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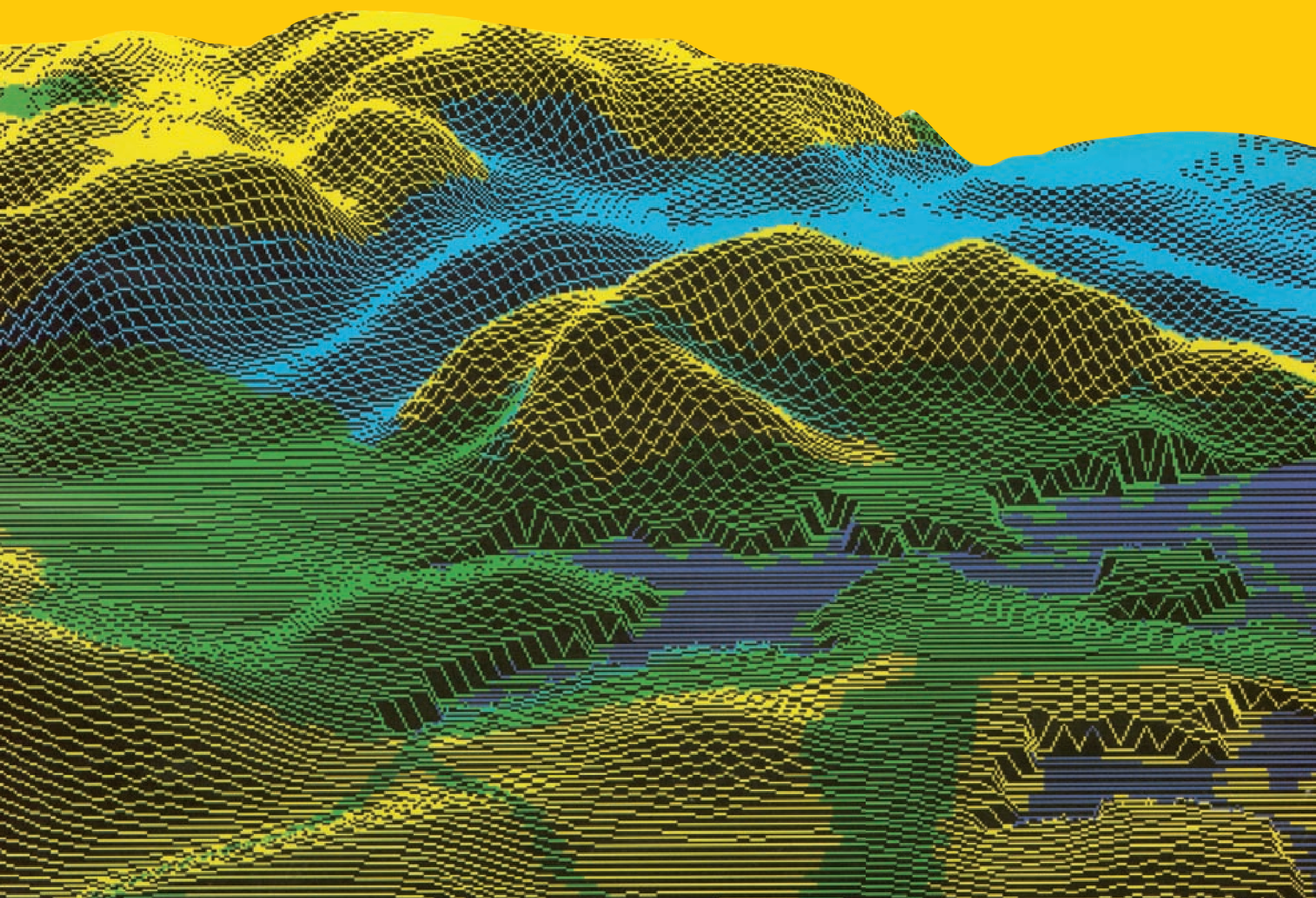

Mine ČSM Karviná Corp. and area recultivation in the space of Karviná Louky.

Photo O. Mikulík

Nová Huť Corp.

Photo O. Mikulík

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Articles

Reports

A Foreword by Editorial Board

The period after 1990 can be characterized by changing economies and by the restructuring of industrial operations in the entire "eastern block" with the changes concerning particularly the areas with dominating heavy industries and coal mining. These industrial branches formed a specific demographic structure with an untypical development of seats while markedly reshaping the face of landscape and environment conditions.

Industrial agglomerations have been paid attention by research teams of various professional orientation already for several decades. There are studies in which the geographers make among other things long-term assessments of the impact of economic activities on the landscape and environment.

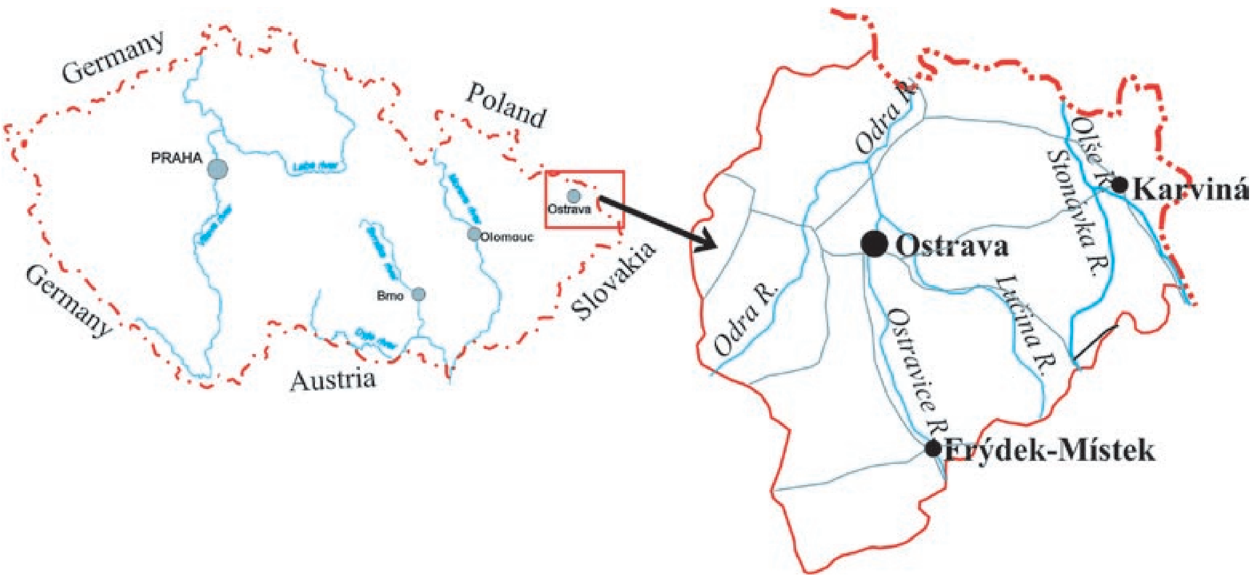
It is not only the Czech Republic that has to struggle with the problems of restructuring in Central Europe but also Poland (e.g. the Katowice region), the former German Democratic Republic (e.g. the Halle-Leipzig-Dresden region), Hungary (e.g. the coal mining area near Pécs), Slovakia, etc.

In the Czech Republic, the region of Ostrava (Fig. 1) was one of areas in which industrialization (heavy industries, deep bituminous coal mining) severely changed the face of the landscape and deteriorated the environment. In 2004, a research project was accomplished within the ASCR Programme of targeted research and development "downsizing deep coal mining and its impacts on processes in lithosphere and environment", and the ASCR Programme of Research Development in the key scientific areas "Impact of climatic and anthropogenic factors on live and inanimate environments" focused exactly on the Ostrava region.

Results from research studies in the Ostrava region were summarized in final and partial reports and a set of maps was prepared that was published in the periodical Documenta Geonica 2004.

This number of Moravian Geographical Reports is devoted to selected new pieces of knowledge from the research programmes on the transformation of the Ostrava landscape and environment after 1990. The studied territory was defined so that the belt of minefields would encircle the space which forms a certain transition zone between the area affected by the mining activities and the wider hinterland of the Ostrava agglomeration in which the adverse influence of economic activities on the landscape and environment is gradually fading.

In order to compare the impacts of restructuring industries on the landscape and environment, the Editorial Board invited colleagues from other post-socialist countries to send results from similar studies. This number includes a contribution from Hungary concerning the situation in Pécs which is affected by coal mining activities in the nearby Mecsek Mts.



Area under study

DOWNSIZING OF BITUMINOUS COAL MINING AND THE RESTRUCTURING OF STEEL WORKS AND HEAVY MACHINE ENGINEERING IN THE OSTRAVA REGION

Petr KLUSÁČEK

Abstract

Relations between the downsizing of bituminous coal mining and the restructuring of steel works and heavy machine engineering in the Ostrava region in the period after 1989, are at issue in this paper. The complexity of the transitional processes is documented by the development of three major corporations in the region of interest: OKD, Corp. (Ostrava-Karviná Coal Mines), Vítkovice, Corp., and Mittal Steel Ostrava, Corp. (formerly Nová huť, Corp.). Attention is also paid to the impacts of transitional change, primarily with respect to the increased unemployment rate and the improvement in environmental conditions. The study is based not only on secondary sources but also on extensive detailed fieldwork data, obtained from the project of targeted research: "Downsizing deep coal mining and its impacts on processes in lithosphere and environment".

Shrnutí

Útlum těžby černého uhlí, restrukturalizace ocelářských výrob a těžkého strojírenství na Ostravsku

Příspěvek se zabývá problematikou útlumu těžby černého uhlí a restrukturalizací ocelářských výrob a těžkého strojírenství na Ostravsku v období po roce 1989, přičemž složitost celého procesu je dokumentována na transformačním vývoji tří největších společností zájmového území: Ostravsko-Karvinských dolů, a.s., Vítkovic, a.s. a Mittal Steel Ostrava a.s. (dříve Nová Huť, Corp.). Velká pozornost je současně zaměřena i na dopady transformačních změn, především na zvýšení míry nezaměstnanosti a na zlepšení stavu životního prostředí. Předkládaný článek se opírá nejen o studium literatury, ale i o detailní údaje z terénního výzkumu, který byl realizován v rámci práce na projektu „Vliv útlumu hlubinného hornictví na děje v litosféře a životní prostředí".

Keywords: *Ostrava region, restructuring, steelmaking and heavy machine engineering, downsizing of coal mining, unemployment, labour productivity, environmental protection*

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1. Introduction

The downsizing of bituminous coal mining and the restructuring of related industrial operations (metallurgy, heavy engineering) can be considered an important topic that is paid global attention also within the framework of geographical research. The research carried out for industrial geography is usually focused on regions with a large concentration of industrial activities such as for example American Manufacturing Belt, Midlands in Great Britain or the Ruhrgebiet in Germany. H. D. Watts sees the "*central question of industrial geography as to why industrial activities grow / decline in particular places*" (Watts, 1987).

The theme of restructuring industrial operations is rather frequented also in the Czech Republic with the attention being paid – similarly as elsewhere in the world – especially to regions with a high concentration of one-sided industrial operations of which one is the Ostrava industrial agglomerations. The today's appearance and metamorphoses of the Ostrava landscape have been to a considerable extent influenced by the past development of industrial manufacture. Thanks to rich deposits of bituminous coal the Ostrava region recorded a great boom of coal mining and metallurgy already at the times of the Austrian-Hungarian Monarchy. The one-sided orientation of the region was later markedly fostered in the period of socialist building activities when the entire Czechoslovak economy concentrated on heavy industry. The so called socialist type of industrialization even had its main and most important centre in metallurgy (Mikulík, 1982). One of the very first steps made by the centrally controlled economy was a so called "steel concept of the country" announced after the February upheaval in 1948, which among other things put emphasis on a necessity of increasing the production of heavy industries in the Ostrava agglomeration.

The one-track orientation on coal mining and heavy industries in the Ostrava region showed its negative effect in the development after 1989 when changes occurred in the structure of manufacturing activities with the processes of transformation, privatization and restitution. Adaptation to the new conditions of market economy brought about the phenomenon of unemployment and wider social impacts on the population in general, particularly so in areas with one-sided manufacturing activities of which one was in the Czech Republic the Ostrava region. The significance of over-dimensioned manufacturing operations in the Ostrava region – mainly oriented to bituminous coal mining, metallurgy and heavy engineering – was put into question after 1989. Changes in the structure and extent of manufacturing activities in the area of study reflected also in other spheres of life. This paper attempts at a documentation of the complexity and impacts of the whole transformation process by means of analyzing the developing situation in heavy industries and in the closely related industries of metallurgy and heavy engineering, with the changes being documented namely on the example of three largest corporation in the region: OKD, Corp., Vítkovice, Corp. and Mittal Steel Ostrava, Corp. (former Nová Huť, Corp.).

The Ostrava research area of interest was investigated within the grant project No. IBS3086005 "Downsizing deep coal mining and its impacts on processes in litosphere and environment". One of important outputs from the project in the field of studying industrial activities has become without any doubts the map "Categorization of industrial areas in the Ostrava region" (Klusáček, Šotnar, 2004) which captures the situation in the region under study at the end of 2003 on the basis of a detailed field research (Fig. 2 – see cover p. 4). The so far conclusive importance of industrial activities for employment in the Ostrava region follows out from Fig. 1[1].

2. Downsizing of bituminous coal mining in the Ostrava region

The tradition of coal mining in the Ostrava region is over two hundred years during which the mining activities considerably affected landscape formation in the area

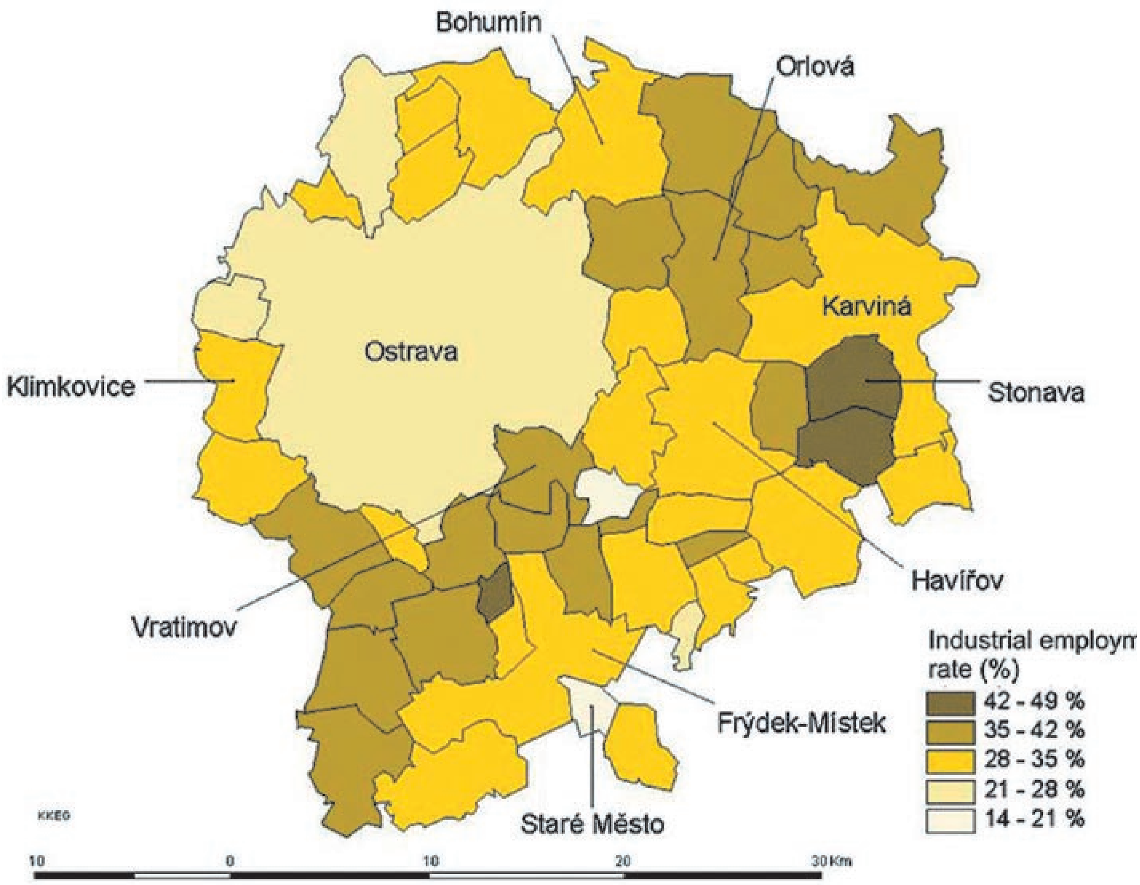

Fig. 1: The share of industrial workers in the Ostrava region in 2001 (Author: S. Martinát)

[1] For purposes of simplification, the Figure includes only the names of cadastral areas with extreme values of the studied phenomenon.

under study. Coal mines are currently operated mainly by OKD, Corp. (member of Karbon Invest, Corp.). Owner of Mine ČSM Stonava is the corporation of Českomoravské doly, Corp. (another member of Karbon Invest, Corp.). Active collieries are today namely occurring in the Karviná district: ČSA (area of colliery premises on the ground surface of about 26.1 km^2), Darkov (25.9 km^2), ČSM (22.1 km^2) and Lazy (17.5 km^2). Other active areas of bituminous coal mining outside the Karviná district are represented by the Paskov-Staříč colliery (40.4 km^2) situated NW of Frýdek-Místek. Passive collieries in which the coal mining activities were closed down occur namely in the territory of Ostrava-City or in its closest hinterland. Examples of down-scaled mining areas can be František, Odra or Žofie collieries.

The above mentioned actual layout of active mining districts in the Ostrava region resulted from a long-term process of restructuring that was launched after 1989. As compared with other countries (Federal Republic of Germany, Great Britain), the downsizing of coal mining in the Czech territory started later this relating to the above mentioned fact of support given to coal mining activities by the centrally controlled economy.

Nevertheless, first opinions criticizing the existing system, emphasizing the need of restructuring and warning against the hitherto way of development in the Ostrava region appeared in the then Czechoslovakia already before 1989, namely among scientists. One of these critical opinions was for example expressed by Jiří Kern in his article from 1969: "*Coal mining and metallurgy represent a foundation of the economic base in the Ostrava industrial agglomeration both with respect to the historical development and with respect to the intensity of incidence. Assessed from the viewpoint of conditions and prerequisites for the ensurance of the future permanent economic growth, it is the industry of coal mining in particular that is considered to have passed the culmination point of its development. Areas in whose manufacturing structure coal mining occupies an important position are losing their developmental dynamics. What was progressive at the end of the 19th and at the beginning of the 20th century, is changing into the regressive now. The Ostrava industrial agglomeration must search for ways of how to substitute the formerly progressive industrial branches with new ones so that the future growth of the region would not stop*" (Kern, 1969). In the same period of time, there are efforts showing within the framework of scientific investigation to learn new lessons from the development of similar mainly one-side oriented regions in western countries. For example, Petr Šindler (1969) compares economic conditions of the Ostrava and Ruhrgebiet industrial agglomerations mentioning as one of possible problems in Ostrava the fact that unlike in the Ruhrgebiet, coal mining and steel manufacture did not induce the development of other industries such as the processing or consumer industries.

The critical voices from the end of the 1960s were not listen to, though and no major steps were made to deal with the situation in 1970 – 1989. On the contrary, the development of coal mining and heavy industries continued (although at a milder pace) to result in the further worsening of environment in the Ostrava region. The Czechoslovak record amount of bituminous coal in history (24.6 mil. tons) was extracted in 1980. At that time, the share of the OKR (Ostrava-Karviná Coal Mining District) district in the national black coal mining and in the national supply of coking coal was 87 % and 100 %, respectively. Coal mining in OKR covered all requirements of metallurgical industry of the then state. The proper downsizing of coal mining and restructuring date back to the period after 1989.

The restructuring of coal mining showed in the field of production mainly by (Trávníček, 2001)**:**

- conspicuous downsizing of bituminous coal mining with the extraction volume in 2004 falling by more than 50 % as compared with 1989
- increased efficiency of coal mining with the contribution of advanced technologies and with coal extraction concentrated into productive coal-beds
- strengthening of new enterprises

Economic and organizational changes during the downsizing of coal mining were as follows:

- 1 January 1991 is the day of foundation of the Ostravsko-karvinské doly Corporation (OKD) which was at 100 % owned by the Fund of National Property until the end of 1994. The OKD structure of owners was changed in 1998 with the state losing its majority stock share and the majority owner becoming the company of KARBON INVEST, Corp.
- Branch collieries merged into group mines
- The Mine of ČSM in Stonava became independent on 1 January 1990 and in 1993 it became a part of the company Českomoravské doly Kladno (Bohemian-Moravian Mines Kladno). OKD was considerably weakened since the Mine of ČSM in Stonava was a new productive colliery with very good economic results.
- Some organizational units and activities capable of selling their produce also outside OKD singled out from OKD.

Measures adopted during the restructuring period in the field of human resources were as follows:

- As compared with the situation in 1989, the number of persons employed in OKD fell by 2004 to less than a fifth – this is well documented by employment development data presented in Fig. 3.

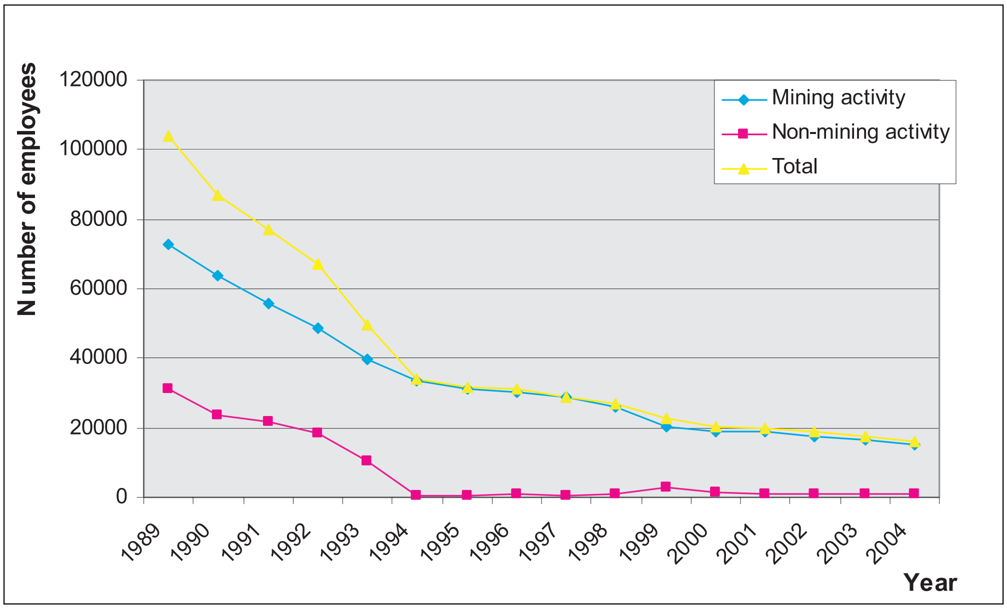

Fig. 3: Development of OKD employee numbers in 1989-2004

- In 1990, the work in underground was prohibited for persons below 21 years of age, and the prohibition due to which the vocational training of apprentices in fact ceased to exist was cancelled again in 1998.
- The highest exposition to dust was made more stringent, i.e. the number of shifts after which the miner must be moved up to the ground surface was reduced.
- Preferential regulations for recruitment and stabilization of workers in OKD were cancelled.

In 1990 – 1991, a total number of 17 000 mine workers were transferred to less hazardous or surface work by the Mine Commission for Social and Health Issues due to health reasons.

3. Transformation of metallurgy and heavy engineering in the Ostrava region

3.1. Transformation of Vítkovice after 1989

The produce of Vítkovice is mainly of metallurgical character. Other products made by Vítkovice are crankshafts and steel works equipment (heavy engineering), equipment for power plants, boiler bodies (power engineering), and environmental engineering products such as sewage water treatment plants. Vítkovice represented the largest closed-production cycle metallurgical and engineering complex in the Czech Republic until 1998 when the production of pig iron was closed there.

A very beginning of the Vítkovice state enterprise transformation was coming to existence of a joint-stock company with the authorized capital of 13.3 milliard CZK on 31 December 1992. To the date, the Fund of National Property of the Czech Republic held 96 % of the stock. In November 1996, Vítkovice, Corp. was approved for managerial privatization. A contract was signed between the government and Rafis Trading in which the latter committed to carry out enterprise restructuring. The company however run out of funds soon due to which Vítkovice started falling in debts with their economic efficiency gradually decreasing. In this period of time a global recession was recorded on the steel market and the engineering production of the enterprise marked a similar decline.

The company's economic situation further worsened and in 1999 Vítkovice had to face a serious economic crisis which resulted in red numbers at the turn of 1999/2000. At that time, Vítkovice did not pay for pig iron (debt of 1.5 mld. CZK), electric energy (0.8 mld. CZK) and gas, the company owed 1 mld. CZK to OKD, 6 mld. CZK to employees and banks. A total debt of the enterprise amounted to 13 mld. CZK.

Thanks to the government subsidy a compensation with creditors was made possible in 2000 through the court, which averted a danger of bankruptcy. Moreover, a daughter company was founded to the Fund of National Property (Osinek, Corp.), which signed to a credit of 1.8 mld. CZK with Konsolidační banka to fund the metallurgical production in Vítkovice. Another credit of 1.8 mld. CZK was meant to finance the engineering production.

The rescue plan transformed Vítkovice into a holding structure which split the original corporation into separate production daughter units which among other include Vítkovice strojírenství, a.s. (Vítkovice-Engineering, Corp), Vítkovice-export (Vítkovice-Export Department, Corp), a.s., Vítkovice CAD/CAM systémy, spol. s r.o. (Vítkovice CAD/CAM systems, Ltd), Vítkovice - realizácia projektov Košice, spol. s r.o. (Vítkovice - Implementation of the Projects Košice, Ltd.), Vítkovice-zkušebny a laboratoře, spol. s r.o (Vítkovice - Test Rooms, Ltd), Vítkovice - údržba, spol. s r.o. (Vítkovice - Service Department, Ltd.), Vítkovice doprava, a.s. (Vítkovice - Transport Department, Corp), Vítkovice lisovna, spol. s r.o. (Vítkovice - Pressing Plant, Corp), Vítkovice ozubárna, a.s. (Vítkovice - Machinery Department, Corp), Vítkovice - stamont, spol. s r.o. (Vítkovice - Building and Construction Department, Ltd.) and Lang Fang Panwei Environmental Engineering, spol. s r.o. (Lang Fang Panwei Environmental Engineering, Ltd.).

The number of employees in the Vítkovice Holding had to be reduced from 12 000 to a half in 2001 – 2002 but the saving measures aimed at the improvement of competitiveness of the company failed. In the first half-a-year of 2003, the loss reported by 12 daughter companies of the Vítkovice Holding was nearly a quarter of milliard Czech crowns with the most serious problems being faced by the daughter company of Vítkovice Strojírenství, Corp. which had to dismiss other 800 employees.

In this situation, the government decided to carry out an expedited privatization of the state share in Vítkovice. Winner of the public tender was Lahvárna Ostrava, Corp. – a company that came to existence in 1999 through managerial privatization of one of the then Vítkovice daughter companies. The shares of Vítkovice, Corp. (68.31%) were transferred onto Lahvárna Ostrava, Corp. by which act the process of privatization of the company was successfully accomplished. A question remains however whether it will be possible to improve the company's economic results in the conditions of economic globalization.

3.2. Transformation of Nová Huť in the period after 1989

Mittal Steel Ostrava, Corp. (former Nová Huť, Corp.) is one of the largest metallurgical corporations in Czech Republic. Its production programme contains a wide range of products from coke to final engineering products, it is therefore a so called integrated production cycle. The corporate organizational structure includes ten manufacturing units as follows: Koksovna (Coking plant), Ocelárna (Steel Works), Válcovny (Rolling Mill), Rourovny (Piping plant), Minihuť pásová (Belt Mini-Smelter), Strojírenský závod (Engineering Works), Výroba a montáže (Manufacture and Assemblies), Energetika (Power Engineering Plant), Automatizace (Automation), Doprava (Transport).

The beginning of changes in this industrial giant date back to 1989 when the original name of the company (Nová huť Klementa Gottwalda, n.p.) was changed to Nová Huť, State Enterprise. In 1992, the state enterprise was transformed into a joint-stock-company with the majority share of the state and the new corporation was given the name Nová Huť, Corp. In the process of privatization, some plants and operations that were formerly belonging in the enterprise singled out into

Fig. 4: Aerial view of the so called Dolní oblast in Vítkovice (Source: www.dolnioblast.cz)

separate trading companies – either daughter companies or associated companies (e.g. Jäkl Karviná, Corp., Nová huť Zábřeh, Corp., Vysoké pece Ostrava-Blast Furnaces Ostrava,) and/or companies established with foreign partners (e.g. MG Odra Gas, Ltd.).

The financial situation of Nová Huť, Corp. began to worsen in 1999 and in the first half of 2000. The business loss reported in 1999 was 3.4 mld. CZK and the company's turnover fell to 25.6 mld. CZK. Similarly as Vítkovice, Nová Huť, Corp. had to face insolvency and the lack of working capital. And again – similarly as in the case of Vítkovice – the enterprise was rescued thanks to the government intervention. Nová Huť, Corp. signed a contract with the Konsolidační banka about a loan for operations to finance the manufacture.

But the economic results of the company were deteriorating in 2001 – 2002 in spite of the state intervention and Nová Huť, Corp. was falling into debts. Its main creditor, a daughter company of International Finance Corporation, warned to take all possible steps leading to the bankruptcy of Nová Huť, Corp. The response of the Czech government was to adopt a resolution on the privatization of the company. The privatization tender had two applicants – the Dutch-Indian LNM and Třinecké železárny Iron Works. In June 2002, a contract was approved by the government on the sales of 67.2 % of the stock of Nová Huť, Corp. discharged from debts to the Dutch corporation LNM.

The decision on the sales of Nová Huť, Corp. to the Dutch company LNM was protested against by Třinecké železárny, Corp. as this company felt considerably harmed by the privatization. Owners of Třinecké železárny, Corp. argumented that their two Ostrava competitors were financially supported by the government while the company of Třinecké železárny, Corp. did not get any subsidy from the state (Třinecké železárny, Corp. was fully privatized already in 1996). Třinecké železárny, Corp. requested a compensation of 2 mld. CZK from the government for the violation of the conditions of fair economic competition. The Czech Ministry of Industry tried to meet the requirement but the transaction failed in the end due to the adverse attitude of EU institutions as the European regulations do not allow to provide a government subsidy to private entities enterprising in this industrial branch.

The new majority owner Mittal Steel Ostrava, Corp., the Dutch-Indian LNM is the second largest world's producer of steel and the steel division of Ispat International is its part. The present owner plans to continue in the restructuring. Mittal Steel Ostrava, Corp. is for example to reduce the number of employees from the current staff of 11 300 to about 8 800 until the end of 2005.

3.3. Impacts of transformation changes

The transformation of big metallurgical corporations reflected in many fields of region's life with the most demonstrable effects being as follows:
a) Reduced environment pollution
b) Increased unemployment

ad a) The reduced environment pollution resulted from several factors. The first of them was a pronounced decrease of production as compared with the period of centrally controlled economy. Also, the metallurgical industry itself went through several crises since 1989 of which the first one developed after the extinction of COMECON markets after 1989 and the second one related to the global crisis of steel market that began in 1997.

The second factor that affected the condition of environment consisted in advanced technologies. Annual costs of environmental engineering structures in Nová Huť, Corp. represented for example some 20 – 30 % of total investment costs in the 1990s. Between 1992 – 1997, emissions of solid particles were reduced five times – namely due to the construction of dust separator in the heat generation plant and thanks to a reconstruction of dedusting in the two agglomerations – and represent at the present time just 2 % of the amount recorded at the beginning of the 1960s. Some other financially demanding investments are in progress, e.g. a reconstruction of dust removal from steel-making tandem furnaces, ecologization of coking batteries and desulphurization and ammonia removal from coke-oven gas.

The third important factor was the displacement of manufacturing operations from unfavourable locations. For example in January 1996, the managements of Nová Huť, Corp. and Vítkovice, Corp. concluded an agreement on the foundation of a separate legal entity – Vysoké pece Ostrava, Corp. as a supplier of pig iron to both founder companies, which enabled a downsizing of the coking plant and blast furnace manufacture in Vítkovice. The main benefit of this agreement was therefore the enforcement of metallurgical operations of primary production out from the immediate centre of Ostrava city, which significantly contributed to improve environment in the so called Dolní oblast in Vítkovice. The Czech government promised 5 mld. CZK for the decontamination of the Dolní oblast. It is expected that the area will be used to build a technological park – industrial zone which should attract new investments. Another part of the area will be used as a technical outdoor museum since the Ministry of Culture declared the area of blast furnaces and coking plant in Vítkovice including the adjacent Hlubina colliery a cultural monument in March 1997.

ad b) The restructuring of heavy industry caused a marked increase of unemployment in the Ostrava region. The situation can be well illustrated also on the case of Vítkovice, Corp. and Nová Huť, Corp. The two corporations recorded a severe decrease in the number of workers, which is shown in the following graph (Fig. 5).

The number of employees working in the largest metallurgical complexes in the Ostrava region (Vítkovické železárny Klementa Gottwalda, Nová huť Klementa Gottwalda, TŽ VŘSR Třinec, Železárny a drátovny Bohumín, Válcovny plechu) amounted to more than 90 000 persons at the end of 1989. In 2002, the number of employees in the successor organizations was about a third. The target number of workers in the metallurgical operations occurring in the region (after the end of restructuring) is likely to be less than 20 000 persons.

Important for the development of employment in the region is also a so called cascading failure which

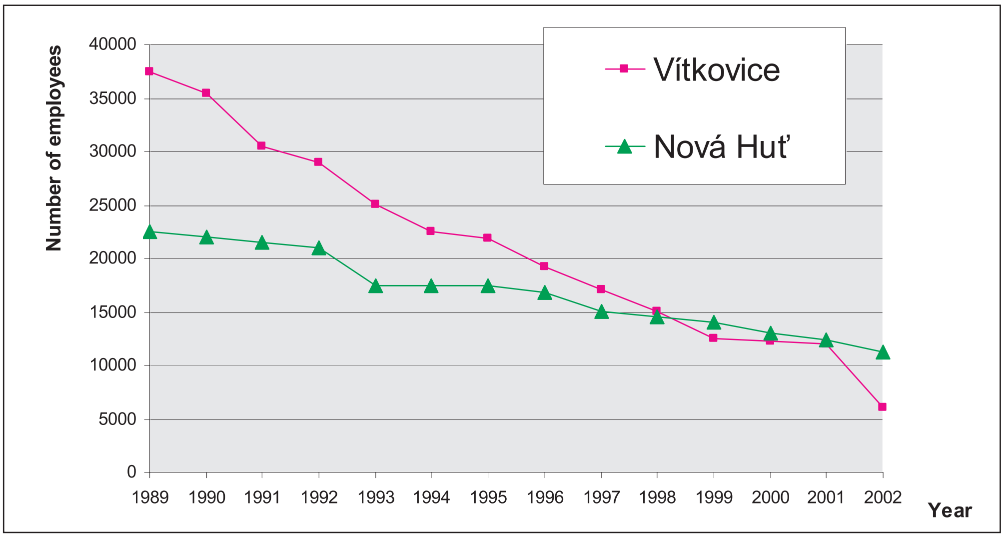

Fig. 5: Development of employment rate in Vítkovice and Nová Huť in 1989 – 2002

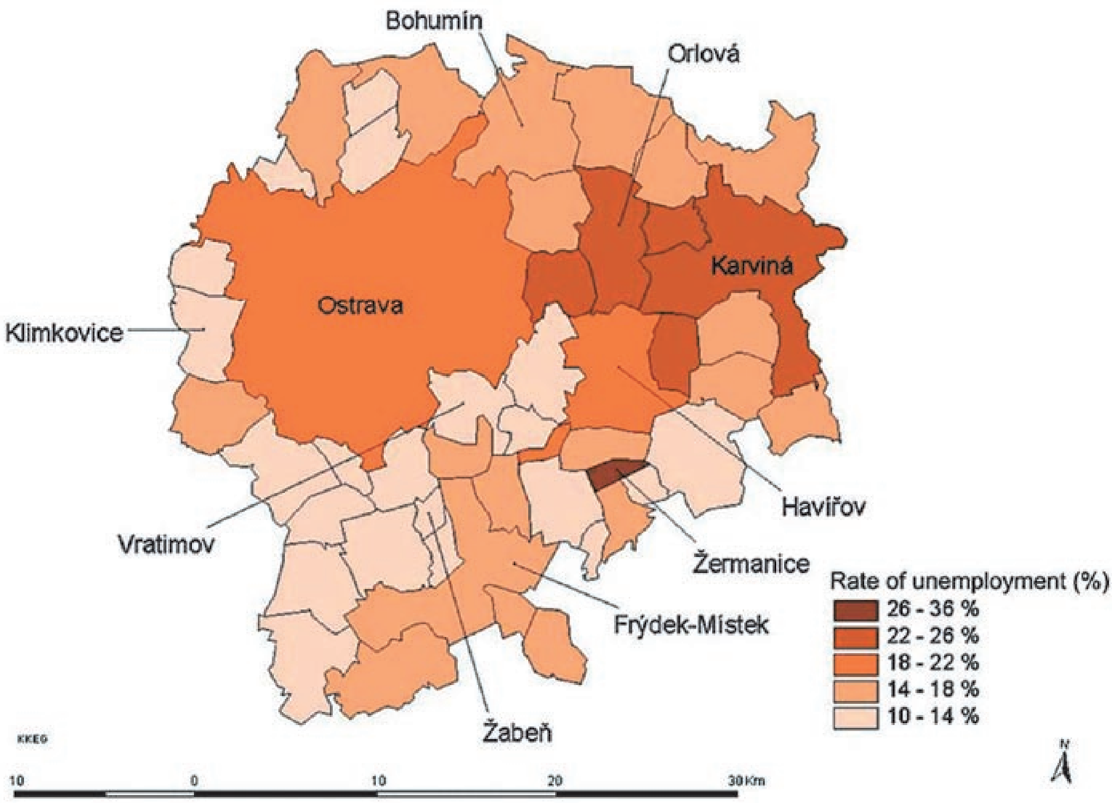

Fig. 6: Rate of unemployment in the Ostrava region to 31 December 2004 (Author: S. Martinát)[2]

[2] *For purposes of simplification, the Figure includes only the names of cadastral areas with extreme values of the studied phenomenon.*

means that there are approximately two to three workers of subcontracting firms per one employee of metallurgical works in Ostrava. At the same time, the rate of unemployment in the Moravian-Silesian Region reached alarming figures in April 2005 as reported by the Ministry of Labour and Social Affairs (http://www.mpsv.cz/scripts/nezamestnanost/okresy.asp): Bruntál (16.2%), Frýdek-Místek (13.4%), Karviná (19.1%), Nový Jičín (11.3%), Opava (11.1%), Ostrava (15.7%). Districts of the area under study were and still are districts of the highest unemployment rate in the Czech Republic together with the districts of Northern Bohemia. Rates of unemployment in cadastral areas of the Ostrava region are presented in Fig. 6 which shows that cadastral units with the developed mining activities (Karviná, Orlová) are one of the most affected areas.

4. Conclusion

The downsizing of bituminous coal mining and the restructuring of large steel corporations affected the studied Ostrava region after 1989 by a conspicuous way. One of negative impacts is a marked increase of unemployment rate which was undoubtedly primarily influenced by the reduced numbers of employees in coal mines and in related industries. In the decrease of employees a certain role was played not only by the decreasing production but also by the parallel pressure on increased labour productivity which was growing in all above mentioned manufacturing companies. Another important role in the process of transformation was that of the state without the help of which both Vítkovice, Corp. and Nová Huť, Corp. would have been likely to declare bankruptcy. At the present time, all three companies are privatized and the main movers of future transformation steps will be their majority private owners.

It is expected however that the industrial giants will have to face further redundancies in line with global trends. German bituminous coal mines employed for example nearly 130 000 workers in 1990 while in 2000 the number of employees was less than a half – 59 000 workers (Wehling, 2004). The region of Ostrava showed similar trends in the period from 1991 – 2001 in which the number of employees was markedly reduced with the change index for the whole area being -37.9% (the total number of industrial workers in 1991 and in 2001 was 173 167 and 107 587, respectively), i.e. employment rate in industry decreased by nearly 38 %. The hitherto course of restructuring and increase of unemployment induced changes in the social environment and in the life style of population in the area of interest (Mikulík, Kolibová, 2003; Kolibová, Mikulík, 2003).

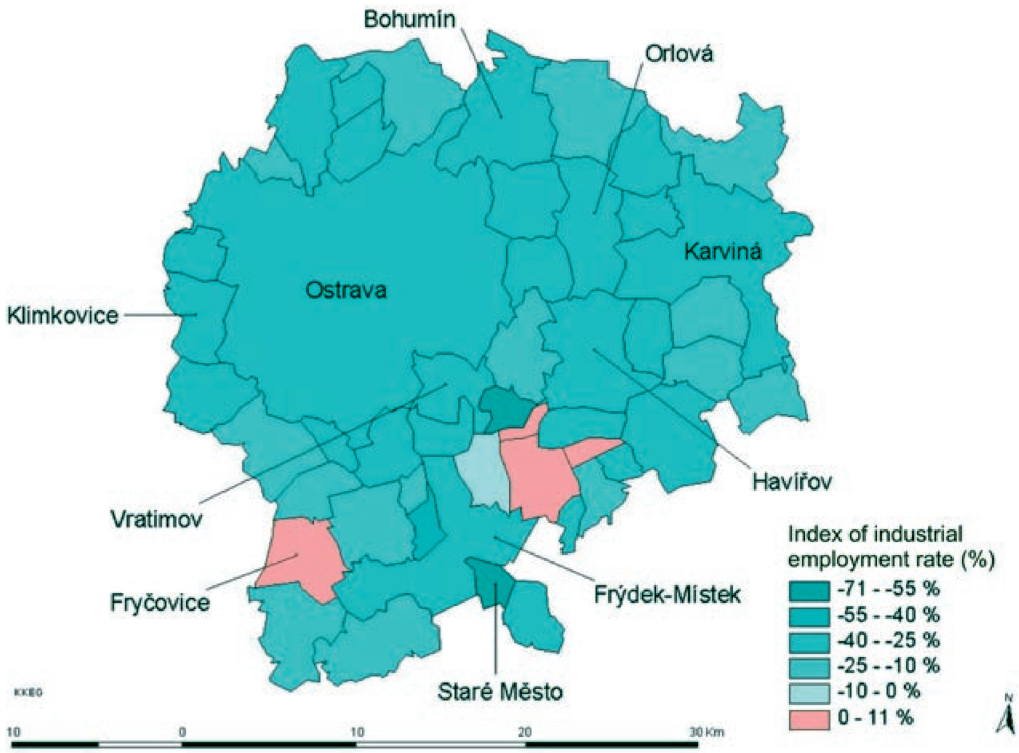

Fig. 7: The index of industrial employment rate in the Ostrava region in 1991 – 2001 by cadastral areas (Author: S. Martinát)[3]

[3] For purposes of simplification, the Figure includes only the names of cadastral areas with extreme values of the studied phenomenon. Some smaller municipalities reached a great relative change, which relates to the low number of members in the statistic sample.

There were also some positive effects of restructuring the giant industrial corporations. One of them is for example a marked improvement of environment quality, which resulted not only from the mere decrease of manufacturing but also from the introduction of advanced (and environment-friendly) technologies. A good indicator of improved environment quality can be considered the pronounced decrease of air pollution by dust aerosols and by sulphur dioxide in the Ostrava region in the period from 1980 – 2000 (Quitt, 2004). It seems logical from the hitherto transformation development that a new prosperity of the Ostrava region cannot be achieved only by developing traditional industries such as extraction of bituminous coal and heavy engineering. This is why the government and non-governmental authorities focus on strategies that would attract developers from more perspective industrial branches (e.g. modern technologies) into the newly created industrial zones.

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THE EFFECTS OF COAL MINING ON THE LANDSCAPES OF THE OSTRAVA REGION

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Abstract

The geological history of the Carboniferous era, surface deposits, including the Quaternary, and surface changes brought about by anthropogenic activities, have influenced the formation of landscapes in the Ostrava region in a direct manner. The deep mining of coal seams resulted in terrain subsidence and in the creation of mine overburden tailings and settling pits, which are new morphological formations in the landscape, often having the effect of a long-term ecological burden. In this paper, attention is given to methane emissions at ground surface levels, to changes in the hydrological system of the region, and to some situations of pumped and discharged mine waters.

Shrnutí

Krajina Ostravska a její ovlivnění těžbou uhlí

Geologická historie karbonu, pokryvných útvarů včetně kvartéru a změny povrchu vyvolané činností člověka, měly zásadní vliv na utváření krajiny Ostravska. Výrazným způsobem se projevila hlubinná těžba uhelných slojí, která byla příčinou poklesů terénu a vzniku odvalů hlušin a odkališť, které jsou novým morfologickým útvarem v krajině a mnohdy působí jako dlouhodobá ekologická zátěž. Pozornost je věnována emisím metanu na povrch, změnám v hydrologické situaci regionu a některým okolnostem čerpaných a vypouštěných důlních vod.

Keywords: *Ostrava region, coal mining, subsidences, mine waste depositions, methane, mine waters, watercourses*

Introduction

The region of Ostrava – situated in the industrial area of Horní Slezsko (Upper Silesia) – was of agricultural character with the scarce settlement before the boom of heavy industries. In the last 200 years it was converted into a densely populated industrial region changed not only by the very existence of heavy industrial works and their impact on environment, but also due to considerable changes in landscape morphology induced by deep mining of bituminous coal. The morphological relief changes to be mentioned are namely surface subsidences and hence changes in groundwater tables, watercourses and water reservoirs, mine waste disposal sites and depositories of products from coal treatment. The circumstances are discussed in this work. Deep mining of coal seams relates to a number of other phenomena such as induced seismicity, pumping and discharge of mine water into surface watercourses, recultivation, etc. The period after the close-down of coal mines after 1990 has specific features, too, such as uncontrolled coal bed methane exits on the ground surface, development of abandoned areas on the premises of mine establishments – so called colliery brownfields, social impacts such as unemployment, migration, etc.

1. Geological development and its impact on the landscape

The Czech part of the Upper Silesian Coal Basin with a segment used for coal mining and known as the Ostrava-Karviná Coal Mining District (OKR) belongs in the Podbeskydská pahorkatina Hilly Land and Ostrava Basin. In geographical terms it is demarcated by the territory situated between the Polish and Czech state borders in the north, by the piedmont of the Beskids Mts. in the east and by the Odra River in the west. In geological terms, the autochton with the Paleozoic sedimentary layer (Devonian, Carboniferous) with the sediments of Eggenburgian, Carpathian and Lower Badenian belongs in the Bohemian Massif. Nappes thrusted over the autochton belong in the Neogene structure of the West Carpathians. The geological development of the region was affected by the extensive denudation and erosion of the Paleozoic fundament connected with the weathering of Carboniferous group of strata (so called red-beds alteration), brown wheathered crust of the Carboniferous, and deep-reaching and long-lasting degasation of the Carboniferous massif. The denudation and erosion of the Carboniferous mountain range was started already prior to the sedimentation of the Kwaczla arkose (Stephanien) as it is known from the Polish part of the Basin. The process lasted from the end of the Carboniferous (ca. 300 mil. years) until the coverage by younger sediments in the Triasic, Jurasic, Cretaceous sediments and Neogene sediments in Poland. The overcovering by younger autochthonous sediments proceeded from SE; its pace was uneven and the extent is known in the territory of the Czech part of the Upper Silesian Basin only from denudations remnants in the basement of the West Carpathian nappes.

A detailed description of the geological structure of surface deposits, i.e. filling of the Outer Carpathian Foredeep (Lower Badenian), nappes of the Outer West Carpathians and Paleozoic can be found in monographs (Menšík et al., 1983; Dopita et al., 1997; Eliáš, 2001) presenting results from the geological research in the region of our interest.

were ventilated, which were gradually linked due to the extension of mining spaces not only by means of mine works by also by means of irregular communication through worked-out areas and cave fields and also through the Carboniferous massif with alterations of red-beds type.

The mining activities in the Ostrava coal mines (from 1776 to the end of coal mining in 1992) gave rise to an underground space of several hundred million cubic meters in volume which has been reduced to about 50 mil m^3 due to gradual flooding and caving consolidation (Takla, Král, 1999). The space is now filled with a blend of mine and coal bed gases rich of methane which leaks to the ground surface through pits and wells, Carboniferous windows and disturbed massif at places of lower crust thickness.

Fig. : Situation of the Upper Silesian Bituminous Coal Basin in relation to the Czech territory

Methane emissions

The migrating gas from the Paleozoic (Carboniferous), secondarily accumulated in permeable strata of the crust. The Quaternary glacial erosion (namely the Estercian glacial 0.8 – 0.4 mil. years ago) eroded the Miocene Lower Badenian sediments down to the Carboniferous fundament, giving rise to so called Carboniferous windows on the Ostrava-Karviná Ridge. Although the outcrops are covered by Quaternary sediments now, mainly by loess of Wurm /Saal/ glaciation, slope loams or make-up grounds, the natural processes connected with the degasation of the Carboniferous massif have been restored and in some cases even intensified due to coal mining effects.

The occurrence of methane in coal mines was given attention after the first severe accident in the Trojice Coal Mine in 1884 when the monitoring of methane occurrence in OKR coal mines was prescribed by law. Large minefields in the entire coal mining district

A methodology was prepared by OKD -Důlní průzkum a bezpečnost a.s. Paskov within the framework of Project No. 1/99 of the Czech Mining Authority on the “Elimination of threats from methane leakages to surface from underground after the end of mining activities” (1999 – 2001) for the classification of areas with respect to a possible methane exit together with a map of territorial categorization for the Ostrava-Karviná Coal Mining District (OKR). The categorization dwells both on the knowledge of geological structure, hydrogeology of the Carboniferous and surface deposits, and on the known localizations of older and existing mine works, wells, extent and depth of underground extraction and undermining. It also contains the hitherto results from methane measurements in soil atmosphere (atmogeochemistry). The “Map of OKR territory categorization” represents a fundamental document for area development planning. Contours of territorial categories were taken over for 1:50 000 maps published in the “Atlas of maps to document the impact of down-scaled deep mining of bituminous coal

[1] Ostrava-Karviná Coal Mines

in the Czech part of the Upper Silesian Basin onto the ground surface and environment" (Martinec et al., 2003). The map depicts the surface area development, distinguishing by colours individual localities with demonstrated and potential uncontrolled leakages of methane and coal-bed gases on the ground surface. The territory was categorized as follows:

- Areas with demonstrated uncontrolled methane leakages to ground surface
- Areas dangerous by uncontrolled methane leakages to ground surface
- Areas endangered by uncontrolled methane leakages to ground surface
- Areas with possible occasional uncontrolled methane leakages to ground surface
- Areas without a danger of uncontrolled methane leakages to ground surface.

OKR (2003). Mining activities are focused on the extraction of coal and/or gas. Other components such as rock waste and water are accompanying and often undesirable products, in some cases even directly limiting agents for mining and occupational safety. Hard hydrogeological conditions for example prevented putting into operation of some localities in the past (e.g. pit Bedřich in OKR).

Withdrawal of material from the massif induces surface movements, subsidences, horizontal displacement, damage of line and other structures, activation of land slides etc. The measure of these manifestations is a function of deposition depth, number and thickness of coal seams, character of accompanying rocks of the Carboniferous, surface deposits and structure of the massif in question.

Area categories	km^2	% of the OKR mining spaces
OKR mining spaces	318.5	100
with possible occasional exits of mine gases	240.8	75.60
endangered by exits of mine gases	15.2	4.78
with dangerous exits of mine gases	14.1	4.43

Tab. 1: The shares of categorized areas in the integrated OKR mining spaces

The hazard of gas leakages on the ground surface, their possible concentration and development of explosive atmosphere when blended with air is eliminated by technical measures according to the actual situation in the respective mine. Dragon (2003) specifies these measures as follows:

- ventilation of mining spaces by main fans – which in fact does not come into consideration in the case of totally closed mines with the liquidation of surface equipments
- active method of protection by degasation, which consists in the controlled exhaustion of gas with an increased content of methane, accumulated behind permanent stoppings and in worked-out underground spaces and disintegrated massif. This procedure has several options in dependence on the current – or accomplished mine scale-down and its relation to the existence of still possibly active mines in the neighbourhood.

2. Surface changes due to coal mining in the last 200 years

History of coal mining is explained in monographs Carboniferous mines of the Ostrava-Karviná Coal Mining District in 1929 and Coal mining in

Rock waste, i.e. accompanying rocks with coal remainders and construction debris from the mine, is the product of development, mining technologies and treatment processes, which is used either directly in the mine as a filling material, or on the ground surface for the construction purposes. The remaining tailings (ca. 30 %) are deposited on waste banks.

Pumped water can more or less improve the quality of surface watercourses in dependence on their chemical properties, increasing in any case their channel capacity.

Mass volumes withdrawn from the rock massif and a brief history of coal mining in the Ostrava-Karviná Coal-Mining District

Total volume of coal extracted in the period from 1782 – 1945 can hardly be expressed in accurate figures. Some data are available from the above mentioned monograph (Carboniferous mines of the Ostrava-Karviná Coal Mining District in 1929). The data describe the significance of the construction of Vítkovice Steel Works in 1829 (production increased from about 6 thous. tons in 1822 to 16 thous. tons in 1832) and namely railways – the first section of the Northern Railway was put into operation in 1847 (extraction increased from 60 thous. tons in 1842 to 168 thous. tons in 1852), and the importance of Mining Railway that was put into operation in December 1862 (production of about 610 thous. tons in 1862 increased to ca. 1200 thous. tons in 1872). Total production of the mining district was then further increasing to reach 6 million tons at the beginning of the 20th century and over 10 mil. tons in 1930. The crisis of the 1930s showed in a production fall to less than 8 mil. tons in 1935. During World War II, the total production of the district increased again and reached over 20 million tons in 1943 – the volume that was achieved again as late as in 1959.

The OKR development in the post-war period can be characterized by several stages resulting both from the economic and political development of the country and from the technical development of mining mechanisms and requirements of occupational safety.

The period from 1945 – 1955 was marked by the restoration of mining operations after the war economy. It was necessary to find new labour force, to replace technical equipment taken away from the country by Germans, and to quickly prepare coal supplies for exploitation. Heavy industries were nationalized and considerable organizational changes took place including fusions of mine enterprises. The first General Development Plan of OKR with a perspective plan of mining district development until 1965 was prepared in 1951 – 1953.

Years from 1956 – 1965 represented a period of intensive investment building of new mines and reconstruction of the existing ones. An engineering organization was founded under the name of Báňské projekty (Mining projects), and there were other supportive enterprises (Báňské strojírny, Ostroj) and research organizations (Scientific and Technical Institute of Coal, Mining Research and Safety). Coal extraction was ensured by extensive methods, steel reinforcement was introduced in working faces for the mechanization of which winning machines and cutter loaders were imported from the Soviet Union.

The period from 1966 – 1975 was in the first three years affected by the economical concept focused on oil, accompanied by a slight decrease of production and by a return to the coal concept several years later. The stage can be characterized by an intensification of mining processes and by a conspicuous growth of labour productivity, introduction of sherers and powered supports, scraper loaders for tunnelling long mine works and belt conveyors, high-performance overhead loaders and roadheaders with boom cutting heads.

After 1975, the performance parameters worsened due to political decisions of the management. A release of price policy after 1990 resulted in the increase of investment costs, delays in the construction of Mine Frenštát, and a non-fulfilment of plans for the concentration of mines as outlined by the 2nd General Development Plan of OKR Development prepared in 1980.

The period from 1992 – 2000 was characterized by the transformation of planned socialist economy to market economy and by the downsizing of coal extraction due to the reduced demand of coal on the part of both domestic companies and exports. In this period of time, all mines of the Ostrava and Petřvald parts of the mining district were closed together with one mine (Mine František) in the Karviná part and one mine (Mine Paskov) in the southern part of the district.

Total amount of coal extracted in OKR from 1782 – 1945 was more than 500 million tons and nearly 1100 million tons of coal were extracted from 1945 – 2000. **This indicates that a total amount of bituminous coal extracted in OKR from 1782 to 2000 was 1.6 milliard tons – of these about 635 million tons in the Ostrava part of the mining district, which is now completely closed.**

OKR production of waste rock was systematically monitored only from 1963. For older periods of time an approximate construction of the parameter had to be made by using the data on raw extraction, volumes of preparatory works driven and waste rock volumes from the investment construction – if the indicators were available.

The calculation of interpolation data until 1963 is missing the initial figures from 1945 or from the period of 1946 – 1950 when developments of new floors – delayed due to the war – were launched and/or deepening along with the excavation of new pits. The calculation of waste production until 1956 was made by extrapolation through extraction for sales increased by 20 % to raw extraction. The percentage corresponds to the series when its value was 21.2 % in 1956, 23.9 % in 1960, and then it gradually further increased up to more than 50 %. The value of 20 % until 1956 is explained by a relatively cleaner method of extraction with individual support of working faces, by a better ratio of extracted coal supplies to waste production from developments and preparatory works, and by the restricted construction of new floors and mines whose intensity developed on the basis of General Development Plan of OKD 1953.

The growing production of waste in raw extraction had an unfavourable influence on a number of factors of which most important were capacities of mine equipments, outputs and coal treatment costs, mine equipment wear, performance parameters of coal extraction, ecological impacts of waste bank volumes on environment, costs of coal mining and selling prices.

Estimates of extracted waste in the period from the beginning of mining in OKR to 1900 are very approximate. If we base them on an assumption that the amount of extracted waste rock was at about 20 % of coal extraction due to coal mining being in fact made by hand before World War II, then the volume of waste extracted in 1782 – 1900 can be estimated at 12 mil. tons. Together with 638 million tons of waste rock since 1991 until today **a total amount of waste rock extracted in OKR at the time of coal mining activities can be estimated at nearly 0.65 milliard tons**.

Availability of serious data on the amount of water that flowed into the mine or was pumped out for the entire period of mining activities is very problematic even in more recent years when the data were included in the OKR statistics. The difficulty is given by the fact that apart from the natural resources (in OKR Quaternary water, water from Badenian collectors, water from aquifers on the contact point of the Carboniferous with the surface deposit, and water of the Carboniferous) there is also technological water brought into the mine at a considerable amount (required for drilling, wetting etc.), and by the fact that a considerable percentage of humidity is exhausted by mine air, not being measured at the mouth of the pumping system of pipes.

It is estimated that an amount of water pumped out from mines of the Ostrava part of the OKR district since 1900 was 1644.2 mil. m^3. Water amounts pumped out in the Karviná part of the district and in the souther part of the OKR district from 1947 to 2000 are estimated at 248.5 mil. m^3 and 13.14 mil. m^3, respectively.

A total amount of water pumped out in OKR mines in the period from 1900 – 2000 is estimated at 2 km^3. Dopita et al. (1997) estimate the amount of saline water pumped in the entire period of coal mining in OKR at about 3 km^3.

3. Terrain affection by subsidences as a consequence of mass withdrawals from the massif

From the general point of view, the effect of mass withdrawn from the Carboniferous by mining activities shows on the ground surface by means of surface deposits. It is not only the effect of geotechnical properties but also the cover thickness and the morphology of the Carboniferous paleorelief that play a role. All these mutually complementary map documents are presented in the atlas of maps on deep bituminous coal mining downsizing in the Czech part of the Upper-Silesian Basin on ground surface and environment (Martinec et al., 2003).

The development of a final **contour of the subsidence basin** at the end of mining results from long-term interferences of individual subsidence basins coming to existence in the extraction of individual working faces in different coal seams at different times. The result is an entirely uncontrollable disturbance of the massif both by subsidence and by a spreading subsidence wave on the edge of local cuphole (sagging, strain displacement). A reliable information on the character and intensity of massif disturbance in individual groups of cover strata does not exist even today, this applying both the the autochthonous massif of the Lower Badenian and at places with developed thick nappes of the West Carpathians. The large territory affected by coal mining and demarcated by the marginal contour is also a space of existing and future building activities both on the surface and in the underground. The disturbance of the massif and even of the Quaternary cover calls for a specific approach at the stage of engineering and geological research. It can be justly assumed that the foundation mode was affected to a lesser or greater extent. The level of aquifer can be expected to rise to an elevation of +210 m a.s.l. in several tens of years after the end of coal mining in OKR and after the end of mine water pumping. This may affect even the geotechnical properties of the massif due to the change in humidity, with all possible consequences for the foundation engineering. The disturbance of massif with small cover thicknesses can be observed also sporadically at the points of firedamp exits onto the ground surface.

Ground surface subsidences and possibilities of using mathematic models

Ground surface protection against the impact of mining activities is feasible if a knowledge exists about the shape of subsidence basin (subsidence basin depth – maximum subsidence, extent of subsidence cuphole and description of its marginal slopes), about the time course of the movement and its reliable prediction. In legal terms, it is namely a determination of the beginning, extent and end of the impacts of coal mining on the ground surface. In economic terms, it is a coexistence of mining activities with other anthropogenic activities on the surface.

In larger deposits similar to the Czech part of the Upper-Silesian Basin it is impossible to carry out all measurements required for a detailed description of the subsidence basin and its development in time. It is therefore not possible in the creation of a map of subsidences (isolines of subsidences – so called isocatabases, isoareas of subsidences) – with respect to the size of the area in question, undermined areas, localization of observation points on the surface and period of observation – to work only with actually measured values. The points of terrestrial observatories are situated in an irregular pattern, only at the places of built-up areas, and the determination of their elevations is as a rule of a relatively short-term validity.

This is why the ground surface subsidence at a given place or in a whole area of interest is calculated according to a method developed by Budryk-Knothe (in Neset, 1984).

According to OKD, a.s. IMGE o.z., a total area of all OKR mining spaces in 2000 was 320 km^2. The area affected by subsidences, calculated according to the above mentioned Knothe‘s method, is demarcated by a zero isoline of subsidences. This area – affected by surface movements (subsidence, horizontal displacement) and subsequent surface deformations (back levelling, radius of curvature, unit longitudinal strain) as a consequence of the manifestation of exploitation activities on the surface- amounted in OKR to a total of 255 km^2 in 2000, which represents 80 % of the affected surface within the total space of minefields.

The area size affected by subsidences in the Ostrava part of the district will be reduced in the future since exploitation works were completely finished there (in 1994) which means that the surface movements diminish or cease to exist. On the other hand, the area of active mines (the Karviná part of the district) may exhibit a certain extension of areas affected by subsidence manifestations as a result of exploitation reaching marginal parts of the Carboniferous deposit and also with the gradually increasing depth of coal extraction.

Table 3 presents area representations of four plotted surface subsidence categories in three monitored time periods: 1961 – 1989, 1989 – 1999, 1961 – 1999. The 4 subsidence categories correspond to the following values: 0-0.1 m, 0.1-1.0 m, 1.0-10.0 m and more than 10 m. The area pattern of these subsidences (categories) in the studied territory follows from Figs 2 and 3.

The Tab. 2 illustrates very well the effect of downsized mining activities in 1990 – 1999 with the category of maximum subsidences (more than 10 m) being absent, the medium surface subsidence category (1 - 10 m) exhibiting a very pronounced decrease (2.4x) and with a slight decrease of the category of small

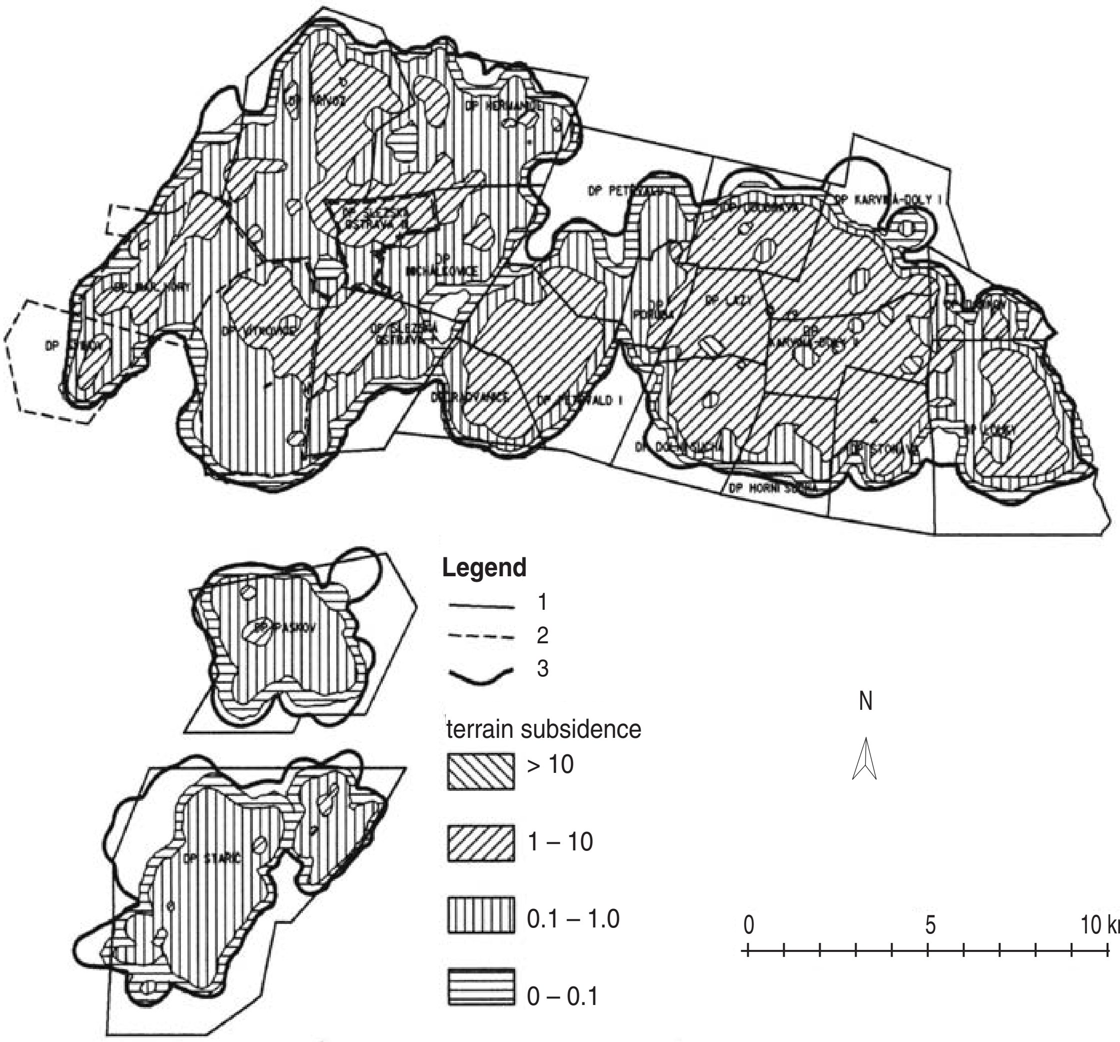

Fig. 2: Isoareas of subsidences from exploitation in 1961 – 1989

Legend: 1 – limits of mine areas; 2 – limits of mine areas with the closed-down mining; 3 – zero subsidence line

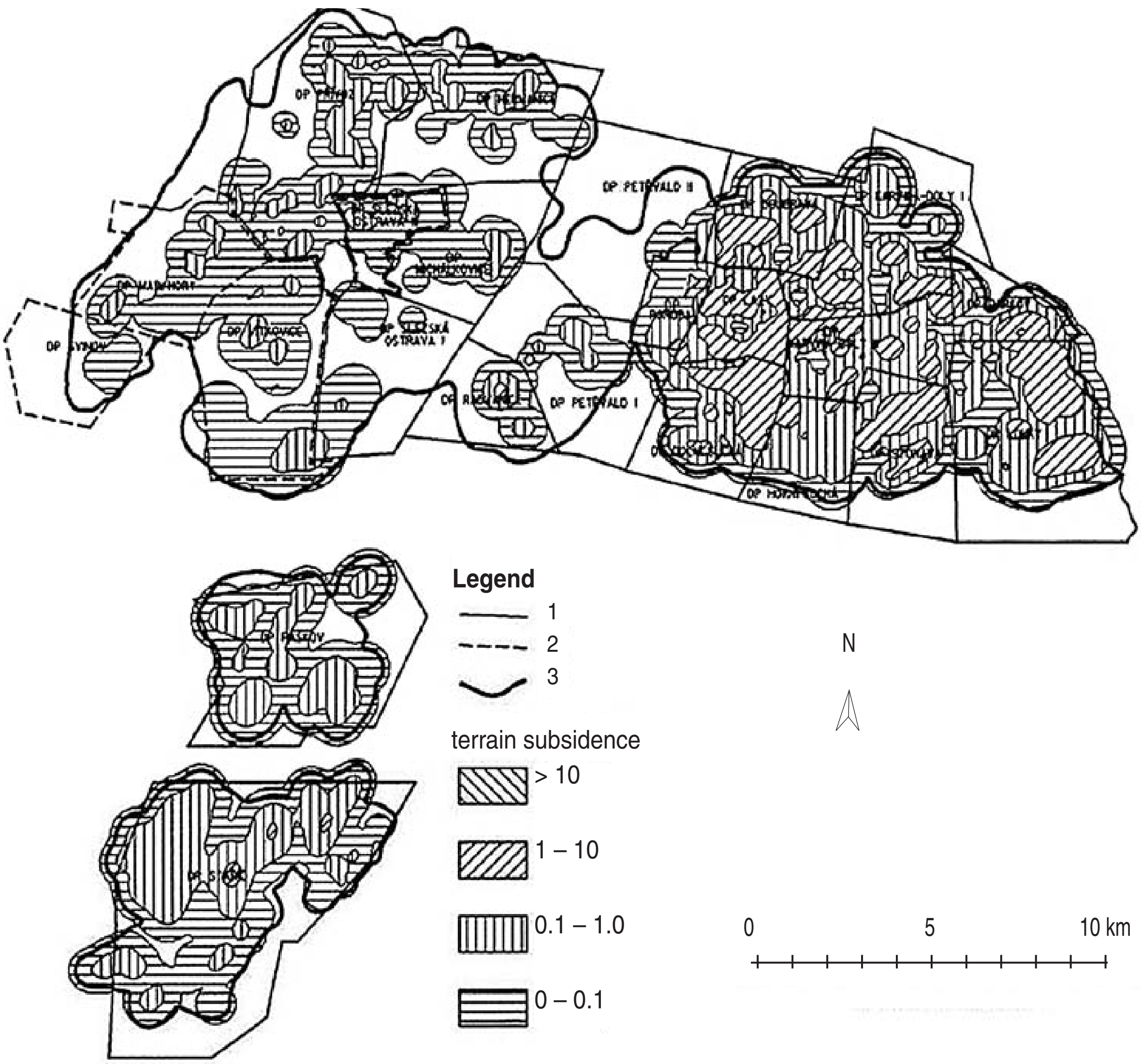

Fig. 3: Isoareas of subsidences from exploitation in 1990 – 1999

Legend: 1 - limits of mine areas; 2 - limits of mine areas with the closed-down mining; 3 - zero subsidence line

subsidences (0.1 - 1.0 m). In contrast, the category of minimum subsidences (0 - 0.1 m) shows a consipicuous increase (2.6x).

quantitative decrease of the burden on the area in question can be seen (1.4x loss in ground surface area with a certain subsidence) (Hortvík in Martinec et al., 2003).

Area representation in km² of surface subsidence categories in the studied periods of time			
Subsidence in meters	Period of time in years		
	1961 – 1989	1990 – 1999	1961 – 1999
0-0.1	43.3	79.2	48.7
0.1-1	115.5	73.1	119.0
1-10	91.5	27.1	100.5
>10	0.9	0.0	3.9
SUMA	251.3	179.4	272.1

Tab. 2: Areas of surface subsidence categories in the studied periods of time

Thus, it follows from the analysis that the decrease of montane activities in 1990 – 1999 as compared with the period of 1961 – 1989 showed in a qualitatively lower burden on the surface (in terms of the size of ground surface subsidences). In the same period of time, a

The area representation of ground surface subsidence categories in the periods under study gives a good picture of subsidence basin volume, or – more precisely – sum of the volumes of partial subsidences on the ground surface (Tab. 3). The volume figures are demarcated from the horizontal plane fitted with a zero isocatabase up to the body delineated within the space by individual isocatabases. The Data in Tab. 3 are based on maps in Figs. 2 and 3 (Isoareas of ground surface subsidences from exploitation in 1961 – 1989 and 1990 – 1999).

	Time period under study		
	1961 – 1999	**1961 – 1989**	**1990 – 1999**
Size of subsidence basin (km^3)	0.434	0.349	0.085
Open space in OKR rock massif developed due to coal mining (km^3)	0.627	0.508	0.119

Tab. 3: Subsidence basin size and extracted amounts in periods under study

A comparison of the share of subsidence basin size in the given period and the extracted amount of coal in the same period gives approximately an coefficient of 0.7 which corresponds to the compaction of rock massif after exploitation close-down in the affected body demarcated by the deepest exploited coal-bed by means of corresponding critical angles of the effect and the surface (Hortvík in Martinec et al., 2003).

As mentioned above, the calculated subsidences do not always answer to actual ones due to the generalization of the calculation model. In the case of Budryk-Knothe‘s method it can be claimed that the calculated vertical movements in the internal part of the subsidence basin are greater as compared with actually measured subsidences while the calculated subsidences on the edge of the basin are lower than those measured in reality, i.e. that the calculated subsidence basin is in reality of a larger extent. The disproportion manifests at places with the existing thick cover of Carboniferous deposits where ground surface subsidences measured in practice often reach outside the contour line of the calculated subsidence basin. One of such localities is for example Mine Stařîč.

Exploitation in the mining space of Stařîč started in 1970. This was also the period of the beginning

Parameter	**OKR – Ostrava part**
Coal beds	86 extractable in the Ostrava group of strata (Dopita et al., 1997)
Coal-bed thickness	Av. 0.73 m (Seam Mohutný 2 – 4 m)
Depth of underground exploitation	Av. over 700 m, Mine Ostrava in 1991 – 1088 m below surface
Accompanying rocks	claystones, siltstones, sandstones, conglomerates
Risks in the course of operation	blow-outs, water burst, CH_4, vibrations
Beginning of exploitation	1776 – award of first mining claims
End of exploitation	1992, 1993
Total amount of extracted coal	635 mil. tons
Waste rock	ca. 230 mil. tons
Pumped water	ca. 1644 mil. m^3
Affected area	130 km^2
Average terrain subsidence	3.96 m
Maximum terrain subsidence	10 m
Affected massif (affected area x av. depth, resp. x maximum depth)	91.0 km^3 max. 141.4 km^3
Extracted materials	423 mil. m^3 (coal); 92 mil. m^3 (waste); 515 mil. m^3 (coal + waste) = TOTAL ca. 0.5 km^3
Ground surface hazards after the end of mining	CH_4 emissions, seismic effects, after effects of subsidences, changes of superficial watercourses
Burdens	waste banks, burning and burnt-out spoil heaps, settling pits

Tab. 4: Some parameters of the Ostrava part of the OKR district

of repeated periodical levelling measurements of state levelling lines running across the area of the Staříč mining space. The control of actually measured subsidences and subsidences calculated from actually broken areas by methods of preliminary calculations revealed that the measured subsidences wer considerably smaller than the calculated ones – in fact by about a half-size. The preliminary calculation of undermining effects made use of data from working faces mined within the extraction space of the Mine Staříč for 1970 – 2000, prepared by ODMG of Paskov Mine (Schenk, 2001). Table 4 presents some parameters from the Ostrava part of the OKR district.

4. Impacts of mining activities on surface watercourses and water reservoirs

Stream regulation is sometimes motivated by a need to rectify flow changes induced by landscape subsidence due to deep coal mining. It is usually not a single reason why the measures are required (flood protection, increased flow profile capacity, ensurance of slope and direction stability of the watercourse, change in the layout of outflow channels, possibly also ensurance of area drainage). An assessment of the urgency of reasons to these measures after a lapse of time is usually very difficult (Brosch, 2005).

A map of watercourses and water surfaces on a scale of 1:50 000 with the designation of categories of their impact by undermining (I to III) and with the differentiation of water surfaces according to their relation to OKD water management is together with explanatory notes presented by Maníček (in Martinec et al., 2003).

Figure 4 brings a differentiation of watercourse sections according to the rate of interventions into their regime

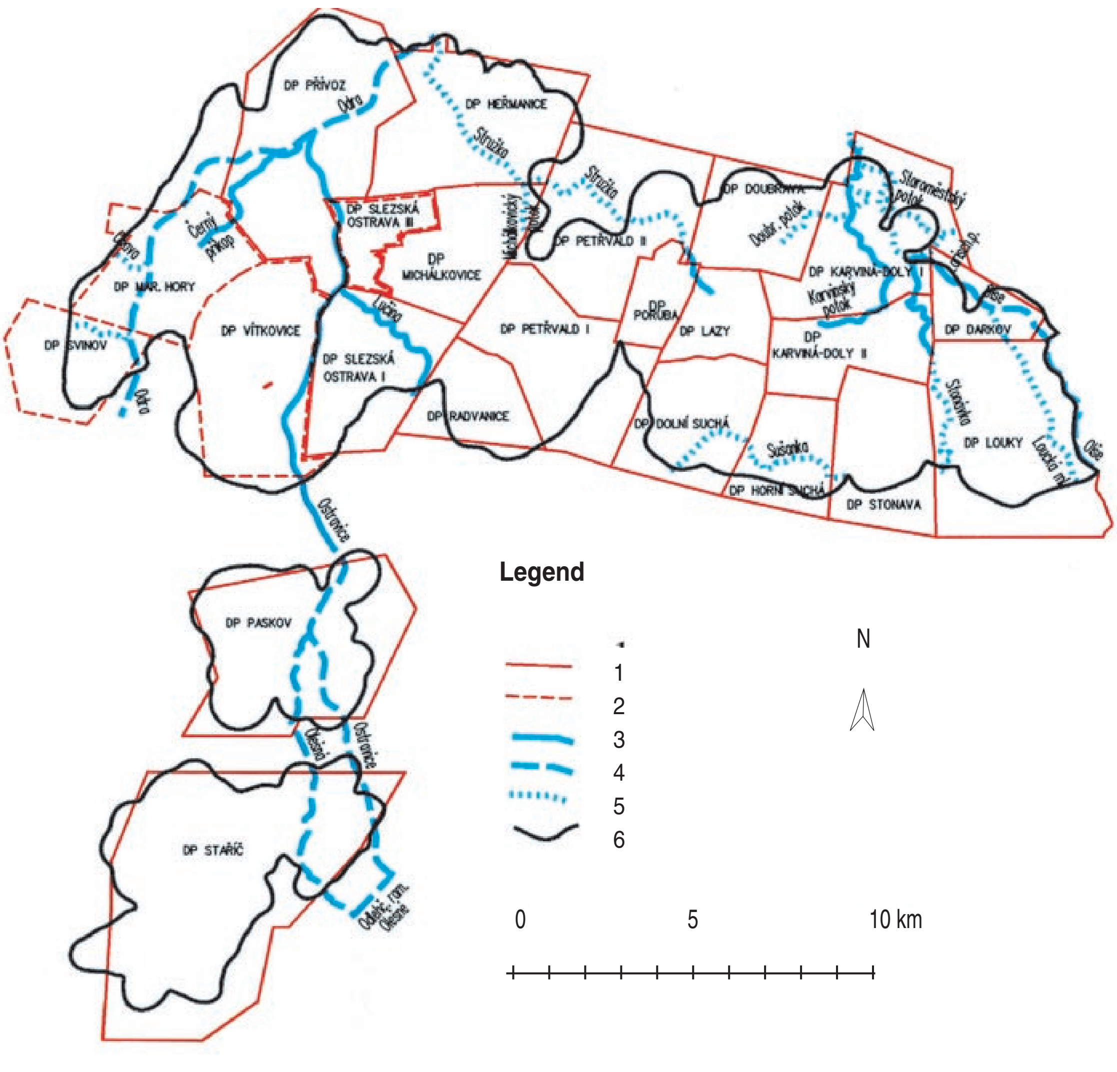

Fig. 4: A map with the outlined sections of affected watercourses

Legend: 1 – limits of mine areas; 2 – limits of mine areaswith the closed down mining; 3 – watercourse sections of dominant influence; 4 – watercourse sections of accompanying influence; 5 – watercourse sections of marginal influence; 6 – zero subsidence line (including complementary facilities) due to coal mining. The categories are as follows:

I Sections of dominant influence – i.e. sections in which the impact of coal mining and the requirement of subsequent interventions into their regime or regulation of their runoff conditions (relaying of channels, technical treatment of channel profile or even creation of new watercourses) were dominant and absolutely conclusive at the time of their implementation

II Sections of accompanying influence – i.e. sections in which the impact of coal mining was one of a range of relatively equal reasons for the implementation of regulatory measures on watercourses and their runoff mode

III Sections of marginal influence – i.e. sections in which the coal mining activity had a low or even negligible impact on runoff conditions, in which a dominant reason for the regulatory measures was other than coal extraction, or sections that did not require any intervention at all.

Watercourse	Watercourse length affected by coal mining activities (in km)
ODRA	15.1
Porubka	1.9
Opava	0.9
Černý příkop	5.0
Ostravice	23.0
Olešná	9.5
Lučina	4.8
Sušanka	7.0
Stružka	10.1
Olše	21.5
Stonávka	7.9
Karvinský potok	8.3
Celkem	**115.0**

Tab. 5: The length of affected watercourses

Water surfaces in the territory of the Ostrava-Karviná coal mining district historically consisted of ponds as the terrain was very favourable for their establishment. Fish ponds and pond systems existing before the industrial boom in the region occurred in the following localities:

- in the Odra River floodplain from Svinov to Heřmanice,
- on the Ostravice R. from Sviadnov to Kunčičky (up to Moravská Ostrava),
- on the Stružka R. from Orlová to Vrbice,
- on the Olše R. from Louky n.O. to Věřňovice
- and partly also fish ponds in the Opava R. from Děhylov to Hošťálkovice.

Economic development in the 19th and namely in the 20th century led in the OKR area to a very conspicuous and dramatic reduction of water surfaces as compared with the former *pre-industrial* situation. At some places it also resulted in a change of the character and nature of these areas, sometimes even in the transformation of their purpose, function and appearance. New water surfaces came to existence for the purposes of coal treatment plants. Former ponds (e.g. Kuboň in the Paskov exploitation space) were used as settling pits and waste rock depositories.

Deep coal mining gave rise to a range of internal drainage areas which formed a continuous flooding of subsidence basins. These inundated areas are at a greater part recultivated with waste rock fillings. An example is the village of Kunčičky on the confluence of the Ostravice and Lučina Rivers in the minefield of Mine Zárubek, at the present time the area of Louky in the mining space of Mine ČSM. Some drainless basins are used as settling pits or left as water surfaces to play a role of landscaping elements.

4.1. Impact of water from coal industry on environment

Waste water produced by coal industry is an important element affecting the region‘s environment. Waste waters consist of mine water, waste water from sewage treatment plants, waste water from coking plants and other kinds of water.

Pollution of watercourses was not studied by anybody until World War II. There was no legislative instrument requiring purification of discharged waters. In the 1950s, watercourses in the studied territory became mere sewers with no sign of life. This applies to the Ostravice R. below the discharge from Vratimovské papírny Paper Mills, to the Odra R. from Zábřeh na Moravě up to the confluence with the Olše R., to the Lučina R. from the discharge opening from Nová huť, to the Olše R. below Třinecké železárny Steel Works, to the Opava R. from Vávrovice during the sugar-beet campaign, and to some other smaller streams. The pollution by industrial waste water became considerably higher than the pollution by communal sewage (Brosch, 2005).

In 1955, the Water Management Act No. 11/1955 Gaz. came to effect, which substituted the hitherto valid law of 1870. But the pollution of watercourses continued in spite of protests from the Polish Republic until 1966 when the Regulation on compensation payments for discharge of unpurified sewage waters No. 16/1966 Gaz., the Water Act No. 138/1973 Gaz., and the setting of indicators for permissible pollution from 1975 came to effect. A visible improvement of water quality in rivers was observed as late as after new investments into sewage water plants in 1985. There are two types of water produced by the coal mining industry – water from coal treatment and coking plants, and mine water pumped from coal mines.

Waste water from the coal treatment plants is drained into three-stage purifying sedimentation tanks. The first stage serves to store sludges, the second stage is for their purification. The third stage is used to withdraw pre-treated water which is introduced into water circulation of sewage treatment plants.

In the 1960s, the production of sludges from the sewage treatment plants amounted to 800 thousand tons a year. Clarifying basins started to be established to separate fine and difficult-to-sediment sludges. Dried out coal sludges were used as fuel in the Dětmarovice Power plant and in households.

Since the 1950s, phenols were removed from the waste water of coking plants by means of their adsorption on coal substance while the biological degradation took place in the clarifying basins. From the 1970s, the waste water from coking plants was purified in dephenolizing stations.

There are no coal treatment facilities and coking plants operated now in the Ostrava part of the OKR district and the settling pits are at a various stage of recultivation or use.

Statistic data of the 1980s indicate that a total production of waste water in OKR amounted to about 65 mil. m^3 per year; of this amount, mine water for the whole OKR district was ca. 20 mil. m^3.

4.2. Discharge of mine water into surface watercourses after the close-down of coal mines in the Ostrava part of the OKR district

For security reasons in the so far active mines in the Karviná district and to prevent inflows or uncontrollable water overflows from flooded mines in the Ostrava part of the OKR district a system of water level maintenance was implemented in the flooded mines. The water surface is maintained at a level which is below the interconnection with active mines in the Karviná part of the OKR district. For these purposes two water pits were established in OKR – the Jeremenko water pit in the Ostrava part of the district, and the Žofie water pit in the partial Petřvald basin with the formerly active Mine Fučík (Dvorský et al., 1992; 2000).

Prognoses of total inflow into the Jeremenko water pit in 1992 and 1997 were 3201 $dm^3.s^{-1}$ and 220 $dm^3.^{s-1}$, respectively (Fasolo, 2003). Actual inflow after the start of pumping in 2001 was about 100 $dm^3.s^{-1}$ (Michálek, Tabášek, 2002). Total amount of water discharged in 2002 surmounted 3 million m^3. Water level in the pit is maintained at about -388 m (according to Adriatic Vertical Datum). The content of sulphate ions /SO_4^{-2}/ in 2002 amounted to an average of 300 $mg.dm^{-3}$, the content of chlorides was about 11550 $mg.dm^{-3}$. In 2003, the content of chlorides decreased to an average of 7500 $mg.dm^{-3}$. Pumped water is discharged directly into the Ostravice River and the whole process is therefore monitored (water level in the pit including operating water level, amount of pumped water and concentrations of chlorides and sulphate ions).

Water level in the Žofie water pit is maintained at – 480 m (according to Adriatic Vertical Datum). This level was chosen with respect to the elevation of a possible interconnection between the former Mine Fučík, now flooded, with mines in the Karviná part of the OKR district by means of red-bed bodies (Dvorský, 2000).

Anticipated amounts of residual inflows (60 $dm^3.s^{-1}$) were not corroborated and the actual residual inflows are at about 40 $dm^3.s^{-1}$. Water is discharged into the Odra River via the retention reservoir of Heřmanický rybník Pond, which enables a continual pumping without interruption. The content of sulphate ions in 2002 was on av. 100 mg/dm^3, the content of chlorides fluctuated from ca. 2200 to 10300 mg/dm^3 (Michálek, Tabášek, 2002).

The issue of the future gradual close-down and flooding of coal mines in the Karviná part of the OKR district and of the subsequent mutual affection of water regime in the entire OKR district has been worked out in documents of Ostravsko-karvinské doly a.s. Důlní průzkum a bezpečnost Paskov (Dvorský, 2000) up to the planned close-down of the last mine in the Karviná part of the district after 2030. The time horizon of the expected course of mine flooding shifts the issue of possible surface affection to a very distant future after 2080. The end of pumping in the Žofie water pit is considered in some variants after 2020. The end of pumping through the Jeremenko water pit can be estimated only on the basis of actual data on residual water amounts inflowing into the liquidated mines and on the time course of flooding in the liquidated Karviná mines.

A prognosis of development after a total stoppage of mining activities in OKR, flooding of all mining spaces and close-down of all water pits can be – according to existing expert opinions – seriously prepared only after actual data on the time course of water level increase in the liquidated mines are available. According to Dvorský (1992, 2000), a tendency is observed in the liquidated mine operations to get flooded to the elevation of +210 m (according to Adriatic Vertical Datum).

The above facts show that the only impact on environment in the Ostrava part of the OKR district by mine water pumping is the discharge into surface watercourses – into the Ostravice R. directly from the Jeremenko water pit, and into the Odra R. via an equalization basin. The room capacity of Jeremenko water pit is sufficiently large, enabling retention of water amount required in a restricted or even stopped discharge into the Ostravice R.

It follows from the estimated amounts of pumped water in the Ostrava part of the OKD district that the mines occurring in this area (including Mine Fučík) pumped more than 13 million m^3 per year in the last years of their activity. The above data show that the amounts of water pumped by the Jeremenko and Žofie water pits in 2002 were less than 3.5 million m^3 which is about 27% of the former amount. Contents of monitored substances recorded a marked decrease, too. A further scum washing can be expected due to the enclosure of affluents from the lower water-bearing sources and prevailing inflow of sweet Quaternary water. In spite of the continuing pumping through water pits the downsizing of coal minining activities in the Ostrava part of the OKR district resulted in a substantial reduction of water amounts discharged into watercourses and thus to a general quality improvement of water in them.

5. Waste banks, settling pits of flotation and coal sludges as a permanent load of the mining landscape in OKR

Waste rock types are defined in the former ON 44 0001 (1966) as rocks surrounding or penetrating into the seam of utility minerals, not containing the utility mineral or containing it at an amount insufficient for its industrial processing. Waste rock types in OKR include conglomerates, sandstones to grawacks, siltstones and claystones with dispersed coal matter and coal residues at a different stage of coalification and admixture of other secondary materials such as wood, iron, cables, construction materials, etc.

From the viewpoint of Waste Law (Act No. 185/2001 Gaz. on wastes), wastes in the case of waste banks and settling pits are referred to as the **wastes from mining activitie**s. According to § 2 these waste types are exempted from the effect of the Waste Law and belong in the effect of the Mining Law (Act. No. 44/1988 Gaz. as amended). The rock mixture on a **waste bank** consists both of cover rocks (a relatively small part) and Carboniferous rocks (conglomerates, sandstones and grawacks, arcoses, siltstones and claystones from excavation of pits, tunnelling and rocks accompanying the coal seams. A specific feature of Carboniferous tailings is the fact that they contain both coal matter finely dispersed in the rocks and loose fragments and coal dust. Waste rock types also include fine-grain flotation sludges and coal sludges developing as a product of advanced coal treatment technologies, which are deposited together with the technological water in sedimentation basins.

Waste rocks remain on spoil heaps and in ground bodies as a permanent component of environment even after the close-down of the coal mine. Hazardous may become waste banks with advanced oxidation of coal matter, burning waste banks and spoil heaps with the gradual downsizing of thermal activity. Burning spoil banks represent a thread by emissions of dust, steam, gases and organic pollutants for several tens of years. A local risk may rise due to the dissolving of secondary minerals from a cooled-down spoil bank. Burnt-out waste banks may represent a danger of slope stability disturbance (land slides) and more intensive washing out of salts into waters. The contamination of surface and underground waters in the vicinity of burning and burnt-out waste banks with chlorides and sulphates is a serious problem that calls for a solution.

Settling basins for flotation and coal sludges

Water management of mines also includes the settling basins. The topography of basins in a map (1:50 000) and their description were published by Latová (in Martinec et al., 2003). The balance of coal sludges and flotation tailings until 1996 was presented by Dopita, Martinec and Černý (in Dopita et al., 1997), the capacity and areas of settling pits in OKR was described by Hlavatá (2001). Preparation plants in the Ostrava part of the OKR district were closed down after 1989 within the programme of downsizing. Remaining preparation plants experienced an extensive refurbishment which resulted in a reduction of sludge volumes to less than 10 %. The settling pits are gradually recultivated. The recultivation of settling pits is as a rule difficult with respect to their physical properties and high moisture content. Underground waters in the surroundings of these settling pits are often contaminated.

6. Conclusion

The paper brings an analysis of some most severe impacts resulting from 200 years of intensive deep coal mining in the OKR district on environment and on the ground surface after the close-down of coal mines in the Ostrava part of the district. After a period of ca. 10 years since the close-down of the coal mines some of the impacts can be evaluated as follows:

- Mining activites led to the displacement of coal, rocks, gases and water from the place of their geological occurrence to the ground surface. While coal (including ash) was the subject of use right on the spot (coal, coke) or at remote places (power plants, steel works, households), methane from the ventilation of coal mines leaked into the atmosphere or was used for degasation. The pumped industrial water left the territory in watercourses without any residues. Tailings on spoil banks and tailings that have become a part of construction works (communications, ground bodies, river dams) have remained in the region which is going to be permanently affected by them.

- Methane emissions to the ground surface continue. Areas were classified as dangerous and endangered by emissions, some of them are subjected to technical measures and monitoring. With respect to the fact that the phenomenon in question is of geological nature, emphasized by the massif disturbance due to coal mining activity, the factor must be taken into account even in the far distant future.
- Surface deformations developed in the area with closed-down coal mining due to undermining tend to a gradual stabilization accompanied by a calming-down of the rock massif. The stabilization can be expected in several tens of years.
- Surface watercourses in areas with closed-down coal mining will be in the future affected by other agents than the mining activities, and possible interventions and stream regulations will follow out of different reasons. A permanent consequence of terrain subsidences is however the extension of possible inundation areas during floods.
- Pollution of surface watercourses with waste water from coal industry has a decreasing trend both due to the decreasing content of salts in the so far pumped mine water from water pits and thanks to the refurbishment of coal cleaning processes and sewage water treatment plants.
- One of terrain subsidence consequences is the development of internal drainage basins that were in the past used as settling pits and which are at the present time recultivated by filling with waste rock or conserved as water surfaces in the landscape.
- Waste banks continue to be a permanent burden of the landscape. They represent a potential geochemical risk by atmosphere and water contamination in case of their fire or low-temperature oxidation. The issue should be paid enough attention also in the future.

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DOWNSIZING OF DEEP COAL MINING IN THE OSTRAVA-KARVINÁ COALFIELD, THE DRAINING OF MINE AND WASTE WATERS, AND WATER QUALITY IN WATERCOURSES

Stanislav ONDRÁČEK

Abstract

An assessment of the impacts of deep coal mining downsizing in the Ostrava-Karviná Coal Mining District (OKR), from the perspective of mine water discharge, is presented in this paper. The amount of mine water and waste water discharged from the coal mines into water streams was gradually decreasing, as a result of the closing-down of mine operations and with the end of coal mining, in a number of OKR localities. This brought about a decrease in dissolved anorganic salts, which were introduced into watercourses along with the mine water. The changes were reflected in the water quality of the streams. In the second half of the 1990s, the content of chlorides exhibited a marked decrease in the Ostravice River (Ostrava-Muglinov), in the Odra River (Bohumín), and in the Lučina River (Slezská Ostrava). In order to protect the still-active coal mines from flooding, however, it was necessary to start pumping the mine water from the enclosed coal mines again. The water is discharged into the Ostravice R. in Ostrava. Hence, an increase was observed in the content of chlorides once again in the Ostravice and Odra Rivers after 2000. In comparison, the changes in the content of sulphates in water streams are different. After 1993, the content of sulphates began to gradually decrease to one half of the values recorded at the beginning of the 1990s.

Shrnutí

Útlum hlubinného hornictví v Ostravsko-karvinském revíru, vypouštění důlních a odpadních vod a jakost vody ve vodních tocích

Článek se zabývá posouzením útlumu hlubinného hornictví v Ostravsko-karvinském revíru (OKR) z hlediska problematiky vypouštění důlních vod. V souvislosti s uzavíráním důlních provozů a s ukončením těžby uhlí na řadě lokalit OKR postupně kleslo množství důlních vod a odpadních vod vypouštěných doly do vodních toků. Snížilo se tak i množství rozpuštěných anorganických solí, které se s důlními vodami dostávaly do vodních toků. Tyto změny se projevily v jakosti vody v tocích. V druhé polovině 90. let 20. století významně klesl obsah chloridů v Ostravici v Ostravě-Muglinově, v Odře v Bohumíně a v Lučině ve Slezské Ostravě. Z důvodů ochrany aktivních dolů před zatopením bylo ovšem nutné začít znovu čerpat důlní vodu z uzavřených dolů. Tato voda je vypouštěna do Ostravice v Ostravě. Po roce 2000 se proto obsah chloridů v Ostravici a Odře opět zvětšil. Odlišný je vývoj obsahu síranů ve vodních tocích. Po roce 1993 začal obsah síranů postupně klesat až na polovinu hodnot ze začátku 90. let.

Key words: *OKR (Ostrava-Karviná Coal Mining District), downsizing deep coal mining, mine water, chlorides and sulphates in water streams*

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1. Introduction

Assessment of downsizing of the deep coal mining in the Ostrava-Karviná Coal mining district (OKR) from the point of the issue of mine and waste water draining into watercourses was the integral part of the project "Downsizing of Deep Coal Mining and its Impacts on Processes in Lithosphere and Environment" resolved by the Institute of Geonics of the Academy of Sciences CR. Impacts of downsizing of the deep coal mining on the environment are versatile and are also reflected in the fact that quantities of mine and waste waters drained by the mines into the watercourses drop step by step in connection with closing of deep coal sites and terminated extraction in a number of OKR localities. Draining of mine and water waters is monitored within the scope of the compiled water balance based on § 22, items 1 and 2 of the Act No. 254/2001 Coll. on waters (Water Act) and based on the Regulation of the Ministry of Agriculture No. 431/2001 Coll., on water balance content, method of its compilation and on the data needed for the water balance. Quality of water in watercourses is monitored within the framework of the water balance. The report is focused on brief determination how downsizing of the deep coal mining in OKR found its expression in the water balance, i.e. in the related reports.

2. Draining of mine and waste waters into watercourses

Quantities of mine and waste waters drained by individual OKR deep coal mining sites into watercourses during the selected years can be seen in the Tab. 1 below. The Table contains comparison of the state in the years 1989, 1994 and 2001. The year 1989 represents the situation prior to commencement of the social and economic transformation, the year 1994 – the state after five years and approximately in the mid 1990s and the year 2001 – the state at the beginning of the 21st century and after ten years of the changes connected with social and economic transformation incorporating also downsizing of the deep coal mining in OKR. The deep coal mining sites are broken down in the Table by the drained water volumes.

To form an idea on drained mine and waste water quantities we can state that the volume of 1 million m^3 of water drained during one year into the watercourse represents roughly 30 litres per second under the condition of uniform and continuous water draining during the whole year. In 1989 – in ten cases of the 29

Year 1989		Year 1994		Year 2001	
Name of the mine (No. of disposal)	Drained water volumes [thou. m^3]	Name of the mine (No. of disposal)	Drained water volumes [thou. m^3]	Name of the mine (No. of disposal)	Drained water volumes [thou. m^3]
1. máj (627493)	3 550.8	Odra (627365)	2 942.2	Dukla (627360)	5 419.9
ČSM (627474)	2 173.3	Dukla (627360)	2 862.8	Darkov (627493)	1 939.2
Vítězný únor (627365)	1 923.6	ČSM (627474)	1 905.6	Lazy (627406)	1 845.7
Dukla (627360)	1 774.1	Darkov (627493)	1 398.5	ČSM (627474)	1 651.5
Zápotocký (627406)	1 643.1	ČSA (627484)	1 381.3	ČSA-Jan Karel (627484)	1 254.9
ČSM (627478)	1 603.6	Lazy (627406)	1 228.0	Doubrava (627410)	1 096.5
ČSA (627484)	1 569.6	Zárubek (627364)	1 227.2	Jeremenko (628052)	974.5
Hlubina (627341)	1 200.0	Fučík (627399)	1 048.2	Dukla (627361)	677.9
Fučík (627399)	1 123.8	Fučík (627411)	922.2	Paskov (627320)	510.7
Fučík (627411)	1 099.3	Doubrava (627410)	877.6	Paskov (628631)	215.8
Vítězný únor (627262)	985.5	Jeremenko (628052)	818.4	ČSM (627478)	131.2
Bezruč (627376)	930.0	Odra (627262)	648.0	Stařič (627325)	117.4
Doubrava (627410)	908.1	Paskov (627320)	549.4	ČSM (628209)	100.2
Šverma (627249)	904.0	Stařič (627325)	382.4	Chlebovice (617068)	99.1
Fučík (627362)	550.6	Fučík (627362)	317.1	Darkov (627932)	88.0
Chlebovice (617068)	421.5	Chlebovice (617068)	232.5	Gabriela (627494)	19.9
Zárubek (627364)	396.0	Fučík (627412)	192.0	-	-
Stařič (627325)	384.1	Heřmanice (627394)	151.0	-	-
Stařič (627322)	366.0	Fučík (627398)	99.1	-	-
Mír (627494)	325.8	ČSM (627478)	89.5	-	-
Rudý říjen (627394)	301.1	Darkov (627932)	47.8	-	-
Paskov (627320)	206.6	Stařič (627314)	46.8	-	-
Doubrava (627408)	168.3	Mír (627494)	41.0	-	-
Stařič (627314)	135.8	Doubrava (627408)	37.6	-	-
Fučík (627412)	127.3	Doubrava (627491)	19.8	-	-
Stařič (627315)	126.1	-	-	-	-
Fučík (627398)	103.1	-	-	-	-
Šverma (627087)	74.8	-	-	-	-
Doubrava (627491)	27.3	-	-	-	-

Tab. 1: Comparison of quantities of mine and waste waters drained by OKR deep coal mining sites into watercourses in 1989, 1994 and 2001 by water balance reports

reported cases of mine and waste water draining from the OKR deep coal mining sites the disposed waters exceeded one million m^3, in 1994 – in 8 gases of the 25 reported ones and in 2001 – in 6 cases of 16 reported ones. In 2001 the annual drained water volumes exceeded 5 million m^3 in one case; we are speaking about the mine Dukla which drained 5 419 900 m^3 of mine and waste waters (i.e. 172 litres per second on average) into Sušanka (the right-hand affluent of the Lučina River) in Havířov. The figure above represents only a small fraction of what is drained by the greatest waste water source in the Ostrava region, by the city of Ostrava. The central waste water treatment plant in Ostrava-Přívoz drained as many as 37 037 900 m^3 (1 174 l.s^{-1}) of waste waters into Odra River in 2001. From the Tab. 1 it follows that the mines Dukla, Darkov (former 1. máj), ČSM and the Mine Odra before its closing (former Vítězný únor) were the greatest sources of mine and waste waters from deep coal mining activities in OKR in the 1990s.

In connection with downsizing of the deep coal mining in OKR the following mine and waste waters from the deep coal mining sites were no more drained into the watercourses during the 1990s.

1. Mine Odra (former Vítězný únor)

Drained the highest mine and waste water quantities from all closed mines into the watercourses. Its closing led to terminated waste water disposal into Ostravice River in Ostrava (93 l.s^{-1} on average in 1994) and also to stopped waste and mine water draining into Odra River in Ostrava (20 l.s^{-1} on average in 1994).

2. Mine J. Fučík

During the last period of its activities the mine drained mine and waste waters into watercourses on five places. The greatest terminated point of water disposal was in Petřvald, where the mine drained 33 litres of water per second on average into Petřvaldská Stružka (brook) in 1994. The cancelled point of waste water disposal in Orlová was a little bit smaller – the mine drained 29 litres of water per second on average into Orlovská Stružka (brook). The point of water disposal into Podleský potok (brook) in Ostrava-Bartovice (10 l.s^{-1} on average in 1994) was also cancelled. The two remaining cancelled points of disposal were of smaller volumes.

3. Mine Zárubek

Closing of the mine led to terminated draining of mine and waste waters into the river Lučina in Ostrava (39 l.s^{-1} on average in 1994).

4. Mine Hlubina

Stopped activities of the mine resulted in terminated water draining from the mine into Ostravice River in Ostrava (38 l.s^{-1} on average in 1989).

5. Mine Bezruč

Closing of the Mine Bezruč was accompanied by terminated water draining from the mine into Lučina River in Ostrava (30 l.s^{-1} on average in 1989).

6. Mine J. Šverma

Closing of the mine led to the following positive results: on the one side terminated draining of lower water quantities (2.4 l.s^{-1} on average in 1989) into Odra River in Ostrava, roughly 700 meters upstream its junction with the river Opava and on the other side terminated draining of much more larger water quantities (29 l.s^{-1} on average in 1989) located on the river Odra by ca 3 km downstream, by the Lhotecký weir.

7. Mine Heřmanice (former Rudý říjen)

Closing of the Mine Heřmanice led to terminated water draining from the mine into Odra River in Ostrava (5 l.s^{-1} on average in 1994).

The 13 cancelled points of mine and waste water disposal from the deep coal mining sites shown above affected directly 6 watercourses in total – Odra, Ostravice, Lučina, Orlovská Stružka, Petřvaldská Stružka and Podleský potok (brook). The affection was eliminated as the consequence of downsizing of the deep coal mining in OKR. The degree of affection differed materially, depending on the watercourse size. In case of small watercourses, e.g. Orlovská Stružka, Petřvaldská Stružka or Podleský potok (brook), the natural water flow of which is of minimum nature only (reaches some tens of litres per second), draining of mine and waste water quantities as shown above represented an important water flow improvement. But on the other hand the water flow of such watercourses as Lučina (with the average water flow in the station in Ostrava-Radvanice of 2.38 m^3.s^{-1}), Ostravice (with the average water flow in the station in Ostrava of 15.47 m^3.s^{-1}) or Odra (with the average water flow in the station in Ostrava-Svinov of 13.7 m^3.s^{-1} and in the station in Bohumín of 48.07 m^3.s^{-1}) was not affected so much by draining of the water quantities as above.

Though the mines in the Ostrava part of the Ostrava-Karviná coalfield were closed, disposal of certain mine water quantities still persists in this part of the coalfield, because the groundwater level has to be maintained at a certain height to prevent water overflow into other parts of the coalfield and flooding of active mines (e.g. Jelínek, Grmela, 2001). Pumping is carried out in the former mine Jeremenko in Ostrava. The pumped water is drained into the river Ostravice. Mine water after-pumping is also one of the consequences of downsized deep coal mining in OKR.

Increased content of dissolved inorganic salts is the characteristic feature for the mine waters from the quality criteria monitored in the water balance reports – in the waters drained into the watercourses. Survey of the total quantities of dissolved inorganic salts (DIS) drained by individual OKR deep coal mining sites into watercourses can be seen in the Tab. 2 below. The Table contains comparison of the state in the years 1994 and 2001 by the data available in the water balance reports.

It follows from comparison of the deep coal mining sites with other DIS sources that the mining sites prevail materially in the category of the greatest DIS sources. In 1994 of the total number of 171 waste water sources in the Ostrava region, which the data about DIS content in waste or mine waters were available for, the category above 10 000 tons of DIS annually accommodated in total 9 sources, six of which were represented by the mining sites. In 2001 of the total number of 164 waste water sources, which the data were available for, the same category accommodated in total six sources, four of which were represented by the mining sites.

Comparison of the state of DIS draining in 1994 and 2001 reveals that quantities of these substances drained by the mining sites into the watercourses were reduced materially in connection with downsizing of the deep coal mining in OKR. The greatest change in the period between the years of 1994 ad 2001 with respect to DIS draining into watercourses is represented by closing of the Mine Fučík. This mine drained mine and waste waters into three watercourses in five points in total (into Petřvaldská Stružka, into Orlovská Stružka and into Podleský brook, a short right-hand affluent of the river Lučina flowing into it on the eastern Ostrava outskirts). Terminated activities in the Mine Fučík led to reduced DIS volumes particularly in Petřvaldská Stružka. A material drop of DIS quantities drained into the watercourses was recorded after the Mine Odra (former Vítězný únor) was closed. The Mine drained DIS particularly into Ostravice River in Ostrava.

Year 1994		Year 2001	
Name of the mine (No. of disposal)	DIS [t.y $^{-1}$]	Name of the mine (No. of disposal)	DIS [t.y $^{-1}$]
Doubrava (627410)	29 936.69	ČSM (627474)	19 758.55
Fučík (627399)	27 724.89	ČSA-Jan Karel (627484)	14 776.45
ČSA (627484)	24 266.68	Doubrava (627410)	12 363.04
ČSM (627474)	24 143.95	Dukla (627361)	12 185.25
Odra (627365)	15 358.28	Lazy (627406)	2 394.80
Jeremenko (628052)	12 415.13	Dukla (627360)	2 036.80
Fučík (627411)	4 659.88	Darkov (627493)	1 347.74
Dukla (627360)	3 964.98	ČSM (627478)	84.95
Paskov (627320)	2 684.37	Darkov (627932)	25.87
Zárubek (627364)	1 986.84	ČSM (628209)	24.25
Lazy (627406)	1 758.50	Staříč (627325)	21.13
Darkov (627493)	1 320.18	Gabriela (627494)	5.11
Fučík (627412)	880.51	-	-
Heřmanice (627394)	875.65	-	-
Odra (627262)	769.18	-	-
Staříč (627325)	233.26	-	-

Tab. 2: Quantities of dissolved inorganic salts drained by OKR mine sites into watercourses in 1994 and 2001 by water balance reports

The Tab. 2 differentiates quite clearly at first sight the category of deep coal mining sites – the greatest sources of DIS draining over 10 000 tons of these substances annually. In 1994 the Mine Doubrava drained the highest DIS quantities of all mining sites (29 937 tons). From all other waste water sources registered in the whole studied territory of the Ostrava region, incl. those not related to the mining activities, higher DIS quantities were drained in 1994 by the pulp mill Biocel Paskov only (35 612 tons). In 2001 the highest DIS quantities were drained by the Mine ČSM (19 759 tons). Greater sources of DIS in 2001 were only Biocel Paskov (20 081 tons) and the central waste water treatment plant of the city of Ostrava (24 445 tons).

3. Water quality in watercourses with respect to the criteria affected mostly by deep coal mining activities

Downsizing of the deep coal mining in OKR and/or changes in drained mine water quantities found expression (to a certain degree) particularly in the values of such water quality parameters like content of chlorides and content of sulphates. The Tab. 3 below shows values of these parameters in the highest control profiles of the state network of water quality monitoring in watercourse of the Ostrava region since 1988 till 2003, i.e. in the continuous period of 16 years. The Tab. 3 reflects step by step changes of the criteria in the period of social and economic transformation after the year 1989 which also comprises downsizing of the deep coal mining. The time series shown in the Tab. 3 contain the characteristic values of the criteria, which are "Classification of Surface Water Quality" according to CSN 75 7221, the values which most probably do not exceed 90 % (C_{90}). Individual values in the time series characterize the sliding two-year periods, starting by the period of 1988 – 1989 and ending by 2002 – 2003. The characteristic values C_{90} are calculated on the basis of the results of water analyses granted by the Czech Institute of Hydrometeorology.

From the Tab. 3 above it follows that chloride content in the river Ostravice, in the control profile Ostrava-Muglinov, and in the river Odra, in the control profile Bohumín, dropped materially in the second half of the 1990s. Due to the fact that the mine water was no more pumped out of the closed mines in the Ostrava part of the Ostrava-Karviná Coalfield, the underground spaces of these mines began to be flooded progressively again. In 2001 the water reached the level when it was necessary to restart its pumping to protect the active mines from being flooded. The pumping is carried out in the former Mine Jeremenko in Ostrava and the mine water is drained into Ostravice. Therefore after 2000 content of chlorides went up again in the rivers Ostravice and Odra.

Two-year period	C_{90}[mg.l-1]							
	Watercourse – control profile							
	Odra – Bohumín		Ostravice – Ostrava-Muglinov		Lučina – Slezská Ostrava		Olše – Věřňovice	
	chlorides	sulphates	chlorides	sulphates	chlorides	sulphates	chlorides	sulphates
1988-1989	285	196	341	310	326	167	1.723	179
1989-1990	282	193	323	335	295	168	1 718	181
1990-1991	236	191	293	327	277	178	1 799	185
1991-1992	303	243	290	318	167	183	2 096	201
1992-1993	308	243	327	318	325	213	2 216	162
1993-1994	267	212	326	252	329	213	2 067	131
1994-1995	159	183	180	189	313	172	1 512	145
1995-1996	151	159	100	203	184	145	1 578	173
1996-1997	129	145	103	196	186	133	1 153	154
1997-1998	121	124	109	174	207	127	1 377	140
1998-1999	78	112	82	158	197	119	1 558	137
1999-2000	84	104	78	146	188	108	1 300	138
2000-2001	94	101	159	145	188	102	1 177	122
2001-2002	103	100	396	134	94	100	959	108
2002-2003	188	131	394	176	101	114	1 365	117

Tab. 3: Characteristic values C_{90} of chloride and sulphate content in watercourses of the Ostrava region in the highest control profiles in the period of 1988 – 2003

By the end of the 1980s and in the first half of the 1990s the content of chlorides and/or its characteristic value C_{90} often exceeded the level of 300 mg.l^{-1} in the river Ostravice, in the control profile Ostrava-Muglinov. With respect to ČSN 75 7221 "Classification of Surface Water Quality" we are therefore speaking about the water of quality class 4, i.e. the water polluted heavily. At the same time the emission limit (standard) determined by the "Government Decree No. 61/2003 Coll. on Ratios and Values of Permitted Surface and Waste Water Pollution" was exceeded here, which limit amounts to 250 mg.l^{-1} for content of chlorides. The values went down after 1994, at first by one half and then, by the end of the 1990s, up to one half of the values from the beginning of the 1990s. In the period of 1998 to 2000 the content of chlorides was even reduced below 100 mg.l^{-1} and water in the river was thus switched to the 1st, i.e. the highest quality class with respect to this indicator. After the year 2001 content of chlorides went again up nearly to the value of C_{90} 400 mg.l^{-1} and water quality was again returned to the class 4.

The development of the content of chlorides in the Odra River, control profile Bohumín, is similar a single difference being the fact that after 2000 the content of chlorides did not show such a marked increase not reaching the value of 200 mg.l^{-1} yet and water in the river is now in the 2nd class of quality with respect to this parameter, i.e. polluted only moderately.

Development of the content of chlorides in the river, Lučina, the control profile Slezská Ostrava, differs from the preceding two control profiles mentioned above. During the predominant part of the first half of the 1990s the content of chlorides ranged above the value 300 mg.l^{-1} or close below the value, i.e. at the border of quality classes 3 and 4 and above the emission limit of 250 mg.l^{-1}. After 1994 content of chlorides is of continuously ascending nature. Since 2001 it ranges round the value of 100 mg.l^{-1}, i.e. on the border of the quality classes 1 and 2.

Content of chlorides in the river Olše, the control profile Věřňovice, is several times higher compared with the profiles in the rivers Odra, Ostravice and Lučina. In the river Olše basin the deep coal mining has not been reduced materially yet and therefore drop of content of chlorides in this river is not so explicit in the course of the 1990s. In the first half of the 1990s the content of chlorides ranged roughly in the interval from 1 700 to 2 200 mg.l^{-1}, i.e. exceeded materially both the emission limit (250 mg.l^{-1}) and the limit value determining the 5th, i.e. the worst quality class (450 mg.l^{-1}). With respect to this parameter we are speaking about the water polluted heavily. After 1994 the content of chlorides was reduced even here and in the period from 1995 till 2003 it ranged roughly from 1 000 to 1 500 mg.l^{-1}. The fact that it is the water of the worst quality class 5 has not been changed anyhow.

As far as the content of sulphates in watercourses is concerned, the Tab. 3, showing four control profiles polluted to the maximum degree, proves that Ostravice River has the highest content of sulphates. In the control profile on this river in Ostrava-Muglinov sulphate content is roughly by one half higher for the whole monitored period compared with all other three profiles. Till 1993 content of sulphates and/or its characteristic value C_{90} in the profile above ranged closely above the emission limit, which is 300 mg-l^{-1} according to the Government Decree No. 61/2003 Coll., i.e. somewhere in the mid quality class 4 determined by the values 250 – 400 mg.l^{-1}. We are speaking about the water polluted heavily. After 1993 content of sulphates began to drop successively. By the end of the 1990s and at the beginning of the 21st century the content of sulphates was by one half lower and reached the value of 150 mg.l^{-1}, i.e. the border of quality classes 2 and 3.

Similar changes took place in the river Odra, control profile Bohumín, with the single difference that content of sulphates is here roughly by one third lower than in Ostravice (Ostrava Muglinov). By the end of the 1980s and at the beginning of 1990s the content of sulphates and/or its characteristic value C_{90} ranged in Odra (in Bohumín) in the mid quality class 3 (or slightly above) determined by the values of 150 to 250 mg.l^{-1}. After 1994 content of sulphates began to drop here successively up to one half of the values from the beginning of the 90th. With respect to content of sulphates water is here in the quality class 2, determined by the values of 80 to 150 mg.l^{-1}, i.e. the water is polluted only moderately by sulphates. Content of sulphates and its development is similar in the river Lučina, in the control profile Slezská Ostrava and in the river Olše, the control profile Věřňovice.

4. Conclusion

Quantities of mine waters drained into the watercourses have been reduced in connection with downsizing of the deep coal mining in OKR. The material drop results particularly from closing of the Mine Odra (former Vítězný únor) and the Mine Fučík. (The Mine Odra drained on average 113 litres of water per second into the watercourses in 1994 and the Mine Fučík – 81 litres of water per second in the same year). Quantities of dissolved inorganic salts drained with the mine waters into the watercourses have been reduced as well. These changes found their expression in quality of water in the watercourses. In the second half of 1990s century content of chlorides dropped materially in the river Ostravice, in Ostrava-Muglinov, in Odra River – in Bohumín and in Lučina River – in Slezská Ostrava. In order to protect the active mines from flooding, the mine water had to be re-pumped from the closed mines. The water is drained into Ostravice River in Ostrava. After 2000 content of chlorides went therefore up again in the river Ostravice and Odra. Development of the content of sulphates in the watercourses differs. After 1993, the content of sulphates began to drop successively up to one half of the values from the beginning of the 1990s.

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BIOGEOGRAPHICAL AND GEOBIOCOENOLOGICAL ASPECTS OF DEEP COAL MINING AND ITS IMPACTS ON NATURE AND LANDSCAPE IN THE OSTRAVA REGION

Jan LACINA, Tomáš KOUTECKÝ

Abstract

The biota and primarily the vegetation of areas affected by deep coal mining have specific features. Due to relief changes (waste heaps and subsidence), the conditions of an abiotic environment in flat basins and hilly lands have been changed to such an extent that one must incorporate other types of natural potential vegetation than in the past. The actual vegetation typically exhibits numerous synanthropic species, including invasive neophytes. Newly developed relief forms exhibit a spontaneous natural succession, which is in some places influenced and disrupted by forest and agricultural remediation. A comparison between the vegetation cover for surfaces of the anthropogenic relief several tens of years ago and at the present time, showed that the number of species is increasing. Even in this devastated landscape, one can observe a range of localities with high biodiversity, including the occurrence of rare animal and plant species. These localities were demarcated as segments in the skeleton of landscape ecological stability. Based on a comparison of biocoenoses resulting from succession and biocoenoses conditioned by re-cultivation, the authors recommend an interconnection of the two processes, with an emphasis on controlled succession.

Shrnutí

Biogeografické a geobiocenologické aspekty vlivů hlubinného hornictví na přírodu a krajinu Ostravska

Biota, zejména vegetace oblasti ovlivněné hlubinným hornictvím má svoje výrazná specifika. Se změnami reliéfu (odvaly a poklesy) se změnily podmínky abiotického prostředí ploché pánve a pahorkatiny natolik, že je zde nutno počítat s jinými typy přírodní potenciální vegetace než dříve. Aktuální vegetace se vyznačuje velkým počtem synantropních druhů včetně invazních neofytů. Na nově vzniklých tvarech reliéfu probíhá spontánní přirozená sukcese, místy ovlivněná a přerušená lesnickými i zemědělskými rekultivacemi. Ze srovnání vegetačního krytu na plochách antropogenního reliéfu před desítkami let a v současnosti vyplynulo, že počet druhů se zvyšuje. I v devastované krajině lze najít řadu lokalit s vysokou biodiverzitou, včetně výskytu vzácných druhů rostlin i živočichů. Tyto lokality byly vymezeny jako součást kostry ekologické stability krajiny. Na základě srovnání biocenóz vzniklých sukcesí a biocenóz podmíněných rekultivačními akcemi, doporučují autoři oba procesy propojit, s důrazem na řízenou sukcesi.

Keywords: *anthropogenic relief, biodiversity, succession, recultivation*

1. Introduction

Decisive in the evaluation of environment condition is the classification of biota as a set of all wild plants and animals and their communities. Namely the vegetation is a landscape element whose response to environment and its changes is flexible and very palpable. It is a good indicator of environment quality and markedly affects the landscape pattern. In these terms, the Ostrava-Karviná coal-mining district (OKR) is known first of all by the synanthropic vegetation colonizing a markedly changed relief and soils. However, a starting point for the evaluation of landscape and environment changes must be the biota's natural condition, particularly the representation and distribution of natural vegetation formations that are to be compared with the current state. This is the only way how the form and intensity of anthropogenic changes in the biotic component of the landscape can be determined. Important is the study of spontaneous succession on the anthropogenic relief and its comparison with the results of recultivation activities. Last but not least, it is also necessary to specify the significance of the area under study for biodiversity protection and to propose measures for the sustained existence and support of environmentally favourable phenomena and processes.

2. Biogeographical characteristics and specific features of the biota

The Ostrava Basin territory with adjacent hilly lands and uplands has an exceptional geographical location within the Czech Republic. It is a contact point of three sub-provinces of the biogeographical province of Central-European deciduous forest – the central Polonian sub-province wedging into the Czech territory from the North links with the Hercynian sub-province in the West and with the Carpathian sub-province in the South to East.

Important for the formation of the local biota and namely vegetation is the fact that the Ostrava Basin connects to the warm Hornomoravský úval (Graben) with the broad depression of Moravská brána (Moravian Gate) which represented an important migration trajectory of thermophytic plants during the post-glacial development and evolution of the vegetation (Šmarda, 1956). Thermophytic plant species did not get to this area only from the South-West (via a so called Danubial route) but also from southern Poland from the North (via a so called Sarmatian route). An excellent example for the occurrence of thermophilic vegetation in the Ostrava region is the village of Kamenná u Staříče with an entirely isolated population of the Pontic geoelement – *Linum flavum* growing among other thermophytes, whose conventionalized flower even found a place in the sign of the mining village of Staříč.

The occurrence of mountain species descending into the Ostrava Basin mesophytic at an altitude of about 250 m a.s.l. and into adjacent hilly lands from the oreophytic of the Beskids Mts. is however more frequent in the studied area than that of thermophytes. Most represented mountain species are *Blechnum spicant*, *Lycopodium annotinum*, *Lastrea limbosperma*, *Gentiana asclepiadea*, *Petasites albus*, *Veratrum album ssp. lobelianum*. There is even one locality (south of the Těrlicko water reservoir) with the occurrence of the species of climax spruce stands – *Streptopus amplexifolius*.

Typical Carpathian plants of the deciduous forests of medium altitudes descending here down to the plain are for example *Carex pilosa*, *Isopyrum thalictroides*, *Dentaria glandulosa*, *Salvia glutinosa* and *Euphorbia amygdaloides*.

The specific features of the studied area, namely of the water-logged Ostrava Basin and adjacent flat hilly lands also reflect in the territorial differentiation into units of potential natural vegetation (Neuhäuslová, Moravec, (eds.), 1997). Broad river floodplains of Odra, Ostravice and Olše Rivers would be occupied by floodplain forests belonging in the vegetation unit of *Pruno-Fraxinetum*, at some places in combination with *Alnion glutinosae*, and in the vegetation unit of *Querco-Ulmetum*. A greater part of the area is classified in the vegetation unit of *Carici brizoidis-Quercetum* which was not determined elsewhere in the Czech territory. Smaller areas (in marginal broken hilly lands and uplands) are occupied by other vegetation units: *Carici pilosae-Carpinetum*, *Tilio-Carpinetum*, *Carici pilosae-Fagetum*, *Luzulo-Fagetum* and *Luzulo-albidae-Quercetum petraeae*, *Abieti-Quercetum*.

A more detailed differentiation of the natural potential (i.e. forest) vegetation is enabled by the geobiocoenological typification.

3. Natural condition of geobiocoenoses

The geobiocoenological typification (Zlatník, 1976; Buček, Lacina, 1999) classifies natural geobiocoenoses into vegetation tiers, and trophic and hydric ranges. The area under study – situated within the range of altitudes from 194 m a.s.l. (the Olše and Odra R. confluence near Bohumín) to 661 m a.s.l. (Kubánkov in the Podbeskydská pahorkatina Hilly Land on the southern edge) – belongs in three vegetation tiers reflecting the harmony between vegetation changes and changes of climatic conditions with the altitude and exposure. A greater part of the area falls in Vegetation Tier 3 which has three variants here: the "normal" 3a Oak-Beech vegetation tier in broken hilly lands, 3b Oak-Coniferous Vegetation Tier with Beech in the flat basin (with typical inversion phenomena), and 3c Floodplain. This specific basin area was formerly classified in the Oak-Coniferous variant of Vegetation Tier 4 (Raušer, Zlatník, 1966; Tichý, 1968) but since the Ostrava Basin is situated at a lower altitude than any other basin occurring in the Czech Republic and its mean annual temperatures are higher, it should be logically classified in Vegetation Tier 3 similarly as the local broad river floodplains. Communities of the Beech Vegetation Tier 4 can be found only in the broken hilly land to upland in the southern part of the territory, which pass into the Fir-Beech Vegetation Tier 4 at the highest elevations and shaded valleys.

Trophic categories representing the links of the vegetation to mineral supplies and soil reaction occurring in the territory under study are as follows: AB oligo-mesotrophic intermediate range, B mesotrophic range, BD mesotrophico-basic intermediate range, BC mesotrophico-nitrophilous intermediate range, and C eutrophico-nitrophilous range. In terms of soil regime moisture dynamics, the flat parts of the area (basin and floodplains) have typically a high share of segments from water-logged and wet hydric ranges (4 – 5). Geobiocoenoses on a more broken relief belong in the normal hydric range (3), and smaller segments of restricted and dry hydric ranges (2 – 1) occur only exceptionally e.g. on the rocky slopes of Landek.

These superstructural units of the geobiocoenological typification (i.e. a certain vegetation tier and a certain trophic and hydric range) define a framework of certain ecological conditions to which a certain natural biocoenosis is bound. The framework is called a group of geobiocoene types (GGT) and it is designated by main tree species of the original composition of natural forests. The studied area contains more than 20 GGTs that are listed below by their geobiocoenological formula in which the first position is for the number of vegetation tier, the second position for letters of the trophic range or intermediate range, and the third position for the hydric range number.

a) GGTs of river and stream floodplains:

3 C (4) 5:	*Ulmi-fraxineta populi superiora*
3 BC – C (4) 5:	*Querci roboris-fraxineta superiora*
3 BC – C (3) 4:	*Ulmi-fraxineta carpini superiora*
3 BC 5:	*Alni glutinosae-saliceta superiora*
3 – 4 BC – C 4 – 5:	*Fraxini-alneta inferiora et superiora*
3 – 4 BC 4 (5):	*Fraxini-alneta aceris inferiora et superiora*
3 B – C 5:	*Saliceta fragilis inferiora*

b) GGTs of basins and flat hilly lands:

3 AB (3) 4:	*Abieti-querceta roboris-piceae inferiora*
3 (A) AB 4:	*Betuli-querceta roboris superiora*
3 B – BC (BD) 4:	*Abieti-querceta roboris-fagi inferiora*
3 B – BD (3) 4:	*Tili-querceta roboris-fagi inferiora*
3 AB 5:	*Betuli-alneta superiora*
3 B – BC 5:	*Alneta glutinosae superiora*

c) GGTs of broken hilly lands and uplands:

3 B 3:	*Querci-fageta typica*
3 BC 3:	*Querci-fageta aceris*
3 BC 1 – 2:	*Querci-fageta aceris humilia*
3 BD 3:	*Querci-fageta tiliae*
4 AB 3:	*Fageta abietino-quercina*
4 BC 3:	*Fageta typica*
	Fageta paupera
4 BC 3:	*Fageta aceris*
4 BD 3:	*Fageta tiliae*
4 C 3:	*Tili-acereta fagi*
5 AB 3:	*Abieti-fageta*
5 B 3:	*Abieti-fageta typica*

It follows out from the above list that the natural forests which occupied nearly the entire territory under study were of a diverse tree species composition, differentiated according to site conditions. A specific feature of the area is the fact that beech, fir and spruce which normally occur only at higher altitudes are observed to have descended into the flat basin down to elevations ranging around 250 m a.s.l. Tichý (1968) who studied the area of about the same size estimated its natural tree species composition as follows: fir (*Abies alba*) 35 %, beech (*Fagus sylvatica*) 25 %, oak (*Quercus robur*) 25 %, alder (*Alnus glutinosa*) 8 %, linden (*Tilia cordata*) 4 %, Norway spruce (*Picea abies*) 2 %, other deciduous species - hornbeam (*Caprinus betulus*), birch (*Betula pendula*), elms (*Ulmus sp.*), maples (*Acer sp.*), ash (*Fraxinus excelsior*) etc. only at about 1 %.

The natural condition has been considerably changed in the course of centuries. The most conspicuous change is seen in the area representation of forests, which fell deep below the country's average of 32.8 % – forest cover percentage in the districts of Ostrava-City and Karviná is only 10.1 % and 11.8 %, respectively. The species composition in the remaining forests was markedly changed with a considerable increase of Norway spruce at the cost of beech and fir which nearly disappeared. A range of introduced tree species were planted. The changes resulted to a certain extent also from coal mining and related activities whose consequences in the biota changes cannot be at all times separated from the consequences of other anthropogenic impacts, though.

4. Present situation with a special regard to the changes of biocoenoses and biodiversity

Changes in the species composition of the biota and biocoenoses in the studied OKR region are multiple, both of large- and small-scale character, negative, indifferent but also positive, high synanthropization of the vegetation with spreading invasive neophytes being a characteristic feature. Withdrawal of the most succeptible species due to phyto-toxic air pollution was observed namely in the past. On the other hand, there were new biotopes coming to existence under the impact of coal mining and related activities, of which some were colonized by very rare biota, animals in particular.

The phyto-toxic air pollution is most likely to be the reason of the withdrawal of fir from local forest stands. Records on the dieback of fir stands in the surroundings of Slezská Ostrava originate already from the beginning of the second half of the 19th century. The woody species commonly occurring in this region in the past ceased to grow here. Apart from the autochthonous Norway spruce, Scots pine and European larch there were other tree species artificially introduced into the local forest stands in the second half of the 20th century – oak (*Quercus rubra*) for broadleaves, pine (*Pinus strobus*, *Pinus nigra*) and spruce (*Picea pungens*) to mention some examples of conifers. However, the local forests are in general dominated by the broadleaved tree species whose representation is very favourable as compared with the national average (21.7 %). In 1998, the share of broadleaved species was 62.9 % in the Karviná district and 63.5 % in the district of Ostrava-City.

The effect of phyto-toxic air pollution also contributed to a gradual withdrawal of succeptible epiphytic lichens which became an important bio-indicator of air quality. Their representation or absence on trees alongside the roads were used by V. Sobotková in 1965 – 1967 to define five zones corresponding to different degrees of pollution. A considerable part of the Ostrava Basin belonged at that time in a so called lichen wasteland, identical with Zone 5 of the worst pollution (Sobotková, 1969). In the last decennium, the succeptible epiphytic lichens have begun to appear rarely again both in the forests and on trees in the unstocked forest land, this being a good evidence of the reduced air pollution.

An illustrative example of nature devastation by coal mining and subsequent sanitation activity can be a pond area in the cadaster of Louky nad Olší south of Karviná. The system of more than ten fish ponds which became a unique refuge of the high biological diversity of plants and animals together with floodplain forests and grasslands in the surroundings was coming to existence already from the beginning of the 16th century and the territory of 33 hectares was decreed in 1970 the state nature reserve of Loucké rybníky (Ponds). During a rescue inventory research in 1978 – 1979, there were for example records on the occurrence of 421 plant species here (Švendová, 1982), 50 molluscs (Mácha, 1982), 377 beetle species (Vondřejc, 1982), 138 butterfly species (Stiova, 1982) and over 100 avian species (Kondělka, 1982). In the mid 1970s, the locality showed a gradual destruction due to the sinking of undermined areas, a clarifying basin was established and a part of the area was filled up with waste rock. The reserve was formally cancelled in 1987. The numerous smaller fish ponds have been replaced in the subsiding area by two extensive water surfaces surrounded by remainders of floodplain woods and semi-cultural grasslands. As compared with the past, the territory suffered a considerable loss of species. It shows however that some even very rare species have survived here or return to their original habitats – e.g. *Salvinia natans* for plants, *Tringa totanus* and some amphibians for animals.

On the other hand, it should not be forgotten that anthropogenic biotopes arisen during coal mining can often exhibit the occurrence of rare and endangered plant and animal species, namely on biotopes left at least partly to spontaneous development. On waste banks we can mention for example the following plant species: *Senecio erraticus*, *Crepis foetida ssp. rhoeadifolia*, *Aethusa cynapioides*, *Pyrola minor*, *Ramischia secunda*, *Epipactis helleborine*, *Euphorbia stricta*, *Carex otrubae*, etc. A waste bank from the Trojice coking plant was even the place of a new finding in the Czech Republic – beetle *Anaspis marginicollis* (Dolný, 2000). Similarly interesting are some sedimentation reservoirs and water-bearing subsidences. Some sedimentation reservoirs between Doubrava and Horní Suchá exhibit the occurrence of the critically endangered shrub of Carpathian gravel bars *Myricaria germanica*. Rare avians bound to numerous places of water and wetland anthropogenic biotopes are for example *Motacilla flava*, *Podiceps nigricollis*, *Circus aeruginosus* and other. Sludge beds near Karviná are places of the finding of three endangered invertebrates – *Libelulla fulva*, *Pontastacus leptodactylus* and *Anodonta cygnea* (Dolný, Ďuriš, 2001).

The area of OKR with the continual displacement of huge volumes of waste rock, soil and other mineral materials is the area in which the **synanthropic vegetation** – well adapted to anthropogenic changes of the substrate – develops at a much higher intensity and extent than in landscapes with no coal mining activities. Its biotope is represented mainly by various types of waste banks, drying out sedimentation basins and other fallow grounds. The synanthropic flora and its role in the process of succession was in the OKD area studied by many authors (e.g. Václav, 1956; Šmarda, 1964; Havrlant, Kincl, Gerlich, 1967; Kilián, 1968; Sobotková, 1994). Typical and most common plant species occurring at younger stages of the vegetation cover development are for example *Chenopodium botrys*, *Chamerion dodonaei* and *Erigeron annuus* while *Calamagrostis epigeios*, *Solidago canadensis* and other frequently become dominant at more advanced stages of development. The synanthropic flora of waste banks is very abundant in species with the occurrence of both autochthonous synanthropic species (apophytes) and those of foreign origin – introduced synanthropic species (anthropophytes). For example a detailed investigation into flora and vegetation of two waste banks at the Staříč Mine (Hettenbergerová, 2002) revealed a total number of 174 herb and grass species of which 103 were apophytes and 33 anthropophytes. Synanthropic plants are doubtlessly very important in the colonization of surfaces affected by changes due to anthropogenic activities, where they spontaneously penetrate as pioneer species. Reinforcing the soil, they prevent both wind and water erosion. Many of them are food source for seed-eating birds, some beautify the devastated landscape at the time of blossom (e.g. *Chamerion dodonaei*). On the other hand, many of them are alergennic with some flowering later in the year (e.g. *Solidago canadensis* and *Artemisia vulgaris*) shifting the exposure time for alergic people to the late autumn. Some synanthropicizing species are so expansive that they develop continuous monocoenoses and hamper a more favourable succession (e.g. *Calamagrostis epigeios*).

A special group of synanthropic plants contains **invasive neophytes**. Species most represented in the OKR district under study are *Reynoutria japonica*, *R. sachalinensis*, *Helianthus tuberosus*, *Solidago canadensis*, *Impatiens* *glandulifera* and *Rudbeckia laciniata*. These species are capable of developing continuous stands which often exclude the occurrence of any other plants, and the centres of their occurrence are usually the surfaces affected by coal mining and sanitation. An example can be the area along the Stonávka River near Karviná with a mere technical recultivation of the table waste rock bank where a monocoenosis of *Solidago canadensis* spread on the covering layer of soil and inpenetrable dense stands of *Reynoutria sp.* developed on the river banks. The invasive neophytes spread along the Odra, Olše and Ostravice Rivers and their tributaries, even outside the devastated area, pushing out the authochthonous plant species of the floodplain forest. A good exhibit of the phenomenon can be seen on the confluence of Olešná R. and Ostravice R. in Paskov where a continuous "jungle" of *Reynoutria japonica* gained the ground in the undergrowth of a floodplain forest remainder. The national mapping of invasive neophytes (Šindlar et al., 1997) showed that it is exactly the Ostravice River watershed (its lower reaches) which is most burdened with the invasive neophytes in the Czech Republic and which represents a concentration of risk factors for their further spread.

Synanthropic trends are shown also by some animals, namely birds. A common synanthropic bird occurring in Ostrava and Karviná and in many other towns is Apus apus nesting on the loft edges of high buildings. Some Ostrava neighbourhoods belong in a small group of Czech localities with the nesting (also in high-reach buildings) Corvus monedula which is rather rare at the present time and therefore one of protected avian species. *Ciconia ciconia* has found its way to the town as well, nesting for example in the central part of Brušperk. The most frequently occurring species bound with their food chain to the stands of synanthropic vegetation on waste banks and fallow grounds are *Carduelis carduelis* and *Carduelis cannabina*.

4.1. Geobiocoene changes and their prognosing

Changes of biota, especially vegetation, are far from consisting only in a large-scale onset and development of substitute communities with the dominance of synanthropic species. Deep coal mining and related activities are an important anthropogenic disturbance agent which can conspicuously and on large areas cause irreversible changes of a range of ecological factors and conditions. Relief changes reflect in the trophic and hydric condition of soils, partly even in some climatic changes. The synergical effect of these changes results in a change of the potential natural vegetation and its fauna. In the sense of geobiocoenological theories, all these changes are perceived as a change of the geobiocoene (Zlatník, 1975; 1976). Apart from the North Bohemian Brown Coal Mining District, the studied OKR area is one of those in the Czech Republic, in which anthropogenic changes of the geobiocoene have developed most extensively (Lacina, 2000; 2003) on an area of several thousand hectares. The obvious geobiocoene changes in the OKR territory are of two types:

- changes resulting from the subsidence of undermined areas
- changes resulting from the development of convex relief forms.

Subsidence circular basins (up to 30 m deep) come to existence in large areas, namely in the flat hilly land of basins and in broad river floodplains. The measure of their groundwater-table saturation at the present and in the future depends on their depths. The hydric range is in any case markedly changed and in addition to hydrobiocoenoses there are favourable conditions here for the growth of the most humid types of the floodplain forest and wetland alder woods. The most frequently occurring changes (expressed by geobiocoenological formulas) are as follows:

3b AB, B, BC (3) 4 —> 3c AB, B, BC 5 (in basins)
3c BC, C (3) 4-5 —> 3c BC, C 5 (in floodplains)

It shows that biotopes of *Alneta glutinosae-saliceta* and *Alneta glutinosae* communities come to existence. For the hilly lands of basins this represents a pronounced change from the communities of the Oak-Coniferous variant (with Beech) of Vegetation Tier 3 (*Abieti-querceta roboris-piceae*, *Betuli-querceta roboris*, *Abieti-querceta roboris-fagi* and *Tili-querceta roboris-fagi* Groups of Geobiocoene Types – GGT). In the broad river floodplains the conditions of subsided areas cause the extinction of "drier" types of the floodplain forest (*Ulmi-fraxineta carpini*, *Ulmi-fraxineta populi* and *Querci roboris-fraxineta* GGTs). Similar changes are caused by the existence of sedimentation reservoirs which however return in their normal hydric range after having dried-out and their trophic ranges can vary according to the character of deposited materials.

No less conspicuous are changes caused by the piling of various waste banks. The highest of them (conical mulloc tips raised in the past) reached a relative super-elevation of up to 90 m. A spoil bank near the Svoboda coking plant in Ostrava-Přívoz is for example rising above the original alluvial plain to an altitude of 273 m a.s.l., nearly reaching the elevation of the near Landek hill (280 m a.s.l.). Even considerably lower table waste banks bring about a change of ecological conditions, namely a change of the hydric range from the water-logged and wet range to the normal and restricted range. The geobiocoene changes can be expressed as follows:

3b AB, B, BC, BD (3) 4 —> (2) 3a AB, B, BC, BD 2-3 (in basins)
3c BC-C, 4-5 —> (2) 3a AB, B, BC, BD 2-3 (in floodplains)

Thus, the rising of various waste banks results in the extinction of conditions for humid to wet sites of the floodplain forest and wetlands and those of usually water-logged sites of the communities of the Oak-Coniferous variant (with Beech) of Vegetation Tier 3, and conditions are being created for the development of biocoenoses of the "normal" 3a Oak-Beech Vegetation Tier. Thanks to the fact that the dark material of spoil heaps is warmth-giving, their sunny slopes at some places suggest a transition towards the warmer Beech-Oak Vegetation Tier 2. This can be illustrated by the onset of some subthermophytes such as *Potentilla tabernaemontani*, *Conyza squarrosa*, and some thermophilic animals. Dolný (2000) mentioned a concentration of warmth-loving and steppe beetle species from some waste banks. Problematic is however a precise determination of the trophic range since in the course of weathering the substrate does not only change its physical properties but also chemism and reactions.

The knowledge of changes conditioned by anthropogenic changes of the geobiocoene is a good base for the prognosing of natural succession and especially for the selection of tree species suitable for recultivation. Important is considered a fact that the prognosis of geobiocoene changes resulting from the anthropogenic disturbance of the landscape is possible (Fig. 1).

5. Assessment of sanitation and recultivation works and spontaneous succession

The issue of sanitation and recultivation works and their evaluation can be hardly separated from the evaluation of the process of spontaneous oecesion and subsequent succession of vegetation on the anthropogenic relief of waste banks and subsidences. It is so because the two processes usually occur simultaneously or one of them is ahead of the other. In both cases the vegetation must cope with changed and often entirely specific site conditions that use to be in the case of recultivations improved only to a certain extent.

5.1. Specific features of anthropogenic ecotopes and their natural colonization by vegetation

Substrate for vegetation on waste banks from coal mines becomes the carboniferous spoil, often taken to the surface from great depths. The material is of typical alkaline to weakly acidic reaction. Its mineral supply of nutrients is relatively good (CaO, K_2O, P_2O_5) but nitrogen and humus contents are low and the microbial colonization is very poor (Grunda, Kulhavý, 1984). Furthermore, thanks to the admixture of sulphates (pyrite and marcasite), the process of weathering gives rise to sulphuric acid which dissolves live minerals and acidifies the developing soil. The dark-coloured tailings are strongly heated namely in

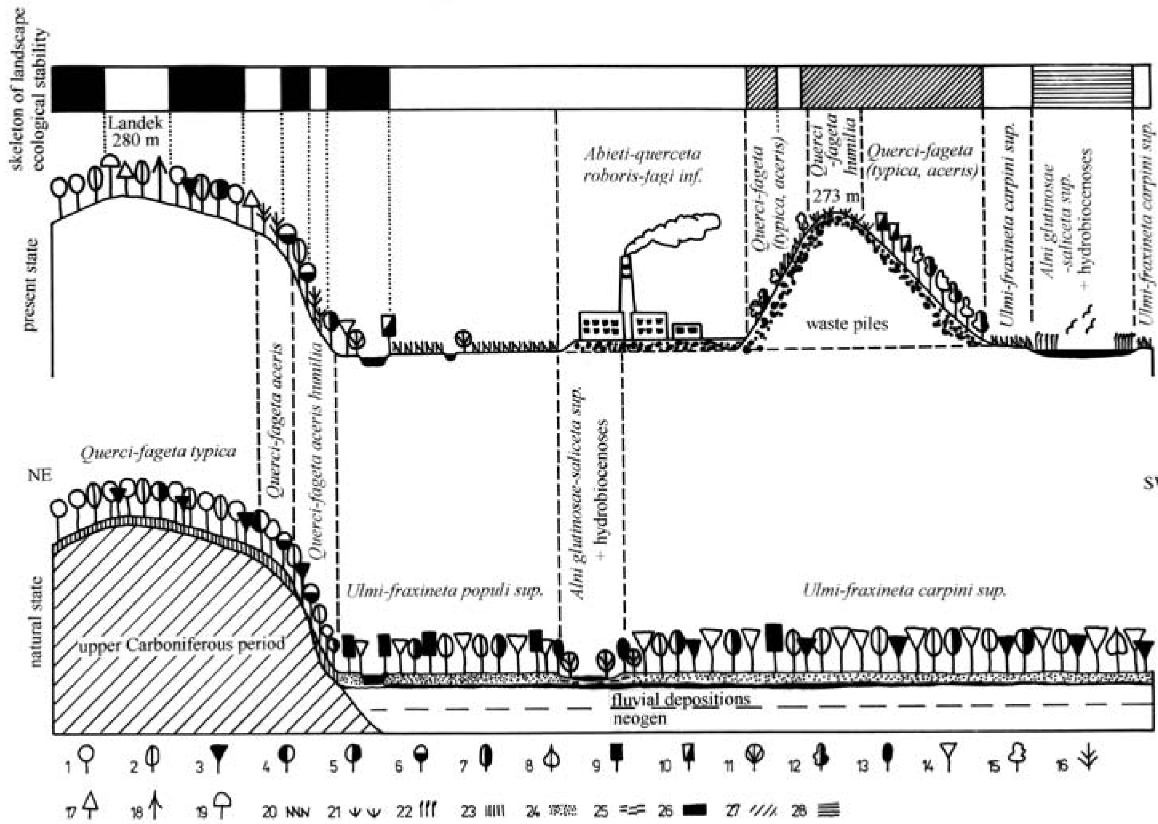

Fig. 1: Changes of Geobiobiocenoses in the mining landscape

*Legend: **Vegetation**: 1 – Fagus sylvatica; 2 – Quercus robur; 3 – Carpinus betulus; 4 – Acer pseudoplatanus; 5 – Acer platanoides; 6 – Acer campestre; 7 – Ulmus laevis; 8 – Tilia cordata; 9 – Populus nigra; 10 – Populus x canadensis; 11 – Salix fragilis; 12 – Salix caprea; 13 – Alnus glutinosa; 14 – Fraxinus excelsior; 15 – Betula pendula; 16 – Robinia pseudoacacia; 17 – Pinus sylvestris; 18 – Picea abies; 19 – Larix decidua; 20 – ruderal derelict land with neophyte predominance; 21 – ruderal derelict land with Calamagrostis epigeios predominance; 22 – reedswamps; **soils**: 23 – cambisoils; 24 – fluvisoils; 25 – gleys; **skeleton of landscape ecological stability**: 26 – ecologically significant segments; 27 – perspective anthropogenic biotopes – terrestrial; 28 – perspective anthropogenic biotopes – swamp and water.*

sunny expositions, their surface temperature frequently getting over 50°C. Koutecký (2004) measured in April when the air temperature reached to 22°C temperatures of 55°C on the surface of the insolated part of the waste bank and only 2°C on the shaded base with the coarse debris (apparently with the remainders of thawing ice). The rate of natural oecesion and succession and the exigence of recultivations closely depend on the shape of the waste banks – the steeper and longer are their slopes, the slower is usually the natural colonization by vegetation, more demanding and usually less successful is the biological recultivation. The vegetation cover (especially that of trees and shrubs) most rapidly develops at the waste bank foot. A very serious problem used to be – and exceptionally still is – the self-ignition of carboniferous spoil banks. The natural spread of vegetation on thermoactive waste banks is very limited and the already developed vegetation cover often extincts.

These very specific site conditions, different on different waste bank types, are the main reason for the process of primary succession not to be continual at all places, i.e. directed unambiguously and with a relatively good flexibility from simpler initial stages of mosses and short-age herbs towards relatively advanced communities of woody species. Initial stages formed by some mosses (most often by *Ceratodon purpureus* and *Bryum argenteum*) together with short-age herbs (e.g. *Chenopodium botrys*, *Chamerion dodonaei*, *Oenothera biennis*) and individually interspersed tree species (especially birch *Betula pendula*) can persist at some particularly unfavourable places (heavily drought-prone slope segments, immediate surroundings of thermoactive waste bank parts) even several tens of years.

A following stage of succession is usually considered to be (e.g. Šmarda, 1964; Sobotková, 1994) the additional saturation of these initial phytocoenoses with perennial ruderal herbs and grasses. Of these for example *Calamagrostis epigeios* develops extensive monocoenoses which relatively well hold the surface of waste banks, preventing both water and wind erosion on the one hand, but on the other hand representing a long-term blocking stage to the development of more advanced communities.

In spite of the above mentioned facts there is a lot of examples to be found on many older mine spoil banks that communities reached through the spontaneous succession a so far most advanced stage with the dominance of woody species, which can be denoted as a "spoil bank grove". However, these stands of woody species are far from resembling an advanced forest that would correspond with its species composition to the natural potential vegetation of the changed geobiocoene type. Determining for the development of spontaneous vegetation cover is the fact that the carboniferous rocks taken up to the surface from the Earth's deep are without any plant diaspores. Therefore, it is very important what kind of species grow in the vicinity and what is their strategy of dispersion. Winners are the species with light-weight seeds which can spread by anemochoric way. A woody species that becomes dominant is therefore *Betula pendula* which can furthermore stand rather well a whole set of extreme conditions of the waste banks and which is therefore justly called a "mother of mine dumps" (Václav, 1956). Other pioneer species of spoil banks in OKR forming the "spoil bank groves" are poplars (*Populus tremula*, *P. nigra*, *P. x canadensis*) and willow (*Salix caprea*) with *Robinia pseudoacacia* which often shows a spontaneous dispersion here. Less frequent is the natural seeding of maples (*Acer platanoides*, *A. pseudoplatanus*), lindens (*Tilia cordata*, *T. platyphyllos*) and ash (*Fraxinus excelsior*). The occurrence of tree species with heavier seeds such as oak (*Quercus robur*) and beech (*Fagus sylvatica*), which spread by zoochoric way, i.e. exactly the species that should have a more significant share in the future species composition, is rare to exceptional. Without the assistance of humans, the vegetation would reach this advanced stage of development probably as late as in hundreds of years. A typical example of the current vegetation is a mosaic of advanced stages of the vegetation cover on a waste bank from the Coking Plant Svoboda in Ostrava (Fig. 2).

Specific conditions are naturally observed also in concave relief forms either conditioned by anthropogenic activities or directly created by them. The margins of water-bearing subsidences exhibit an onset of wetland species such as *Phragmites australis* and *Typha latifolia*, self-seeding of willows (*Salix sp.*) and alders (namely *Alnus glutinosa*). Certain selection in the species composition of littoral hems may result from the presence of salinated mine waters. A difficult and mainly unfavourable situation with respect to the spontaneous colonization by vegetation can be seen in various types of sedimentation reservoirs which contain materials of diverse physical and chemical properties.

5.2. History of recultivations and their scope

A considerable dustiness of loose waste bank materials and their high succeptibility to water erosion at abundant precipitation, and last but not least also their ugly appearance have led already from the beginning of the 20th century to efforts focused at an acceleration of the process of spontaneous succession of vegetation by artificial plantations or sowing. The first successful greening of spoil banks was the plantation of tree species on the waste bank at the Zárubek Mine in Slezská Ostrava, which was made in 1919 by prof. A. Štěpán and his students (so called Štěpánův sad Orchard). And

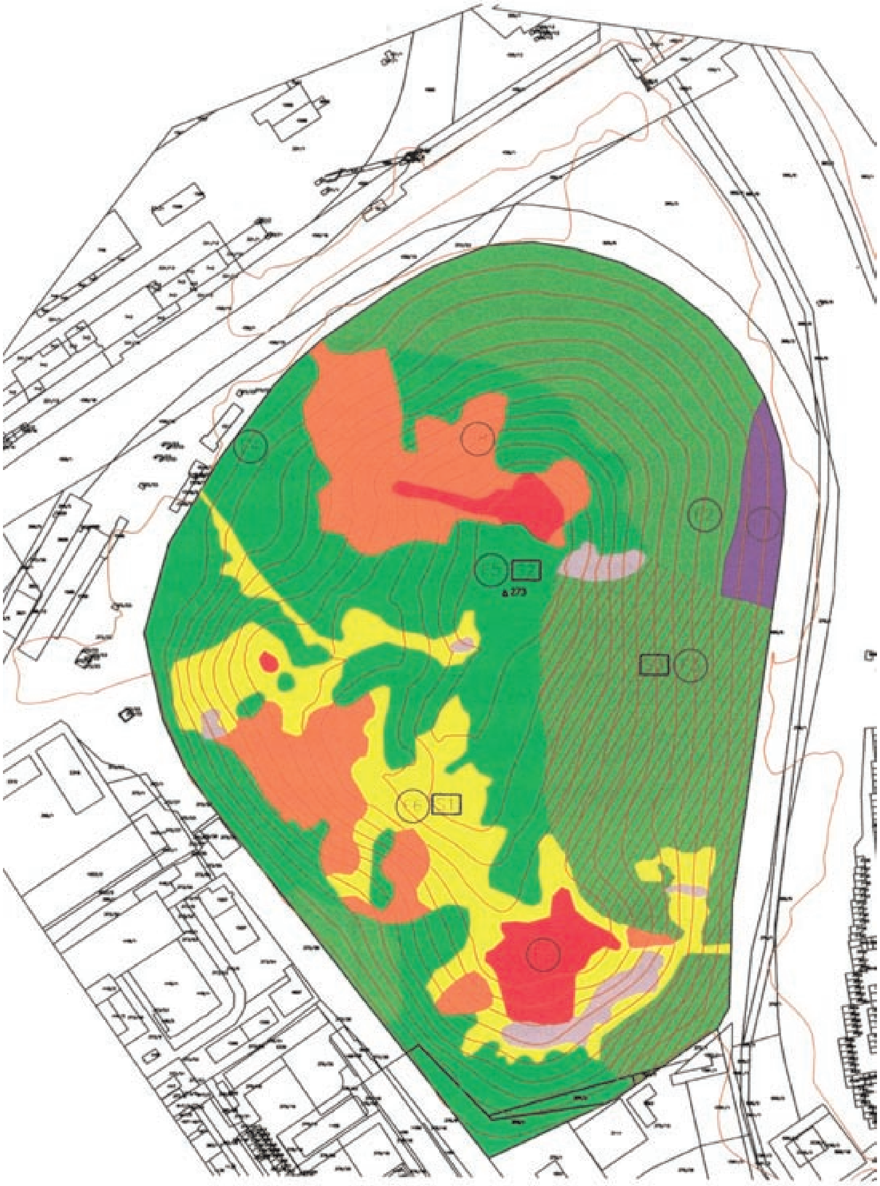

Fig. 2: Current vegetation Wase bank – Svoboda Cokong Plant
Legend: Stands from natural seeding; Fallow land with dominant Solidago canadensis; Fallow land with dominant Calamagrostis epigeitos; Stand of Robinia pseudoacacia; Stand of Populus x canadensis; Thermally active surfaces; Intitial stages of succession on tailings; Recultivation planting combined with self-seeding; (F5) Designation of phytocoenological relevé; [S1] Designation of soil profile

there are more plantations known from the period of the 1st Republic – e.g. on the conical waste banks near the Tivoli entertainment park (today called Černá louka), on the waste bank from the Odra Mine in Ostrava-Přívoz (so called Lesík na Oderce) etc. These first recultivations were however of random character.

An important step forward to a systematic greening of spoil banks and filled subsidence basins was the foundation of an independent enterprise OKD Rekultivace in 1962. A workplace of the Research Institute of Ameliorations specialized in biological recultuvations came to existence in the very next year. A number of research plots were established on selected waste banks. The development of biological recultivations was apparent at the beginning of the 1970s when a cooperation started to develop with a special-purpose forest enterprise in Šenov.

The total extent of recultivations from their beginning to the present time is difficult to be expressed in figures one of reasons being the insufficient and non-uniform record-keeping, and another reason being the fact that the territory was continually subjected to further mass displacement of materials and their withdrawals, to extensive subsidences and their filling in which some of the formerly recultivated areas apparently ceased to exist. There is a lot of useful partial data, though.

In his pioneer study, M. Havrlant (1968) dealt not only with the shapes of mine spoil banks but also with their vegetation cover. He made a description of 121 "mounds" in the OKR territory, whose total area was 649.7 ha, which means that an average size of these spoil dumps ranged from 0.1 – 37.3 ha). Of these, more than 40 spoil banks were at least partly recultivated (usually by silvicultural methods), 18 spoil dumps were without any vegetation cover or with an only very scarce vegetation, and the rest of them were at least partly covered by a spontaneously developing vegetation of herbs, grasses and woody species.

The same author (Havrlant, 1980) made an assessment of the condition of the OKR anthropogenic relief after ten years by similar methods. Thanks to the consolidation of mine dumps the total number of them decreased to 85 but their total area was nearly doubled (1238.6 ha) with the largest waste bank reaching an area of 110.52 ha. Of this number of waste banks 30 were at least partly recultivated (only 3 into farming land), 20 "live" waste banks in the regime of replenishment or withdrawal were nearly without any vegetation, and the rest of them were at least partly covered with herbaceous, grassy, woody and mixed vegetation, mainly developed from self-seeding. At the same time, there were 6 waste banks from the metallurgical operations (total of 271.08 ha) of which 5 were partly recultivated. Partly recultivated was also a spoil heap from the chemical operations (MCHZ Hrušov) at a total area of 3.52 ha. In addition to the spoil banks, studied were also the subsidences and terrain mirrors – a total of 108 localities at a total area of 1483.1 ha. Only 2 localities were partly recultivated.

The method of recultivation very much depends on the shape of the anthropogenic relief and this is why certain differences exist between the Ostrava section (with a significant share of conical waste banks with steep slopes) and the Karviná section (with mainly flat table spoil banks). It follows from the protocol of 122 spoil mounds in the Ostrava-City district (OKD, IMGE, 1996) that recultivated areas passed for use to Lesy ČR (Forests of the Czech Republic), Forest Administration Šenov and to agricultural enterprises (namely State Farm Hlučín) were about 84 ha and 80 ha, respectively. This shows that the silvicultural and agricultural recultivations were relatively balanced. A different situation existed in the Karviná district with a total area recultivated between 1981 – 1985 being 284 ha, of which 248 were converted to farming land (Folwarczny, 1997). However, a part of the recultivated farming plots were not further used and the fallow lands became centres of the dispersal of ruderal species including invasive neophytes.

Updated records on the waste banks and sludge basins in OKR (OKD, IMGE, 2003) suggest that in a total number of 46 existing spoil heaps (19 in Karviná, 21 in Ostrava, 6 in the southern part of the mining district), sanitation and recultivation works were accomplished only in 3 waste banks, 21 waste banks were subjected to partial sanitation and recultivation works which are continually in progress, and a project documentation had been prepared or was in preparation for the remaining waste banks. A similar situation can be seen in the case of 36 sludge pits (24 in Karviná, 6 in Ostrava, 6 in the southern part of the area), where the elimination of consequences from coal mining activities was accomplished only in 5 waste banks and in other 10 of them the sanitation and recultivation works were in progress. The remaining waste banks were either used for the extraction of the deposited material or a subject to prepared recultivation projects.

A total balance of recultivations in OKR as at 1 July 2000 based on the "Synoptical map of mines with plotted settling pits, active and recultivated waste banks" (OKD, IMGE, 2000) is as follows: Sanitation and recultivation works were accomplished and in progress on 2805 and 3377 hectares, respectively.

Interesting was the development of the share of silvicultural and agrotechnical recultivations in the course of the tens of years. The period before the mid 1970s was dominated by the planting of tree species. A turning point was Act No. 125/1976 Gaz. On the protection of farming land resources, which strictly requested a recurrent recultivation of farmland used for the mining of minerals. Exemptions were not permitted although a soil suitable for covering the tailings was often missing as the top soil and subsoil layers disappeared in the large water-bearing subsidences. The agrotechnical recultivations – namely in the Karviná section of the coal mining district – dominated until the end of the 1980s. According to Beneš (2003), the situation is turning to an opposite extreme at the present time when a greater part of plots planned for recultivation is afforested and the areas are very rarely grassed or left as water formations.

5.3. Research and prospects of recultivation

Recultivation of anthropogenic relief forms with the the material of diverse physical and chemical properties is a very demanding task whose success can vary. In silvicultural recultivations it depends on the selection of suitable tree species, method of establishing plantations and also on the subsequent tending, decisive in agricultural recultivations is the selection of grass-herbaceous mixture (if the target use is not a field or an orchard). In the history of several tens of years the recultivation works were paid rather a random attention of research at the beginning, which later became more systematic.

In 1933, the Society of Natural Sciences in Ostrava (chief executive Ing. Midlmayr) put together a list of tree species suitable for the specific conditions of the Ostrava region, at that time with a special emphasis on their resistence to flue gases. The list contains 68 tree and shrub species (49 deciduous and 19 coniferous) with a clear dominance of non-autochthonous species (48) over autochthonous ones (20). The following long-term practice showed that hardly a third of the species are more or less fitted for the afforestation of spoil heaps and many other species were used at least experimentally. Records of various kind document that there is more than 30 tree and shrub species that have been up to now used in the recultivation of waste banks, settling basins and filled subsidences. Domestic species used for the purpose were maples (*Acer pseudoplatanus*, *A. platanoides*), linden (*Tilia cordata*, *T. platyphyllos*), ash (*Fraxinus excelsior*), birch (*Betula pendula*), alder (*Alnus glutinosa*, *A. incana*), poplar (*Populus nigra*), hornbeam (*Carpinus betulus*), oaks (*Quercus petraea*, *Q. robur*), willows (*Salix sp.*), elms (*Ulmus sp.*), mountain ash (*Sorbus aucuparia*), European larch (*Larix decidua*) and Norway spruce (*Picea abies*). Introduced broadleaved tree species used in the recultivations were namely oak (*Quercus rubra*), black locust (*Robinia pseudoacacia*) and poplar cultivars (*Populus x canadensis*), *Aesculus hippocastanum*, *Tilia tomentosa*, *Acer negundo*, *Ailanthus altissima*. Introduced conifers were *Pinus nigra* and *Picea pungens*, less frequently also *Pinus strobus* and *Picea omorica*. Planted were also ornamental shrubs e.g. *Eleagnus angustifolia*, *Rosa rugosa*, *Syringa vulgaris*, *Ligustrum vulgare*, *Forsythia sp.* and other.

It is obvious from the above list that a preference has been given to broadleaved (so called soil-improving) tree species whose litterfall readily humifies, thus improving the soil, and to tree species with a good resistence to phyto-toxic air pollution. And it was also kept in mind that at least some of the plantations should have an aesthetically impressive park apperances. It can be seen that main functions of these tree plantations were those of soil protection and hygiene, in some cases recreation and production.

An apparently first evaluation of the quality and growth of recultivation plantations in the Ostrava region was made by F. Hladík (1942). In his plantations of six tree species established by hole and mound planting methods the best growth in the first thre years was recorded in European black pine and European larch. Hladík assumed that lindens and *Pinus strobus* would do well on the waste banks, but only as complementary species, and he totally excluded spruce from the recultivation.

E. Václav (1956) extends on his experience from the spontaneous overgrowing and afforestation of six waste banks localized in the Karviná part of the coal mining district. Appropriate tree species appear to him birch and black locust; of other species he recommended ash, linden, hornbeam, maples, alder, pine and other. He also advised to make most of the natural self-seeding, pointing out that we have to know the hitherto course of the succession to be able to imitate it and to accelerate it in a desirable way.

V. Gerlich and M. Kincl (1968) carried out measurements of some mensurational characteristics of older plantations in three localities in 1965: in Štěpánův sad (Orchard) established in 1919, in a wood called Na Oderce (established in 1933) and in a wood near the Jan Šverma Mine (established in 1941 – 1942). Their measurements demonstrated that at least some tree species can reach a considerable wood mass production. The highest yield class I was observed in birch (*Betula pendula)*, yield class II was recorded for example in maple (*Acer pseudoplatanus)*, oak (*Quercus rubra)* and pine (*Pinus strobus)*. The lowest yield classes (VII – VIII) were typical of poplar and black locust. The authors concluded that silvicultural recultivation is technically and economically more appropriate than agrotechnical recultivation and that apart from their primary soil-protecting and hygienic function the plantations of tree species can also fulfil the function of production. In this context it cannot be but mentioned that after nearly 40 years Koutecký (2004) observed in Štěpánův sad and in the wood Na Oderce worsened yield classes in birch and maple and on the other hand considerably higher yield classes in black locust and poplar than in 1965.

In 1999 – 2001, growth analysis of young plantations was made in three localities in the Karviná section of the district by L. Knápková and B. Stalmachová (2003). Highest increments of seven monitored tree species were found in the introduced pine (*Pinus nigra*) and spruce (*Picea pungens*) but the two species suffered from the yellowing of needles and their consequent falling. The authors concluded that a greater success on relatively young recultivated waste bank was observed in domestic deciduous tree species with a broader ecological valence – namely maple (*Acer platanoides*) and linden (*Tilia cordata*). Higher increments were in this context recorded on waste banks with a high-standard silvicultural recultivation following after a substrate make-up. However, a number of authors warn that a coverage of tailings with the compacted clay soil is entirely wrong. There is also some information about the growth of some tree species not showing any difference in the comparison of plantations established right on the spoil and plantations established on the waste bank improved by the coverage.

The vegetation of grasses and herbs and the effectiveness of its soil erosion control on spoil banks was studied for example by D. Smolík (1965) who analyzed roots of herbs and grasses most frequently occurring on five waste banks with steep slopes in Ostrava. He found out that most species had typically a relatively low root strength and any calculation on the reliability of their erosion control effect would be irrealistic. A somewhat better firmness of the root system is exhibited by reed *Calamagrostis epigeios*. The author recommends, apprently also with respect to pratotechnical use of the species, the sowing of some grasses and papilionaceous herbs. An analysis of root systems of herbs and grasses growing on waste banks was also made by M. Havrlant (1968) who concluded that considerably important for the reiforcement of surfaces namely on slopes are grasses with their ligamentous roots.

A more comprehensive view of the complex links and diffusion of the spontaneous succession and silvicultural recultivations in particular brings T. Koutecký (2004) who studied the vegetation cover and soil conditions in the Koksovna (Coking Plant) Svoboda spoil bank in Ostrava-Přívoz (Fig. 3) and in the complex of waste banks from the coal mines of Petr Bezruč, Ema and Trojice in Slezská Ostrava. In both cases a possibility existed to compare the present condition with the condition of the vegetation cover several tens of years ago. It was found out that the number of represented plant species considerably increased – in the Koksovna Svoboda waste bank from 82 at the beginning of the 1980s to 143 at the present time. This high increase of species (by 74%) of which most came to existence spontaneously apparently relates to the calming down of waste bank fires that formerly used to continually damage the newly developing vegetation cover. The number of grass and herb species recorded on the complex of waste banks from the mine of Petr Bezruč at the turn of the 1960s and 1970s and now was 158 and 198, respectively, with 47 species not detected any more during the present investigation, which means that a total number of newly appeared herb and grass species was 87. Quantitative and qualitative changes in the species composition have multiple reasons here: the continual piling-up of waste banks, the calm-down of spoil heap fires, subsequent plantations and the spontaneous self-seeding of woody species and their development into enclosed canopies. It can be demonstrated that typical forest herb and grass species began to newly appear within the growing woody stands (as compared with the end of the 1960s), which even become dominant on shaded slopes – *Dryopteris filix-mas*, interspersed *Dryopteris carthusiana*, *Senecio ovatus*, *Brachypodium sylvaticum*, *Circarea lutetiana* and other. A detailed mapping revealed that in both cases the stands from self-seeding together with the recultivation stands combined or even suppressed by the self-seeding dominate over the stands that were merely planted. The share of grass-herbaceous fallow lands dominating in the past has markedly decreased at the present.

Considerations about a further prospect and methods of recultivation called for a comparison of the development of the spontaneous self-seeding and that of the recultivation plantations. Koutecký (2004) found out that an artificially established stand would be established more readily and would exhibit a higher quality at the age of about 20 years than a stand developed from self-seeding. Artificial plantations use to be more diverse in species composition but it

Fig. 3: All-aged stand on the eastern slope of the Svoboda coking plant *(Photo T. Koutecký)*

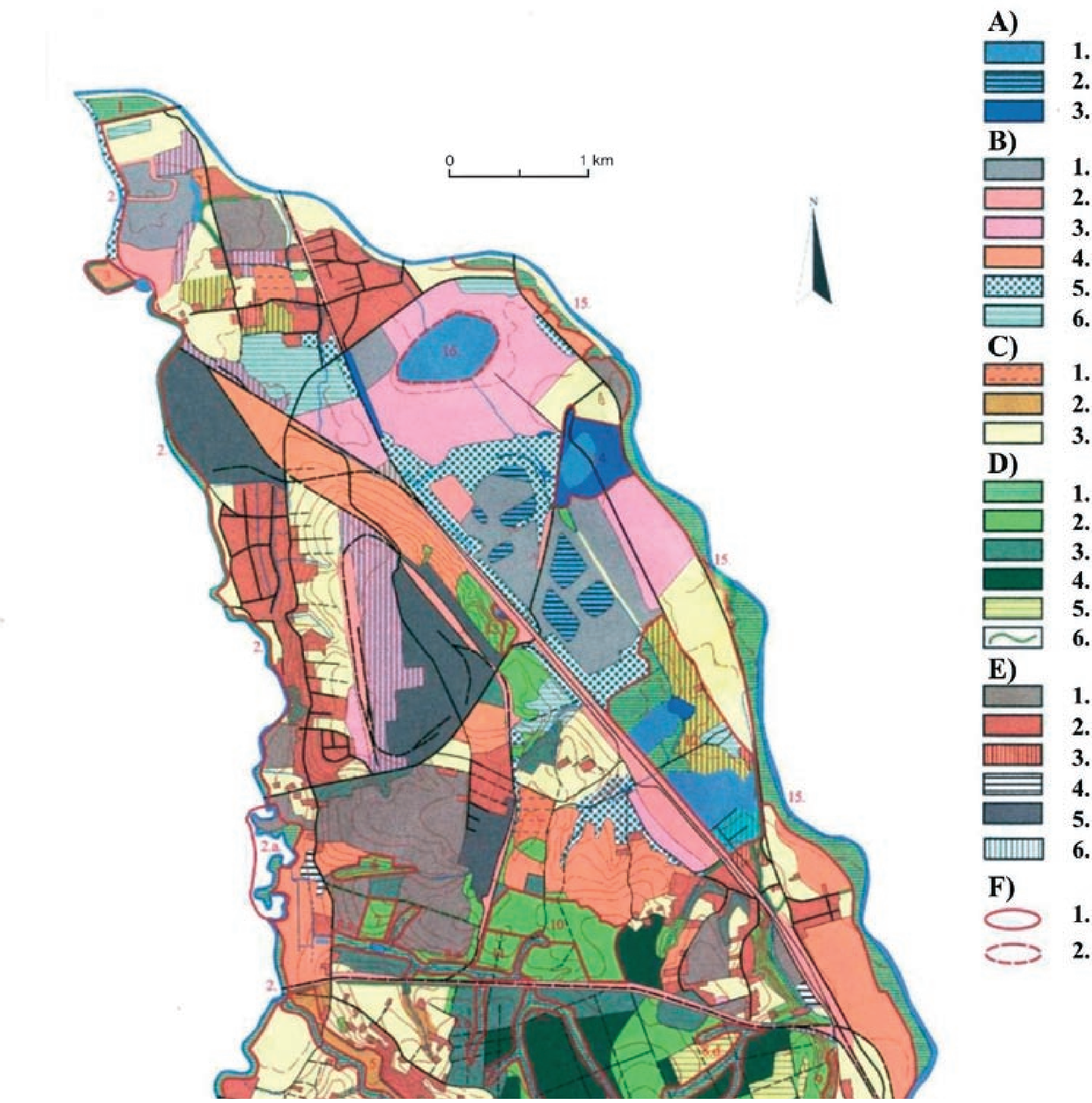

Fig. 4: Biotopes of mining areas - ČSM I, ČSM II and Darkov
Legend:
A) Water and wetland biotopes: 1 - Fish ponds and stream pools; 2 - Irrigated settling pits; 3 - Moist to wetland fallow lands (reeds);
B) Fallow grounds: 1 - Freshly piled spoil banks without vegetation; 2 - Grass-herbaceous ruderal fallow grounds on backfill with low degree of coverage and dominant great willow herb; 3 - Grass-herbaceous ruderal fallow grounds on backfill with nearly total coverage and dominant chee reed grass; 4 - Ruderal fallow grounds in place of former fields, grasslands and pastures; 5 - Woody fallow grounds with the degree of tree species coverage over 50 % and dominant birch, willows and poplars; 6 - Areas recultivated by silvicultural methods;
C): Perenial grasslands: 1 - Meadows with dominant naturally growing hydrophilic species; 2 - Semi-cultural grasslands; 3 - Cultural grasslands (often ruderalized)
D) Forests: 1 - Floodplain forests (including alluvial plains of streams); 2 - Broadleaved forest stands; 3 - Mixed forest stands; 4 - Coniferous forest stands; 5 - Young growths and clearcuts; 6 - Tree lines (including narrow riparian stands)
E) Other: 1 - Fields; 2 - Settlements with gardens and orchards, garden colonies with cottages; 3 - Depopulated areas (mosaic of grasslands with the natural seeding of tree species, wild fruit orchards); 4 - Agricultural enterprises; 5 - Industrial developments - often with ruderal fallow grounds; 6 - Biotopes with the natural seeding of woody species and degree of coverage below 50 %
1: Ecologically significant landscape segments
2: Perspective biotopes conditioned by anthropogenic activities
1. The Olše R. floodplain; 2. The Stonávka R; 2a Meanders of the Stonávka R.; 3. The Bobří meander; 4. The Chotěbuzka R.; 5. Floodplain meadows near the Chotěbuzka R.; 6. The Smolkovecký potok Brook; 7. The Smolkovecký háj Grove; 8. The Loucké forest brooks a,b,c,d; 9. The Chotěbuzské bučiny Beech; 10. The Loucké olšiny Alder; 11. The Loucké lipiny Linden; 12. The Loucké fish ponds and meadows; 13. Wetlands below the ČSM I Coal Mine; 14. Wetlands on the Horní louka Meadow; 15. The Olše River and its floodplains; 16. The Darkovské moře Sea

is usually a mosaic of even-aged monoculture groups. Self-seeded stands of pioneer species are on the one hand lower in the number of species but varied in terms of age, i.e. better structured and creating favourable conditions (namely light) for other woody species, better than the newly enclosed stands from plantations. Thus, valuable broadleaved tree species begin to find way into the older spontaneously developed stands and the difference in the tree layer species composition between the artificially established and self-seeded stands is balanced.

6. Area significance for the conservation of biological diversity

Although the OKR area of our interest exhibits very severe anthropogenic disturbances in its many sections, there is a range of near-natural up to natural ecosystems (geobiocoenoses and hydrobiocoenoses) conserved there – often with rare (particularly protected and endangered) plant and animal species. The area significance for the conservation of biological diversity was emphasized by many experts in botany and zoology, and an aggregative study was made by A. Rafajová (2004). An important fact is that the localities with valuable biodiversity occur also outside the network of the hitherto decreed 22 small-scale protected areas. Biogeographical research in the minefield of the ČSM Coal Mine disclosed for example 16 ecologically important landscape segments (Fig. 4), and even several tens of them were revealed in the minefield of the Staříč Coal Mine. Namely the landscape of the ČSM Coal Mine field heavily impacted by anthropogenic changes has some ecologically valuable localities occurring on waste banks and subsidences, i.e. on typical relief forms resulting from deep coal mining. These landscape segments with favourably developing near-natural biocoenoses are called perspective biotopes conditioned by anthropogenic activities and these perspective biotopes are included in the skeleton of landscape ecological stability. A specific problem of the colliery landscape is the fact that it is a place of extinction of some perspective biotopes (due to the filling of subsidences and withdrawal of tailings from waste banks) and at the same time a place where other new perspective biotopes arise. Thus, the skeleton of ecological stability is of a "mobile" character in these regions (Lacina, 2004).

It appears that at least some of these biotopes conditioned by anthropogenic activities should be left to spontaneous development if possible, and the strategy is also supported by the "Natura 2000" project of the European Union. In the course of years when they were left to the spontaneous development, some water-logged and water-bearing subsidences became habitats of a range of avian species endangered on a European scale (e.g. *Botaurus stellaris*, *Ixobrychus minutus*, *Circus aeruginosus*, *Sterna hirundo*, etc.) and amphibians (e.g. *Bombina bombina*, *Bombina variegata* and other). There are also many types of natural habitats advised in the Czech Republic for conservation purposes exactly within the framework of the above mentioned "Natura 2000" project (Chytrý, Kučera, Kočí (eds.), 2001) - e.g. V1D (Macrophyte vegetation of naturaly eutrophic and mesotrophic stagnic waters), M1.1 (Reed beds of eutrophic stagnic waters), M1.3 (Eutrophic vegetation of muddy substrata) and K1 (Willow carrs).

7. Conclusion

Biogeographical research in the area of downsizing deep coal mining in the Ostrava region corroborated that the area in question is of exceptional geobiocoenological significance with remarkable processes of spontaneous development on the anthropogenic relief.

It follows from the research and from other works that due to various ecological, economic and social reasons an unambiguous promotion of either various types of sanitation and recultivation constructions or on the other hand only a spontaneous succession would not be reasonable. An optimum solution appears to be the return to the pioneer idea advocated by E. Václav (1956) of a suitable interconnection of the two processes. A basic principle for the regeneration of devastated segments of the coal mining landscape should therefore be seen in the controlled succession (Stalmachová, Frnka, 2003; Šiřina, 2003) in which a spontaneous process of greening is used at a greatest possible extent, regulated according to actual needs and combined with artificial plantations or sowings. A return to the original landscape is not possible and in fact not needed. On the contrary, the specific features of these anthropogenic sites should be utilized in a proper way and incorporated in the changed landscape both to improve its pattern and to increase its ecological stability.

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COLLIERY BROWNFIELDS AND THE MASTER PLAN OF OSTRAVA

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Abstract

Former industrial cities deal among many other things with problems related to abandoned areas of former factories. As much as 148 ha of such areas were left after former collieries (colliery brownfields) in the city of Ostrava territory. One of significant factors for a successful regional development is the master plan. This article describes a proposal of the approach and decision-making criteria (a model) that will help to evaluate and to choose the best future function for such areas. The approach is aimed at brownfields in cities' urban areas. The proposed model was applied on areas selected from the master plan of Ostrava and results are mentioned and discussed in this article.

Shrnutí

Colliery brownfields a územní plán města Ostravy

Bývalá industriální města se dnes potýkají kromě jiných problémů s opuštěnými areály bývalých podniků. Na území města Ostravy vzniklo jen po důlních provozech 148 ha těchto ploch. Jedním z faktorů rozvoje je územní plán. Tento příspěvek přináší návrh postupu a možná kritéria (hodnotící model) pro určování budoucí funkce. Tento návrh platí převážně pro území v intravilánech obcí. Navrhovaný hodnotící model byl aplikován na vybrané plochy v územním plánu města Ostravy. Výsledky aplikace jsou také v tomto příspěvku obsaženy.

Key words: *colliery brownfields, abandoned areas, mining recession, evaluation model, master plan of city of Ostrava, Czech Republic*

Introduction

The city of Ostrava went through a lot of changes in the last decade of the twentieth century. The main impulse for these changes is seen in the conversion of heavy industry and mining recession. The recession started with the Czech government resolutions No. 264/91 and 691/92, which abolished mining activities on the Jan Šverma, Ostrava, Heřmanice and Odra collieries and the Ludvík facility of Julius Fučík colliery, which had mined in the Ostrava part of the mining district. This relatively fast approach resulted in a massive loss of jobs (e.g. Julius Fučík Mine employed over 20 thousand people in 1990) (Kolektiv autorů, 2003), in an unemployment increase in the region and also in an appearance of so called colliery brownfields, which term is used to refer to areas of former collieries no longer utilized for their original purpose, mostly abandoned now and representing a burden for their surroundings. Ostrava has about 148 ha of these areas, which was 4.5 % of city's industrial areas in 1994 (Kuta, Kuda, 2004).

What are the colliery brownfields

Brownfields or depressed zones (the term introduced by the Ministry of Regional Development in about 2003 without exact definition), is a worldwide recognized term that mostly refers to areas and estates inside urban areas that have lost their function and utilization and that are likely to represent an environmental threat.

Consequently, Coal mine (US) or Colliery (UK) brownfields are areas of former mining companies (i.e. technical background, headgears, administrative buildings, coal separating plants, etc.). Term brownfields doesn't refer to the whole area influenced by the mining activity.

In the context of brownfields the term greenfields is also frequently used – describing the land that has not been built-up yet, or buildings erected on the land that had never been used before for building (Cambridge Advance Learner´s Dictionary), usually representing fields or meadows.

Why it is necessary to deal with abandoned areas of with former mining facilities?

Seemingly small amount of such areas in Ostrava could lead to the conclusion that they do not represent a major problem. But their situation in the urban structure of the city is more important than merely the extent of these areas. Fig. 1 contains marked locations of individual closed down collieries (those are collieries closed down because of recession). It can be seen in the figure that the areas of former mines are situated in the urban area of the city. Moravská Ostrava and Přívoz are stand for a historical centre of Ostrava. The figure further explains a future utilization of these areas which were assigned by the master plan of the city. Following sections contain further information about the colliery brownfields relationship to the masterplan. The existence of these areas within a densely built-up district is the main reason why it is necessary to deal with the regeneration of colliery brownfields in Ostrava.

Related reasons are as follows:
- economic,
- environmental,
- aesthetic,
- safety,
- greenfields.

They are thoroughly described in the following paragraphs.

Economic reasons

The first of them is an undeniable fall of real estate pricing in the vicinity of abandoned, usually deteriorating and not too pleasant areas. Regeneration of the area to a more acceptable shape leads to the increase of real estate prices in the neighbourhood (Kolektiv, 2004).

Another consequence connected with the lacking utilization of the area is the fiscal effect. If an area doesn't generate any profit, then it doesn't pay any taxes which in the transformed form make a part of cities' budget. There is also a tax from real estates that in its total goes into the accounts of city districts. These fiscal incomes can be used to foster development of these districts.

Yet another effect is the loss of jobs without their at least partial restoration. It results in the decrease of population income and subsequent weakening of purchasing power. Providing of new job opportunities on the brownfields leads to the opposite effect - increase of purchasing power.

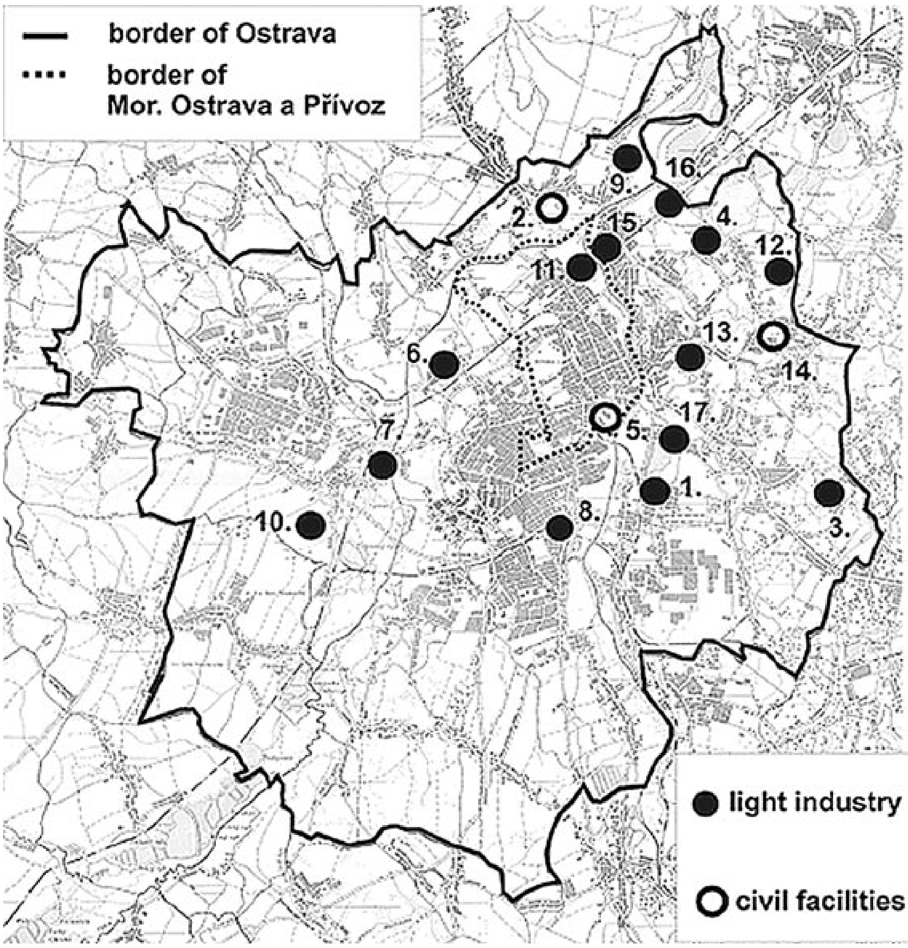

Fig. 1: Location of collieries which were closed down during the recession and their assigned utilization according to the masterplan of the city of Ostrava (Vyhláška města Ostravy, 1994) (numbers correspond to numbers in Tab. 3)

Environmental reasons

Brownfield usually carries environmental risks. Sometimes the environmental risks incline to migrate out of the area. These situations sometimes represent also a potential health risk for citizens or some other part of environment. Then it is inevitable to decontaminate the area. (This applies rather to areas after heavy industry operations rather than mining, except of localities with preparation plants or coking plants).

Aesthetic reasons

Apart from inattractive view for inhabitants living in neighbouring areas, the half-ruined objects in the city center give the whole region a very bad reputation. It is necessary to be aware of the fact that potential investors coming into the region are very sensitive to the city's look and are unlikely to make investments at places they are not impressed with. The region that has undergone recent structural changes should be interested in giving a good impression, if it was interested in attracting investors.

Safety reasons

Safety reasons can be divided into two groups of safety threats. The first one is related to the buildings which fall into disrepair gradually and may have damaged statics.

There is a risk of serious and even fatal injuries connected with any presence in such a locality (e.g. playing children). The second group of problems is related to temporary and unregistered inhabitants of these areas, who inhabit these areas without property owner's permission and the vicinity of these objects is then affected or even threatened by their presence.

Greenfields

Sustainable development of city and region comprises also farmland protection. Many new developments are planed to occupy farmland. Brownfields regeneration – so that they can be utilized by a developer or investor – could then lead to reduced construction on greenfields and simultaneously it could contribute to attracting proper investments to the urban area of the city.

The above mentioned reasons lead to a conclusion that the regeneration of brownfields should be a part of the city's development strategy as one of the main targets. The master plan – or its possible amendment to reflect the latest knowledge – is one of important factors that can contribute to a new utilization of abandoned areas.

The master plan of Ostrava and colliery brownfields

The master plan of Ostrava was ratified in 1994. All collieries in the Ostrava part of the OKR mining district had been closed down already and the physical liquidation of mines had been finished or was in progress. The master plan groundwork was thus prepared when mining companies stopped mining and they were liquidating shafts, but the buildings were still in a good shape and equipped with all necessary buried services. The original idea was based on an instant reuse of the existing objects. But as the proprietory relations at that time did not make it possible for town authorities to enter the process with a greater vigour, there are only two types of the future use in the Master Plan, viz. light industry and museum (civil amenity) (see Fig. 1). Therefore only two kinds of the future utilization appeared in the master plan – light industry and a museum (civil amenities) (see Fig. 1).

It is obvious at the present time that many of the sites remained almost totally abandoned, buildings delapidated or even demolished, buried services disconnected and internal infrastructure in desolation. The objects are or are likely to be planned for demolition.

A model was prepared as a part of the grant project "An optimum approach to the regeneration and future utilization of abandoned industrial areas in the region of Ostrava" reg. No GAČR 103/03/P064, which evaluated the suitability of future utilization of individual areas based on a complex evaluation of their present state with attention to neighbouring areas. The model output with the conclusion on whether the future use designed by the masterplan is still suitable in 2004 and whether there are some other possibilities of use is mentioned later on in this work.

The new construction law which is currently negotiated by the Parliament of the Czech Republic and waiting for ratification is going to require revisions of older master plans. An output given by the model should be particularly helpful in the preparation of the new master plan revision.

Evaluation model

The model for evaluating an appropriate possible utilization has three separate modules, which are based on evaluating criteria whether the area is suitable, suitable under certain conditions, or unsuitable for light industry, civil facilities or housing (see Fig. 2).

The model uses three criteria – spatial utility of an area, surrounding areas and traffic accessibility. There were other criteria considered for the model such as

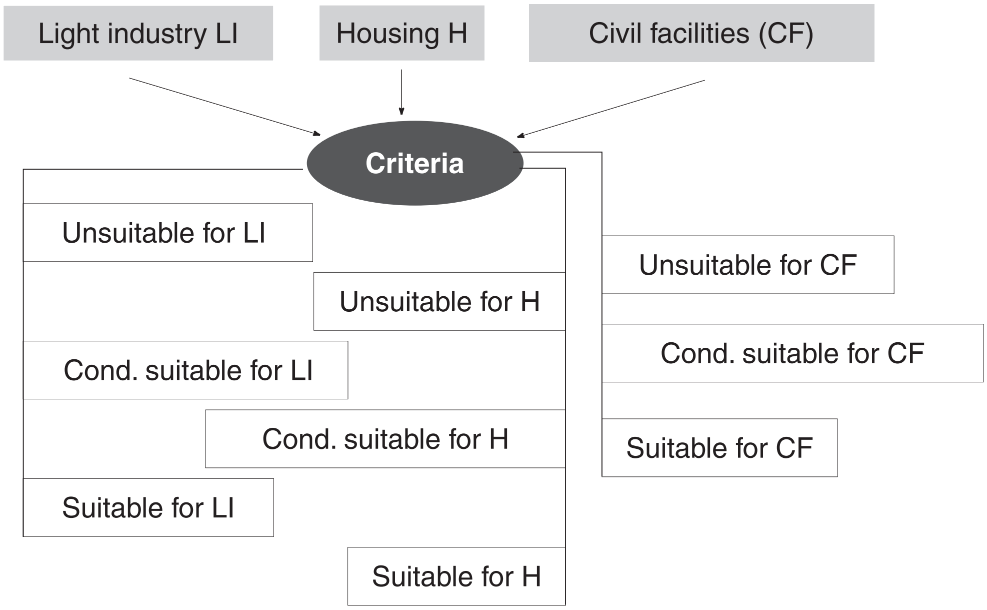

Fig. 2: Block scheme of the evaluation model
LI– light industry, H – housing, CF – civil facilities

contamination or land prices, but they were ruled out due to their financial nature which is not necessarily connected to functional aspects, which the master plan is dealing with.

Area utility

Unlike some other abandoned industrial areas, those after former collieries have certain common specific features. It is for example the existence of liquidated pits around which a safety zone is constructed at all times. The minimum safety zone size as stipulated in the Decree issued by the Czech Mining Authority ČBÚ 52/1997 Gaz. (Vyhláška ČBÚ č. 52/1997) must reach by at least 20 m behind the outer perimeter of the pit masonry. The surrounding area of all liquidated pits has been or will be in the near future declared closed for any construction works. In practice, the construction closure for safety zones is defined as a circular area of 25 m in diameter with the centre located in the middle of shaft shank, which represents an area of about 2000 m^2 (0.2 ha) for one pit. The premises can include several of these safety zones with a construction closure. Apart from the construction closures, there is also a problem with using the space between the construction closure and the area boundary in the case that the space is too small e.g. for the location of a hall. This part of the land property is therefore further called a lost area. The size of such a lost area was set up by testing (lost area size was calculated for selected land properties and compared with the size of construction closures) at a 0.5 multiple of the area sum of construction closures.

Spatial utility of an area informs the potential candidates on how much of the area can be really utilized. This criterion is used only for the light industry part.

Surrounding areas

This criterion was worked out by using a method of verbal rating (Říha, 2004). This approach is used to describe positive and negative influences and their impact on the individual types of future use. The verbal rating becomes a basis for the assignment of auxiliary points for the different types of surrounding areas (Vojvodíková, 2004).

The auxiliary points are summed for each measured area and divided by the number of distinct types of surrounding areas.

Traffic accessibility

Traffic accesibility is a very important aspect for the potential future user. The Model evaluates accessibility in terms of the following road types: Expressway, distributing roads (by-passes), and service roads. Expressways are designed for speeds of 80 – 100 km/h, being as a rule directionally divided and placed on the borders of functional units. A connection to the expressway is assumed. Distributing roads form the basic skeleton of a city, being connected to the expressway. Service roads are city's inner roads of mostly social importance, placed among the existing buildings (Marhold, 1996).

	auxiliary points for LI	auxiliary points for H	auxiliary points for CF
light and heavy industry	1	10	5 (HI10)
commercial area	1	3	1
farmland	3	3	1
forest or park	3	1	1
civil facilities or accommodation	8	1	1
individual housing	10	1	1
group housing	10	1	1

Tab. 1: Auxiliary points for the criterion of surrounding areas
HI – heavy industry, LI – light industry, H – housing, CF – civil facilities

The model uses again a verbal description of the above mentioned road types as a basis for the decision about the area's suitability for the particular future use. A more detailed analysis of these was published in (Vojvodíková, 2004).

	suitable	suitable under certain conditions	unsuitable
spatial utility	> 75%	75% - 50%	< 50%
surrounding areas	< 2	2 - 5	> 5
traffic accessibility	> 2	2	1

Tab. 2: Binding conditions of criteria for the future use of light industries

Then auxiliary points are assigned (they are assigned so that the model can be used as a software module to add to the information system of the city). The light industries will prefer the best traffic accessibility in the future, the quiet zone will be preferred for housing and a compromise between the traffic accessibility and the impacts of noise from heavy traffic will be preferred for civil facilities.

The model for light industry allocates 3 points to by-passes and 1 point to service roads. Considered is the value of communication of the highest rank running along the perimeter or in an immediate vicinity of the premises. (This means that if there are two roads running along the perimeters of the premises - one by-pass road and one service road - the site is not allocated 3+1 points in the model but only 3 points.) An expressway with a slip-road up to 500 m is given a bonus point.

Housing and civil facilities are allocated 5 points for an expressway at a distance of up to 300 m, 1 point for just a service road, 2 points for both a service road and a by-pass within the reach, and 3 points for a by-pass only - with the auxiliary criterion of noise being taken into account.

Criteria evaluation

Each of the aforementioned criteria specifies whether the area is suitable, suitable under certain conditions or unsuitable. The following table lists binding conditions for the light industry future use.

Model application output

In order to test the model application 17 different areas were chosen from the former collieries in the cadastral area of Ostrava left after recent mining recession which started in 1989. The master plan (Vyhláška města Ostravy č. 3/1994) assigned a light industry future use to 14 of them and a civil amenity (museum) – to the remaining three of them. None of them was assigned a future use for housing. Tab. 3 contains a comparison between the future use assigned by the master plan and the model application output.

Fig. 3 shows the model appliacation output in a different way. Circles show which types are suitable for each area (more than one guarter of a circle) or which types are conditionally suitable (exactly one quarter of a circle).

Discussion of the model output

Localities assigned an identical future use by both the master plan and by the model application.

The model proved that the area of Mine Jan Šverma in the Mariánské Hory city quarter is suitable for a light industry operation while being totally unsuitable for housing or civil facilities.

The area of Mine Stachanov was also assigned a light industry future use by both the master plan and the model.

No.	colliery name	MP	LI	H	CF
1.	Alexander	LI	U	CS	S
2.	Eduard. Urx	CF	U	S	CS
3.	Fučík III- Ludvík	LI	U	S	S
4.	Heřmanice I	LI	CS	U	S
5.	Hlubina	CF	CS	U	CS
6.	Jan Šverma- Mar hory	LI	S	U	U
7.	Jan Šverma Svinov	LI	CS	U	U
8.	Jeremenko	LI	CS	U	S
9.	Koblov	LI	U	S	CS
10.	Oderský	LI	CS	U	U
11.	Odra	LI	CS	U	CS
12.	Oskar	LI	U	S	CS
13.	Petr Bezruč	LI	U	CS	S
14.	Petr Cingr	CF	U	U	CS
15.	Stachanov	LI	S	U	CS
16.	Vrbice	LI	CS	U	U
17.	Zárubek	LI	CS	CS	S

Tab. 3: Model output for individual areas
MP - master plan assigned, LI - light industry, H - housing, CF - civil facilities, S - suitable, CS - suitable under certain conditions, U - unsuitable.

The area of Mine Petr Cinger (also called Mine Michal) was designed to be used as a museum by the master plan. In fact the museum of industry has been established there already. This was proven to be a good choice of the model output.

Similarly, the areas of Mine Jan Šverma and Mine Oderský in the city quarter of Svinov and the area of Mine Vrbice were found correctly assigned a light industry future use by the master plan from the viewpoint of the model output.

Localities marked by the model as more suitable for future use type different from that assigned by the master plan.

The model marked the area of the former Mine Fučík III – Ludvík as suitable for housing or civil facilities. The master plan's assignment of a light industry future use was evaluated as unsuitable by the model.

The area of Koblov colliery was evaluated by the model as suitable for housing as well as for civil facilities (in contrast, it has found the use of light industries unsuitable).

Alexandr colliery is currently designated by Master plan for a light industry. From the viewpoint of the model and because of the conservation of valuable cultural technical monuments it would be better to use it for a civil facility. Should it be possible to reduce the railway noise level, the use for housing would be suitable as well.

The area of Oskar colliery was designated for a light industry operation. But it's unsuitable for this type of use because of insufficient traffic accessibility. The model found this area suitable for housing and civil facility.

The area of Mine Petr Bezruč is today also designated for a light industry operation, but from the model's perspective it seems totally unsuitable for this use as it is situated in the neighbourhood of forest and housing areas and its terrain is rather broken. Suitable is on the other hand its utilization as a civil facility or it can be suitable under certain conditions also for housing.

Localities suggested by the model an additional possible future use to the use assigned in the master plan.

The area of Eduard Urx colliery, where a mining museum has been established, was evaluated by the model as an area suitable for housing as well as for civil facilities. With respect to other conditions as outcrops of coal beds on the surface and archaeological value of the place we can declare the already implemented new utilization as very suitable.

The area of the former Mine Heřmanice 1 was assigned a light industry future use. The model suggested also its suitability for a civil facility.

The area of Mine Hlubina was designated for a museum in the master plan. In case that the objects in the area

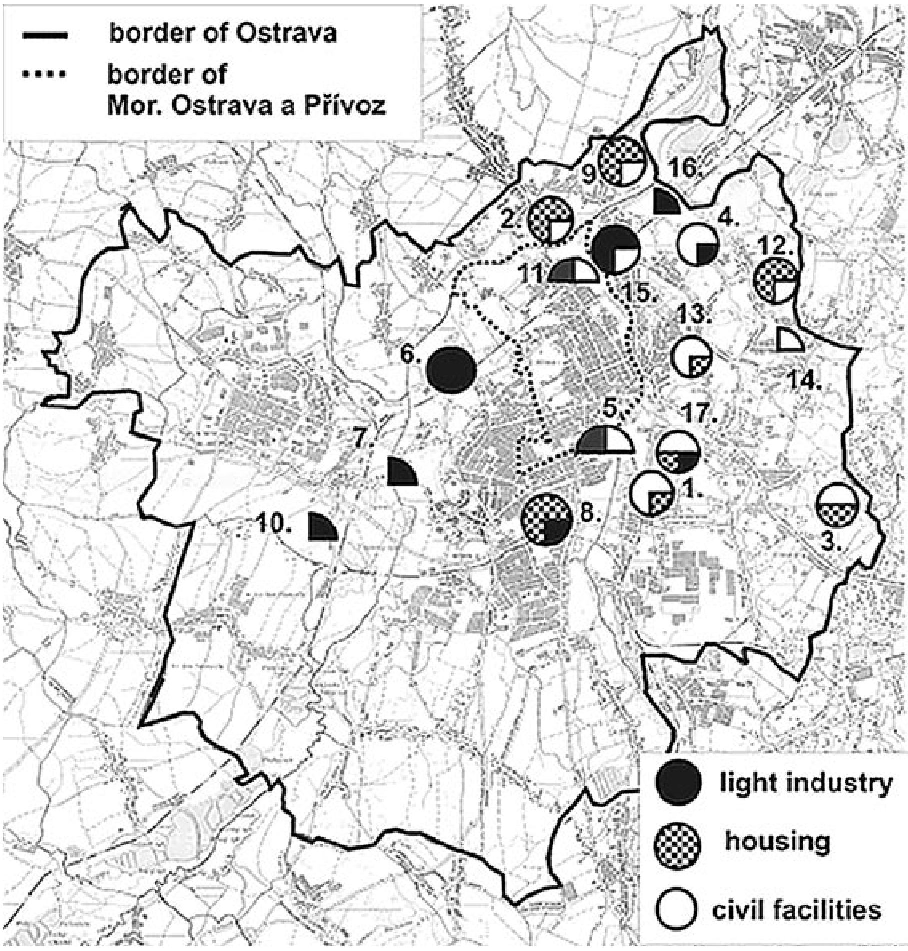

Fig. 3: Proposal of future utilization according to the model output (number marking is identical to numbering in the Tab. 3)

lose their monument status, this area could be used also for a light industry.

The area of Mine Odra in the Přívoz city district is suitable not only for a light industry operation but also for housing because of its location similarly as the area of the former Mine Jeremenko where the water pit is in function, which pumps water from flooded shafts of liquidated collieries in the Ostrava part of the OKR mining district. After the discontinuation of its function, the area can be used for civil facilities. Current estimations expect discontinuing of its functions in the following decades.

The area of Zárubek colliery was assigned a light industry future use. Its location would be suitable also for housing or civil facilities.

Conclusions

The preparation of master plan and its ratification is a long-term process and any changes are difficult to be implemented in a short-term horizon. The master plan can support or block the solution of the problem of brownfields and their potential novel use. Due to the fast recession of mining the areas were assigned a light industry future use which was coherent with the plan of instant reuse. Some areas with technical monuments were assigned a future use as museums.

The application of the evaluation model showed that the master plan suggested a suitable future use for six of seventeen evaluated areas. Five areas were given a different more suitable future use by the model output, especially for housing or civil facilities, and for the remaining six areas the model confirmed the master plan's assignment but suggested also other equally suitable possible utilizations.

With respect to the fact that a prediction of the further development of areas defined as brownfields is very difficult, it would be useful to include into the concept of the novel construction law the possibility of a less stringent or optional function for the future use of the brownfields, and to put emphasis - according to the model adopted in some other countries (Great Britain) - on the placement of housing facilities in these areas.

Acknowledgement

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DOWNSIZING OF MINING IN PÉCS

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Abstract

Coal mining in the Mecsek Mts. reshaped the face of Pécs several times. Coal mining activities were observed to culminate during the era of Socialism in the second half of the past century when the city and the region became a citadel of mining. The last decade has been recording a downsizing of coal extraction and the mining industry is losing its significance. A new strategy is seen in the effort focused on the creation of an ecological city and an eco-region.

Shrnutí

Útlum těžební činnosti v Pécsi

Těžba uhlí v pohoří Meczek přetvořila vzhled města Pécz a jeho okolí již několikrát. Těžba uhlí dosáhla svého vrcholu ve druhé polovině minulého století za éry socialismu, kdy se město i kraj staly baštou hornictví. V posledním desetiletí dochází k útlumu těžby a hornictví ztrácí svůj význam. Nová strategie rozvoje je spatřována ve snaze o vytvoření ekologického města a ekoregionu.

Key words: *downsizing of coal mining, uranium mining, Pécs, Pécs region, Hungary*

The oldest hard coal mines of Hungary opened in the district of Pécs

Hungary's oldest coal mine – called Brenbergbánya – is situated near Sopron, where brown coal from the Miocene era has been mined since 1767. Almost at the same time, in 1769, the first bituminous coal layers were discovered in the Mecsek Mountain near Pécs. This site today is situated within the cadastral area of Pécs (in the Northern part of the city) where active coal mining was going on until 31 December 2004. The utilisation of bituminous coal mined here started already in 1782 in many places of the Mount Mecsek. Regarding its geological age this coal is a high calorie bituminous coal, created in the Liassic layer of the Jurassic era. It has a coking capacity, thus it is the only metallurgical coal occurring in Hungarian coal fields. Thus, since 1830 it could play an important role in the Hungarian coal market, constituting a significant basis for the First Danube Steamship Company, right until the end of World War II (Babics, 1952).

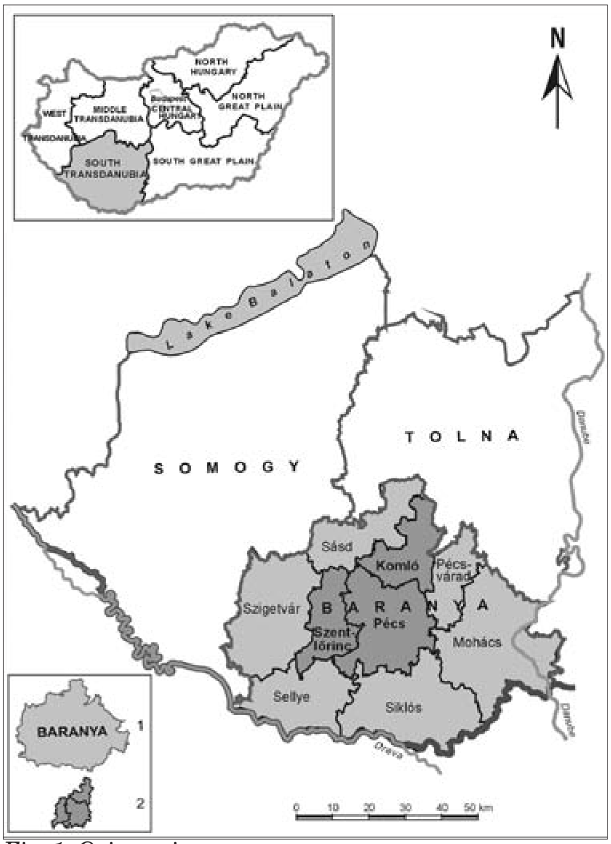

Fig. 1: Orientation map

1. Significance of Pécs coal for Hungarian economy

In 1833, the territory of active coal mines situated near Pécs covered only 3492 m^2. This was the time that meant a final stage and an end of small scale production in the mining industry. Large scale deep mining and intensive coal production started to develop from the middle of the 19th century. This brought to surface great quantities of coal for further industrial use as well as dead rock that remained on the site thus destroying environment and landscape. The impact sphere of the coal mining industry greatly enlarged, and so many new shafts were opened in the vicinity of Pécs such as Pécsbánya, Szabolcs, Komló and the northern side of the Mecsek Mountain. Coal from Pécs became an increasingly significant factor in the developing heavy industry - as it is a strategic element of steel and metal industries. In the period from 1960 – 1970, the production of coal was almost 4 mil. tons per year here, although the production costs were continuously increasing due to unfavourable geological conditions of deep working mines. In spite of the fact that the technically exploitable coal deposits were huge, the production was decreasing year by year due to the apparent and increasing economic crisis of the 1980s (see Tab. 1).

In 2004 only a few hundred people were involved in re-cultivation programs.

2. Uranium mining in Hungary raises special problems of environmental protection

Uranium mining and the related ore enrichment process raise a series of problems in both the heavy and chemical industries. In Hungary (in the Pécs region) the industrial uranium mining started in 1957 and was closed down in 1997. Permian green (greyish green) sand-stone contains much of uranium ore in the Mecsek Mountain, that together with a Triassic surface deposit forms a huge anticline closing in the East. There were three areas suitable for industrial exploration demarcated there by the end of 1955. The mines in these sites are qualified as dust-harmful (causing silicosis and radiation danger). The radiation danger was primarily due to radon gas and its fission products.

Year	Economically exploitable (industrial) reserve on 1 January			Production of previous year, million tons
	total	Contracted with working mines		
	million tons		%	
1980	467.2	188.3	40	3.24
1985	596.0	175.5	29	2.95
1990	504.7	103.9	21	2.40
1994	238.5	51.2	21	0.97
1995	223.7	36.5	16	1.01
1996	225.6	38.3	17	0.86
1997	223.0	35.7	16	0.96
1998	195.2	7.9	4	0.93
1999	199.0	11.7	6	0.88
2000	198.7	11.2	6	0.74
2001	198.2	10.8	5	0.74
2002	197.7	10.2	5	0.64
2003	197.0	9.5	5	0.66
2004	199.0	8.9	4	0.67

Tab. 1: Production of bituminous coal
Source: Hungarian Geological Survey.

It is clear from column 3 of Tab. 1 that in 2004, only 0.67 million tons of coal was mined in the Mecsek mines. This was the last year of production here. On 31st December the production was terminated even in the last surface mining cuts. Following to this closure only the environmental re-cultivation programs remained to be done. Approximately 130 million m^3 of bituminous coal and 100 million m^3 of dead rock have been surfaced in the Mecsek region. Comparing the above mentioned two quantities, we can understand and clearly see the environmentally destructive and double effect of the mining industry. Firstly, as a result of exploiting materials in deep-mining large unstable and sunk territories were left. Secondly, artificial hills of dead rock have been erected that clashed with and destroyed the landscape around them.

The downsizing of mining industry in the South Transdanubian region brought along also significant social tensions because it led to the serious downsizing of mining workforce. While in 1980 the number of people employed in the mining industry around Pécs amounted to 34 446, in 1990 this number was only 19 682 persons.

A half of the site's ore deposit was exploited by the end of 1997, that is 18 million m^3 (46 mil. tons) of rock, i.e. 10 million m^3 (25 million tons) of uranium ore. The processing of the ore gave 21 million kg of uranium metal. 32 million m^3 of water were used for processing raw uranium ore, 30 million m^3 of it being mine inflow, the rest normal drinking water. The uranium was obtained from the above mentioned 18 million m^3 of ore but due to its low concentration (approx. 0.1%) almost the entire quantity of ore became dead rock that was deposited on the surface. Almost a half of the entire mass of debris is rough rock that was piled up in refuse dumps and percolation hills. To gain extra uranium of dead rocks deposited in the percolation hills have been processed further through sodic dilution. This improved the efficiency of the uranium industry. The other half of refuse dumps as well as the slurry resulting from chemical concentration processes were placed in slum-deposit. This slurry contained chemicals used in the dilution process as well as the dead rock debris itself. Both in the ore and in the untreated dead rock a radioactive balance exists among the fissile materials of U-238. Due to chemical treatment this balance was disturbed in the percolation hills and sump deposits. The re-cultivation of these sites is presently going on, the operation being financed entirely from the state budget. The cost of these re-cultivation works sums up to 18 billion HUF (Hungarian forint) that is to 72 million EUR. This sum pays for the liquidation of environmental damages caused by the uranium mines, and provides the opportunity toward the renewed utilization of the territory.

3. Closed mines and grave environmental damages

In the Pécs region (especially the Mecsek Mountain) there are 153 objects recorded as causing significant and grave environmental damages (abandoned mines, refuse dumps, percolation territories of uranium mines, slurry deposits etc.) (Fig. 2).

In the Pécs Komló region the territory of dead rock deposits makes up to 882 hectares. Of this 214 hectares have been re-cultivated, 668 hectares still wait for re-cultivation. The largest quantity of dead rock was produced in the deep working mines that was deposited on the spot. Although certain parts of the mines have been filled up already, dead rock deposits around them have not been re-cultivated or set back into the landscape. Planning of methods for their measuring and liquidation is under process. Their reuse is not possible due to their low coal and ore contents, high salinity of running waters and possible self-ignition of the re-piled material cause problems during re-cultivation. Dead rock from the surface mining is used to refill deep mines. Due to the insufficient quantity of usable dead rock new forms of landscape have to be necessarily planned here. Waste material coming out of the West-Mecsek uranium mines is low in fissile material and thus not re-usable. Their liquidation complying with the requirements of radiation protection can be done. Dead rock in Uranium mining is the result of the percolation treatment and ore benefication methods. Their re-cultivation after the production closure has been started (see above).

In the case of mines producing raw material for the construction industry we do not always have to count

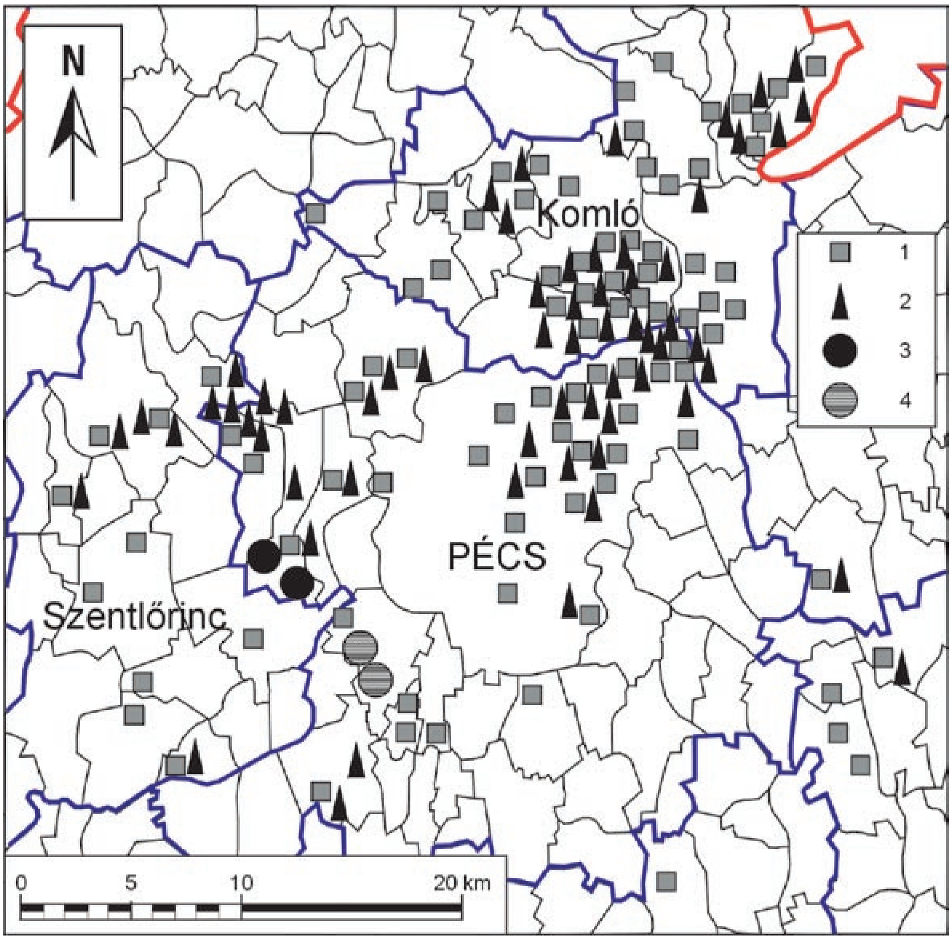

Fig. 2: Environmental damages and danger caused by coal mining in the Pécs-Komló region
Legend: 1 – closed mines, 2 – refuse dump, 3 –percolation area of uranium mines, 4 – slurry deposits

with waste material. As this raw material is produced by the surface mining technology, dead rock is placed in the courtyards or in the approximate vicinity of the mines. After the closure of the mines, dead rock can be utilised almost everywhere. An insufficient quantity of the material could cause problems here in reshaping the landscape. Extra quantities of dead rock can be utilised in the construction of dams and embankments, in field works etc. Instead of opening new sites for the construction material, it is rather possible to make use of tailings from sand mines, coal mines and quarries.

In Table 2 we summarise the list of damages in landscapes caused by mining activities:

I. Natural elements	II. Artificial elements
1. Disturbance of underground rock	1. Settlement environment (residential and working place)
2. Changing the landscape forms	2. Industrial establishments (working plants, shafts)
3. Diminishing of crop land	3. Construction elements
4. Changing hydrology (surface, subsurface)	4. Infrastructure (surface and near surface linear establishments)
5. Flora and fauna	

Tab. 2: Degradation of environment elements caused by mining

A significant problem represents the fact that the mines in Northern Pécs form a chain and reach the downtown area of the city. Some mines or ancillary shafts reach into residential areas. Sinking of the surface at various degrees has been experienced in the region of Pécs, Komló and Mázaszászvár.

In Pécs and Komló significant disturbances occurred in the linear infrastructure as well as damages in buildings.

Surface mining is going on in the vicinity of the deep working shafts, and both are located close to inner city area, or partly reaching into residential areas as well. These were formed as deep holes out of which the hole reaching Pécs directly (Pécsbányatelep) has been re-cultivated. Refuse dumps are usually situated around the mines, a few of them can be found in the inner parts of Pécs and Komló. They are typically placed near settlements. We can distinguish 19 large refuse dumps in the Pécs region, a few of them being interconnected or situated very close to one another.

4. Summary

Mining in the Mecsek Mountain has reshaped the face of Pécs several times. During the first period of some two hundred years of the harmonious development of mining, a university city with great historical importance and of significant cultural values (as evidenced in the old city that is part of the World Heritage), acquired an industrial character as well. After World War II, during the socialist era, the city and its region became a "citadel" of mining. Since the mines have closed, this character has changed into a "ruin", after only thirty years in operation. The new challenges evident at the end of the 20th century and the beginning of 21st century now pose the question whether Pécs and its region can meet the requirements of sustainable development. A new development strategy in this direction can be seen in the efforts to form an eco-city and eco-region. Pécs plays an integral part in the European city network, with an active role in the Central European division of labour. Accordingly, the city's economic development strategy has set priorities in the establishment of scientific and technology parks, industrial parks, conference centres, exhibition and fair centres, health tourism developments (in the Harkány region), as well as the development of the university, together with a rapid remediation and revitalisation of land subject to environmental disturbances by the mining industry.

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GEOGRAPHY IN EUROPE OF REGIONS

The 6th Moravian Geographical Conference CONGEO '05

The 6th international geographical conference was held in Luhačovice in August 2005. The Conference was attended by geographers from the Czech Republic, Italy, Canada, Hungary, Germany, Poland and Sweden, and for two days it became a stage where 23 papers in various partial disciplines of geography were presented of which an absolute majority were published in the proceedings Geography in Europe of Regions. The individual contributions concerned a wide range of regional geographical issues. A lively discussion followed the contribution presented by Bryn Greer–Wooten from the University of York (Canada) and devoted to the contemporary problems of regionalization and regions in the European concept. Papers focused on environmental issues and ecological problems were dominating and interesting for the conference participants were papers discussing the role of small towns in the system of settlement. Attention was also paid to possibilities of using regional information for atlas creation, namely with respect to its contents and a possibility of digital expression.

The conference participants took part in an excursion which was to make them acquainted with the region of eastern Moravia. They were informed about the history and the present of the regional town of Zlín and they were shown the adjacent town of Otrokovice, affected by a severe flood in 1997. They visited one of the most prominent places of pilgrimage in Moravia – the basilica of Virgin Mary Assumption on the Holy Hill of Hostýn, Bystřice pod Hostýnem (as an example of the small town), and R. Jelínek distilleries in Vizovice – an important exporter of spirits.

The end of the Conference was devoted to a discussion concerning the next CONGEO '07 conference to be held in August 2007 and focused on "Regions and Localities in New Europe". Partial themes suggested for CONGEO '07 are as follows: Regional Perspectives as a Result of Human Impact on Landscape and Environment, Society in Urban and Rural Context, and Regional Economy and Society. The venue of the CONGEO '07 conference is proposed to be one of towns in the Vysočina (Upland) region – for example Telč whose historical town core is enlisted by UNESCO as a part of the world's heritage. The first circular of the conference will be publicized on the Branch websites and disseminated to geographical workplaces in autumn 2006.

Antonín Vaishar

Landscape recultivation in the area of Karviná Doly (Space of the Church of St. Peter from Lakantgara).

Photo O. Mikulík

Garden colonies can be seen even in the immediate vicinity of coal mines.

Photo O. Mikulík

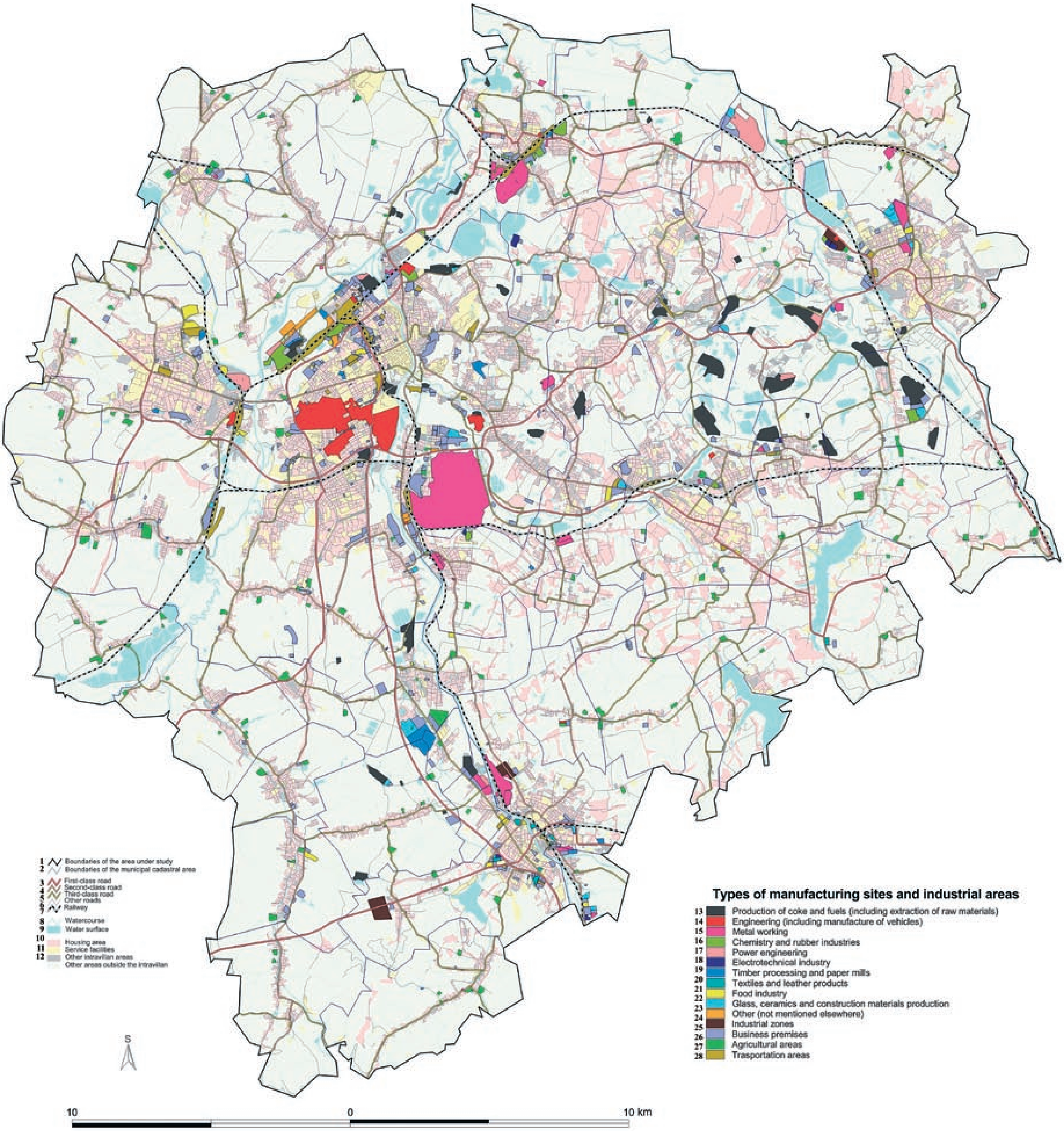

Fig. 2: Categorization of industrial areas in the Ostrava region (Klusáček, Šotnar, 2004)

Legend: *1 – Boundaries of the area under study; 2 – Boundaries of the municipal cadastral area; 3 – First–class road; 4 – Second–class road; 5 – Third–class road; 6 – Other roads; 7 – Railway; 8 – Watercourse; 9 – Water surface; 10 – Housing area; 11 – Service facilities; 12 – Other intravillan areas 13 – Other areas outside the intravillan*

Types of manufacturing sites and industrial areas: *14 – Production of coke and fuels (including extraction of raw materials); 15 – Engineering (including manufacture of vehicles); 16 – Metal working; 17 – Chemistry and rubber industries; 18 – Power engineering; 19 – Eletrotechnical industry; 20 – Timber processing and paper mills; 21 – Textiles and leather products; 22 – Food industry; 23 – Glass, ceramics and construction materials production; 24 – Other (not mentioned elsewhere); 25 – Industrial zones; 26 – Business premises; 27 – Agricultural areas; 28 – Transportation areas*