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Petr Bujok*, Martin Klempa*, Pavel Pospíšil, Robert Rado***, Michal Porzer*, Jakub Ryba*, Martin Bláha*, Aleš Poláček***

ANALYSIS OF THE HAZARDS OF THE BAZALY FOOTBALL STADIUM IN OSTRAVA IN TERMS OF ENVIRONMENTAL IMPACT

1. INTRODUCTION

The catalogue geohazard base of *Česká* geologická služba (CGS – Czech Geological Survey) is part of a geological data portal established in 2006. The geohazard database is a place where information about potentially hazardous geofactors in the Czech area is collected and shared. The base also contains the most important sources of data and references to respective regulations and law. Geohazards have been catalogued and described by CGS specialists representing various disciplines, depending on the origin and conditions in which geohazards were generated, geographical distribution, time character, associated processes, social impact, type of hazard, monitoring methods, etc.

Geofactors of the natural environment belong to organic phenomena shaping and influencing the landscape and quality of nature, including the natural environment. In the Czech Republic, the risk of the occurrence of geofactors which have an impact on the natural environment are specified in respective directives and law. The term ‘geohazard’ refers to natural catastrophes connected with processes in the Earth crust. In this paper, ‘geohazard’ will be associated with anthropogenic natural phenomena and human activity connected with the existing risks for the football ground.

The influence of man on the lithosphere can be reduced to ‘anthropogenic geology’, or more precisely, ‘anthropogenic tectogenesis’. Among the natural factors influencing the movements of the crust are surface seismic movements, mainly the movement of surface strata during earthquakes, isostatic movements, formation of sinkholes when underground voids and caverns collapse, deformations in areas of active faults, deformations associated with volcanic activity and gravity forces (landslides, mud slides, stone slides). Among similar phenomena having an impact on the Earth’s crust are also effects evoked by human

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* VŠB-Technical University of Ostrava, Faculty of Mining and Geology, Ostrava Poruba, Czech Republic
** VŠB-Technical University of Ostrava, Faculty of Civil Engineering, Ostrava Poruba, Czech Republic
*** AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, Krakow, Poland

activity. Anthropogenic subsidence of the Earth crust is most frequently caused by mining activities, the extraction of liquid minerals and burdening the rock mass with building objects.

In the case of underground extraction, the hazarded is determined with the twist angle equal to about 20° from vertical, though damage on the surface may obviously appear further from the area thus defined. In most cases, the surface subsides, the difference between the height of the neighboring areas increases and gives rise to the landslide phenomena.

Extraction and use of resources of the lithosphere always means considerable interference with the geological setting of the given area. The deposits themselves and the natural environment are hazarded by mining. Anthropogenic geological processes have a direct and indirect impact through independent factors which change the natural geological processes.

The following natural hazards can be distinguished in the monitored area of the BAZALY stadium based on the CGS geohazard catalog:

- coal-bed methane,
- waste and reclamation materials,
- anomalously high concentration of heavy metals and metalloids,
- areas weakened by underground extraction,
- post-extraction old workings,
- vertical movement, following tectonic disturbances,
- landslides.

2. RESEARCH AREA ON THE FOOTBALL STADIUM BAZALY

The football stadium BAZALY, former seat of football club FC Baník Ostrava, was localized on a slope (bearing the same name) at the Ostravica River in the Silesian Ostrava area (Fig. 1).

The geohazard was analyzed on the order of Ostrava Municipal Office.

Ostrava belongs to those Czech areas where the biggest conflict is observed between coal extraction, present and planned development of the city infrastructure and environmental protection.

In areas of intense deep coal extraction, the mining damage in Ostrava and in the post-mining areas manifests it self in subsidence and surface deformations, leading to damage to the surface infrastructure.

Since the late 1950s, anomalous and spatially limited damage of building infrastructure has been observed in Hladno (now part of Ostrava) in Silesian Ostrava. Damaged objects and communication routes were located in the "Petr Bezruč" mine i.e. between Stromovka through Hladnov to the court building on the other bank of the Ostravica River (Fig. 2).

The remaining damage to the infrastructure was ascribed to mining activity. However, their northwest/southeast course is nearly perpendicular to the documented faults. Hladnowska tectonic disturbance, or as it is also called the Silesian-Ostrava fault, is considered to be a manifestation of disturbances dating back to the Carboniferous time. Some experts believe that the direction of zone of damage to the infrastructure coincides with that of the Jaklowiec beds exploited at the turn of 18th and 19th century. The spatial correlation of the course of damage

Fig. 1. Localization of research areas – BAZALY football stadium within the city of Ostrava (red ellipse shows the Hladno district in the Slezská Ostrava district where the BAZALY football stadium is located)

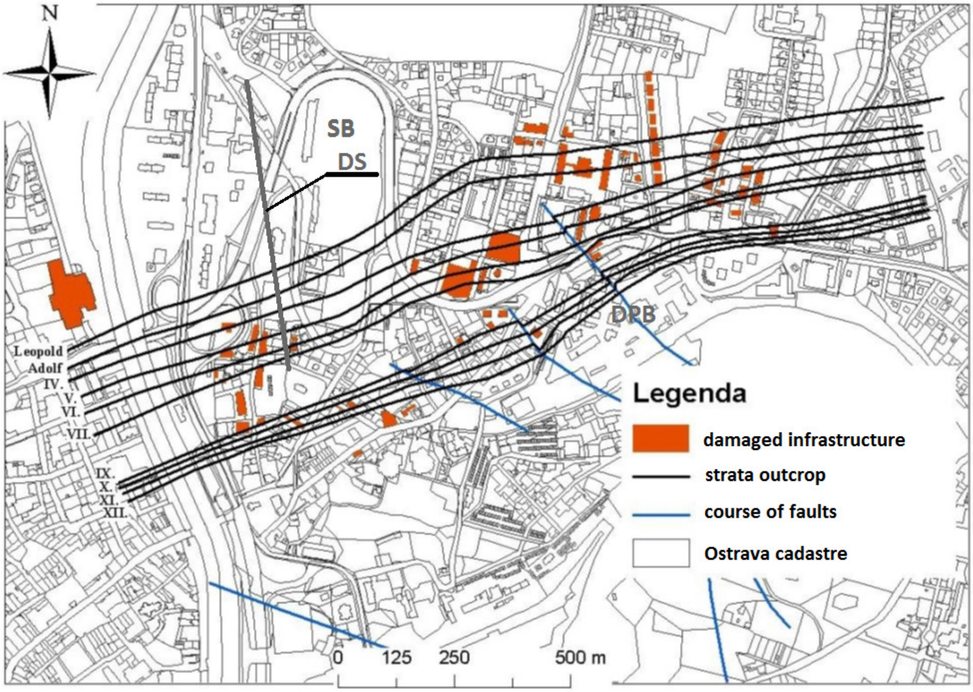

Fig. 2. Correlation of the damage of objects with reference points (SB – stadium BAZALY, DPB – "Petr Bezruč" mine, DS – Old Adit)

with the orientation of the Jaklowiec beds was also confirmed by geophysical measurements. Basalt quarries were also present in the research area. Basalt spheres of 0.1 m to 3.0 m diameter (called 'BAZALY' at that time) were found in the sand and clay layers.

The analyzed area is diversified as far as its spatial development is concerned. The most important aspects are the close proximity of the city center (less than 1 km) and partially hilly character of Hladnov. From the geological-engineering point of view, this area is very disadvantageous as far as the construction and maintenance of infrastructure are concerned because of the mining-induced rock mass.

Apart from the damage to residential, industrial and transport infrastructure, other behaviors of the loosened rock mass can hardly be predicted. The intensity of deformations and strains will vanish with time. The opposite may also happen and the phenomena will intensify under the influence of impacts such as the elevation of heavy objects, changes to the level or/and flow of groundwater, etc. If the subsoil is additionally stabilized to minimally protect the further activity of man, no forecasts can be made for the future.

3. RESEARCH WORKS REALIZED IN THE BAZALY STADIUM

For the sake of a complex evaluation of the state of the analyzed area and a description of hazards according to the Czech Geological Survey standards, geochemical, geoengineering and geophysical analyses were performed to help make a complex evaluation of the analyzed area.

Methane and carbon dioxide surface screening

During the realization of works, the area was screened to verify the CH_4 and CO_2 concentration in soil air in the BAZALY stadium. The area was divided into two parts, i.e. the main stadium and the adjacent area with a training stadium.

The research methodology was as follows: the study area was divided into smaller sites and the readouts were made according to the established grid of measurements. The mesh of the measurement grid in the central stadium totaled 10 m × 5 m, and the measuring points for the training stadium and adjacent areas were distributed in a grid of mesh 10 m × 10 m. The soil samples were collected from boreholes of diameter Ø = 8 mm and depth of ca. h = 1 m. Measurements were performed with a G750 Polytector II. This measuring device can be used as a single- or multi-gas detector for the simultaneous monitoring of gas hazards.

After sucking in the air from the soil, the device determined CH_4 and CO_2 content in the sample. 242 measuring points were identified in the entire research area. Measuring points were placed in the accessible sites of an open space, where the stadium infrastructure could not be damaged during measurements. The heated area of the stadium, remaining developed sites with buildings, grandstands and offices were excluded from analyses. The CH_4 content at the measuring points ranged between 0.05 and 0.2 vol.

The analysis of the obtained measurement results shows an increased methane concentration which can be treated as geohazard. Monitoring boreholes AV1÷AV8 were drilled in places of higher CH_4 concentration. They were equipped with a system for the constant measurement of methane content in soil.

Geophysical surveys

Geophysical surveys were planned as noninvasive research works which do not interfere with the rock mass when determining disturbances in it in the analyzed area and establishing places for further research with the use of drilling technology. Geophysical surveys were performed in the summer and then the results were interpreted and drilling jobs followed. Taking into account the build of the soil and rock mass in the analyzed area, and the expected geohazards, two methods were applied: Electrical Resistivity Tomography (ERT) and Ground Penetrating Radar (GPR).

ERT method (Electrical Resistivity Tomography)

The ERT method (sometimes called resistivity tomography or multicable) is presently the most frequently applied resistivity method for recognizing the surface geological build, anomalies in the soil and determining quasi homogeneous geological units and objects. This method is considered to be very useful for identifying old workings. This measurement methodology links two classic d.c. resistivity methods, i.e. Electrical Profiling (EP) and Vertical Electro Sounding (VES).

The measurements were performed with an ARES-200E, i.e. automatic geoelectrical system involving a multi cathode cable (one cable with 8 electrodes). The works realized with this apparatus are illustrated in Figure 3.

Fig. 3. Measurements with the ERT method. Unwound cable with electrodes, profiling no. 8

By using a method involving multi electrode resistivity measurement with an ARES 200E in the BAZALY stadium we can obtain a great amount of apparent resistivity data measured by four symmetrically distributed points, thanks to which the boundaries of quasi uniform measurement environment can be determined. This profiling is exemplified in Figure 4.

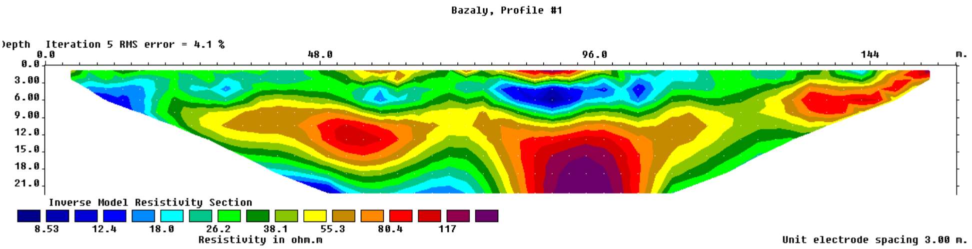

Fig. 4. ERT 1 profile with distinct maximum measured resistivity of the measured area marked in a red to red-to-brown color

GPR method (Ground Penetrating Radar)

The GPR method relies on the propagation of electromagnetic wave pulses (radio waves) of high frequency between 10 MHz to 1000 MHz in the ground. This method belongs to non-invasive methods of surveying ground medium. Besides, this method is mobile and allows for acquiring considerable high resolution data in a short time at a relatively low cost. The accuracy of the obtained data depends on the properties of the ground in the research area, type of soil and vegetation growing on it, saturation with groundwater or other fluids and electrical conductivity (dielectric constant) of the ground.

Disadvantageously for GPR, the depth interval changes with the physical properties of the ground in the study area. The presence of layers such as clays, silts, hydrated sands, i.e. beds containing water or anthropogenic materials of high electrical conductivity result in lower efficiency of the GPR method. This method can be used if the physical properties of the body can be contrasted with the properties of the background in which it resides.

The homogeneity of the ground environment in the shallow part was analyzed with a Swedish geophysical radar RAMAC/GPR by MALÅ GeoScience AB (device in operation shown in Fig. 5).

Fig. 5. Measurements with the GPR method with a 50MHz non-screen antenna, diagonal profiling

The results of surveys in the research area were worked out in the form of radiographs with the specialist RadExlorer 1.42 software. They document the shallow vertical profile of the ground in the research area. The analyses reveal that that the ground medium is partly or completely built of anthropogenic materials introduced to that place or rock medium with anthropogenic material of the displaced rock mass (Fig. 6). The surveys performed with boreholes proved the presence of both types of ground, i.e. introduced anthropogenic materials (gravel or various size building debris) and also displaced local materials, e.g. fragments of the basalt which was extracted in that area.

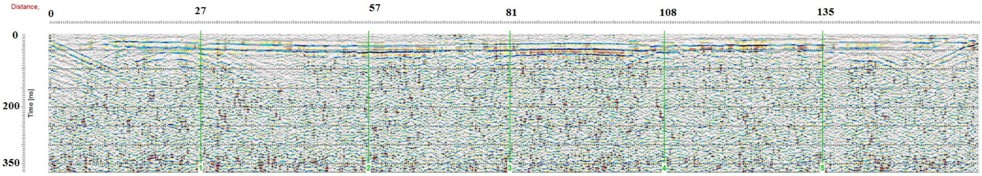

Fig. 6. GPR 4 profile (longitudinal axis of grand stadium) with a noticeable change of parameters of rock mass in the shallow zone. Anomalous area is localized at a distance of 22 and 108. The anomaly at a distance of 108 roughly coincided with the Autumn sinkhole of 1997

Anomalies were observed in the profilings. They were interpreted as the presence of basalt fragments in the ground medium, and then verified with drillings. This explains the registered geophysical anomalies and interpretation of radar images from the profiling sites.

All of the performed GPR profilings have strong interferences in deeper parts, which can be seen in the presented profiling example (Fig. 6). They are caused by the presence of materials having magnetic properties, therefore the anomalies detected with ERT at a depth below 14 m could not be registered with GPR.

The geophysical data were verified with an invasive method, i.e. with research boreholes.

Drilling jobs were performed in both analyzed areas to a depth of about 20 m. The surveys with the ERT method determined anomalies in the rock mass at a depth exceeding 10 m. Measured resistivity anomalies were observed mainly in the southern part of the main stadium. In 1997, the ground subsided in this area, probably due to the ongoing mining operations.

The GPR method used in this particular ground was less useful and efficient because of the presence of rubble containing basalt, which disturbed the propagation of electromagnetic waves. This method was definitely more accurate than ERT in reference to the homogeneous shallow part of the ground in the analyzed area.

4. ANALYSES WITH THE DRILLING METHOD

Shallow atmogeochemical monitoring boreholes

Eight boreholes were performed and equipped in the analyzed area. These were atmogeochemical boreholes (Fig. 7) denoted as AV 1–8. Their distribution depended on the following factors: size, morphology and accessibility of the analyzed area as well as results of methane screening and presence of carbon dioxide based on the results of results of the remaining measurements (ERT and GPR). The research boreholes were aimed at long-term monitoring for the presence of methane and carbon dioxide in the surface, undeveloped zone of BAZALY stadium.

Atmogeochemical boreholes were drilled with a rig MVS-1 at a depth of about 1.5 m. Their diameter equaled 0.8 m (80 mm) and were cased with synthetic pipes, slotted in the lower part, with z lag packing and pack. The boreholes were equipped with ball valves, through which soil air was collected statically or dynamically. A schematic of boreholes AV 1–8 is presented in Figure 8.

Fig. 7. Atmogeochemical borehole AV-3 in stadium BAZALY

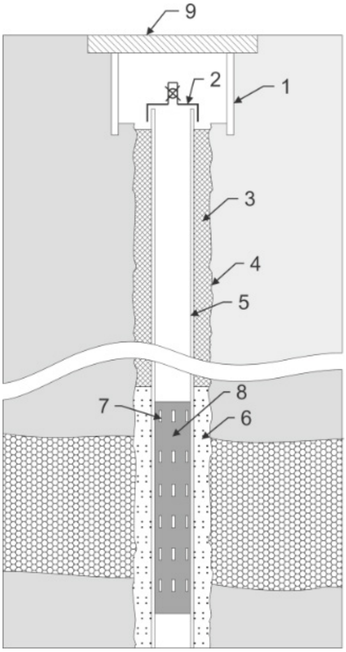

Fig. 8. Equipment installed in atmogeochemical borehole: 1 – protective casing of wellhead; 2 – wellhead with a ball valve; 3 – clayey sealing; 4 – borehole wall; 5 – synthetic pipe; 6 – pack (washed sand); 7 – slotted screen; 8 – lag packing; 9 – concrete plate

Hydrogeological monitoring boreholes

Eight hydrogeological boreholes MV 1–8 were also drilled in the analyzed area. They were located on the basis of similar criteria to the atmogeochemical boreholes. These boreholes were used for determining the geological setting of the analyzed area and establishing the homogeneity of the ground and hydration. Thanks to the applied equipment and long-term monitoring, such boreholes also provide information about possible contamination of the ground. These boreholes can be also used for the rough analysis of methane and carbon dioxide in the near surface zone (with additional equipment). The boreholes were distributed according to the criterion that they should be localized in the higher risk sites. They were also correlated with the boreholes of the AV series.

These boreholes were also performed with a rig MVS-1 to various depths (depending on the drillability of the ground) with a tool of diameter 0.8 m (80 mm). The boreholes were cased with polyethylene pipes 0.75 m (75 mm) in diameter.

In the course of drilling works with a rig HVS-04A by K-Geo s.r.o. the coring technique was also used (Fig. 9). This is a hydrogeological rig with greater installed power as compared to the geological rig MVS-1. This device was used because of the necessity of drilling barely drillable strata at small depth from 1 m to 5 m below the surface. These works definitely required a bigger rotational torque and axial weight on the bit, which could not be provided by the rig MVS-1.

A total of 5 core boreholes were drilled (JV 1–5). They were equipped in a similar way to the monitoring ones. These boreholes were performed to verify the geological setting and detect groundwater in the area of BAZALY stadium. All boreholes were cased, thanks to which measurements could be made. Three of these boreholes were used for hydrogeological surveys.

Fig. 9. Rig HVS-04A while drilling borehole JV-1

The analysis of drilling jobs revealed that the ground in the analyzed place was strongly non-homogeneous. Geological profiles changed with the place of drilling. There were deposited various materials, especially blast-furnace slag (a serious geohazard – heavy metals can be washed out), clayey slag, dusty clays and building rubble. The introduced mass of various materials was found in all boreholes (AV, MV i JV).

Basalt sites are frequently applied in the analyzed area, from completely weathered, through locally weathered to massive fragments with olivine inclusions, sometimes also in the form of basalt spheres), which can be found at a depth of 1.5–2.0 m to 13 m. In this case it is not clear whether this is old introduced material (e.g. old heap in the place of former basalt extraction), or basalt from Miocene Eggenburg sediments (Quaternary basement). The Eggenburg strata were drilled at a depth of 4.0–5.0 m, whereas Carboniferous beds were drilled with one borehole. It assumed the form of a weathered, light brown, medium grain mica sandstone starting at a depth of 5.3 m. Groundwater was found only in three boreholes.

5. EVALUATION OF GEOHAZARDS IN THE BAZALY STADIUM

Methane in coal basins

The presence of methane was confirmed by some monitoring boreholes. In the case of geohazards, methane may uncontrollably accumulate in surface objects, cellars, canals, etc. This means a potential geohazard for the existing buildings, risk of explosion, air and groundwater contamination and the so-called greenhouse effect.

Waste and recultivation materials; anomalous concentrations of semimetals and heavy metals

Waste materials were found in most of the boreholes in the BAZALY stadium. In the case of these materials, geohazard may generally come from blast-furnace slags, from which heavy metals can be washed out and then penetrate groundwater.

Areas disturbed with underground mining, and resting on tectonic disturbances

Old mines and underground military constructions dating back to the times of WWII can be found in the monitored area. This area has a complex development, besides in the 19th century raw minerals were extracted there with shallow excavations. No detailed or complete documentation of old workings and nonliquidated post-extraction coal workings of the 18th, 19th and the first half of the 20th century exists. These files were damaged at the during bomb raids at the end of WWII.

For these reasons, the localization of old workings and underground infrastructure may rely only on incomplete data coming from inhabitants of that area and historical records. The detailed analyses revealed that an inactive old working probably adheres to the Jaklowice Adit (Fig. 2). An air raid shelter from WWII is probably located close to the south boundary of the research area. The localization of the object and its corridors have not been precisely confirmed by the analyses.

Vertical deformations in the analyzed area along a tectonic fault can also be evoked by changes in vegetation, varying water content in the rock mass, tremors and vibrations, and increased load causing higher shear stresses.

Among obvious hazards are also disturbed stability caused by incomplete, insufficient or improperly old workings, presence of old shallow workings, which have not been precisely localized yet.

With time, the closed old mines lose their stability due to exogenic processes. This loss is a function of the physico-mechanical and deformation properties of the rock mass, depth of deposition of underground workings and tectonic disturbance. When the strength of the caprock is exceeded, the mine workings undergo caving (gradually or rapidly), which may also appear on the surface (subsidence trough, sinkhole, cone, discontinuity of terrain, etc.). Another important threatening factor is the potential outflow of gases to the surface.

Landslides

A potentially unstable rock medium was indicated on the western edge of the analyzed area. This is a landslide area catalogued by the Czech Geological Survey under the number 6609.

The instability at the western edge of the analyzed area, inclined to the west from the training stadium, probably is caused by a combination of various factors, e.g. morphology of terrain and its transformation over the long time of spatial development. The rock and ground media are strongly diversified in this area; they reach weathered subsoil at various depth, and their lithology is formed by the Upper Carboniferous strata, on which Tertiary and Quaternary sediments are deposited. Moreover, the rock environment is disturbed with locally occurring basalt blocks and veins.

6. CONCLUSIONS

FC Banik Ostrava played its last match in the BAZALY stadium in the years 2014/2015 and then the object was closed. Plans were made to renovate and transform this place into a football school for children. The stands and part of the infrastructure were to be liquidated and substituted with new infrastructure with small stands and a new background. The surface of the stadium was to be divided into smaller objects, where children could practice. The revealed presence of all of the predicted geohazards creates a serious problem in view of the new designation of the stadium. The strongly nonhomogeneous ground and rock medium is the major problem as far as earth, construction and engineering works are concerned. The geomechanical properties of the ground and the rock subsoil are expected to considerably change, their carrying capacity will probably change, and methane may move in the rock mass in that area.

For social and environmental reasons, this area should undergo constant monitoring. Monitoring should prevent and minimize the unfavorable impact of the discussed hazards on the crew at the construction stage, users and visitors. This will help protect the whole ecosystem in the vicinity of the stadium and minimize the consequences of the potential impact. The monitoring will provide reliable long-term data for people living and working in the neighboring area.

REFERENCES

[1] Černý I. (ed.): *Uhelné hornictví v ostravsko-karvinském revíru*. Anagram, Ostrava 2003.

[2] Geohazardy, portál ČGS. http://www.geology.cz/geohazardy, 2016.

[3] Klát J., Slíva K.: *Kronika počátku hornictví v Ostravě 1750–1830*. Ostrava 2011.

[4] Martinec P.: *Vliv ukončení hlubinné těžby uhlí na životní prostředí*. Pro Ústav geoniky AV ČR vydalo nakladatelství Anagram, Ostrava 2006.

[5] Vopasek S.: *Dějiny hornictví: Aneb jak to bylo s uhlím na Ostravsku*. Repronis Ostrava, Ostrava 2005.

[6] Slivka V. et al.: *Závěrečná zpráva analýzy možných geohazardů v lokalitě fotbalového hřiště Bazaly (parcelní čísla 1706, 1708, 1709/1) Slezská Ostrava.* VŠB-TUO, Ostrava 2015.

[7] Zářický A.: *Ve stínu těžních věží: Historie dobývání kamenného uhlí v petřvaldské dílčí pánvi od počátku prospektorské činnosti do roku 1906*. Filozofická fakulta Ostravské univerzity, Ostrava 2004.