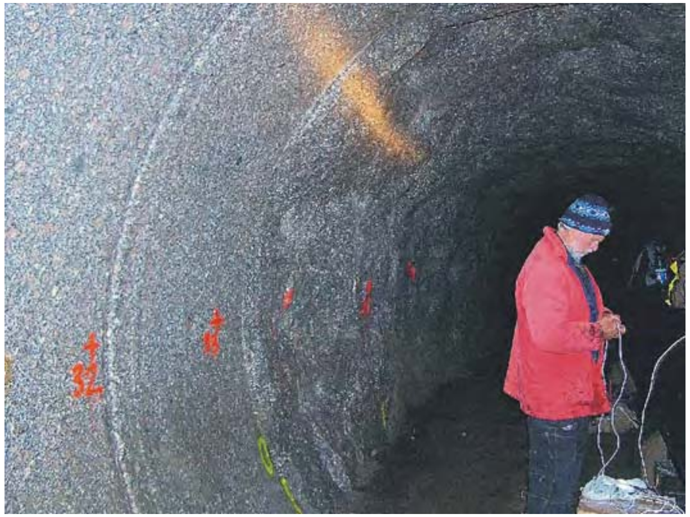

Fig. 2: Look on the gallery (interface between machine-driven and hand-driven parts of the tunnel).

The reason for paying attention to the gallery in Bedřichov is the fact of very serious considerations regarding the construction of deep-seated radioactive waste repository. This repository should be developed in the 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. Within this task, also an underground research workplace in the Bedřichov gallery has been step by step developed (see Klominský J, 2008). The work in the gallery started at the beginning of the 21st century by the geological mapping of the walls and partly also by the observation of the hydro-geological conditions. This was followed by mounting dilatometers to measure movements in joints and by highly accurate laser measurement of the gallery surface in the places of transition between machine-driven and hand-driven parts of the tunnel. From 2004 on, the investigation using the geophysical methods has been conducted. 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. At present, the establishment of an extensive information network is under way, which allows to perform systematic monitoring of the selected physical parameters in the gallery, their transfer to the central computer placed at the gallery beginning and the data transfer to the research workplace located at the Technical University in Liberec.

The geophysical investigation started by retrieval of information from earlier geophysical works. They included works performed within the engineering-geological investigation for the purposes of reservoir and drainage gallery (i.e. the gallery where currently the research is under way) construction. Nevertheless, crucial in our case can be considered the measurement using the method of velocity profiling, which was conducted on the entire drainage gallery wall by Votoček R. in 1982 (in Němeček V. and coll. 1982). The measurement was conducted at the time when the gallery surface was still entirely uncovered. At present, for safety reasons, the most weakened zones are protected by concrete coat.

2. The history of the geophysical measurements in the Bedřichov gallery

Already in 2004, the geophysical investigation primarily focused on the area of transition between the machine-driven and hand-driven parts of the tunnel, i.e. the surroundings of metre 893 (150 m below the ground level). The works comprised the following complex of methods:

- Seismic measurement
- Resistivity tomography
- Parametric measurements using the geological radar
- Method of spontaneous polarization
- Parametric measurements using proton magnetometer
- Parametric measurements to detect stray currents

Originally, only pilot profiles were considered, whose aim was to identify the basic properties of the medium. Nevertheless, the work results were interesting in such a degree that it was recommended and also step by step confirmed at the site meetings that the geophysical works should have the character of the monitoring and that the methodology of measurement should be complemented, as appropriate, by additional techniques.

The entirely new aspect, which should be systematically studied in the Bedřichov gallery, relates to the finding of existence of strong stray currents in the gallery. The presence of stray currents was first indicated during the measurement using the geological compass. Our works performed in 2004 confirmed the existence of stray currents having at the same time demonstrated that the field concerned is an intricate parasitic field, which also contains the electromagnetic component (i.e. higher harmonic derived from 50 Hz).

The seismic measurements, as assumed, detected the existence of propagation of seismic waves showing high velocities, which confirmed the presence of low-disturbed solid rocks. At the same time, the measurement pointed out two important findings. The first finding is the fact that the measurement conducted in the rock massifs requires a seismic apparatus allowing very dense sampling (on order of tens of microseconds and for certain tasks even first microseconds). The latter finding is the fact that changes in seismic velocities in solid rocks are not major changes and that also changes in the rock properties are often at the detection limit (which is logical, because the rock virtually everywhere shows similar properties of the solid medium).

The method of resistivity tomography (the measurement using the multielectrode resistivity apparatus) already during the pilot measurements yielded the crucial finding that the resistivity measurements in the solid rock are realizable and that they provide reproducible results. The resistivity cross sections acquired by the measurement largely show extremely high specific resistivity values. Nevertheless, in dependence on time (or in dependence on changes in moisture content) in some of the structures there occur certain changes in resistivity values.

The parametric measurements using the geological radar indicated certain limitations of this method in the natural conditions of the gallery. The antenna motion on an uneven wall considerably affects the character of records. In the records there are highlighted various technical elements (nailed spikes in the rock, etc.). The application of borehole radar would mean the disturbance of the solid rock medium and increased costs. At present, we have no clear evidence of the fact that borehole radar sounds allow perfect trending and narrowing of the radar beam to the optimal direction. In relation to the radioactive waste repository, the radar technology will certainly be applied; nevertheless, the technique still requires certain development.

The parametric measurements using magnetometer demonstrated in the Bedřichov gallery the existence of strong parasitic electromagnetic fields. These measurements were therefore followed by the detection of stray currents and spontaneous polarization.

In the following period, the measurements using the method of resistivity tomography and the seismic method were gradually improved and extended. At present in the gallery, 9 profiles, each reaching a length of approx. 30 metres is available, serving to conduct more or less regularly the resistivity measurements and the seismic measurements. The profiles are situated in a fan-shaped array from a foot-wall across the top to the opposite foot-wall. All the mentioned profiles are located at a transition between machine-driven and hand-driven parts of the tunnel. In 2010, the measurements were extended for so-called comparative locations, i.e. two new bases were prepared. One of them is situated around picket 160 m (40 m below the ground level) and the latter around picket 1250 m (140 m below the ground level) from the gallery entrance.

Profile lines close to the tunnel floor and 1.5 m above the tunnel floor were prepared there for the measurement. The aim of, for the present, parametric resistivity measurements and seismic measurements is to find out to what extent the measurements are affected only by changes over time and to what extent by changes with a position.

In 2010, also the parametric measurements using the TDR (Time Domain Reflectometry) method started. It is a measurement of dielectric constant, whose values can be converted to the determination of rock moisture. In the event of success of the pilot works, the monitoring of changes in moisture content (see the resistivity measurements) might be complemented also by this technique.

In 2010, also pilot measurement using a special micro-seismic three-channel apparatus intended for the investigation of solid rocks was conducted. The works were performed under the leadership of J. Vilhelm (Faculty of Science of Charles University in Prague) and the data processing by his team is currently under way.

3. The issues of parasitic electric fields (stray currents)

In conducting the measurements in the tunnel, parasitic (stray) currents endangering the technical condition of metallic parts of the water conduit were detected. A similar situation might also occur in the future deep-seated radioactive waste repository, therefore, these issues have to be paid due attention. In the case of the Bedřichov gallery, the source of parasitic fields are two electric generators placed at the gallery beginning and termination, and of not negligible effect are also leakages of currents from high-voltage transmission lines that are located on the ground surface. Based on the measurement at stray current bases (in the gallery and on the ground surface), the profile measurement using the method of spontaneous polarization, tentative vertical electric sounding (VES) and the measurement using VLF method, the geoelectric model of the studied medium was produced (see Fig. 3). The problem is complicated, among others, by the fact that not only the effect of parasitic (stray) currents in connection with the so-called soil corrosion is actually concerned. The problem also includes the presence of the electromagnetic field caused probably by higher harmonic frequencies of the primary alternating currents (50 Hz).

We note that the presence of stray currents in the technical facilities has to be monitored in accordance with both the Czech and European standards. In the case of detection of adverse facts it is necessary to put in place effective remedial measures. According to the author`s knowledge the issue of stray currents in preparing deep-seated repositories in the world has not been so far systematically attended to.

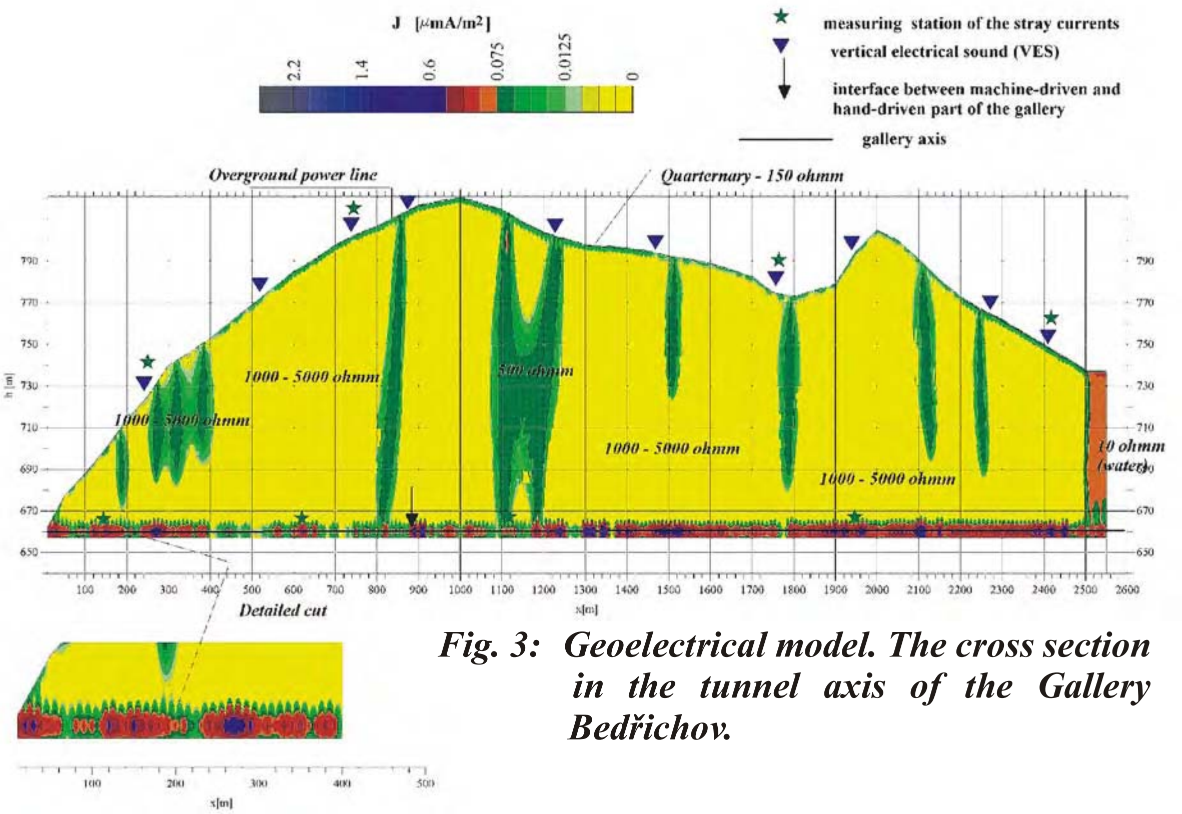

Fig. 3: Geoelectrical model. The cross section in the tunnel axis of the Gallery Bedřichov.

In our research we consider important the finding that stray currents are able to penetrate also through conductive (tectonic) structures of the massif at long distances (hundreds of metres). It can be deduced that this may also be of effect on the character of groundwater movements (see for example filtration potentials of natural electric fields in Semjonov A.S. 1968 and Bárta & Beneš 2003).

4. The issues of resistivity tomography

The conditions for resistivity measurements in solid rocks are considerably extreme. Ionic conductivity is ensured only via the joint system (if it is water-bearing). Electron conductivity cannot be assumed for the majority of solid rocks. Even in these conditions it has been demonstrated, already in earlier investigations, that the measurement using advanced apparatuses is possible and reliable.

In the area of interest, holes for the electrodes of the multi-electrode system were drilled. In total 9 profiles, each reaching a length of 32 metres is available. These profiles serve for the measurement using the method of resistivity tomography, and also for the subsequent

Fig. 4: Preparing for fixation of geophysical sensors (geophones, electrodes).

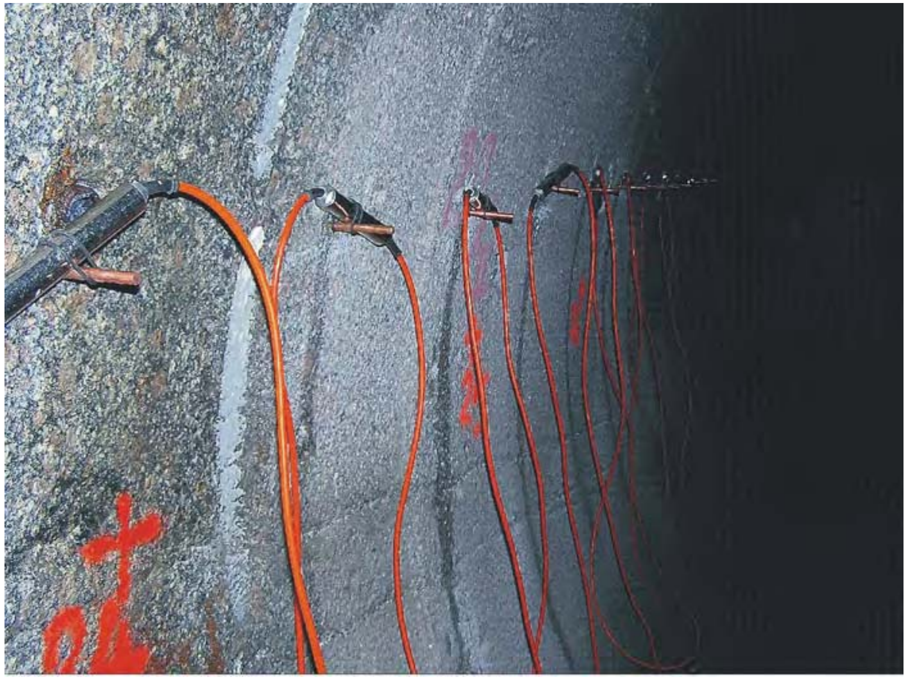

Fig. 5: Electrodes and cables for resistivity tomography.

measurement using the seismic method. The profiles are laid out in regular spacing from the gallery bottom over the top of the gallery back to the gallery bottom.

The measuring system electrodes are fixed in minor holes drilled in the rock. The spacing between the electrodes at a profile line is always 0.5 m; picketing at the profile is arranged so that metres begin nearer the gallery entrance, the transition between the machine-driven and hand-driven parts of the tunnel is at metre 15.5. The measurement then continues further to the gallery inwards. The fixing of the electrodes is shown in Fig. 4 and 5.

In the course of the investigation, the resistivity measurements were largely repeated several times a year, most often every three months (in dependence on the financial status of the project). Each phase of the measurement was immediately processed to allow, as appropriate, to modify the measurement technology, to correct erroneous data, etc. The measured data files, i.e. the databases of apparent resistivities for the individual measured profiles, were converted from the original format (*MCD) of the geophysical apparatus to the format of the Golden Software programmes (*.dat). The databases modified in this way were complemented by the information on the ground surface hypsography and finally the databases were processed using the programme Res2Dinv. This means that the groups as such as well as changes in the selected profiles can be easily compared.

Although routinely repeating procedures were used in the interpretation of resistivity cross sections, it has to be admitted that there exists also a certain subjective influence of the processer on the final work result. In the final presentation it is always important, for example, the selection of the image colour scheme, the density of grid, etc. For this reason it was decided that in addition to the processing based on the imaging techniques appropriate statistical methods would be used also to monitor changes in apparent resistivities in the basic database tables. This means that it was assessed to what extent the measured values were changing or not changing, without any modification converting apparent resistivities to the real resistivities (including other modifications).

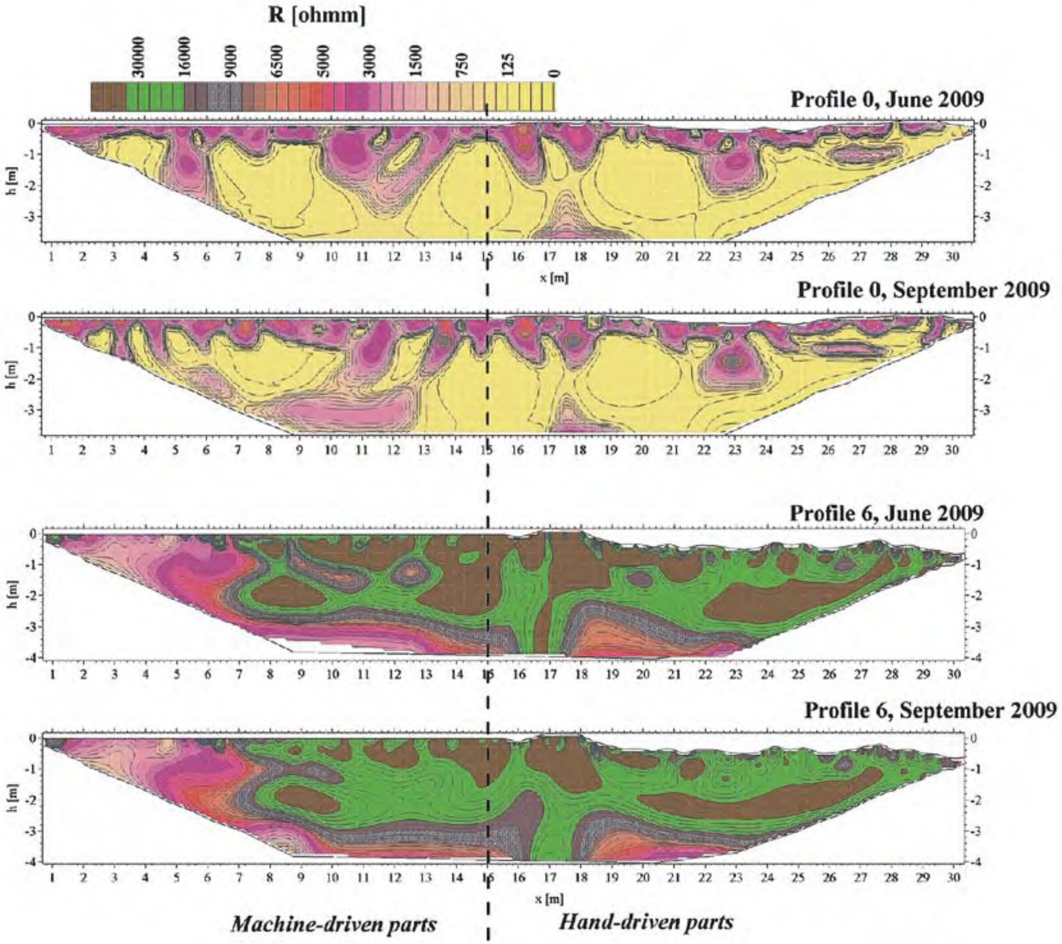

Fig. 6:* *Confrontation of the resistivity cross sections over time (example).The profile P0 is located on the bottom, the profile P6 is situated on the top of the gallery.

The measurements using the method of resistivity tomography demonstrated that:

- resistivity cross sections show demonstrable changes over time. In our opinion, the changes primarily relate to variable moisture of the joint systems and variable mineralization of water. Probably also pressure changes (opening or closing of joints) are indirectly shown.
- resistivity cross sections from the gallery bottom show markedly lower resistivity values compared to resistivity cross sections measured higher in the gallery wall or in its top.

Although the measured data already served to produce a large number of image data and other documentation, we present in Fig. 6 at least one example illustrating the character of resistivity cross sections and their changes over time.

5. The issues of the seismic measurements

At present, the seismic measurements are conducted at all available profiles prepared at a transition between the machine-driven and hand-driven parts of the tunnel (nine profiles) and at two comparative bases (i.e. two profiles around the pickets of 160 metres and 1250 metres).

At first insight, the rock environment in both the horizontal and vertical directions behaves as a quasi-homogeneous medium. By a seismic hammer blow several types of the seismic waves are produced. The seismic wave showing the velocity of propagation of around 5500 m/s is evidently a longitudinal seismic wave. This wave is worse observable, its first pick, the magnitude of amplitude and frequency are not always constant and the wave identification here and there requires certain experience. Another wave type shows the seismic velocity of around 3300 m/s. This wave appears to be very distinctive, showing a low attenuation of amplitudes with a distance from the source of the seismic impulse. The wave can be legitimately considered to be a transverse wave or a surface wave. With a fair probability it can be admitted that the records obviously show a mix of both waves. In the professional practice, especially civil engineering practice, a surface wave and a transverse wave are often confused in calculations. The reason for that is, among others, that a surface wave velocity differs from a transverse wave velocity by only 0.1 of its value. In conducting the measurement in the gallery it has to be taken into account that the seismic impulses are not excited at a simple half-space surface (planar interface rock/air). The medium observed by us then may also be affected by this fact and the waves may show even the character of any seam waves.

In detailed insight into the measured seismic travel times we may find out that the seismic waves in more distant points from the seismic sources slightly refract, i.e. slightly higher seismic velocities are shown there. This means that the medium in a very detailed investigation shows with a depth (with a distance towards the inside of the rock massif) a positive velocity gradient.

To analyze the seismic data from the Bedřichov site we have to especially take into account the following mathematical formulations expressing the basic behaviour of the seismic waves in the given rock environment. These input parameters allow us to start to convert the information on the behaviour of elastic waves to a reliable knowledge of the geomechanical properties of the studied medium. The basic equations for seismic wave propagation are presented below.

For a longitudinal wave v_p:

$$v_p = \left[E \times \rho^{-1} \times (1-\sigma) \times (1+\sigma)^{-1} \times (1-2\sigma)^{-1}\right]^{-0.5}. \qquad (1)$$

For transverse wave v_s:

$$v_s = \left[E \times \rho^{-1} \times 2^{-1} \times (1+2\sigma)^{-1}\right]^{-0.5}, \qquad (2)$$

where E = modulus of elasticity determined by the seismic measurement [MPa],
ρ = bulk density (rock density) [kg/m^3],
σ = Poisson’s number.

From the previous equations, Poisson’s number σ can be determined by modifying to the equation:

$$\sigma = \left(2\,v_s^2 - v_p^2\right) / \left(2\,v_s^2 - 2\,v_p^2\right). \qquad (3)$$

The basic equation for a Rayleigh’s surface wave propagation can be expressed, for example, as follows:

$$\frac{c_R^6}{v_s^6} - 8\frac{c_R^4}{v_s^4} + c_R^2 \times \left(\frac{24}{v_s^2} - \frac{16}{v_p^2}\right) - 16\left(1 - \frac{v_s^2}{v_p^2}\right) = 0\,. \qquad (4)$$

where C_R = phase velocity [m/s],

v_s = transverse wave velocity [m/s],

v_P = longitudinal wave velocity [m/s].

The thickness of the surface layer is directly proportional to a length of the seismic Rayleigh wave. The exact relation between the wave length and the layer thickness is more complicated. Basically, the layer thickness is equal to the half of the wave length. More exact determination requires applying some of the computer programmes to analyze dispersion curves or to apply calibrating plots for the particular medium.

The considerations required to analyze the data acquired from the measurements in the solid rock environment in the Bedřichov gallery should also include the expression for the seismic qualitative factor Q_{seis}, i.e.

$$Q_{\text{seis}} = \left(2\pi/\Delta E\right) \times E_{\max}\,, \qquad (5)$$

where E_{max} = expression for the maximum of energy expended for the entire cycle, and

E = energy loss during the cycle.

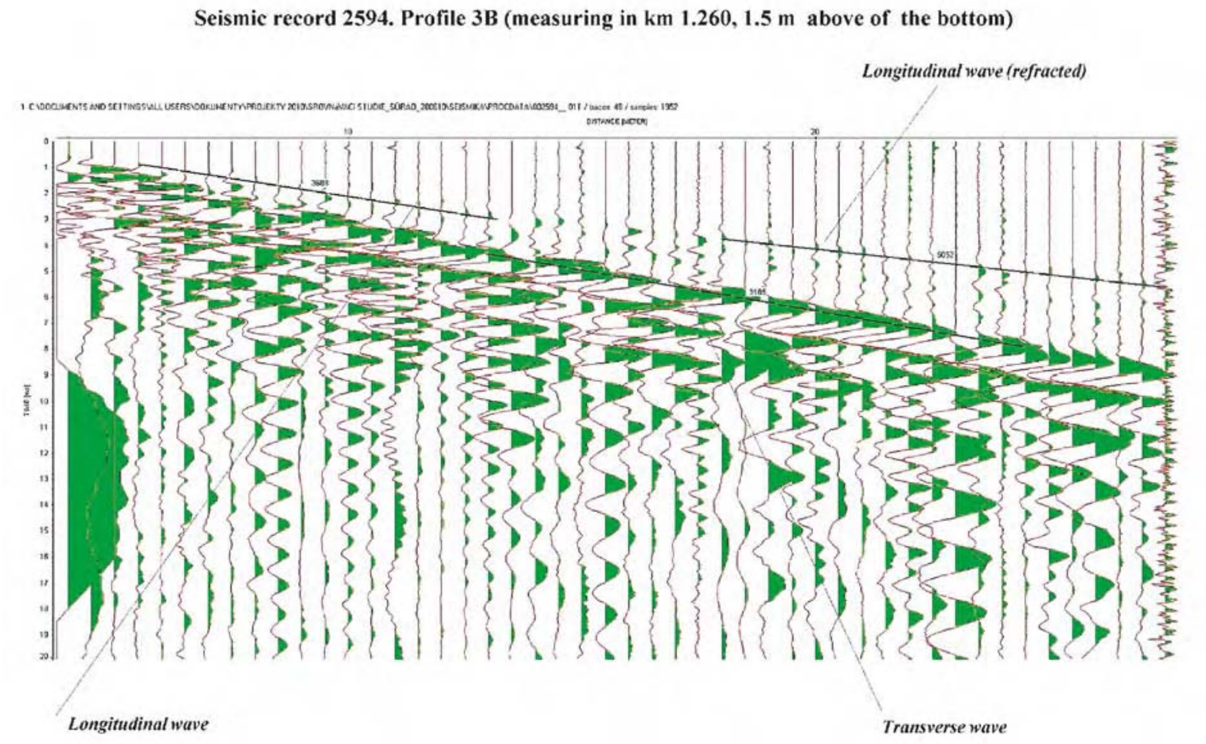

Fig. 7: The characteristic example of a seismic record from the Gallery Bedřichov.

This equation can be practically applied by means of studying the dynamic characteristics of the seismic waves and it probably opens up a way for the method which may objectively characterize the solid rock environment. Similarly, there exist another equations for the qualitative rock assessment, see Barton N. 2006 and Butler D.K. 2005.

Using an extensive sample of velocities of a „quick“ (longitudinal) and a „slow“ (transverse) wave we have calculated the representative value of the Poisson’s number σ for the medium close to the gallery surface, which is:

$\sigma = 0.17$.

This value corresponds to a good solid rock; however, it can be assumed that entirely intact rock would show even a lower value. For illustration, a typical seismic record from the Bedřichov gallery with the interpretation notes is presented in Fig. 7.

6. Pilot measurements using TDR method

To gain a deeper insight into the issues of groundwater movements around the gallery wall, the seismic measurements and the resistivity measurements were extended in 2010 for pilot measurements using *TDR (Time – Domain Reflectometry)* method. This method allows conducting direct „in situ“measurement of the dielectric constant in the medium between two or three grounded electrodes. As the dielectric constant of the soil or rock environment is largely influenced by the presence of water, it is possible, based on a series of experimental measurements using calibration relations to simply convert the measured dielectric constant values to bulk moisture of the studied space (in Topp, Davis, Annan 1980) . A certain disadvantage is the fact that the penetration depth of these measurements is given by the maximal depth of insertion of the measuring electrodes. In the conditions of the Bedřichov gallery it is therefore necessary to use a professional impact drill, nevertheless, despite its use, the preparation for the placing of electrodes is labour-intensive. TDR method, as we found out already earlier, is appropriate, for example, for the monitoring of water infiltration, or the contaminants within a network of stable measuring electrodes. So far, this method has not been applied in the solid rock environment. We assume that an eventual success of the pilot measurements would allow especially bettering assessing the effect of the hydrological conditions on the results gained by the method of resistivity tomography.

Fig. 8: Connection of electrodes for TDR measurement.

So far, pilot measurements using TDR method were conducted in two cycles at the following four locations:

- gallery metre 172.43 in a height of 1 m above the tunnel bottom,
- gallery metre 172,43 in a height of 0.5 m above the tunnel bottom,
- gallery metre 1248.75 in a height of 1 m above the tunnel bottom,
- gallery metre 1248.75 in a height of 0.5 m above the tunnel bottom.

The performed measurements of the dielectric constant demonstrably documented time variations in moisture conditions. The differing character of TDR reflection curves documents moisture changes in the surface part of the gallery and indicates that changes also depend on the character of the tunnel driving (machine-driven part and hand-driven part of the tunnel). For illustration, photo of TDR measuring system is shown in Fig. 8.

7. Conclusions and plans for the future

- The works proceed in line with the scheduled objectives and aims. The method of resistivity tomography demonstrably shows local changes in resistivity values over time. It is highly probable that these changes relate to changes in moisture and groundwater mineralization. Based on this finding it can also be hypothesized that changes in water content relate to changes in state of stress of the massif. The results of the seismic measurements in the basic insight characterize the medium as the quasi-homogeneous medium. Only a detailed study allows finding out, for example, a slight increase in the seismic velocities from the gallery towards deeper parts of the massif, and also local changes in the velocities relating, for example, with the local increased rock fracturing.

- The measurements conducted using the method of resistivity tomography at the comparative bases that were established in 2010 show the similar results compared to those acquired at the traditional base at km 0.893 (transition between the machine-driven and hand-driven parts of the tunnel). The profiles close to the tunnel bottom always show lower resistivities, compared to the profiles laid out higher in the gallery wall. This phenomenon mainly relates to higher moisture close to the gallery bottom and also to a differing composition of the place concerned (concrete, residues of rock fragments, etc.). However, resistivity values in detailed investigation depend not only on moisture content but reflect also the petrographic character of the rock and the level of its fracturing. In other words, the continuous and repeated measurements conducted at a longer profile may yield findings on time changes and also on the geological setting of the massif.
- The preliminary conclusions from TDR measurements support the intention to continue to monitor the detected changes in moisture, and possibly to extend the monitoring for the course of time and depth variations in moisture.
- The seismic measurements conducted at the comparative bases again clearly demonstrated the presence of a so-called „quick“ (probably a longitudinal) wave (the velocity of around 5000 m/s) and a so-called „slow“ (probably a transverse or a surface) wave (the velocity of around 3000 m/s). The slow wave, abstractedly from the source, is always shown very distinctly. The quick wave shows poorly distinct amplitudes and a possibility of its detection is markedly influenced by the seismic source location and by the geophones location.
- Already the current status of knowledge leads to a recommendation to extend the monitoring to be permanently conducted also at the newly established bases at km 0.160 and km 1.250. The extension of the work will allow to better separate time changes (time domain) from spatial changes (spatial domain).
- For further investigation it is necessary not only to continue to acquire new data, but also to start a deeper study of the identified effects. In this respect, it appears advisable to prepare several themes for diploma theses or doctoral theses.
- The research leads to a conclusion that the resistivity image as well as the seismic image of solid rocks is more complicated than how it could be assumed on the basis of the general geophysical knowledge. The monitoring of the real development of the deep-seated repository will require the geophysical works to be performed and evaluated by a specialized team with sufficient experience gained in experimental sites.

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