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THE JOSEF REGIONAL UNDERGROUND RESEARCH CENTRE (JOSEF URC)

REGIONALNI PODZEMNI ISTRAŽIVAČKI CENTAR JOSEF

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Abstract

The Josef Gallery, located in the central Bohemia region of the Czech Republic was first excavated in 1981 as an exploration complex for the potential mining of gold. In 2007, the gallery was substantially reconstructed to house the Josef Underground Educational Facility (Josef UEF), which subsequently became an autonomous workplace under the direction of the Czech Technical University in Prague. At the beginning of 2010, the UEF was renamed the Josef Regional Underground Research Centre (Josef URC) which, along with the extensive underground complex, features modern above-ground facilities. One of the most important roles of this research center is to provide practical in-situ instruction in the fields of geotechnical engineering, geology, geochemistry, radiochemistry and radioecology. The training of future experts in this authentic underground setting involves the participation of several other Czech universities and numerous experienced specialists from outside the academic sphere. The IAEA (International Atomic Energy Agency) has added the Josef URC to its prestigious list of international training canters involved in the "Training in and Demonstration of Waste Disposal Technologies in Underground Research Facilities – A Network of Centers of Excellence" project.

Sažetak

U rudniku Josef, čija je lokacija u centralnom području regije Bohemia, Češka, prva iskapanja su provedena 1981. u svrhu istraživanja za moguće vađenje zlata. Godine 2007. rudnik je znatno rekonstruiran da bi primio podzemni edukacijski objekt (PEO) Josef, koji je nakon toga postao zasebna jedinica pod upravom Češkog tehničkog sveučilišta u Pragu. Početkom 2010. PEO je preimenovan u Regionalni podzemni istraživački centar (RPIC) Josef koji, zajedno s velikom mrežom, podzemnih prostorija, predstavlja moderni istraživački objekt. Jedna od najvećih uloga ovog istraživačkog centra je praktična in situ obuka na polju geotehničkog inženjerstva, geologije, geokemije, radiokemije i radioekologije. Obuka budućih eksperata u ovom autentičnom podzemnom okolišu uključuje participaciju nekoliko drugih čeških sveučilišta i brojnih iskusnih specijalista van akademskih krugova. Međunarodna agencija za nuklearnu energiju (IAEA - International Atomic Energy Agency) dodala je Josef svojoj prestižnoj listi međunarodnih centara za obuku uključenih u projekt „Obuka i demonstriranje tehnologija za odlaganje otpada u podzemnim istraživačkim objektima – mreža centara izvrsnosti" (Training in and Demonstration of Waste Disposal Technologies in Underground Research Facilities – A Network of Centers of Excellence).

1. Introduction

In 2007, the Centre of Experimental Geotechnics (CEG) of the Faculty of Civil Engineering (FCE), Czech Technical University in Prague (CTU) opened a new workplace – the Josef Underground Educational Facility. The initial idea of establishing an FCE CTU experimental underground facility was inspired by the Edgar Experimental (university) Mine which is run by the Colorado School of Mines in Golden, USA. The establishment of a similar facility in the Czech Republic was in response to the need for the further development of experimental research in an in-situ environment. This facility should be able to provide students with experience in working in real underground conditions through practical training and for linking education and research with the needs of industry. The facility is located 60 km from the Czech capital, Prague (the location of the main CTU campus). The workplace was primarily intended for research and the teaching of CTU students specializing in underground construction techniques (Pacovský et al., 2007; ~~see~~ Fig. 1).

Figure 1. The Josef gallery portals.

Slika 1. *Portali galerije (rudnika) Josef*

As the activities of the Josef UEF gradually expanded, so did the need for extending the above-ground support facilities. Therefore, the decision was made to construct a new building near the entrance to the underground complex which will house above-ground laboratories and an experimental hall with auditoriums and support facilities for teachers and also will provide research space for regional businesses thus enhancing the cooperation of the university establishment with the business sector. At the beginning of 2010, the original Josef Underground Educational Facility was upgraded in terms of facilities to form the Josef Regional Underground Research Centre.

2. History

The Josef exploration gallery was excavated as part of renewed gold prospecting activities which commenced in 1981. The revival of gold mining in this area was seriously considered; however, the highest concentrations of gold occur at depths of up to 300 m implying that gold would have to be extracted by open-pit mining. Moreover, the separation of gold would require the use of an environmentally unfriendly cyanide process.

It was decided that mining operations should be discontinued since ore extraction and dressing would result in the devastation of an area of natural beauty and recreational potential, and consequently, operations came to an end in 1991. In 2000, the entrance portals were fitted with concrete plugs to prevent unauthorized access to the underground areas. Consequently, commercial gold exploitation is currently not envisaged and is considered extremely unlikely in the future.

The abandoned exploration gallery was converted to form the Josef Underground Educational Facility (Josef UEF) in 2007 subsequently to become the Josef Regional Underground Research Centre (Josef URC) in early 2010.

3. Geology

The Josef gallery is found in the Psí Hory gold-bearing district, which is located mainly in the Proterozoic Jílové Belt, in rock more than 600 million years old. Central Bohemian Plutonic granitoid rock subsequently penetrated the Jílové Belt during the Variscan orogenesis. In the Psí Hory area, the Jílové Belt consists of volcanic rock of both basic and acidic composition (basalts, andesites, dacites and rhyolites) in the central area with subvolcanic plagiogranites at its eastern edge as well as gold bearing acidic to intermediate tuffs (Morávek et al., 1992; ~~see~~ Fig. 2).

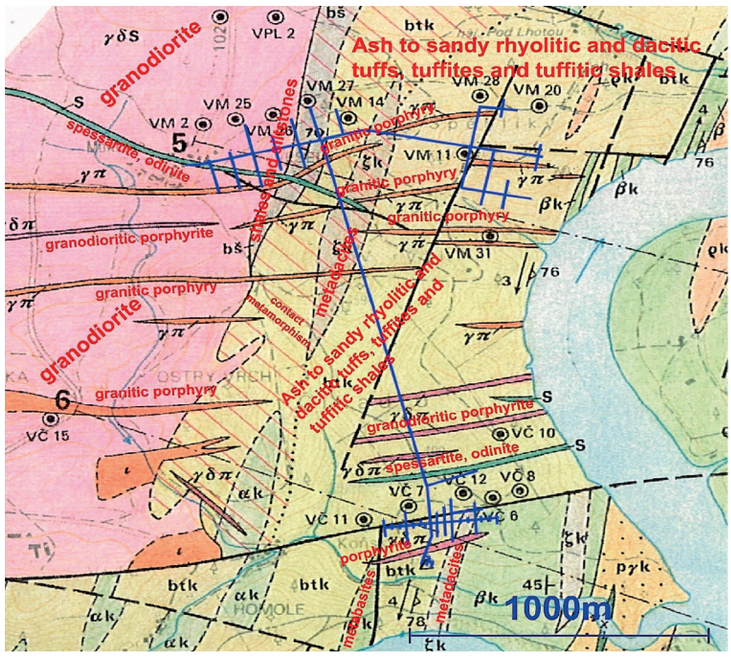

Figure 2. Scheme (blue lines) and geology of the Josef Gallery.

Slika 2. *Shema (plave linije) i geologija galerije Josef*

The overburden consists of a volcanic-sedimentary formation composed mostly of tuffs and tuffitic shales. To the west, the Psí Hory mining district extends to the margin of the biotitic-amphibolic granodiorite of the Central Bohemian Pluton. Towards the end of the 20th century, the Psí Hory district was systematically explored in connection with the potential revival of gold mining. There are two gold-bearing deposits in the area – the Čelina deposit, mined as early as the middle ages, and the Mokrsko deposit. The Čelina deposit and the eastern Mokrsko ore-zone are situated in the tuffs and vulcanites of the Jílové Belt. Most of the western Mokrsko ore zone lies in the granodiorite of the Central Bohemian Pluton.

The gold reserves in this area are some of the richest in Europe. According to recent estimates, local deposits contain up to 130 t of precious metal. Gold mineralisation is concentrated in quartz veins and is mostly very fine grained. The average gold content in the rock is no higher than 2 g/t, which explains why the Mokrsko deposit escaped the notice of medieval miners; its potential was not fully recognised until the 1980's.

Geological diversity is one of the major benefits of the Josef gallery. There are two basic geological formations (tuffit and granodiorit), each with a very different history and contact zones. Moreover, each of the formations exhibits different physical and material properties which change in character towards the contact zone and which feature a variety of local fracture zones and intrusions. This provides a high level of flexibility with regard to choosing the right place for conducting experiments depending on the conditions required, for example fracture systems, rock stability, rock strength, mineralogy, etc.

4. Basic description of Josef gallery

The exploratory Josef gallery was driven within the context of extensive research operations in the Psí Hory gold-bearing district. The Josef gallery passes through Veselý hill, across the rock massif in the NNW direction. It connects two gold-bearing deposits – Čelina deposit and Mokrsko deposit, which are named after villages found in their vicinity. The 1835 m long main drift is interconnected at its end with the surface via a 144 m high ventilation chimney. There are main cross cuts in the area of Mokrsko and Čelina linking the main drift; shorter drifts lead to the sides of the cross cuts. The total length of underground galleries amounts to 7853 m; their cross-sections range from 14 to 16 m^2, approximately 90% of excavated spaces are unsupported. The overburden height varies from 30 m (Čelina-West) to 180 m (Mokrsko). With the exception of the Čelina-East area, where the galleries were driven at other two levels, the entire underground excavation was carried out at a single level. Two 80 m long tunnels with cross-sectional areas of 40 m^2 lead to the underground from two entrance portals (~~see~~ Fig. 3).

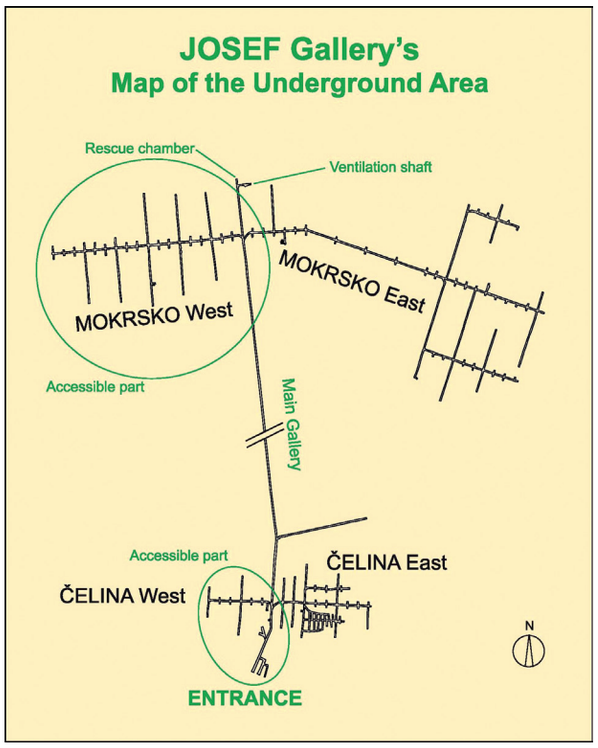

Figure 3. Underground area.

Slika 3. *Podzemni prostor*

5. Teaching in the underground

One of the main reasons for developing the underground experimental workplace of the Faculty of Civil Engineering was the effort to expand and increase the level of the practical courses, taking into consideration the fact that it was often discussed at meetings with representatives of construction contractors that the practical preparation of future engineers in a real underground environment was insufficient.

Since the 2007–2008 Academic Year, regular teaching of subjects focused on problems associated, for example, with underground structures, rock mechanics, material engineering, engineering geological survey, land surveying and underground mapping has been performed, both in Bachelor's and Master's degree programs. Students solve experimentally focused Bachelor's, Master's and Doctoral works at this facility.

In 2009, the main drift was brought into service throughout its length (1865 m). As a result, the opportunities for other ways of using the underground in the Mokrsko-West area were expanded. An inter-university underground laboratory (InterLab) was established in one of the gallery side niche in this area with the support by the Czech Ministry of Education, Sports and Youth. Four universities, namely the Faculty of Civil Engineering and the Faculty of Nuclear Sciences and Physical Engineering of the CTU in Prague, the Institute of Chemical Technology, Prague,

the Technical University of Liberec and the Masaryk University, Brno decided to join their scientific capacities and jointly participate in the development and operation of the underground laboratory. The decision was made taking into consideration the necessity for comprehensive and systematic solving of multidisciplinary problems regarding the development and operation of gas storage caverns, deep level underground disposal of spent nuclear fuel or underground storage of CO_2. Seeking optimum solutions to the above-mentioned topics requires the long-term preparation of specialists (students), not only theoretical but also practical, comprising the possibility of experimental education in the in-situ environment (see Fig. 4). First students were greeted by the InterLab in June 2010. Approximately 1300 students took turns in the underground provided by the Josef gallery from the beginning of teaching in the autumns of 2007 to 2010.

Figure 4. Interuniversity laboratory.
Slika 4. *Međusveučilišni laboratorij*

6. Experimental research

It was obvious from the initial idea about bringing the underground into service that, the experimental in situ research would become no less important in the Josef gallery.

The recent development in the Josef gallery complex fully confirms this assumption. Till now, 6 research projects have been accomplished in the underground areas of the Josef gallery, 9 projects are being implemented and others are under preparation. Both Czech and foreign parties participated and participate in solving the projects. As far as the topics are concerned, the majority of them is focused on two areas: the research associated with the problems of developing a deep-level repository (DR) for spent nuclear fuel and high-level radioactive waste (HLW) and the research into gas permeability of the rock mass.

6.1. 1st in-situ project

The first, and till now the longest-running experiment conducted in the Josef gallery (2006 – 2010) was the TIMODAZ, an European experiment carried out in collaboration of 14 European research institutes and universities (see Fig. 5). The project investigated the influence of long-term thermal load on the stability of the lining of the tunnel where containers with spent nuclear fuel are stored. Repository tunnel lining stability must be secured for an extremely long period of time, mainly for reasons of the potential future retrieval of the radioactive waste container. The experiment was based on two physical models – a laboratory model at the CEG laboratory in Prague and an in-situ model at the Josef gallery (Vašíček & Svoboda, 2011).

Figure 5. TIMODAZ experiment
Slika 5. *Pokus TIMODAZ*

6.2. Partnership with RAWRA

The Radioactive Waste Repository Authority (RAWRA) is a long-term partner and/or client for the experimental research in the field of disposing of spent nuclear fuel. Topics are based on the need to systematically explore and verify the properties of materials which are expected to be used for the construction of an engineered barrier of underground radioactive waste repository. It is also necessary to develop technologies to be applied for these materials.

This circuit is associated with projects focused on the research into properties of bentonite-based materials exposed to long-term effects of heat and a saturation medium with extreme effects, for geotechnical research into the possibility to use the sprayed bentonite technology for the structure of the sealing layer of a deep-level repository.

Another subject of the research with RAWRA is the experimental in-situ simulation of vertical placement of a container with spent nuclear fuel in the DR. A blind edit in the Mokrsko-West area, where prevails high-quality granitic rock, was selected for this unique experiment in the Czech Republic, named the Mock-up Josef. A preparation phase preceded the drilling for the repository wells. It consisted of the scaling of the excavated space and clearing of the bottom up to the primary rock and casting of

concrete slabs required for the stabilization of the drill rig. Based on the parameters recommended for the material to be used for the geotechnical barrier, B75 bentonite from the Obrnice dressing plant was selected for the construction. This bentonite is technologically modified natural bentonite and its characteristics were verified by a series of tests performed in the CEG laboratory. At the moment a heating device which will simulate heat loading induced by the container with the HLW is being tested and the production of pressed bentonite blocks for the construction of the barrier is in progress (Pacovský et al., 2011; see Fig. 6).

Figure 6. Niche with wells for the Mock-Up experiments.
Slika 6. *Slijepi hodnik sa zdencima za "Mock-Up" pokuse*

6.3. Gas permeability research

Gas permeability of the rock mass is the subject of an extensive research project being solved by the Centre of Experimental Geotechnics at the FCE jointly with Mott MacDonald Praha Ltd within the framework of the Ministry of Industry and Trade project – TIP Programme. Gas permeability of rock mass is being researched in the context of the idea of developing underground facilities storing energy media, capturing and storing underground carbon dioxide. Last but not least, the research is associated with storing of radioactive waste. Till now no reliable methodology exists, which could be used for designing the method and extent of monitoring of the safe operation of the above-mentioned underground workings. Disposing or storing of matters in the underground requires perfect, unquestionable monitoring systems, which are capable of detecting possible leaking of these matters to the surrounding environment. Underground areas of the Josef gallery, owing to the varied geological environment, represent unique conditions for in-situ testing in the field of the research into the gas permeability (Svoboda & Smutek, 2011).

7. Josef regional underground research center

In 2010, the Centre of Experimental Geotechnics at the FCE was awarded a grant from the Enterprise and Innovation Operational Programme for the "Josef Regional Underground Research Centre" (Josef URC) science and technology park project. A long time unused two-storied building in the above-ground complex of the Josef gallery became a basis for the Josef URC. It is a former head house, which grew dilapidated after the end of exploratory operations in 1991 and which was obtained by the FCE of the Czech Technical University as a gift from the owner of the working, the Ministry of the Environment.

The Josef URC uses existing capacities provided by underground areas and the existing above-ground hinterland. At the same time it expands the possibilities of using the parts of the gallery which were brought into service and offers space and services to the world of business, particularly to innovative companies. It is also hoped that it will serve as a business incubator for newly emerging firms.

The principal objectives of the Josef URC are:

- the support for industrial research;
- technological development and innovations focused first of all on new technologies, competitive products and services in the field of underground structures;
- the more rapid transfer of research results to practical applications;
- the training and re-qualification of workers in underground construction techniques;
- marketing support, expert services and accredited testing.

There is no other science and technology park in the Czech Republic or Europe offering such an infrastructure, environment and scope of services comparable to the Josef URC. Its uniqueness lies in the functional interconnection with a vast complex of underground areas available at the Josef gallery. Thus the fusing of the Josef URC and the already operating above-ground complex gave rise to a work place which prepares experts in underground construction in real conditions and, at the same time, businesses are able to find the very best facilities for their own research.

The reconstructed service building offers space on three floors with a total area of 914 m^2 including office facilities, a multifunctional conference room, an experimental hall, accredited laboratories and technical support facilities (Fig. 7). Over 300 m^2 of floor area is available to businesses on a rental basis. Interior spaces are equipped with office furniture and information technologies. Modern apparatus and equipment are available in the laboratories. In the area of information technologies, there is e.g. the multifunctional data network with the internet connec-

tion, which serves as a backbone for all communication, audiovisual installations in the conference room and a digital telephone system.

Partners of the project are subjects from the commercial sphere, public authorities, the towns and the Mining Museum Příbram. The project is supported by the International Atomic Energy Agency (IAEA) having its seat in Wien and the ITC School (School of Underground Waste Storage and Disposal), Switzerland.

Figure 7. Josef URC building.

Slika 7. *Zgrada podzemnog istraživačkog centra Josef*

8. Training activities

The Josef gallery complex has started to build its position even on an international scale. Owing to the Josef gallery presentations in foreign conferences and seminars introducing it as an unique area for practical training as well as experimental research, two training visits took place in this facility this year. The first of them was a part of a training course "Fundamentals of Geological Disposal 2011", which was held from 14th to 23rd June 2011 in Prague by the Centre of Experimental Geotechnics (CEG) at the FCE of the Czech Technical University in cooperation with the ITC School, a Swiss international organization. Among the parts of the course there was a two-day practical training ran by lecturers and doctoral students from the CEG at the Josef URC. Twenty young experts from 13 countries all over the world got acquainted, first theoretically and then in-situ conditions, with three topic circuits, namely the procedures applied during the measuring of gas permeability of the rock mass, the methods of the underground construction monitoring and the procedure for the application of the spray-applied backfill. The most important aspect of the entire training was the integration of the participants into all activities (see Fig. 8). This opinion was confirmed both by representatives of the ITC School and by all attendees, who received a certificate proving the successful passing through the training course.

Figure 8. Core drilling.

Slika 8. *Bušenje jezgre*

The other international event was a three-week teaching course, which took place within the framework of PETRUS II, a three-year European project whose objective is to establish a concept of Europe-wide system of preparation of experts dealing with problems of the treatment of radioactive waste. The CEG has participated in this project since 2009. The course was attended by 10 students from France, Spain, Finland, Great Britain and the Czech Republic. The major part of the training took place in the Josef gallery complex. In the laboratories of the newly reconstructed Josef URC building, the students tried to apply methods for determining properties of bentonite (e.g. the degree of saturation, the swelling pressure etc.). In the underground, they acquainted themselves with the measurement of convergences, core drilling, monitoring of temperatures and the technology of developing a sealing bentonite barrier at a deep-level underground disposal site. All of that was conducted under the leadership of the CEG teachers and doctoral students (see Fig. 9). Next days the training continued by lectures delivered by teachers from the Aalto University of Helsinki. European collaboration within the area of storing radioactive waste is very profitable and it is important that this trend continues even in the future.

Figure 9. Bentonite properties determination.

Slika 9. *Određivanje svojstava bentonita*

9. Conclusion

It is obvious that the intentions which were defined on the reopening of the abandoned mining working gradually start to be brought into being in the Josef gallery complex. It has already been for five years that the practical training and practical teaching of university students are performed. Research projects have been realized in several side niches, the underground serves to international training activities and cooperation with entrepreneurial subjects is starting to work owing to the Josef URC science and technology park. Initial marketing activities have appeared – HILTI CR Ltd and BASF Construction Materials, Czech Republic Ltd have shown interest in the presentation of their products. Another long-term objective is to expand the international cooperation by incorporating countries outside the European Union. Negotiations on the cooperation with Chinese colleagues from the Beijing Research Institute of Uranium Geology are in progress and even partners from, for example, Korea, Russia and Croatia have exhibited their interest.

Acknowledgements

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